

**What does it take to treat municipal wastewater  
in developing countries?  
An econometric analysis of Mexican municipalities**

A thesis approved by the Faculty of Environment and Natural Sciences at the Brandenburg University of Technology Cottbus – Senftenberg in partial fulfilment of the requirement for the award of the academic degree of Doctor of Philosophy (Ph.D.) in Environmental Sciences

by

Diplomvolkswirt, Magister Artium der  
Philosophie, Wirtschaftswissenschaften und Romanistik (Spanisch)

**Lutz Philip Hecker**

from Karlsruhe in Baden-Württemberg, Germany

Supervisor: Professor Dr. rer. pol. Frank Wätzold

Supervisor: Dr. rer. pol. Gunther Markwardt

Day of the oral examination: 06.10.2017

## I. Acknowledgements

First and foremost, I would like to thank my supervisors, Prof. Dr. Frank Wätzold and Prof. Dr. Gunther Markwardt, for giving me this great opportunity to work on the thesis. To Prof. Wätzold I am incredibly grateful for providing me an absolute professional, supportive, humanly and inspiring environment and for his keen and genuine instructions and extraordinary intellectual and motivational guidance throughout all phases of the PhD. To Prof. Markwardt I am exceptionally grateful for providing me extremely helpful comments on technical and methodological aspects, structuring the thesis and for giving me the opportunity to tap into his outstanding expert knowledge in the fields of development economics and econometrics.

Moreover, I would like to express my deep gratefulness to Mrs. Regina Kirsche of the Chair of Environmental Economics of the Brandenburg University of Technology for her indispensable support in managing my PhD project successfully. In addition, I would like to thank individuals and institutions all over the globe that supported me in various ways. Especially, I thank Prof. Dr. Bachar Ibrahim, Xueyan Yang, Dr. Befikadu Legesse, Dr. Alex Combat, Nonka Markova-Nenova, Mary Nthambi, Zhenzhen Hao, Henintsoa Arison, Oliver Schöttker, Dr. Astrid Utte Sturm, Emeline Hily, Marie Majaura, Johanna Götter, Charlotte Gerling, Dr. Regina Neudert, Dr. Dieter Leßmann, Prof. Manfred Wanner, Prof. Marion Martienssen, Prof. Michael Schmidt, Dr. Birte Seffert, Dr. Dmitry Palekhov, Michael Mannel, Prof. Diego Paredes, Prof. Juan Mauricio Castaño, Prof. Ana Patricia Quintana Ramirez, Dr. Elizabeth Montaña Becerril, Dr. David Barkin, Paloma Caloca, Henestrosa Zarate Milton, Ruiz Cervantes Miguel Angel, Soeren Rued, Corinna Kuesel, Dr. Jürgen Baumann, Tobias Reinhardt, Rojo Andres Maurer, Elisabeth Duerr, Anabel Palacios Moreno, Melina Armijo, Dirk Marx, Dr. Werner Würtele, Dr. David Yakubu Anambam, Dr. Eric Ambe Asoh, Dr. Kwaku Apau, parents & siblings, family, and many more.

I also thank the legendary Japanese swordsman Miyamoto Musashi for writing the book of five rings and Kung Fu fighter and actor Mark Dacascos for shooting the documentary “Samurai” on Miyamoto Musashi. Both works have been an indispensable source of motivation for me during the writing of this PhD.

## II. Abstract

Water pollution is a major issue in developing countries. 2.2 of the 2.3 billion people who suffer annually from waterborne diseases live in this part of the world. Moreover, it causes the deterioration of aquatic ecosystems the living of billions of poor people depend on. A major source of water pollution is the discharge of untreated municipal wastewater. On average, cities in developing countries discharge 80-90% of their sewage untreated. Though treatment of municipal wastewater remains a huge challenge in developing countries, the situation is not equally adverse all over the place. Treatment rates vary substantially across localities. From this observation, the question arises what drives and what impairs wastewater treatment in a developing country. No quantitative analysis of this topic has been performed yet at the municipal level in a developing country.

Therefore, this thesis investigates the impact of social factors on municipal wastewater treatment in Mexican municipalities in order to gain insights on what improves wastewater treatment in a developing country. 846 of the 2,456 Mexican municipalities treat a share of their municipal wastewater that ranges from single-digit percentages to full coverage while the majority of municipalities treats no wastewater. The study relies on econometric techniques to scrutinize 10 hypotheses on the relationship between social factors and wastewater treatment. More precisely, it applies binary outcome models to estimate the conditional probability wastewater treatment takes place in a municipality for a sample of 2,290 Mexican municipalities. In addition, it applies the Tobit and Fractional logit model to estimate the percentage of treated municipal wastewater depending on social factors for 425 municipalities.

The thesis identifies geographic spillovers, environmental federalism, institutional aspects like the corporatization of municipal water service, urbanization, per capita income and its distribution as significant influencing factors. A significant effect of education, ethnic heterogeneity, female participation in municipal politics and water scarcity is not found. In addition, the involvement of superior government tiers of a developing country in the funding of municipal wastewater treatment infrastructure seems to mitigate the influence of social factors on wastewater treatment. Based on these findings, the thesis develops policy recommendations to improve municipal wastewater treatment in developing countries.

Keywords: Environmental performance, wastewater treatment, geographic spillovers, environmental federalism, municipal water governance, developing countries, fiscal equalisation.

### III. Abstract (deutsch)

Wasserverschmutzung ist eines der Hauptprobleme in Entwicklungsländern. 2,2 der 2,3 Milliarden Menschen, die jährlich durch kontaminiertes Wasser erkranken, leben in diesem Teil der Welt. Zudem werden aquatische Ökosysteme zerstört, von denen das Überleben von Milliarden armer Menschen abhängt. Eine wichtige Ursache von Wasserverschmutzung ist unbehandeltes Abwasser. Im Durchschnitt entsorgen 80-90% der Kommunen in Entwicklungsländern ihre kommunalen Abwässer unbehandelt. Obwohl die Abwasserbehandlung insgesamt ein drängendes Problem darstellt, ist die Lage nicht überall gleich schlecht. Behandlungsraten variieren erheblich zwischen Gemeinden in Entwicklungsländern. Aufgrund dieser Beobachtung stellt sich die Frage, welche Faktoren die kommunale Abwasserbehandlung in Entwicklungsländern begünstigt und welche sie behindert. Keine quantitative Analyse hat dieses Thema soweit auf kommunaler Ebene in einem Entwicklungsland erforscht.

Deshalb untersucht diese Dissertation den Einfluss sozialer Faktoren auf die kommunale Abwasserbehandlung in mexikanischen Kommunen, um dadurch Einsichten darüber zu gewinnen, was die kommunale Abwasserbehandlung in Entwicklungsländern verbessert. 846 der 2,456 mexikanischen Kommunalkreise behandeln Anteile ihrer Abwässer, die zwischen einstelligen Prozentsätzen und der vollen Abdeckung variieren. Die Mehrheit behandelt kein Abwasser. Die Dissertation verwendet ökonometrische Methoden für die empirische Validierung von 10 Hypothesen über Kausalzusammenhänge zwischen sozialen Faktoren und kommunaler Abwasserbehandlung. Konkret finden binäre Ergebnismodelle Anwendung, um die konditionale Abwasserbehandlungswahrscheinlichkeit für 2.290 mexikanische Gemeinden zu schätzen. Das Tobit- und Fractional-Logit-Modell schätzen darüber hinaus den Anteil behandelter Abwässer in Abhängigkeit von sozialen Faktoren für 425 mexikanische Gemeinden.

Die Dissertation identifiziert geographische Spillover-Effekte, Umweltföderalismus, institutionelle Aspekte wie die Schaffung kommunaler Wasserbetriebe, Urbanisierung, Pro-Kopf-Einkommen und dessen Verteilung als signifikante Einflussgrößen. Ein signifikanter Einfluss von Bildung, ethnischer Heterogenität, Frauenanteil in der Kommunalpolitik und Wasserknappheit wird nicht festgestellt. Zudem scheint die Beteiligung von übergeordneten Regierungsebenen bei der Finanzierung von Abwasserinfrastruktur den Einfluss von sozialen Faktoren zu reduzieren. Auf der Basis dieser Ergebnisse entwickelt die Dissertation Politikempfehlungen für eine verbesserte kommunale Abwasserbehandlung in Entwicklungsländern.

## IV. List of abbreviations

ACOOA	National Water Association of Commercial Departments
AIC	Akaike's information criterion
ANATEC	National Water Association of Technical Departments
ANEAS	National Association of Water and Sanitation Utilities
ANNCA	National Association for a New Water Culture
APAZU	Program of Municipal Water Supply and Sanitation in Urban Areas
BOD	Biochemical oxygen demand
BOD <sub>5</sub>	Biochemical oxygen demand in 5 days
CAN	Mexican National Water Commission
CDI	National Commission for the Development of Indigenous Peoples
CFE	Federal Electricity Commission
CIA	Central Intelligence Agency
CIDAC	Investigation Center for Development
clog-log	Complementary log-log model
CO <sub>2</sub>	Carbon dioxide
COD	Chemical oxygen demand
CONAGUA	Mexican National Water Commission
CONAVI	National Commission of Housing
CONEVAL	The Mexican National Evaluation Council of Policies of Social Development
CR	Criticality Ratio
D.F.	Federal district of Mexico-City
DGAPA	Department for Municipal Water and Sanitation
Dgp	Data-generating process
DOF	Official gazette of the Mexican Federation
EI	Education Index
EKC	Environmental Kuznets Curve
EYSI	Expected Years of Schooling Index
FI	Falkenmark Water Stress Indicator
FONADIN	National Infrastructure Fund
GDP	Gross domestic product
GDP per capita	Gross domestic product per capita
GLM	Generalized linear model
HDI	Human Development Index

HL	Hosmer-Lemeshow test
IDB	Inter-American Development Bank
IGASA	Global Indicator of Access to Basic Water Services
IMTA	Mexican Institute of Water Technology
INAFED	The Mexican National Institution for Federalism and Municipal Development
INEGI	National Statistical Bureau
IPL	International poverty line definition
IRMB	Index of Basic Municipal Regulation Implementation
IV	Instrument variable
IWQ	Index of water quality
IWRM	Integrated Water Resource Management
KC	Kuznets Curve
LAEAC	Water Law of Aguascalientes
LAN	National Water Law
LCEA	Inauguration Law of the State Water Commission of Morelos
LFD	The Federal Duties Law
HL-test	Hosmer-Lemeshow test
LPM	Linear probability model
LR-test	Likelihood-ratio test
Mex\$	Mexican Peso
MLE	Maximum likelihood estimation method
MYSI	Mean Years of Schooling Index
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary least squares estimation method
PEH	State Water Programs
PND	National Development Plan
PNH	National Water Program
POPS	Persistent organic pollutants
PPP	Purchasing-power-parity
PRODDER	Water Rights Refund Program
PROFEBA	Federal Attorney for Environmental Protection
PROMAGUA	Modernization Program for Water Utilities
PROMAGUA	Modernization Program for Water Utilities
PROSANEAR	Federal Program of Wastewater Treatment

PROSSAPYS	Program for the Construction and Rehabilitation of Municipal Water Supply and Sanitation Systems in Rural Areas
PROTAR	Program of Wastewater Treatment
REPDA	Registry of Water Duties
RNM	National Monitoring Network
ROC-curve	Receiver operating characteristic curve
SALUD	Ministry of Health
SARH	Ministry of Agriculture and Hydraulic Resources
SEDESOL	Ministry of Social Development
SEMARNAP	Ministry of the Environment, Natural Resources and Fisheries
SEMARNAT	Mexican Ministry of Environment and Natural Resources
SHCP	Ministry of Finance
SNIM	Mexican National System of Municipal Information
SRH	Ministry of Hydraulic Resources
SS	Suspended solids
TPBS	Toxic, persistent, and bioaccumulable substances
UNDP	United Nations Development Programme in Mexico
UNO	United Nations Organization
UNSTATS	United Nations Statistics Division
US\$	Dollar of The United States of America
USA	United States of America
WB	World Bank

## V. Table of content

I.	Acknowledgements .....	i
II.	Abstract .....	ii
III.	Abstract (deutsch) .....	iii
IV.	List of abbreviations .....	iv
V.	Table of content .....	vii
VI.	List of figures .....	xi
VII.	List of tables.....	xii
VIII.	List of figures – appendix.....	xiii
IX.	List of tables – appendix.....	xiv
1.	Introduction.....	1
1.1	Background.....	1
1.2.	Statement of the problem.....	2
1.3.	Objective and approach of the thesis .....	4
1.4.	Significance and major findings of the study .....	5
1.5.	Structure of the thesis.....	10
2.	Background.....	11
2.1.	Description of the study area .....	11
2.1.1.	Geography and climate .....	11
2.1.2.	Demographics.....	13
2.1.3.	Socioeconomics .....	14
2.1.4.	Politics .....	16
2.2.	Water availability in Mexico .....	18
2.2.1.	Water supply .....	19
2.2.2.	Water consumption.....	20
2.2.3.	Net water availability .....	22
2.3.	Water quality in Mexico .....	24
2.3.1.	Surface water .....	24
2.3.2.	Groundwater .....	28
2.4.	Sources of water pollution .....	28
2.5.	Status quo of wastewater treatment in Mexico .....	31
2.5.1.	Municipal wastewater treatment .....	32
2.5.2.	Industrial wastewater treatment .....	36
2.6.	Summary of chapter 2 .....	37
3.	Municipal (waste)water governance in Mexico .....	39



3.1.	Historic overview .....	40
3.1.1.	Centralization of municipal water governance .....	40
3.1.2.	Decentralization of municipal water governance .....	41
3.1.3.	Corporatization and modernization .....	42
3.2.	Municipal water governance legislation .....	45
3.2.1.	National Legislation .....	45
3.2.2.	Legislation of federal states .....	47
3.2.3.	Municipal legislation.....	48
3.3.	Organizational landscape of municipal water governance .....	49
3.3.1.	The national level .....	49
3.3.2.	The federal state level .....	55
3.3.3.	The municipal level.....	57
3.4.	Summary of chapter 3 .....	59
4.	Literature review: Economic features of wastewater and social drivers of municipal wastewater treatment .....	61
4.1.	Economic features of wastewater.....	62
4.2.	Social drivers of municipal wastewater treatment .....	65
4.2.1.	Per capita income .....	65
4.2.2.	Income inequality .....	70
4.2.3.	Institutional quality .....	77
4.2.4.	Spatial environmental spillovers and proximity.....	86
4.2.5.	Population density and urbanization .....	90
4.2.6.	Education.....	92
4.2.7.	Gender.....	93
4.2.8.	Ethnic heterogeneity .....	96
4.2.9.	Water availability.....	98
4.3.	Summary of chapter 4 and statement of the hypotheses .....	99
5.	Methodology .....	102
5.1.	Specification of the dependent variable .....	103
5.2.	Specification of independent variables and data collection .....	105
5.2.1.	Per capita income .....	105
5.2.2.	Income distribution .....	106
5.2.3.	Institutional quality .....	107
5.2.4.	Spatial spillovers and spatial proximity .....	111
5.2.5.	Population density, concentration and urbanization.....	114
5.2.6.	Education.....	115

5.2.7.	Female participation in local politics.....	117
5.2.8.	Ethnic heterogeneity .....	118
5.2.9.	Water availability.....	120
5.3.	Econometric models selection .....	122
5.3.1.	Binary outcome models.....	122
5.3.1.1.	Logit model.....	125
5.3.1.2.	Probit model.....	126
5.3.1.3.	Complementary log-log model (clog-log).....	127
5.3.1.4.	Linear probability model (LPM).....	128
5.3.2.	Tobit and selection models .....	129
5.3.2.1.	Tobit model .....	129
5.3.2.2.	Fractional logit model.....	132
5.4.	Summary of chapter 5.....	133
6.	Case 1: Binary outcome models and the probability of municipal wastewater treatment.....	135
6.1.	Descriptive statistics.....	135
6.2.	Parameter estimations.....	142
6.3.	Interpretation: Marginal effects.....	148
6.4.	Goodness of fit and prediction quality.....	152
6.4.1.	Mc Fadden's and adjusted R2 .....	152
6.4.2.	Hosmer-Lemeshow goodness of fit test.....	153
6.4.3.	Predicted vs actual outcomes .....	157
6.5.	Model robustness.....	163
6.5.1.	Inclusion of net water availability .....	163
6.5.2.	Modification of independent variables .....	165
6.5.2.1.	Municipal wastewater treatment in nearby municipalities.....	166
6.5.2.2.	Percentage of urbanized population.....	167
6.5.2.3.	Classification of federal states.....	169
6.5.3.	Endogeneity.....	170
6.6.	Summary of chapter 6.....	173
7.	Case 2: Tobit and Fractional logit and the percentage of treated wastewater .....	176
7.1.	Descriptive statistics.....	176
7.2.	Tobit model estimation and interpretation .....	179
7.3.	Goodness of fit and prediction quality.....	181
7.3.1.	Pseudo R2 and Linktest .....	182
7.3.2.	Fitted vs. actual shares of treated wastewater .....	183
7.4.	Tobit model estimation for lognormal data .....	186

7.5.	Fractional logit model estimation .....	187
7.6.	Summary of chapter 7 .....	190
8.	Summary and discussion of results .....	193
8.1.	Empirical findings of the case study .....	193
8.2.	Interpretation of the empirical findings .....	196
8.3.	Shortcomings and future research .....	214
8.4.	Policy recommendations .....	216
9.	Appendix .....	220
9.1.	Appendix tables .....	220
9.2.	Appendix figures .....	273
10.	Bibliography .....	280

## VI. List of figures

Figure 1: Territory of México.....	12
Figure 2: Annual volumes of municipal and industrial wastewater in m <sup>3</sup> /s, 1985-2012 .....	29
Figure 3: BOD <sub>5</sub> loads of municipal and industrial wastewater in Mexico (tons), 2000-12.....	30
Figure 4: Volumes of generated, collected and treated municipal wastewater, 1998-2012.....	32
Figure 5: BOD <sub>5</sub> loads of municipal wastewater in Mexico, 2000-12 .....	34
Figure 6: Municipal wastewater treatment plants in Mexico, 2012 .....	35
Figure 7: Volumes of generated and treated industrial wastewater, 1998-2009.....	36
Figure 8: BOD <sub>5</sub> loads of industrial wastewater in Mexico, 2000-09.....	36
Figure 9: Household incomes and average environmental pollution .....	73
Figure 10: Six measures of contiguity.....	112
Figure 11: Cumulative distribution functions of the logit, probit, and LPM .....	124
Figure 12: Plot of moving average of wastewater treatment and independent variables .....	140
Figure 13: ROC-curve of logit model 1 .....	162
Figure 14: Distribution of share of treated wastewater (186 municipalities), 2010.....	177

## VII. List of tables

Table 1: Types of water consumption subject to abstraction sources in Mexico, 2012 .....	21
Table 2: Criticality Ratios and water stress in Mexican hydrological districts, 2012 .....	23
Table 3: Description of dependent and independent variables, binary outcome models .....	136
Table 4: Summary statistics for dependent and independent variables, binary outcome models ....	136
Table 5: Correlation of wastewater treatment and independent variables, selection.....	138
Table 6: Results of binary outcome models, selection.....	143
Table 7: Sample means of independent variables (model 1).....	149
Table 8: Marginal effects of binary outcome models, selection .....	150
Table 9: Predicted vs. actual outcomes for logit model 1 .....	158
Table 10: Parameters of neighmun with radii of 25, 50, 100 and 1,000 km (logit model 1) .....	166
Table 11: Parameters of urban and urbanII for logit model 1 and 2.....	168
Table 12: gdpicap and eduind parameters of 2005 and 2010 (logit model 1 and 2).....	171
Table 13: Correlation of omitted variables with gdpicap and fracind .....	177
Table 14: Summary statistics, tobit model.....	178
Table 15: Tobit estimation on share of treated municipal wastewater.....	180
Table 16: Marginal effects of tobit model.....	181
Table 17: Linktest on the tobit model .....	182
Table 18: Distribution of fitted and actual treatment shares, if Share_WWT>0, tobit .....	184
Table 19: Distribution of fitted and actual treatment shares, if Share_WWT<0, tobit .....	185
Table 20: Tobit estimation on the logarithm of share of treated municipal wastewater.....	186
Table 21: Fractional logit estimation on percentage of treated wastewater .....	188
Table 22: Distribution of fitted and actual treatment shares, fractional logit.....	189

## VIII. List of figures – appendix

Figure A.1: Surface water quality in Mexico, 1990-2002 and 2003-12 .....	273
Figure A.2: BOD <sub>5</sub> -classification of surface water in Mexico (%), 2003-2012.....	273
Figure A.3: COD-classification of surface water in Mexico (%), 2003-2012 .....	274
Figure A.4: Investment in municipal water by field of application (in Mex\$ bn), 2002-14.....	274
Figure A.5: Investment in municipal water by sector of origin (in Mex\$ bn; %), 2014.....	275
Figure A.6: Plot of moving average of wastewater treatment and log <sub>10</sub> of ind. variables.....	276
Figure A.7: ROC-curve of logit model 2 .....	277
Figure A.8: ROC-curve of probit model 1 .....	277
Figure A.9: ROC-curve of probit model 2 .....	278
Figure A.10: Distribution of share of treated wastewater (425 obs.), 2010 .....	278
Figure A.11: Distribution of ln Share_WWT (425 obs.), 2010 .....	279

## IX. List of tables – appendix

Table A.1: Country ranking of renewable water availability per capita, 2011 .....	220
Table A.2: Country ranking of annual water withdrawal per capita, 2003-2013 .....	221
Table A.3: Country ranking criticality ratio, 2003-2013 .....	222
Table A.4: Wastewater treatment in federal states, 2011.....	223
Table A.5: Investment in municipal water (in Mex\$ MN), 2002-14 .....	224
Table A.6: Investment in municipal water by field of application (in Mex\$ MN), 2002–14 .....	225
Table A.7: CONAGUA programs for wastewater treatment (in Mex\$ mn), 2014.....	225
Table A.8: Distance matrix of Mexican municipalities (in km) .....	226
Table A.9: Correlation of wastewater treatment and independent variables (WWT=1), complete ..	227
Table A.10: Wald test for planind and regind, logit model .....	227
Table A.11: LR-test logit model 1 and 2 .....	227
Table A.12: Results of binary outcome models, complete.....	228
Table A.13: OLS estimation of model 1 .....	229
Table A.14: Logit estimation of model 1 .....	230
Table A.15: Probit estimation of model 1 .....	231
Table A.16: Cloglog estimation of model 1 .....	232
Table A.17: OLS estimation of model 2 .....	233
Table A.18: Logit estimation of model 2 .....	234
Table A.19: Probit estimation of model 2 .....	235
Table A.20: Cloglog estimation of model 2 .....	236
Table A.21: Probit estimation of model 1 with surface.....	237
Table A.22: Probit estimation of model 2 with surface.....	238
Table A.23: Heteroskedastic probit estimation of model 1 .....	239
Table A.24: Heteroskedastic probit estimation of model 2 .....	240
Table A.25: Logit marginal effects of model 1.....	241
Table A.26: Logit marginal effects of model 2.....	242
Table A.27: Probit marginal effects of model 1.....	243
Table A.28: Probit marginal effects of model 2.....	244
Table A.29: Heteroskedastic probit marginal effects of model 1.....	245
Table A.30: Heteroskedastic probit marginal effects of model 2.....	246
Table A.31: HL-test logit model 1, 10 groups .....	247
Table A.32: HL-test logit model 2, 10 groups .....	247
Table A.33: HL-test probit model 1, 10 groups .....	247
Table A.34: HL-test probit model 2, 10 groups .....	247
Table A.35: Wald tests for interaction in logit model 1 .....	248
Table A.36: HL-test logit model 1 with interaction, 10 groups .....	248
Table A.37: HL-test logit model 2 with interaction, 10 groups .....	248
Table A.38: HL-test probit model 1 with interaction, 10 groups.....	249
Table A.39: HL-test probit model 2 with interaction, 10 groups.....	249
Table A.40: HL-test logit model 1 with interaction, 4 groups .....	249
Table A.41: Logit estimation of model 1 with interaction terms .....	250
Table A.42: Logit estimation of model 2 with interaction terms .....	251
Table A.43: Probit estimation of model 1 with interaction terms .....	252
Table A.44: Probit estimation of model 2 with interaction terms .....	253
Table A.45: Predicted vs actual outcomes in logit model 2 .....	254

Table A.46: Predicted vs actual outcomes in probit model 1 .....	254
Table A.47: Predicted vs actual outcomes in probit model 2 .....	255
Table A.48: Predicted vs actual outcomes in logit model 1 with interaction.....	255
Table A.49: Logit estimation of model 1 with watavail and urban (1,201 obs.) .....	256
Table A.50: Logit estimation of model 1 without watavail (1,201 obs.) .....	257
Table A.51: Logit estimation of model 1 with watavail and without urban (1,201 obs.).....	258
Table A.52: Logit estimation of model 1 with neighmun50 (radius=50km).....	259
Table A.53: Logit estimation of model 1 with neighmun100 (radius=100km).....	260
Table A.54: Logit estimation of model 1 with neighmun1000 (radius=1,000km).....	261
Table A.55: Logit estimation of model 1 with neighmun250 (radius=250km).....	262
Table A.56: Logit estimation of model 1 with neighmun500 (radius=500km).....	263
Table A.57: Logit estimation of model 1 with urbanII.....	264
Table A.58: Logit estimation of model 2 with urbanII.....	265
Table A.59: Logit estimation of model 1 with state categories.....	266
Table A.60: Logit estimation of model 2 with state categories.....	266
Table A.61: Logit estimation of model 1 with gdpicap2005 and eduind2005 .....	267
Table A.62: Logit estimation of model 2 with gdpicap2005 and eduind2005 .....	268
Table A.63: Logit regression of model 1 with gdpicap2005 and without eduind .....	269
Table A.64: Probit estimation of model 1 with IV registered cars per 1,000 inhab.....	270
Table A.65: Linktest of fractional logit .....	271
Table A.66: Test statistic for tobit .....	271
Table A.67: Test statistic for fractional logit .....	271
Table A.68: Fractional logit estimation without gdpicap outlier.....	272
Table A.69: Tobit estimation without gdpicap outlier .....	272



# 1. Introduction

## 1.1 Background

In recent decades, the issue of water pollution has become pressing as more than 50% of the global freshwater bodies and coastal areas have become seriously polluted (Vigneswaran and Sundaravadivel, 2004; Mara, 2003). Eventually, this adverse development feeds back to society as deteriorating water quality increases seriously the risks to human health (Corcoran et al., 2010). Worldwide, 2.3 billion people suffer from waterborne diseases (Jalan and Ravallion, 2003; Wang and Yang, 2016). More than five million people die annually as a result of getting in contact with contaminated water. On average, polluted water causes ten times more fatalities every year than wars (UNO, 2002; Azizullah et al., 2011).

The most common groups of pollutants are pathogens like bacteria, viruses and protozoas, inorganic pollutants like acids and toxic metals, anions and cations like nitrates, phosphate, sulphates, and organic pollutants like oils and greases. If these components exceed certain thresholds in water, they pose a serious risk to the health of human beings (Azizullah et al., 2011). Pathogens cause potentially life threatening diseases like hepatitis, cholera, dysentery, cryptosporidiosis, giardiasis, diarrhoea and typhoid (Jalan and Ravallion, 2003; Cutler and Miller, 2005; WB-SCEA, 2006; Roushdy et al., 2012; Wang and Yang, 2016). In particular, inorganic pollutants increase the carcinogenic risk (Morales-Suarez-Varela et al., 1995; Lin et al., 2000; Ebenstein, 2012; Lu et al., 2015; Wang and Yang, 2016).

Furthermore, pollutants do severe harm and damages to ecosystems and the environment (Azizullah et al., 2011). On the one hand, substances that are toxic to humans potentially also threaten other creatures (Duke et al., 2005; Lindsay and Dubey, 2009; Corcoran et al., 2010). On the other hand, the environment suffers from nutrient pollution. Particularly from the presence of anions and cations eutrophication arise. Eutrophication describes the phenomenon of the prevalence of plant biomass in freshwater and coastal aquatic ecosystems mainly due to the increased discharge of phosphorus and nitrogen into soil and water bodies (Glibert, 2008, Nyenje et al., 2010; Corcoran et al., 2010; Malik et al., 2015). Algae proliferation and the increase in the population of other aquatic microorganisms can result in the consumption of all available oxygen and, in consequence, to the spreading of aquatic dead zones (Diaz and

Rosenberg, 2008; Rockström et al., 2009). Eutrophication is nowadays a major global issue (Corcoran et al., 2010). Worldwide, 245,000 km<sup>2</sup> of coastal areas have been turned into dead zones to the present day (Diaz and Rosenberg, 2008).

Martínez et al., (2007) estimate that coastal ecosystems provide annually services that are worth US\$ 25 trillion to humanity. Thus, the spreading of dead zones and the deterioration of aquatic ecosystems adversely affect human wellbeing by causing huge economic losses in sectors like the recreational and fishing industry, shoreline protection, and food security (Martínez et al., 2007; Lange and Jiddawi, 2009; Jenkins et al., 2009; Nelleman et al., 2009; Corcoran et al., 2010; Hernández-Sancho et al., 2010).

Beside contaminated runoffs from agricultural land use, forestry and livestock farming, untreated wastewater is the major source of water pollution and threat to water quality (Gilbert, 2008, Nyenje et al., 2010; Azizullah et al., 2011; Malik et al., 2015). It is estimated that worldwide every day about 2 million tons of untreated sewage are dumped into waters and soil (Azizullah et al., 2011). Wastewater is defined as water that has been used by either households, industries or commercial and public entities and that is of no further use without prior treatment due to its level of contamination (Raschid-Sally and Jayakody, 2008; UNSD, 2012; Malik et al., 2015). If collected in municipal sewage systems, wastewater is classified as municipal wastewater. Wastewater that is discharged directly into the environment and that originates from purely industrial sources like the mining or petrochemical sector is specified as industrial wastewater (CONAGUA; 2015a).

## **1.2. Statement of the problem**

To reduce or eliminate negative effects on human wellbeing and the environment improving and increasing municipal wastewater treatment becomes an essential task (IOC/UNESCO, 2011). This holds in particular true for developing countries. The big majority – about 2.2 billion – of the 2.3 billion human beings that are yearly affected by waterborne diseases live in this environment (Jalan and Ravallion, 2003; Azizullah et al., 2011). Treatment of municipal wastewater remains a big challenge in most parts of the underdeveloped world. On average, cities in developing countries continue to discharge 80-90% of their sewage untreated into the aquatic environment (Senzia, 2003; UNEP, 2010; Miller, 2013). It is estimated that even

emerging economies treat only 25% of collected municipal wastewater properly (Baum et al., 2013; World Water Development Report 2015). In contrast, shares of treated wastewater are relatively high in more developed countries. Typically, 80% to 100% of municipal wastewater is treated (UN Water, 2008; Corcoran et al., 2010; Malik et al., 2015; Wang and Yang, 2016). The associated small number of victims of waterborne diseases emphasises the importance of a proper treatment of wastewater. At the same time, treatment rates of municipal wastewater vary substantially within developing and emerging countries. While the majority of municipalities in a developing country commonly do not treat any wastewater, a significant variance in treatment rates is frequently observed among municipalities that engage in municipal wastewater treatment (UNSD, 2011; OECD, 2013; FAO, 2013; Pinsent Masons Water Yearbook, 2013; Malik et al., 2015). In this context, the question arises what drives and what impairs wastewater treatment in a developing country.

In order to answer this research question, the thesis investigates the case of Mexico. This country faces severe issues of water quality and challenges in municipal wastewater treatment that are rather representative for a developing and emerging economy. In Mexico, water pollution is one of the major causes of environmental deterioration (SEMARNAT, 2009). Internationally, Mexico ranks poorly in terms of surface water quality as it occupies only the 106<sup>th</sup> position out of evaluated 122 countries (UN, 2003; Aboites et al., 2008). In addition, underground water resources are reported to be heavily contaminated (Jiménez Cisneros et al., 2007; Hansen et al., 2011). Like in many other developing countries, a major pollution cause is the discharge of untreated wastewater (SEMARNAT, 2008 and 2009). By 2009, only 37.1% of municipal wastewater received treatment (CONAGUA, 2011a). At the same time, treatment levels differ substantially at the subnational level. By 2010, 846 of the 2,456 Mexican municipalities treated a share of their municipal wastewater that ranged from single-digit percentages to full coverage. The majority of municipalities treated no municipal wastewater (CONAGUA, 2010b and 2013b). This observed variety in treated shares across municipalities qualifies Mexico as a suitable study case.

### **1.3. Objective and approach of the thesis**

The aim of the thesis is to identify drivers and obstacles that cause or impair the treatment of municipal wastewater in a developing country and gain insights that allow to develop policy recommendations for an improved wastewater treatment performance in developing countries.

To answer this research question, the thesis assumes the perspective of economic science. In particular, it borrows its views from the discipline of environmental economics. However, also other important fields of the economic domain like behavioural economics, the economics of public good provision, political economy and the economic concept of external effects are recurred to. Thus, the research approach of this thesis might be located best at the borderline between the particular field of environmental economics and general economics.

Generally, the management of wastewater does not happen in a social vacuum. Treating wastewater is not only a technical and management issue engineers and technocrats have to solve (Molle et al., 2009; Watson et al., 2009; Pacheco-Vega, 2013; Woodhouse and Muller, 2017). Prior to any technical implementation, the will of a society to treat wastewater must manifest and find its expression in respective political decisions. From there, the insight follows that certain characteristics of a society may be crucial to trigger or impede the treatment of municipal wastewater.

Accordingly, the thesis develops 10 hypotheses on socioeconomic, demographic and institutional features of Mexican municipalities that may foster or impair the treatment of municipal wastewater. It draws mainly on economic research that explicitly investigates the link between characteristics of a society and its environmental performance (e.g. Dinda, 2004; Hosseini and Kaneko, 2013; Wong and Lewis, 2013; Sundström and Mc Right, 2013; Berthe and Elie, 2015).

To scrutinize the validity of the 10 hypotheses the thesis applies econometric analysis. The thesis measures municipal wastewater treatment performance of a Mexican municipalities in two different manners: 1) as the probability municipal wastewater treatment takes place in a Mexican municipality, and 2) as the estimated percentage of treated municipal wastewater in a Mexican municipality. Lack of data at the municipal level impairs adopting an econometric approach that considers directly the actual share of treated municipal wastewater. In contrast,

data on whether municipal wastewater treatment takes place or not in a municipality is available for almost all of the 2,456 Mexican municipalities. In addition, official sources provide estimations of the percentage of treated municipal wastewater for 511 Mexican municipalities. To estimate the conditional treatment probability the thesis relies on binary outcome models, in particular on Standard Logit and Probit. Supplementary runs use the Linear Probability Model (LPM), Complementary Log-Log (Cloglog), and Heteroskedastic Probit. To regress the estimated percentage of treated municipal wastewater on social characteristics of Mexican municipalities, the Tobit and Fractional Logit model are applied.

#### **1.4. Significance and major findings of the study**

Surprisingly, relatively little quantitative research has been performed to explain differences in wastewater treatment performance among countries, regions or localities (Grossman and Krueger, 1995; Liu et al., 2007; Song et al., 2008; Shua et al., 2012). To my best knowledge, none of the previous quantitative studies have investigated yet the relationship between social characteristics and municipal wastewater treatment performance at the municipal level in a developing country.

Overall, the results of the empirical analysis supports the hypothesis that socioeconomic, demographic, and institutional characteristics matter. Differences in the social structure of a Mexican municipality explain a good deal of the observed variation in municipal wastewater treatment performance. More precisely, the thesis finds municipal wastewater treatment performance to spill over among neighbouring municipalities, i.e. municipalities whose neighbours treat municipal wastewater are more likely to treat also their wastewater. Mechanisms like competition, learning and mimicking effects may explain this phenomenon (Simmons et al., 2006). Several studies have scrutinized the existence of geographical spill overs of environmental performance (Maddison, 2006 and 2007; Verdolinia and Marzio, 2011; Costantini et al., 2013). However, to my best knowledge, no study has investigated yet the phenomenon of the geographical spillover of successful environmental and sanitation policies in developing countries at the local level. The findings of the study may serve as an interesting starting point

of further research on how the implementation of sanitation flagship projects at local levels in developing countries may catalyse environmental protection in a region.

Secondly, institutional factors like the quality of the general administration of a municipality and the corporatization of public municipal water service provision are confirmed to foster municipal wastewater treatment performance significantly. In the last two decades, 457 of the 2,456 Mexican municipalities have outsourced the administration of municipal water service from the general municipal administration to public water utilities (CONAGUA, 2014b). The aim of this measure has been to foster the institutional soundness of municipal water administration by creating a more managerial and professional orientation, and, above all, by shielding the institution from corrupting political influence (Barkin, 2011; Herrera and Post, 2014). Though many structural deficiencies in the efficient management of the municipal water service continue to exist after corporatization was initiated in the early 1990s in Mexico (Quadri de la Torre, 2008; Saltiel, 2008; Barkin, 2011), public water utilities seem to be able to perform better in municipal wastewater treatment than non-outsourced municipal water supply departments. This empirical finding might be of particular interest for a nascent scientific debate on the outcome of corporatization and outsourcing of public services to public enterprises (Herrera and Post, 2014). The few empirical studies performed on this topic produced mixed results (Granados and Sánchez, 2014). The Mexican case may be identified as a relative success story that gives empirical credit to the view that corporatization has the potential to improve the quality of a public service.

Thirdly, the belonging of a municipality to a particular Mexican federal state influences largely its performance in municipal wastewater treatment. This empirical outcome suggests that environmental federalism and decentralization diversify environmental performance. This hypothesis features prominently in the scientific debate on decentralization and its effect on environmental performance (List and Gerking, 2000; Millimet, 2003; Sigman 2008, Herrera and Post, 2014). To my best knowledge, no study has investigated yet the particular effect of decentralism on the service provision of municipal wastewater treatment at the subnational level in a developing country. Differences in the quality of sanitation governance of federal states may explain why the belonging of a municipality to a particular Mexican federal state impacts significantly its wastewater treatment performance. Future research may perform a more detailed, qualitative interstate comparison of water governance in order to gain further

insights in institutional and organizational settings that facilitate municipal wastewater treatment in a developing country.

Fourthly, the involvement of superior government tiers is crucial to align developments in the sanitation sector among lower tier jurisdictions in a developing country. Frequently, it is beyond the financial, administrative and technical capacity of municipalities and their administrations in a developing country to establish and operate municipal wastewater infrastructure by themselves. For this reason, they apply, like in Mexico, for funding the national government or the governments of other superior governmental layers provide (Briceño, 2008; Olivares and Sandoval, 2008; Peña et al., 2013; SEMARNAT, 2014a; CONAGUA, 2015a). Yet, the existence of these funding mechanisms seems to be a main reason why the econometric models, applied in this thesis, are not able to explain all of the observed variance in municipal wastewater treatment performance. To some extent, the selection criteria of national and federal state funding programs for benefiting municipal entities differ from social characteristics that predestine municipalities to treat municipal wastewater or not. For instance, some programs cater exclusively or partly the needs of marginalized or rural population. Other programs support municipalities with increased percentages of indigenous population (Olivares and Sandoval, 2008; Peña et al., 2013; CONAGUA, 2015a and 2015b). Usually, economic research considers those social characteristics to impact adversely the environmental performance of a community. Generally, the findings of the thesis lend empirical support to the hypothesis that fiscal equalisation and financial compensation from superior governmental layers are important mechanisms to overcome or, at least, mitigate identified deficiencies at the municipal level (Ring, 2002; Boadway and Shah, 2007; Santos et al., 2012). This hypothesis has been relatively little scrutinized empirically (Wunder et al., 2008; Santos et al., 2012).

Fifthly, the empirical analysis confirms a positive significant influence of per capita income, urbanization and unequal income distribution on municipal wastewater treatment performance. In economic research, it is a widely held view that richer people have a higher demand for environmental quality (Shafik, 1994; Scruggs, 1998; Dinda, 2004; Bo, 2011). Consequently, they seem to urge municipal administrations more vigorously to internalize negative externalities and to treat municipal wastewater to provide a clean environment as a local public good. Moreover, a more affluent municipal population is more likely to be able and willing to con-

tribute financially, e.g. as tax or service fee payers, to the establishment and operation of municipal wastewater treatment infrastructure. High degrees of urbanization, in turn, seems to require the intensification of treatment efforts to offset pollution which is usually, *ceteris paribus*, the higher, the higher the population density in a given area (Stern, 2005; Wong and Lewis, 2013). In addition, economies of scale are present in the service of municipal wastewater treatment as the construction, operation and maintenance of a centralized wastewater treatment infrastructure contain a substantial fraction of fix costs (Parkinson & Tayler, 2003; Massoud et al., 2009). Thus, a higher number of population in a given area seems to be crucial for the funding of municipal wastewater treatment infrastructure. In this case, more individuals may share in the associated costs reducing in this way the per capita financial burden to affordable levels. Finally, the empirical finding of a significant positive correlation between unequal income distribution and wastewater treatment performance supports the following argumentation: 1) Richer strata of society have higher preferences for environmental quality than poorer parts (Shafik, 1994; Scruggs, 1998; Dinda, 2004; Bo, 2011). 2) Rich people are better able to exert political influence in unequal societies to implement policies that meet their preferences (Roemer, 1993, Scruggs, 1998, Berthe and Elie, 2015). Accordingly, affluent people favour municipal wastewater treatment and lobby successfully in the political arena of a municipality for its implementation. This might be possible as lower classes tend to copy attitudes and behaviour of more dominant parts of society (Roemer, 1993; Berthe and Elie, 2015). Moreover, the interests of the rich might coincide with the general preference of a relative poor median voter in unequal societies for higher expenditures on public goods (Meltzer and Richard, 1981). Hence, a poor median voter may support municipal policies that envisage a clean living environment and municipal wastewater treatment. However, caution should be exercised with this interpretation as the GINI coefficients after taxes and transfers of Mexican municipalities do not vary greatly. In consequence, income distribution may not have a great power in explaining differences in treatment performance in the particular case of Mexico.

Sixthly and lastly, the thesis finds no empirical support for a significant direct influence of education, ethnic homogeneity, female participation in municipal politics, and water availability on municipal wastewater treatment performance. Theoretically, one assumes that educated people know the risk untreated wastewater poses to the human health and environment. Thus, they should actually prefer to see municipal wastewater to be treated in their living



environment (Munasinghe, 1999; Bimonte, 2002; Meyer, 2015). In turn, homogeneity in the ethnic composition may promote social cohesion which may allow for a better cooperation to provide public goods and to reduce the risk to externalize harm on other parts of society (East-erly and Levine, 1997; Alesina et al., 1999 and 2003; Alesina and La Ferrara, 2005). In addition, female participation in municipal politics may influence positively municipal wastewater treatment performance as social norms encourage women to be generally more cooperative and to assume the role of caregivers and nurturers in the family and society (Blocker and Eckberg, 1989; Mc Stay and Dunlap, 1983; Mohai, 1992; Hunter and Hatch, 2004; Torgler and García-Valiñas, 2007). As such, they are considered to assume a view on the world that focuses more on relationships in society and maintenance of life in general which includes the conservation of the environment (Mc Stay and Dunlap, 1983). One may argue that municipal policies made by women may reflect this general attitude. Finally, if water availability is limited the recycling of used water might become a viable economic strategy (Zetland, 2011). Reusing municipal wastewater requires prior treatment to ensure adequate water quality though (Devia et al., 2007; Boland Angelakis and Gikas, 2014).

An explanation for the insignificance of education and ethnic homogeneity may be that they affect municipal wastewater treatment performance indirectly through their interrelation with per capita income. On average, less educated people and ethnic minorities are poorer. In particular the link between per capita income and education has been validated to be close (Zanden et al., 2014). Similarly, according to the empirical outcomes of this thesis female participation in municipal politics has only a significant positive influence on municipal wastewater performance once its interaction with GDP per capita is controlled for in the applied econometric regression models. On the other hand, the insignificance of reduced water availability as a driver of municipal wastewater treatment may be explained by wrong incentives the Mexican national water legislation provides to municipalities that face water scarcity. Bad data quality might be another reason as the used data reflects only roughly the real degree of water scarcity on the ground.

The empirical findings of the thesis may also allow to develop policy recommendations. Due to the diagnosed differences in the institutional quality of sanitation governance of federal states one may propagate the establishment of closer and more institutionalized links among municipal water administrations to facilitate or foster learning and knowledge spill overs. In

addition, the selection criteria of aid programs of superior governmental tiers may be fine-tuned to target municipalities that are in particular need of support due to their adverse social characteristics. Finally, the promotion of sanitation flagship projects in regions of developing countries where municipal wastewater treatment does not take place might trigger a region-wide domino effect due to the spatial spillover of successful environmental policies.

## **1.5. Structure of the thesis**

The structure of the thesis is as follows: Chapter 2 gives an overview of important geographic, demographic and socioeconomic features of Mexico. In addition, it provides information on the water availability and quality, and the status quo of municipal wastewater treatment in quantitative terms. Chapter 3 describes municipal (waste)water governance and the corresponding institutional landscape in Mexico in historic, legislative and organizational terms. Based on the heterogeneity across Mexican municipalities, observed in chapter 2 and 3, and a thorough review of the economic literature on the causal link between social characteristics and environmental performance, chapter 4 develops 10 hypotheses on social characteristics of municipalities possibly affecting municipal wastewater treatment performance in a developing country. Chapter 5 selects the econometric regression models the thesis applies to scrutinize the derived hypotheses empirically. In addition, it specifies municipal wastewater treatment performance and the social characteristics of a municipality as measurable dependent and independent variables. Following, chapter 6 and 7 perform regression analyses on two different indicators of municipal wastewater treatment performance: 1) The probability wastewater treatment takes place in a municipality, and 2) the estimated percentage of treated municipal wastewater. Chapter 8 summarizes the empirical findings of the thesis and draws conclusions on what factors drive municipal wastewater treatment in a developing country. In addition, it links the thesis' empirical findings with the general economic research on environmental performance. Lastly, a brief outlook on future research topics, shortcomings of the thesis' approach and policy recommendation are given.

## **2. Background**

Chapter 2 gives a detailed overview over socioeconomic, demographic, and geographic aspects of Mexico and the Mexican society. The aim of this background chapter is to get a general idea about the environment within which municipal wastewater treatment takes place or not in Mexico. Attention is also paid to what extent those aspects vary at the municipal level as observed heterogeneity in the social structure of Mexican municipalities may help to identify potentially important drivers and obstacles for municipal wastewater treatment in a developing country. Thus, the descriptions of the study case in chapter 2 lay the foundations for the development of hypotheses in the proceeding chapters of the thesis.

Chapter 2 is structured as follows: Subchapter 2.1 provides information on important geographic, socioeconomic and demographic features and portrays Mexico as a rather typical emerging developing country. Subchapter 2.2 discusses the status quo of water availability and water consumption patterns in order to get an impression to what extent water scarcity constitutes a pressing issue in different regions of the country. In addition, subchapters 2.3 and 2.4 summarize the status quo of water quality of surface and underground water and the major sources of water pollution. Following, subchapter 2.5 investigates the status quo of wastewater treatment in Mexico in quantitative terms. Subchapter 2.6 summarizes the chapter's findings and links them to the overall structure of the thesis.

### **2.1. Description of the study area**

#### **2.1.1. Geography and climate**

With an extension of 1,964,375 km<sup>2</sup> the United Mexican States – so the official name of Mexico<sup>1</sup> – rank 13<sup>th</sup> in the list of the world's biggest countries, right behind the Democratic Republic of Congo and Saudi Arabia, and closely followed by Indonesia. Its exact location is between the latitudes of 32° 43' 06" North and 14° 32' 27" North and the longitudes of 86° 42' 36" West and 118° 22' 00" West being roughly divided in the middle by the Tropic of Cancer (latitude of

---

<sup>1</sup> In the following, the thesis uses the terms 'Mexico' and 'United Mexican States' indiscriminately.

23° 27' North) (CONAGUA, 2012a). Figure 1 depicts the territorial extension of the United Mexican States.



**Figure 1: Territory of México**

Source: © OpenStreetMap-Contributors. [Online]. Available: <http://www.openstreetmap.org/copyright> (Accessed 27 November 2017 at <http://www.openstreetmap.org/#map=5/24.187/-101.646>).

In the north, Mexico borders on The United States of America (USA), in the south and south-east, on Guatemala and Belize. 72.2% of the external borders are surrounded by sea, with 50.8% by the Pacific in the west and 21.4% by the Atlantic (Gulf of Mexico and Caribbean Sea) in the east. Altitude levels range from sea level to 5,610 meters whereby the country's average elevation is 1,500 meters. In north-south direction, the mountain ranges Sierra Madre Oriental and Sierra Madre Occidental traverse the country dividing it into three major regions: The Mexican Altiplano (plateau in English) in the centre which is further limited by the cordillera of Sierra Madre del Sur in the south, and the eastern and western lowlands in the coastal areas.

In addition, Mexico is divided into three main climate zones. Whereas almost all of the country's northern half – including the central highlands as well as the Peninsula of Baja California

– falls into the classification of subtropical, (semi-)arid zones, most parts of the southern half – including the Peninsula of Yucatan, the Mexican Isthmus and the southern pacific coastal area – classify as hot and humid tropical zones. Frequently, subtropical and tropical zones are separated by stretches with tempered climate, mainly located along the west side of the Sierra Madre Occidental, the east side of Sierra Madre Oriental, and in central Mexico. Apart from that, small islands with cold climate exist in the Mexican highlands. In total, 51.1% of the national territory constitute arid subtropical zones, 25.9% hot and humid tropical zones, 23% tempered zones, and merely 0.01% cold zones (INEGI, 2015a).

### 2.1.2. Demographics

According to most recent census data, Mexico's population amounted in 2010 to about 112.5 million (INEGI 2010). Since 1930 and 1950, when only 16.5 million and 26 million people lived on Mexican soils, population numbers multiplied by almost 580% and 440%. The increasing trend is expected to continue in the future. Official statistics estimate a population of about 121 million for 2015. Based on this number, Mexico ranked 12<sup>th</sup> in the list of the world's most populated countries in 2015 (CONAPO, 2015; CIA, 2015a).<sup>2</sup>

Over the 20<sup>th</sup> century, Mexico transformed from a rural to an urban society due to migration and higher reproduction rates in urban areas (CEPAL, 2012). While in 1900 only 28.3% of the population lived in urban areas, this share increased to 50.7% in 1960 and 76.8% in 2010 (INEGI, 2011; SEMARNAT, 2013).<sup>3</sup> Correspondingly, rural population grew 0.7% annually whereas urban areas 3.1% from 1950 to 2010. As a result 26 million Mexicans lived in 2010 in rural and 86.5 million in urban areas (INEGI, 1950, 1970, 1990, 2000, 2010). The majority of urban population concentrates in 59 metropolitan areas (*zonas metropolitanas* in Spanish).<sup>4</sup> While metropolitan areas occupy only 8.7% of the national territory they harbour 56.8% – i.e. 63.8 million people – of total population. In contrast, peasant population lives dispersed in 170,000 villages (SEMARNAT, 2013).

---

<sup>2</sup> The European Union (EU) is included in this ranking as a federation that homes the worldwide third biggest population.

<sup>3</sup> Generally, cities and towns with 2,500 or more inhabitants are considered as urban areas.

<sup>4</sup> A metropolitan area is defined as an intermunicipal agglomerations of at least 50,000 inhabitants or as a municipality with a minimum population of 1 million (Sedesol et al., 2012).

Beside the urban-rural divide, the Mexican society comprises several ethnicities. Worldwide, Mexico has the 11<sup>th</sup> biggest indigenous population (CIA, 2015a). According to the official population census of 2010 (INEGI, 2010), 60% of the Mexican population are mestizos, 10% indigenous while 29% are of European and about 1% of African descent. The population composition of Mexico is the result of its particular history. The mestizos are the outcome of the cultural melting of the rich indigenous cultures of the Aztec, Maya, Olmec, Toltec, Teotihuacan, and Zapotec and the European immigration, mainly from Spain, after the colonialization of the Mexican territory by the Spanish Empire. Afro-Mexicans are mainly the descendants of slave communities (Encyclopædia Britannica, 2017). 6.9% of the population speak indigenous languages (INEGI, 2010). Most of indigenous people live in rural municipalities of the central federal states of Puebla, Veracruz, Hidalgo, San Luis Potosí, and Guerrero, or of the southern federal states of Oaxaca, Yucatán and Chiapas. In addition, also some northern states like Sonora and Sinaloa home ethnic minorities. At the municipal level, the percentage of indigenous population in total municipal population vary from 0% or single digit percentages in most municipalities to up to 100% in few cases (INEGI, 2010).

### **2.1.3. Socioeconomics**

With a gross domestic product (GDP) of US\$<sup>5</sup> 1.3 trillion and a per capita GDP of US\$ 10,325 (at current prices in 2014), the World Bank classifies Mexico as an upper middle income country. In terms of overall GDP, Mexico ranked 15<sup>th</sup> on a global scale in 2014, in terms of per capita GDP 68<sup>th</sup>. Within Latin America, only Brazil generates a higher GDP. However, in terms of per capita GDP, Mexico is only slightly above the region's average of ca. US\$ 9,900 in 2014 and lags behind countries like Chile, Argentina, Panama, Brazil, and Costa Rica (World Bank, 2015a). At the municipal level, per capita income varies substantially across Mexico. While GDP per capita is about US\$ 8,700 in an average municipality, per capita income is only about US\$ 2,400 in the poorest and as high as US\$ 47,000 in the richest municipality. Mainly due to the oil wealth off the east coast of Mexico some of the municipalities located in this region have a much higher per capita income than the rest of the country (INAFED, 2015).

---

<sup>5</sup> I use the denomination in US Dollars instead of Mexican Pesos as this may help to facilitate a better understanding for the international reader of the thesis.

From 1961 to 2014, real GDP and real per capita GDP grew by annual rates of 4.1% and 2.8%, respectively. Consequently, a good share of economic growth resulted in an improved average living standard and was not merely due to ongoing population growth. Economic development has been mainly industry and manufacturing, and partly service sector driven. From 1965 to 2014, their respective shares in Mexican GDP increased from 26.8% to 34.4%, and from 59.5% to 62.3%. In contrast, agriculture played no significant role as its share decreased from 13.7% to 3.3% in the same period (World Bank, 2015a).

As part of Latin America, Mexico belongs to the world region with the most uneven income and wealth distribution. Accordingly, Mexico had a rather high GINI coefficient of 48.01 after taxes and transfers in 2012.<sup>6</sup> Based on World Bank estimations, only 7 countries reported for that particular year higher GINI coefficients after taxes and transfers – all of them located in Latin America with Honduras (57.4) and Haiti (60.79) heading the list. By comparison, European countries have the most equal income distribution after taxation and transfers with countries like Norway and Slovenia scoring 25.90 and 25.59 (World Bank, 2015b). There is also variation among Mexican municipalities. Municipalities report GINI coefficients after taxes and transfers that range from as low as 29 to as high as 59 (CONEVAL, 2015).

The high Mexican GINI coefficient after taxes and transfers is also mirrored in diverging income shares held by the highest and lowest 10% of the Mexican population aggregating to 38% and 2% respectively. According to the international poverty line definition (IPL), 2.7% of the Mexican population lived in extreme poverty and 10.3% in poverty in 2011 (World Bank, 2015c).<sup>7</sup> In addition, the Mexican National Evaluation Council of Policies of Social Development, CONEVAL, classifies 21 million Mexicans (19%) as being exposed to alimentary poverty, and 58 million (51%) as suffering from material poverty in 2010 (CONEVAL, 2015; SEMARNAT, 2013).<sup>8</sup>

---

<sup>6</sup> The GINI coefficient measures inequality in relation to two extreme points – 0 and 100. A Gini coefficient of 0 represents the extreme of income perfectly equally distributed in a society, and the coefficient of 100 the extreme of income perfectly unequally distributed, i.e. the richest person has all income of his or her disposal. Generally, two types of the GINI coefficient are distinguished: before and after taxes and transfers. While the GINI coefficient before taxes and transfers measures how the income is distributed before the state gets involved in the allocation of the resources of an economy, the GINI coefficient after taxes and transfers indicates the income distribution after the intervention of the state. Throughout, the thesis refers to the GINI coefficient after taxes and transfers.

<sup>7</sup> According to IPL, people are extremely poor if they have at their disposal less than US\$ 1.90, and poor if they have less than US\$ 3.10 \$ a day at purchasing power parity (PPP) in 2011 prices (World Bank, 2015c).

<sup>8</sup> CONEVAL defines alimentary poverty as a person's inability to purchase the basic Mexican food basket, and material poverty as a person's inability to satisfy his or her demand on basic food, health, clothing, living, transport, and education (CONEVAL, 2015).

In terms of overall social development, Mexico ranks currently 74<sup>th</sup> in the list of most developed countries with a value of 0.75 in the Human Development Index (HDI) of the United Nations Development Programme UNDP (UNDP, 2015). The HDI combines the measurements of achievements in the particular fields of health, education and material wellbeing into a single value between 0 and 1 whereby values closer to 1 represent better living conditions. The health dimension is assessed by life expectancy at birth, the education dimension by mean of years of schooling for adults aged 25 years and more and expected years of schooling for children at school entering age. Material standard of living is measured by gross national income per capita (UNPD, 2015).

As of average life expectancy at birth, Mexico ranked with 74.4 years (72.1 for men and 77.5 for women) 78<sup>th</sup> on an international comparison in 2014. Overall, last decades have seen constant progress as in 1930 life expectancy was only about 34 years (INEGI, 2015b; WHO, 2015; CIA, 2015b). With regard to education, expected school attendance for Mexican children at school entering age was 13.1 years in 2014 while the mean of years of schooling for Mexican adults aged 25 years and more was, like in previous years, relatively low with only 8.5 years. This means that internationally Mexico ranks in the middle in terms of education (UNPD, 2015). Within the country, the education level varies at the municipal level. While, for instance, delegations of the Federal District of Mexico-City perform outperform the national average by far, several municipalities particularly in southern federal states perform rather poor in a national comparison (PNUD, 2014).

#### **2.1.4. Politics**

After an almost a century lasting struggle between federalists and centralists in the aftermath of independence from Spain in 1821, the Constitution of 1917 (*La Constitución de 1917*; official name: *Constitución Política de los Estados Unidos Mexicanos* in Spanish) constitutes Mexico as a federal republic with the official name of United Mexican States (*Estados Unidos Mexicanos* in Spanish). Articles 43 and 115 of the constitution distinguish three governmental tiers: the federation, states, and municipalities (*la Federación, los Estados and los Municipios* in Spanish). Generally, a tier is defined as a governmental layer that disposes of a political executive (Treisman, 2002). To date, Mexico consists of 31 federal states and the federal district of Mexico-City (*Distrito Federal de la Ciudad de México, D.F.* in Spanish). Those entities, in turn,



are divided into 2,440 state municipalities (*municipios* in Spanish) and 16 city districts (*delegaciones* in Spanish)<sup>9</sup> in the case of Mexico-City (INEGI, 2015a).<sup>10</sup> As will be described in further detail in chapter 3, institutions of all three governmental tiers happen to be heavily involved in the governance of municipal water supply and sanitation in Mexico, be it as normative-regulating, legislating or financing-administrating entities.

At the federal level, the General Congress (Honorable *Congreso de la Nación* in Spanish), the President (*Presidente de los Estados Unidos Mexicanos* in Spanish), and – inter alia – the Supreme Court of Justice (*Suprema Corte de Justicia* in Spanish) represent the legislative, executive and judiciary power respectively. The General Congress comprises of two-chambers, the Chamber of Deputies (*Cámara de Diputados* in Spanish) and the Senate (*Cámara de Senadores* in Spanish) whereby the Chamber represents the Mexican people and the Senate the Mexican states. The Mexican people elect directly the president for a six-year term (*el gonderenio* in Spanish), without the possibility of re-election. The president holds, among other things, the competence to nominate the department secretaries of his or her administration. Finally, the Supreme Court of Justice assumes as major task to control the other powers assuring a constitutional conduct (Constitución Política de los Estados Unidos Mexicanos, 1917; DOF, 2016). Article 116 of the Mexican constitution mandates the implementation of division of powers at the state level whereby state constitutions specify the details. Like at the national level, the office term of the holder of the executive power at the state level, the state governor (*gobernador* in Spanish), is generally restricted to six years, without the possibility of re-election.

---

<sup>9</sup> For the sake of simplicity the thesis will not distinguish between municipalities and districts and use municipalities for both terms indiscriminately unless otherwise stated. Overall 2,456 municipalities existed in 2010 in Mexico.

<sup>10</sup> Generally, the actual size of a municipality varies greatly by extension and population within and across federal states. With 570, Oaxaca is the state entity having the highest number of municipalities whereas, on the other extreme, Baja California and Baja California Sur comprise only 5 municipalities (INEGI, 2015b). Commonly, municipalities include several locality types like cities (*ciudades*), towns (*pueblos*), villages (*aldeas*), and rural scattered settlements (*Ejididos y Ranchos*). Usually one of the bigger settlements functions as the municipal capital (*cabecera municipal*) by hosting the municipal government. On the other hand, some smaller municipalities include only few or, in some extreme cases, only one locality. The largest municipalities extend a couple of dozen of thousand square kilometres with Ensenada in Baja California being the biggest (51,952 km<sup>2</sup>). It includes 1,709 localities of different sizes. The other extreme are municipalities with a coverage of only single-digit square kilometres like Papalotla in the Federal State of Mexico (3.2 km<sup>2</sup>) which includes only 2 localities.

A huge spread is also observed in terms of population. The biggest municipalities inhabit several million people whereby the district of Iztapalapa in Mexico-City is the biggest with ca. 1.8 million inhabitants. In contrast, other municipalities home only tiny populations like Santiago Tepetlapa in the state of Oaxaca. In 2010, it was home to only 131 dwellers (SNIM, 2015).

In addition, governors and representatives of legislative state bodies have to be elected directly in a popular vote. So called state tribunals (*tribunales* in Spanish) assume the state juridical power (Constitución Política de los Estados Unidos Mexicanos, 1917; DOF, 2016).

Article 115 of the Mexican constitution outlines the governmental structure of the municipal level (Constitución Política de los Estados Unidos Mexicanos, 1917; DOF, 2016). Accordingly, a municipality is governed by a city council, a so called “*ayuntamiento*”, which is free (*libre* in Spanish) in the sense that it exercises the competences granted by the federal constitution exclusively and without unsolicited interference of the federal state government. Its obligatory composition consists of the municipal president (*presidente municipal* in Spanish), the aldermen (*regidores* in Spanish), and the receiver(s) (*síndico(s)* in Spanish). Approximately, the three components act as executive, legislative and judicative whereby their competences vary to some extent according to respective state and municipal organic laws (*leyes orgánicas estatales y municipales* in Spanish) (Aguilar Amilpa, 2010).

Endowed with plenitudes of power, the municipal president – sometimes also called mayor (*alcalde* in Spanish) – assumes the leading role while the other bodies figure basically as supervisory authorities of the executive. The members of “*el ayuntamiento*” are elected for 3 years in popular ballots<sup>11</sup> without the option of re-election in the immediate succeeding term.

## **2.2. Water availability in Mexico**

In order to assess the degree of water availability in an area, one needs to put water supply in relation to water consumption, i.e. to the demand side. If consumption exceeds water supply in an area one may generally speak of the prevalence of water scarcity. If supply exceeds demand, an area may classify as water abundant. In the following, the status quo of water supply and consumption is described to see to what extent water scarcity poses a threat to human health and the environment in different regions of Mexico.

---

<sup>11</sup> As an exception of the general rule, the constitutions of the federal states of Coahuila de Zaragoza and Veracruz de Ignacio de la Llave extended office terms to 4 years as of 2006 and 2014 (Código Municipal para el Estado de Coahuila de Zaragoza, Article 41, 2001; Constitución Política del Estado de Veracruz de Ignacio de la Llave, Article 70, 2012).

### 2.2.1. Water supply

Water supply in Mexico is measured in total annual renewable water volumes available per capita (CONAGUA, 2008b, 2010a, 2011a, and 2013b, 2014f). For a particular year, its amount is calculated by dividing the total annual renewable water resources in an area by its population in that year. Renewable water consists mainly of two components: 1) internal annual precipitation, and 2) net annual water inflow from abroad (FAO, 2003).

According to the Mexican National Water Commission CONAGUA, Mexico receives on average an annual rainfall of 1,489 km<sup>3</sup>. It is estimated that 71.6% evaporate immediately whereas 22.2% run off in rivers and creeks and 6.2% trickles into the soil and recharge aquifers. Annual net imports from neighboring countries are estimated to amount to 115.6 km<sup>3</sup> on average. Overall, Mexico has 471.5 km<sup>3</sup> of total annual renewable water at its disposal (CONAGUA, 2013b, 2014d and 2014f). Rainfall patterns vary geographically and seasonally. On the one hand, 68% of the annual long term average rainfall of 779 mm (CONAGUA, 2013b) occur from June to September while the rest of the year is rather dry. On the other hand, the peninsula of Baja California receives as the most arid region in Mexico only the 11<sup>th</sup> part of the annual rainfall of the most water abundant areas located in South-Mexico. On national average, per capita water availability dropped steadily from 17,742 m<sup>3</sup> in 1950 to 4,261 m<sup>3</sup> in 2009 (Cortés et al., 2011). As average volumes of renewable water didn't change considerably this trend is mainly caused by high population growth.<sup>12</sup>

According to the widely used Falkenmark Water Stress Indicator (FI) (Falkenmark and Widstrand, 1992; FAO, 2008), a country faces water stress when annual renewable freshwater availability per person drops below the threshold of 1,700 m<sup>3</sup>. If water availability is below the thresholds of 1,000 m<sup>3</sup> and 500 m<sup>3</sup> it enters a stage of chronic water shortage and absolute water scarcity. With an average per capita water availability of 4,261 m<sup>3</sup>, Mexico does not classify as a particularly water stressed country. However, conditions differ across regions. Due to low precipitation levels and/or high population density, per capita renewable water resources fall short of the FI-thresholds of 1,700 and 500 m<sup>3</sup>/habitant/year in several parts of Mexico. In particular, the Mexican hydrological-administrative districts of Lerma-Santiago-Pacífico (1,535 m<sup>3</sup>/habitant/year), peninsula of Baja California (1,187 m<sup>3</sup>/habitant/year), Río

---

<sup>12</sup>Mexico's population more than quadrupled over the last 60 years to 112.5 million in 2010 (cf. subchapter 2.1.2).

Bravo (1,077 m<sup>3</sup>/habitant/year), and Valley of Mexico (153 m<sup>3</sup>/habitant/year) are prone to water shortages (CONAGUA, 2013b). Overall, only 26.8% of renewable water is available in 5 of the overall 13 Mexican hydrological-administrative districts. However, 47.8% of the population live in these very same districts where also 55.5% of the GDP is produced. This puts further pressure on water resources as water consumption tends to increase with higher incomes. Of exceptional dramatic is the situation in the Valley of Mexico where Mexico-City is located which disposes of only 0.8% of the national renewable water resources, but is home to 19.8% of the Mexican population producing 21.3% of the country's GDP (CONAGUA, 2010a).

On an international comparison, Mexico ranks continuously 86<sup>th</sup> to 89<sup>th</sup> in terms of total renewable water availability per capita (CONAGUA, 2008b, 2010a, 2011a, 2013a). Table A.1 in the appendix provides an overview of the world's top 21 countries with highest total renewable water availability per capita and other selected countries in 2011. Somewhat contrasting to Mexico, 10 Latin-American countries make it into the top group reflecting the fact that the region as a whole is water abundant (WWAP, 2015). On the mainland, only El Salvador (4,200 m<sup>3</sup>), being a small country by extension and population, encounters a similar situation. Within the entire region, only Caribbean islands have less water per capita at their disposal, mainly due to a significantly higher population density. The country with less per capita water availability is Haiti (1,400 m<sup>3</sup>). On the other hand, with a per capita availability of 4,100 m<sup>3</sup> Mexico ranks higher than industrialized countries like France (3,300 m<sup>3</sup>), the UK (1,900 m<sup>3</sup>), and Germany (2,300 m<sup>3</sup>) (FAO, 2015).

### **2.2.2. Water consumption**

Generally, water consumption is measured as the annual quantity of water withdrawn per capita for agricultural, industrial and municipal purposes from renewable surface water resources, renewable and fossil groundwater, and the use of desalinated water and treated wastewater (FOA, 2015).

**Table 1: Types of water consumption subject to abstraction source in Mexico, 2012**

Type of water consumption	Water source		Total volume (km <sup>3</sup> /year)	Percentage of abstraction
	Surface (km <sup>3</sup> /year)	Subterranean (km <sup>3</sup> /year)		
Agricultural use	41.2	22.2	63.3	76.6
Municipal use	4.7	7.3	12.0	14.5
Industrial use	direct abstraction	1.4	1.9	4.0
	electric energy	3.6	0.4	4.9
Total	51	31.8	82.7	100

Source: CONAGUA (2013b). Estadísticas del Agua en México, Edición 2013, p. 47, modified by the author.

Table 1 provides information on absolute volumes, the percentages of different consumption types, and corresponding water source types the Mexican National Water Commission CONAGUA reports for 2012. According to this data, 61.6% of overall water consumption were abstracted from superficial water bodies like rivers, creeks and lakes whereas the remaining 38% originated from subterranean sources like aquifers. Since 2001 this ratio shifted slightly in favor of underground sources as subterranean extraction increased by 28% and surface abstraction only by 16% from 2001 to 2012 (CONAGUA, 2013b).

In terms of water use, as with most countries, water is mainly abstracted for agricultural irrigation accounting for 77% (2012) of overall water consumption. Worldwide, Mexico ranks 7<sup>th</sup> in terms of irrigated area. About 6.5 million hectares – about 23% of all cultivated land in Mexico – is equipped with irrigation facilities. This corresponds with an infrastructure of water storage capacity of 1.3 m<sup>3</sup> per capita. In this regard, Mexico occupies 31<sup>th</sup> as compared to international standards. Almost two-thirds of the 63 km<sup>3</sup> agricultural water consumption came from surface sources (CONAGUA, 2013b).

Municipal and industrial water consumption account for relatively small fractions – 14.5% and 9% respectively. Municipal water is supplied to municipal drinking water networks in order to satisfy the demand of domestic, public, business and service entities. Industrial water consumption comprises volumes for the production of goods and power generation, with the exception of hydropower, and volumes industries extract directly from water sources and not from municipal networks.

For municipal water consumption, subterranean water is the major source as 61% of consumed volumes are abstracted from this source. Since 2001 demand has increased by 25% whereby the additional demand has been disproportionately satisfied by surface water bodies. Respective volumes increased by 42%. Industrial abstraction draws only recently predominantly on underground sources as the increase in demand of 23% since 2001 was entirely met by this source type.

In terms of total water withdrawal per capita, Mexico ranks with 665 m<sup>3</sup>/inhabitant/year 29<sup>th</sup> among 81 countries data is available for in 2003-2013 (see Table A.2 in the appendix). Within Latin America, it ranges in the upper mid-field with Chile (2,126 m<sup>3</sup>), Guyana (1,818 m<sup>3</sup>), and Surinam (1,208 m<sup>3</sup>) being at the top and Honduras (224 m<sup>3</sup>), Bolivia (199 m<sup>3</sup>), and Haiti (143 m<sup>3</sup>) at the bottom of the list (FAO, 2015).

### **2.2.3. Net water availability**

To evaluate a country's degree of water scarcity one needs to relate water supply and consumption to see whether demand exceeds supply. For this purpose, Alcamo et al., (1997) developed the so called Criticality Ratio (CR). They define it as the ratio of water use to water availability in a watershed, country or region. The higher the ratio the higher the water stress an area is exposed to. Broadly, Alcamo et al., (2000) classify countries with a CR above the threshold of 40% as having severe water stress and below as having a relatively eased water situation. In addition, they define, more narrowly, five ranges. Criticality Ratios

Above 80% are considered as situations of 'very high water stress',

Between 80% and 40% of 'high water stress',

Between 40% and 20% of 'mid water stress',

Between 20% and 10% of 'low water stress', and

Below 10% of 'no water stress'.

With a Criticality Ratio of 17% (Table 2), Mexico is classified as a country with low water stress and ranks only 43<sup>th</sup> among the 132 countries that have at least once reported their CRs since 2003 (FAO, 2015). As Table A.3 in the appendix details, not surprisingly mainly countries from the Middle East top this list due to their arid and desert like climate. Within Latin America only island states report CRs higher than Mexico's CR though, e.g. Dominican Republic with a CR of 30.4%.

In contrast to Mexico's relatively low national CR, northern and central parts of Mexico, marked by low precipitation rates and/or high population density, experience high to very high water stress levels. According to official CONAGUA data (2013b), 8 of the 13 Mexican hydrological-administrative districts suffered in 2012 from, at least, high water stress. In particular, the Valley of Mexico-City (District XIII) and the Northwest District (District II) are severely affected (CRs of 136% and 84% respectively; see for details the following Table 2). Though the majority of the 13 Mexican hydrological-administrative districts face water stress, Mexico classifies as a country nonetheless as having no water stress. The reason for that is the huge water abundance in the sparsely populated south of Mexico. I.e. water stress is mainly a distribution issue as the majority of the population does not settle in the water abundant areas of the country.

**Table 2: Criticality Ratios and water stress in Mexican hydrological districts, 2012**

No.	Hydrological-administrative districts	Total volume of consumed water (hm <sup>3</sup> )	Renewable water (hm <sup>3</sup> /year)	Degree of water stress (CR in %)	Level of water stress
I	Península de Baja California	3,895	4,999	77.9	High
II	Noroeste	6,989	8,325	83.9	High*
III	Pacífico Norte	10,460	25,939	40.3	High
IV	Balsas	10,652	22,899	46.5	High
V	Pacífico Sur	1,508	32,351	4.7	None
VI	Río Bravo	9,397	12,757	73.7	High
VII	Cuencas Centrales del Norte	3,734	8,065	46.3	High
VIII	Lerma-Santiago-Pacífico	15,047	35,754	42.1	High
IX	Golfo Norte	5,630	28,115	20.0	Mid
X	Golfo Centro	5,076	95,124	5.3	None
XI	Frontera Sur	2,273	163,845	1.4	None
XII	Península de Yucatán	3,353	29,856	11.2	Low
XIII	Aguas del Valle de México	4,720	3,468	136.1	Very high
Total	national	82,734	471,498	17.5	Low

Source: CONAGUA (2013b), Estadísticas del Agua en México, Edición 2013, p. 59, modified by the author.

\* Note: CONAGUA attributes only CRs above 100% a very high level of water stress. 1 hm<sup>3</sup> = 1 million of m<sup>3</sup>.

## 2.3. Water quality in Mexico

Beside quantitative aspects the quality of available water is also of high relevance to assess the overall water situation of a country. According to the Sectorial Program of Environment and Natural Resources 2007-2012 (*Programa Sectorial de Medio Ambiente y Recursos Naturales* in Spanish; SEMARNAT, 2009)<sup>13</sup> of the national Mexican government, water pollution poses one of the major problems Mexico is facing in regard of environmental deterioration. It mentions three areas that are negatively affected: ecosystems and natural habitats, human health, and the spoilage of potentially usable water sources. Major pollution cause are the discharge of untreated municipal, industrial, and agricultural wastewater (SEMARNAT, 2008 and 2009).

Since 1990 CONAGUA publishes regularly data on water pollution gathered within the National Monitoring Network (*Red Nacional de Monitoreo* (RNM) in Spanish). In 2012 5,150 observation stations collected data on the physical, chemical, and bacteriological quality of surface and groundwater sources across Mexico. Based on these observations, the commission issues regulations on water supply, wastewater treatment and discharge (Hansen and Juárez, 2011; CONAGUA, 2013b).

### 2.3.1. Surface water

With respect to surface water, CONAGUA has changed several times the evaluation methods as well as the classification scheme of evaluated water bodies (CONAGUA, 2005 and 2013b). In consequence, it is rather difficult, if not impossible, to compare results of different years in order to detect possible trends in time. At the same time, other institutions like universities, research institutes, private companies, international agencies or other Mexican government organizations only have executed localized and temporary sampling and evaluation projects (Jiménez Cisneros, 2007 and 2008; Barkin, 2011). Thus, no other monitoring program exists with a nationwide cover.

---

<sup>13</sup> The “Programa Sectorial de Medio Ambiente y Recursos Naturales” establishes the set of objectives, strategies and targets through which the environmental sector will attend, in the field of environmental sustainability, the objectives and strategies defined in the National Plan of Development (*Plan Nacional de Desarrollo* in Spanish) at the beginning of the 6-year term of the Mexican presidency (SEMARNAT, 2009).



Nonetheless, official data suggests that contamination has been significant throughout the reporting period (Jiménez Cisneros, 2007; Hansen & Juárez, 2011). From 1990 to 2002 the evaluation was based on the so called Index of water quality (IWQ; *Índice de Calidad del Agua (ICA)* in Spanish). This index, originally designed by Dinius (1987) and adapted by León and González (1991 and 1992) to Mexican circumstances, is composed of 15 to 18 contamination and water quality parameters of which the most important are: dissolved oxygen, BOD<sub>5</sub>, coliform count, E.coli, pH, alkalinity, hardness, chloride, specific conductivity, temperature, colour and nitrate (SEMARNAT, 2002; Jiménez Cisneros, 2007). These parameters are then included at different weights in the index. Values of the IWQ vary between 0 and 100 whereby zero represents the worst and 100 the best water quality possible.

According to official IWQ figures, the majority of the monitored water bodies exhibit high, heavy or excessive levels of contamination. The Mexican Ministry of Environment and Natural Resources SEMARNAT reports concentrations of faecal coliform bacteria, pathogens, orthophosphates, nutrients, fats, oils and grease as being of major concern in the time before 2002 (SEMARNAT, 2002; Aboites et al., 2008; Jiménez Cisneros, 2008). As the left part of Figure A.1 in the appendix details, 18% to 28% of the surface water bodies scored below a value of 50 of the Water Quality Index while 41% to 65% ranged in the interval of 50 to 69 in the period between 1990 and 2002 (CONAGUA, 2005 and 2013b; Jiménez Cisneros, 2007 and 2008).

Throughout the 1990s, CONAGUA considered scores below 50 as heavily contaminated or of bad quality and scores from 50 to 69 as contaminated or at best of medium quality. At the turn of the millennium, the score interval for highly contaminated water was significantly reduced to levels below 23. Simultaneously, water bodies with score values of 30-49 were, somewhat euphemistically, relabelled from “heavily contaminated” to “only for industrial and agricultural purposes usable”. Waters with scores of 50-69 were renamed as of “major treatment requiring” instead of “contaminated”. This softening process in the classification scheme seems to have continued over time, especially through a major shift in monitoring methods in 2003 when the IWQ was substituted by mainly 2 new indicators in order to measure water quality: 1) biochemical oxygen demand in 5 days (BOD<sub>5</sub>), and 2) chemical oxygen demand (COD).<sup>14</sup>

---

<sup>14</sup> For a detailed discussion of the topic see e.g. Jiménez Cisneros (2007).

BOD<sub>5</sub> is defined as the amount of oxygen that bacteria extract from the water within 5 days in order to oxidize and degrade biodegradable organic matter whereas COD is defined as the number of oxygen that is required to oxidize all organic matter which is present in the water either due to natural processes or anthropogenic pollution (Usman and Dickertin, 2015). An increase in BOD<sub>5</sub> and COD indicates a likely reduction in the oxygen concentration dissolved in the water. This affects negatively aquatic ecosystems as from nutrient pollution in terms of high levels of BOD<sub>5</sub> and COD eutrophication and algae proliferation may arise. While an increase in the population of aquatic microorganisms like algae can result in the consumption of all available oxygen, eutrophication can trigger anoxic conditions and, in turn, fish die-offs (Malik et al., 2015).

In addition, CONAGUA and other government organizations (e.g. SEMARNAT, 2013) also partly report data on regular components of anthropogenic wastewater like phosphorus, nitrate, and, in recent years, also on total suspended solids (TSS). High concentrations in water of those elements may not only trigger eutrophication and algae proliferation but also provide beneficial living conditions for a wide range of organisms like bacteria, virus, protozoans that are potentially harmful to human health (WHO, 2011; Malik, 2015).

In terms of BOD<sub>5</sub>, CONAGUA classifies surface water as

Excellent if BOD<sub>5</sub> is  $\leq 3$  mg/L,

Of good quality if BOD<sub>5</sub>  $>3$  and  $\leq 6$  mg/L,

Acceptable if BOD<sub>5</sub>  $>6$  and  $\leq 30$  mg/L,

Contaminated if BOD<sub>5</sub>  $>30$  and  $\leq 120$  mg/L, and

Heavily contaminated if BOD<sub>5</sub>  $>120$  mg/L.<sup>15</sup>

Regarding COD, surface water is

In excellent conditions if COD is  $\leq 10$  mg/L,

Of good quality if COD  $> 10$  and  $\leq 20$  mg/L,

Acceptable if COD  $> 20$  and  $\leq 40$  mg/L,

Contaminated if COD  $> 40$  and  $\leq 200$  mg/L, and

Heavily contaminated if COD  $> 200$  mg/L.<sup>16</sup>

---

<sup>15</sup> Cf. CONAGUA, 2005, p. 64.

<sup>16</sup> Cf. CONAGUA, 2005, p. 64.

In contrast to the IWQ based classification before 2003, CONAGUA classified in 2003 only 5.3% of monitored bodies as heavily contaminated and 14.3% as contaminated in terms of BOD<sub>5</sub>. On the other hand, two-thirds were classified as having excellent (51.8%) or at least good water quality (12.9%). Throughout the years, a slight decline in the share of heavily contaminated and contaminated water in regard of BOD<sub>5</sub> contamination is observed. However, also the share of surface water with excellent water quality decreased substantially by more than 10% while, on the other hand, the percentage of water bodies with good quality more than doubled (CONAGUA, 2005 and 2013b; Jiménez Cisneros, 2007 and 2008).

As of COD, 11% of water bodies were heavily contaminated, 20.4% contaminated, 21.4% of good and 28.8% of excellent water quality. In terms of COD, the share of heavily contaminated water bodies decreased whereas the one of excellent water bodies increased from 2003 to 2012. However, this positive trend is paralleled by a decrease of the fraction of surface water with good water quality and an increase of contaminated water bodies (CONAGUA, 2005 and 2013b; Jiménez Cisneros, 2007 and 2008).<sup>17</sup>

As a bottom line, though CONAGUA changed the water classification scheme and watered it down by considering only BOD<sub>5</sub> and COD levels on a regular base water contamination seems to remain at significant levels to date according to official numbers. This evaluation is also confirmed a great many times by studies on particular surface water bodies like, for instance, the big Mexican lakes of Chapala and Pátzcuaro (Anda Sánchez and Maniak, 2007; Bravo Inclán et al., 2008). Also internationally, Mexico ranks in terms of surface water quality relatively poor as it occupies only 106<sup>th</sup> position out of evaluated 122 countries being outperformed by many Latin American countries like Argentina, Brazil, Cuba, Costa Rica, Chile, Panamá, El Salvador, Jamaica, Ecuador, Peru, Bolivia, Guatemala, Nicaragua, Honduras, Paraguay (UN, 2003; Aboites et al., 2008).

---

<sup>17</sup> The right-hand side of Figure A.1 in the appendix details the development of Mexican surface waters from 2003 to 2012 based on the newly established BOD<sub>5</sub> and COD indicators. Complementary to Figure A.1, Figure A.2 and Figure A.3 in the appendix visualize the water quality classification of surface water bodies in terms of BOD<sub>5</sub> and COD contamination for single years between 2003 and 2012.

### **2.3.2. Groundwater**

Data on groundwater contamination is even scarcer than on surface water. Again, one has to rely again almost exclusively on official CONAGUA data (Jiménez Cisneros et al., 2010). Nationwide, the Mexican National Monitoring Network (RNM) disposes of 1,108 observation sites (2013). However, since 2006 the scope of reporting is rather narrow as it is mainly performed on the phenomenon of salination due to salt water intrusion in coastal areas in consequence of overexploitation or leaching of salty soils in arid or semiarid regions. In 2012, 47 of the 653 Mexican aquifers, in their majority located in north-west Mexico and in the northern part of the central Mexican plateau, were reported to be affected by the phenomenon of salination (CONAGUA, 2013b).

Before 2006, CONAGUA published also information on other major forms of contamination like high concentrations of fluorine and arsenic, either natural or artificial, and infiltration of untreated anthropogenic wastewater. According to this data, at least in 8 aquifers in central Mexico and the peninsula of Yucatan ammoniac nitrogen and nitrate levels exceeded the legal maximum of Mexican drinking water standards (Graniel et al., 1999; Muñoz et al., 2004; CONAGUA, 2005; and Jiménez Cisneros et al., 2007).

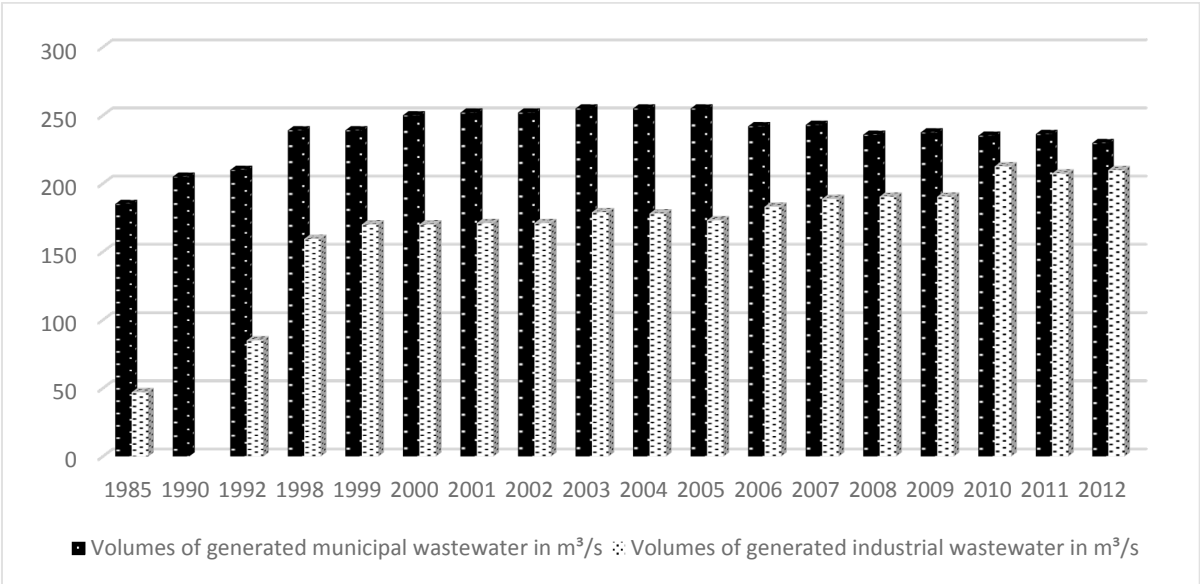
In addition, independent studies found evidence of faecal contamination being present in various underground water reservoirs, for instance, in the greater region of Mexico City (Ryan, 1989; Gallegos et al., 1999; Jiménez Cisneros et al., 2007). According to Hansen et al., (2011), at least 33 scientific studies have been executed on chemical contaminants, categorized as Toxic, Persistent, and Bioaccumulable Substances (TPBS) and Persistent Organic Pollutants (POPS). Overall, 17 TPBS have been identified as being of major concern in aquifers across all of Mexico.

### **2.4. Sources of water pollution**

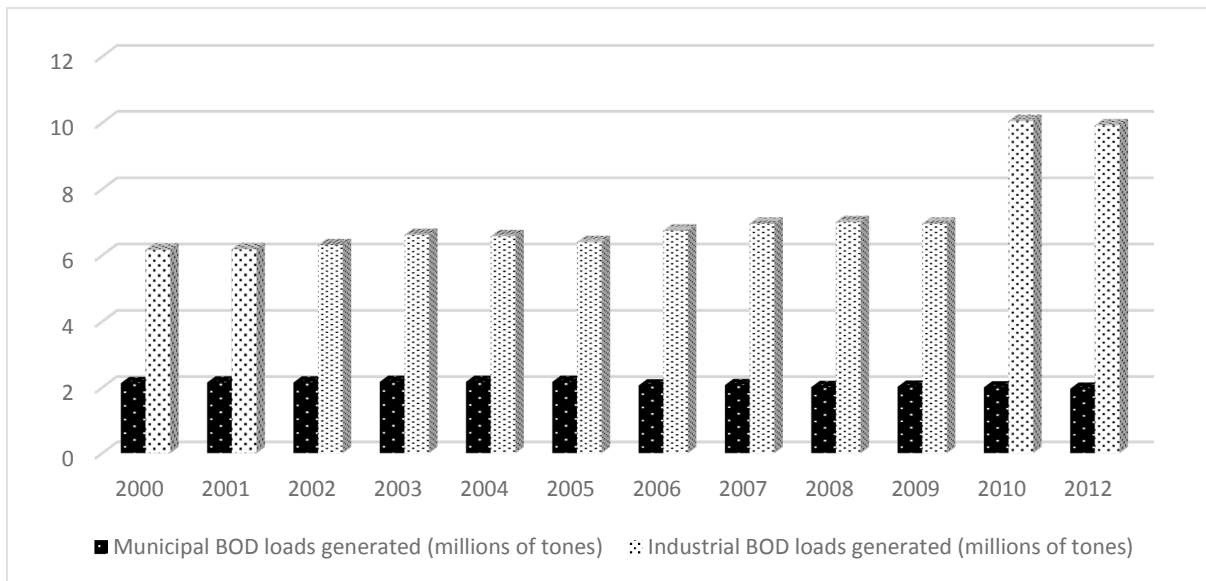
The heavy levels of water contamination described in the previous chapter originate from several sources. Generally, water pollution is the result of uncontrolled release and discharge of either solid or liquid waste into water bodies. Two classes of pollution exist: point-source pollution and non-point source pollution. Point-source pollution is the emission of pollutants

from a confined source like pipes or outfalls. In contrast, non-point source pollution occurs in a diffuse manner and has as such a high variety in its origins, for instance, polluted runoff or seep from farm land, forestry or soils or contaminated condensations from the atmosphere. Due to the great diversity of pollution sources, the reliable assessment of non-point source pollution involves a great deal of difficulties. This fact often results in the lack of meaningful data. As of point-source pollution, a distinction is commonly made between the municipal and industrial domain as major pollution sources. The municipal domain comprises wastewater originating from municipal sewage systems, while industrial facilities discharge polluted water directly into water bodies or the environment. Data availability on point-source pollution is generally better due to the more localized nature of the pollution (Jiménez Cisneros, 2007; SEMARNAT, 2009; Hanley et al., 2013).

Although CONAGUA unofficially concedes that non-point source pollution is a major issue in Mexico as estimated 70% of the water pollution is caused by agriculture, deforestation and poor waste management, no official data is available on this pollution type (Aguilar Ibarra and Pérez Espejo, 2007). On the other hand, CONAGUA releases annual estimates on aggregated volumes of generated wastewater and pollution charges in terms of BOD<sub>5</sub> originating from industries and municipal sewage networks. The following Figures 2 and 3 depict respective developments in recent decades.



**Figure 2: Annual volumes of municipal and industrial wastewater in m<sup>3</sup>/s, 1985-2012**  
 Source: Own creation, based on CONAGUA (2002, 2003, 2005, 2006, 2007, 2008b, 2010a, 2012a, 2014a) and Peña et al., (2013).



**Figure 3: BOD<sub>5</sub> loads of municipal and industrial wastewater in Mexico (tons), 2000-12**

Source: Own creation, based on CONAGUA (2002, 2003, 2005, 2006, 2007, 2008b, 2010a, 2012a, 2014a) and Peña et al., (2013).

Predominantly due to the ongoing population growth, municipal wastewater generation increased from 1985 to 2012 (cf. dark scattered bars in Figure 2; SEMARNAT, 2013). Somewhat surprisingly, generated volumes peaked in 2005 at a level of 255 m<sup>3</sup>/s<sup>18</sup> and decreased since then steadily to around 230 m<sup>3</sup>/s in 2012. No official explanation has been given for this decreasing trend. In the light of ongoing population growth one would have expected generated volumes to increase accordingly. Most likely, the reported reduction is merely the artificial result of a change in the estimation equation of generated municipal wastewater and does not correspond to significant changes in actual wastewater generation.

In order to estimate volumes of generated wastewater it is uniformly assumed that a certain percentage of municipal water supply is turned into wastewater – usually 70 to 80%. In this context, CONAGUA indicated that it changed several times this percentage in its calculations of aggregated volumes of generated wastewater for Mexico (RAS, 2000; IMTA, 2014a; CONAGUA, 2007). In consequence, it is rather likely that the reported decrease in municipal wastewater generation results merely from changes in the calculation method.<sup>19</sup>

<sup>18</sup> 255 m<sup>3</sup>/s is the volume of municipal wastewater produced on average in a second in 2005. In order to get the total volume generated in 2005 one needs to multiply this figure by 31,536,000 as a general year consists of this amount of seconds.

<sup>19</sup> See also subchapter 5.1 for a more detailed discussion of this topic.

As of industrial wastewater, the white scattered bars in Figure 2 show that volumes increased substantially from 1985 to 2012, mainly due to intensified economic activities. A particular steep hike in volumes took place during the 1990s followed by a sideward movement during the first decade of the 21<sup>th</sup> century. In 2010, volumes exceeded for the first time in history the level of 200 m<sup>3</sup>/s plateauing since then around 210 m<sup>3</sup>/s slightly below the aggregated volume of municipal wastewater. According to SEMARNAT (2009), the main polluting industries are the sugar, oil, chemical and agroindustry. In 2008, for instance, the sugar industry accounted for 28%, the oil industry for 19%, the agroindustry for 17%, and the chemical industry for 6% of generated industrial wastewater.

In terms of BOD loads, Figure 3 reveals that aggregated annual BOD<sub>5</sub> loads of municipal wastewater volumes remained approximately at the level of 2 million tonnes throughout the reporting period of 2000-2012 whereas industrial wastewater loads increased from levels of around 6 million tonnes to levels close to 10 million tonnes (cf. white and dark scattered bars in Figure 3). Interestingly, though volumes of generated industrial and municipal wastewater approximately match each other (both around 200 m<sup>3</sup>/s) industrial emissions contain BOD<sub>5</sub> loads that are three to five times higher than in the municipal sector.<sup>20</sup> Overall, official data attributes municipal wastewater volumes and industrial point source pollution a significant role in the deterioration of Mexican water sources.

## **2.5. Status quo of wastewater treatment in Mexico**

Though municipal and industrial wastewater continue to be major sources of water pollution in Mexico to the present day (cf. subchapter 2.6) recent decades have also seen progress in the treatment of wastewater. The following provides a summary of the status quo of municipal and industrial wastewater treatment to grasp the extent of the mitigation of water pollution in different regions of Mexico.

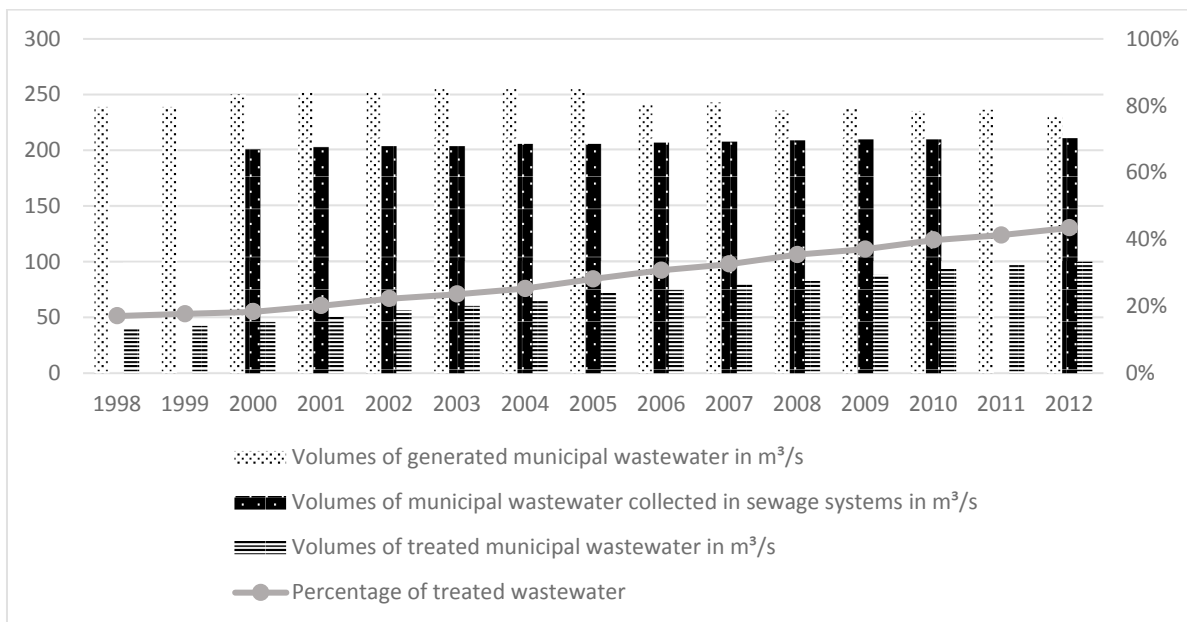
---

<sup>20</sup> In addition, one has to keep in mind that industries usually also discharge a wide range of harmful substances into water bodies which are not necessarily accounted for if water pollution is measured in term of BOD<sub>5</sub> loads (Jiménez, Cisneros 2007).

### 2.5.1. Municipal wastewater treatment

In recent years, an increasing share of generated municipal wastewater volumes has been treated before it is discharged into the environment. According to official CONAGUA data, 99.8 m<sup>3</sup>/s of 229.7m<sup>3</sup>/s of generated municipal wastewater in 2012 received some kind of treatment. This corresponds with a treatment rate of 42.5% (CONAGUAa, 2014a).

As Figure 4 illustrates, treatment rates of municipal wastewater increased steadily in the last two decades. Though the topic of wastewater treatment became a point of discussion in Mexican politics as early as 1973<sup>21</sup> actual treatment rates surpassed the 20% mark only after the turn of the millennium (Garza, 2008).<sup>22</sup> Since then, the annual share of treated volumes increased gradually to the recent mark of 42.5% (see for details Figure 4).



**Figure 4: Volumes of generated, collected and treated municipal wastewater, 1998-2012**

Source: Own creation, based on CONAGUA (2002, 2003, 2005, 2006, 2007, 2008b, 2010a, 2012a, 2014a), Peña et al., (2013).

\* For 1998, 1999, and 2011, no data on collected volumes of municipal wastewater is available.

<sup>21</sup> In this year, Mexican legislation established for the first time in history legally binding guidelines for the establishment of wastewater treatment plants.

<sup>22</sup> As of 1990, for instance, 93% of municipal wastewater continued to receive no treatment (Tortajada, 2002).



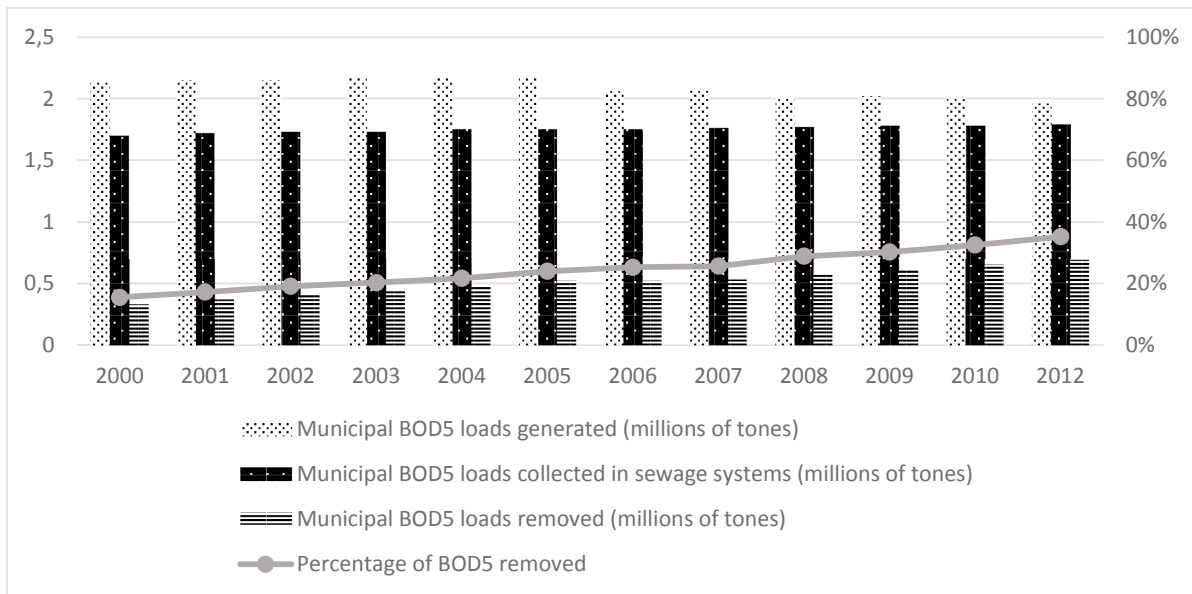
The reason why the establishment of wastewater treatment facilities gained momentum only recently, though respective legislation existed since the early 1970s, is mainly due to the fact that emphasis was put first on building other crucial components of municipal water infrastructure like drinking water and sewage systems. Before treatment can take place in central systems, wastewater needs to be collected. However, in 1970 only about 60% of Mexican households disposed of a direct drinking water access, and only 41% were connected to sewage systems or septic tanks. Thus, preconditions for a systematic treatment were only met when coverage gradually reached 80% in more recent decades (Barkin and Klooster, 2006). According to CONAGUA, national coverage to municipal sewage systems reached 91% in 2012 whereby 97% of the urban and 70% of the rural population were connected (CONAGUA, 2014a).

In addition to treated volumes of municipal wastewater, CONAGUA also provides annual data on removed BOD<sub>5</sub> loads. According to this source (CONAGUA, 2014a and 2014c), treatment measures removed about 35% or 0.7 of the generated 2 million tonnes in 2012. As Figure 5 details, removal rates increased steadily and approximately in line with treated volume shares in the period from 2000 to 2012. Back in 2000, treatment plants screened out only about 15% of generated BOD<sub>5</sub> loads (see for details Figure 5).<sup>23</sup>

---

<sup>23</sup> Predominantly, municipal wastewater treatment takes place centralized in Mexico. Central wastewater treatment is worldwide the most used method, particularly, in developed countries (Bakir 2001; Mara, 2003; Massoud et al., 2009; Libralato et al., 2012). It comprises three main components: i) a sewerage system, ii) a wastewater treatment plant, and iii) a reuse and/or disposal system of treated wastewater and sewage sludge. The sewerage system collects the wastewater from households, public buildings, businesses, and industries, and channels it to a central wastewater treatment plant which treats the wastewater of an entire area. After treatment, purified wastewater is discharged either into water bodies or on land, or reused for irrigation in agriculture or industrial purposes. The separated sludge is disposed either in landfills, incinerated or applied to fields as fertilizer depending on respective regulations.

The actual wastewater treatment process comprises up to three stages. Primary or mechanical treatment removes greases, suspended and floating solids by using gravity, screening, skimming and also chemical methods that accelerate the settling of sediments. In this way, 20% to 50 % of bio oxygen demand (BOD) and 50 to 70% of the suspended solids (SS) content is extracted from the wastewater. The secondary treatment stage applies biological methods whereby microbes digest either under aerobic, i.e. in the presence of oxygen, or anaerobic conditions, i.e. without oxygen, the remaining organic matter in inorganic components, mainly water (H<sub>2</sub>O), carbon dioxide (CO<sub>2</sub>), and ammonia (NH<sub>3</sub>). The generated solid sediment is removed by settling. After secondary treatment, usually 85% of BOD and SS is removed. Tertiary treatment applies predominantly more sophisticated biological and chemical methods for the removal of BOD and SS still present in wastewater (Pescod, 1992; Karia and Christian, 2013; Henze et al., 2008).

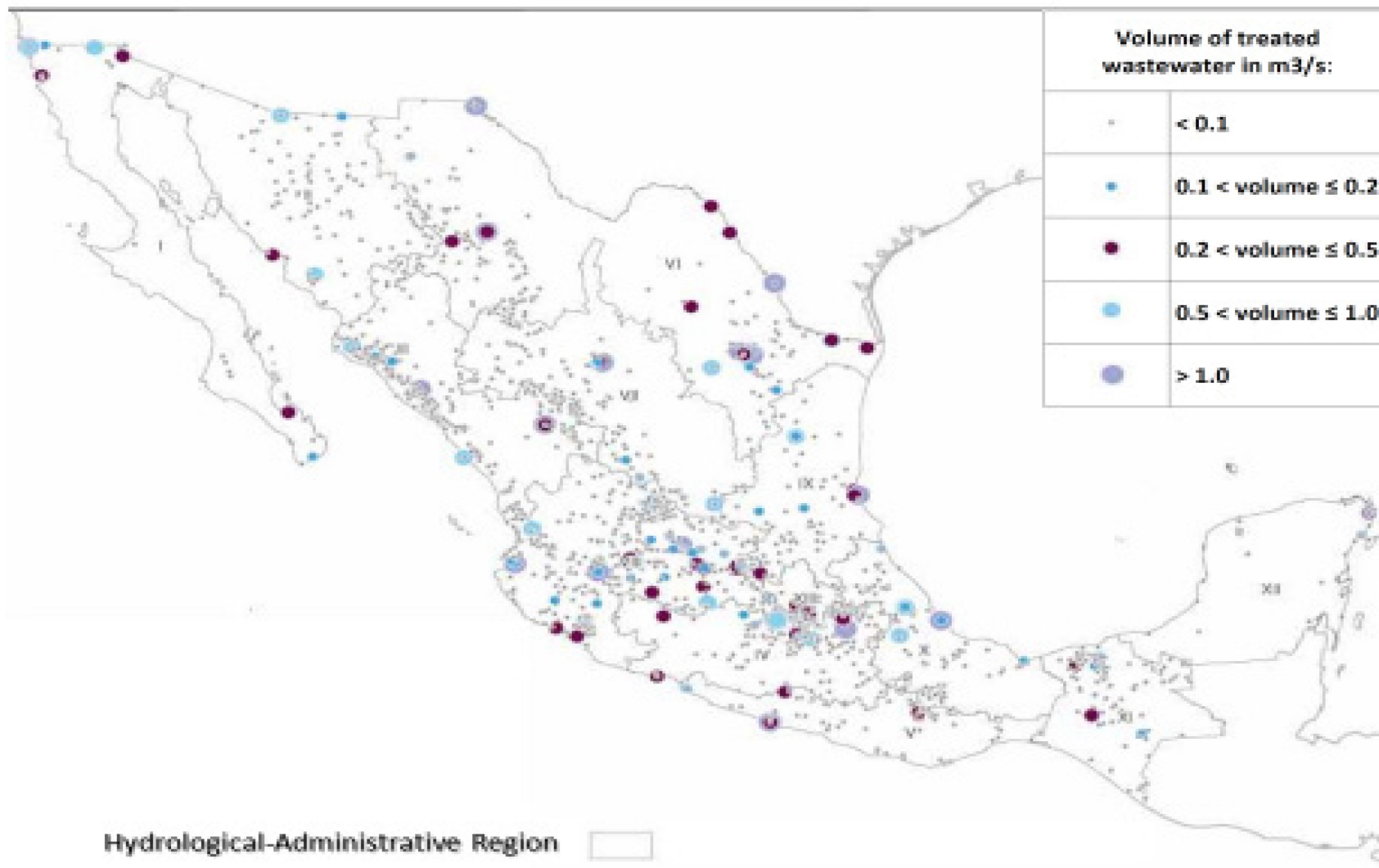


**Figure 5: BOD<sub>5</sub> loads of municipal wastewater in Mexico, 2000-12**

Source: Own creation based on CONAGUA (2002, 2003, 2005, 2006, 2007, 2008b, 2010a, 2012a, 2014a), Peña et al., (2013).

At the same time, treatment levels differ greatly not only across the 31 federal Mexican states and the Federal District of Mexico-City but also among the 2,456 Mexican municipalities. At federal state level, treatment rates of the collected municipal wastewater range from as low as 2.7% in Yucatán to 100% in Aguascalientes and Nuevo León (CONAGUA, 2013a). Table A.4 in the appendix details treatment shares for each Mexican state for the year of 2011.

The municipality level mirrors the diverse picture in treatment rates of municipal wastewater at the state level. Figure 6 shows the location of 2,186 plants that existed in 2010. By this year, 1,606 or 65% of municipalities still had no treatment plants at all. The remaining facilities were spread among 846 municipalities whose treatment shares ranged from single-digit percentages to full coverage (CONAGUA, 2013b). As can be seen in Figure 6, the majority of installed treatment facilities are relatively small and dispose of a treatment capacity of below 0.1 m<sup>3</sup>/s (grey dots in Figure 6). In addition, several treatment plants with higher treatment capacities scatter over the entire country (illustrated by the bigger colored circles in Figure 6). Facilities with the greatest treatment capacities of over 1m<sup>3</sup>/s are represented by purple circles.

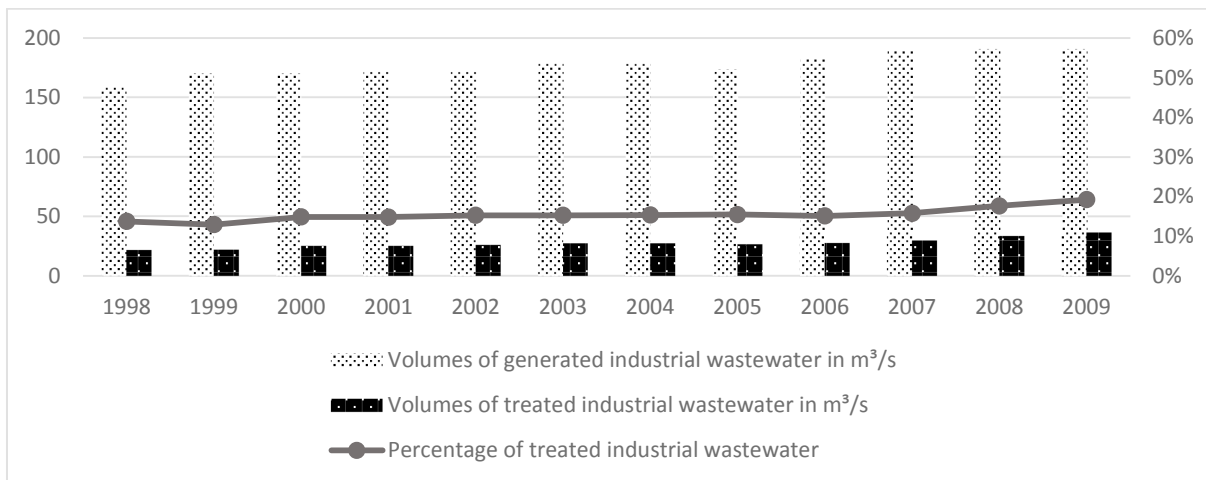


**Figure 6: Municipal wastewater treatment plants in Mexico**

Source: CONAGUA (2012d), Estadísticas del Agua en México – Edición 2012, p. 54, modified by the author.

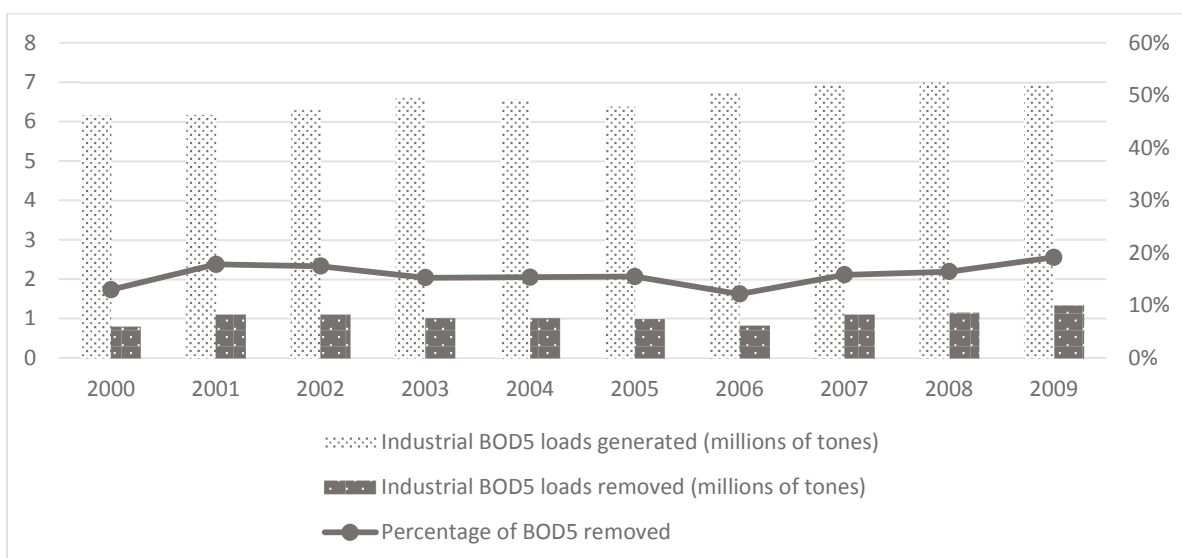
## 2.5.2. Industrial wastewater treatment

In contrast to municipal wastewater treatment where improvements have been substantial, purification of industrial wastewater lacks behind to the present date. In 2009, only about 19% received some kind of treatment though generated volumes are almost as high as municipal ones and contain generally rather high BOD<sub>5</sub> loads. Both, treatment rates of wastewater volumes and removal rates of BOD<sub>5</sub> loads increased only slightly from around 14% and 15% to about 19% and 20% from 2000 to 2009. See for more details Figures 7 and 8.



**Figure 7: Volumes of generated and treated industrial wastewater, 1998-2009**

Source: Own creation, based on CONAGUA (2002, 2003, 2005, 2006, 2007, 2008b, 2010a, 2012a, 2014a), Peña et al., (2013).



**Figure 8: BOD<sub>5</sub> loads of industrial wastewater in Mexico, 2000-09**

Source: Own creation based on CONAGUA (2002, 2003, 2005, 2006, 2007, 2008b, 2010a, 2012a, 2014a), Peña et al., (2013).

## 2.6. Summary of chapter 2

As background part, chapter 2 of the thesis has given a detailed overview of the study case. It provided information on the socioeconomic and demographic development of the Mexican population and on geographic characteristics of Mexico. As a typical emerging developing country, the Mexican nation has experienced a continuous growth of GDP per capita and a deep transformation from a rural to an urban society over recent decades (World Bank, 2015a). Along with this, average life expectancy increased as well as the national level of education (UNDP, 2015). At the same time, per capita income is highly unequal distributed among Mexicans and significant parts of society continue to be marginalized (CONEVAL, 2015). In addition, a high ethnic heterogeneity characterizes Mexico. About 10% of the population are of indigenous descent (INEGI, 2010; Encyclopædia Britannica, 2017). Apart from the aggregated numbers of the national level, socioeconomic and demographic aspects vary significantly at the municipal level as social and economic development and the composition of the population is by no means the same all over the place. Potentially, these observed social differences may explain a good deal of the difference in the treatment of municipal wastewater across Mexican municipalities.

Also geographical aspects vary across the Mexican territory substantially. While water supply is abundant in southern Mexico, broad parts of the north are dry. In the centre of the country, the high population density produces high degrees of water stress (CONAGUA data, 2013b). Overall, per capita water availability dropped on average from 17,742 m<sup>3</sup> to 4,076 m<sup>3</sup> in the period 1950 – 2012 (Cortés et al., 2011; FAO, 2015). Beside the issue of water scarcity, several regions face severe water quality issues. In particular in densely populated areas, Mexican underground water resources are reported to be heavily contaminated (Jiménez Cisneros et al., 2007; Hansen et al., 2011). In terms of surface water quality, the country as a whole ranks poorly as it occupies only the 106<sup>th</sup> position out of evaluated 122 countries (UN, 2003; Aboites et al., 2008).

A major cause of water pollution is the discharge of untreated wastewater (SEMARNAT, 2008 and 2009). By 2009, only 37.1% of municipal wastewater received some kind of treatment (CONAGUA, 2011a). At the same time, treatment levels differ substantially at the subnational level. By 2010, 846 of the 2,456 Mexican municipalities treated a share of their municipal wastewater that ranged from single-digit percentages to full coverage, while the remaining

majority of municipalities treated no municipal wastewater (CONAGUA, 2013b). This observed variety in treated shares of municipal wastewater across Mexican municipalities qualifies Mexico as a suitable study case to identify drivers and obstacles that cause or impair the treatment of municipal wastewater in a developing country.

### 3. Municipal (waste)water governance in Mexico

After the description of socioeconomic and demographic features of the Mexican society and the status quo of the availability of water, water pollution and the progress of wastewater treatment in Mexico in chapter 2, chapter 3 highlights the institutional environment within which municipal wastewater treatment takes place or not in Mexico. Municipal wastewater treatment is an elementary component of the water governance of a society. Water governance is defined as “the range of political, social, economic and administrative systems that are in place to develop and manage water resources and the delivery of water services [like municipal wastewater treatment] at different levels of society.”<sup>24</sup> As such it is deeply interrelated with the general political system as, in modern societies, allocative and regulatory decision making involves usually political institutions (Batchelor, 2007). This assessment applies also to Mexico where the state is by far the most important actor in water governance. In the field of municipal water and sanitation, the current Mexican governance is mainly the product of a complex web of interactions of stakeholders across all three governmental tiers which evolved mainly since the middle of the 20<sup>th</sup> century (Olivares and Sandoval, 2008).

Observed heterogeneity in the institutional structure of municipal water supply and sanitation governance across Mexican municipalities may help to identify potentially important drivers and obstacles for municipal wastewater treatment in a developing country. Thus, the description of the institutional landscape of municipal water management in chapter 3 lays the foundations for the development of hypotheses in the proceeding chapters of the thesis. Chapter 3 is structured as follows: Subchapter 3.1 provides an overview of historic developments of municipal water supply and sanitation governance. This is necessary as the status quo in Mexico can only be understood properly if seen as the result of complex interactions of all governmental tiers in Mexico in recent decades. Following, subchapter 3.2 outlines the current Mexican legislation for municipal water supply and sanitation governance. Subchapter 3.3 gives an overview of the actual organizational landscape of municipal water supply and sanitation governance, and identifies relevant key players over all governmental tiers. Subchapter 3.4 summarizes the chapter’s finding and connects them to the overall structure of the thesis.

---

<sup>24</sup> See Batchelor, 2007, p.1 and Rogers & Hall, 2003.

### **3.1. Historic overview**

The development of recent decades can be approximately distinguished into three phases: a) centralization of the control of municipal water supply and sanitation governance at the national government tier (1948-83), b) decentralization to federal states and municipalities (1983-1989), and c) corporatization and modernization of the municipal water administration (since 1989).

#### **3.1.1. Centralization of municipal water governance**

From 1948 to 1983, the national governmental level was primarily in charge of municipal water governance. The involvement of the national government into water governance started in the aftermath of the Mexican Revolution (ca. 1910 – 1920) (Aboites Aguilar, 1998; Rolland and Vega Cárdenas, 2010). Before 1948 the national government focused on the construction of large scale irrigation districts to keep the promise of “land and liberty” for middle income farmers dating from the revolutionary time (Wester and Vargas-Velázquez, 2009). However, as urbanization accelerated in the 1940s due to increased population growth and rural-urban migration the federal government shifted efforts to urban water supply and sanitation. Although those services fall genuinely into the competences of municipalities, national government authority intervened due to the lack of financial, technical, and administrative capacities. Traditionally municipal administrations were engaged in labour-intensive, little technical fields like garbage collection, policing, and traffic control. Thus, the construction and operation of capital-intensive and complex systems like municipal water supply were usually beyond the scope of municipal governments in Mexico (Pineda Pablos and Salazar Adams, 2008; Briceño, 2008).

In 1948, the Mexican Ministry of Hydraulic Resources (SRH; *Secretaría de Recursos Hidráulicos* in Spanish) created the Department for Municipal Water and Sanitation (DGAPA; *Dirección General de Agua Potable y Alcantarillado* in Spanish) to bundle and intensify national efforts for the construction of municipal water supply and sewerage networks. In January 1949, the National Law of Sanitation Engineering (*Ley Federal de Ingeniería Sanitaria* in Spanish) assigned officially the administration of municipal water systems with national (co)funding to



SRH. A complementary national regulation delegated the operative management of municipal water systems to so called National Committees for Municipal Water Supply (*Juntas Federales de Agua Potable* in Spanish). These committees were located in the municipalities but remained under the strict auspices of the DGAPA in Mexico-City. Generally, DGAPA hold control of all strategic planning and investment decisions (DOF, 1949). In 1972, the first National Water Law (*Ley Federal de Aguas* in Spanish) confirmed the leading role of the federal executive authority and specified, for the first in Mexican history, provisions on the prevention and control of municipal wastewater (Rendón, 1997; Pineda Pablos and Salazar Adams, 2008). One year later, the regulation “*Reglamento para la Prevención y Control de la Contaminación de Aguas*” stipulated that, with the exception of purely domestic sewage, discharged wastewater had to be reported to SRH and meet the minimum standards of the Mexican Sanitation Code (*Código Sanitario de los Estados Unidos Mexicanos* in Spanish) also issued in 1973 (Martínez Omaña, 2006; Garza, 2008).

### **3.1.2. Decentralization of municipal water governance**

During the 1970s the centralized municipal water governance run into crises. The accelerated urbanization and population growth in the sixties and seventies resulted in an increased demand for municipal water and sanitation service that exceeded the administrative and financial capacities of the national government in the long run. By 1973, the SHR had provided water service to 1405 localities and supervised, in 1976, 876 national and 183 municipal committees. A heavy financial burden for the central bureaucracy resulted also from the mentality of not paying for service provision, popular among municipal population. Little local involvement in past decades had triggered the perception that the national government level is exclusively in charge (Pineda Pablos and Salazar Adams, 2008). Thus, broad consensus emerged among government elites towards the end of the 1970s that restructuring in form of decentralization and municipalisation of public water services is required. The looming Mexican debt crises and its eventual outbreak in 1982 reinforced those beliefs with the national tier running short of funds (Barkin and Klooster, 2006; Collado, 2008). Consequently, President José López Portillo (1976-1982) decreed in 1980 to convey municipal water systems to lower governmental levels (Martínez Omaña, 2006; Briceño, 2008). His successor, Miguel de la Madrid (1982-

1988), enshrined the municipalisation of municipal water services into the Mexican Constitution in 1983 (Sandoval, 2008; Pineda Pablos and Salazar Adams, 2008).

In consequence, national authorities involved in municipal water governance transferred the construction and administration of the municipal water supply and sanitation systems to the state governments (DOF, 1983). In a next step, the governments of federal states had to decide whether to decentralize further to the municipal level. Direct municipalisation was not a viable alternative as municipal administrations had no experience in managing municipal water systems so that corresponding technical, financial and administrative capacities had to be built first. However, mainly due to the severe economic crises and tight public budgets, municipal administrations received, beyond the formulation of legal and normative principles, little help throughout the 1980s from superior levels to enhance operative capacities. In consequence, state authorities decentralized only hesitantly. By 1988, only 11 out of the 32 federal entities<sup>25</sup> had municipalized their systems. It took a majority of 21 states<sup>26</sup> until 1996 to municipalize (CONAGUA, 1989; Alcántara Palma, 1996; Pineda Pablos and Salazar Adams, 2008; Briceño, 2008; OECD, 2013).

### **3.1.3. Corporatization and modernization**

Due to the ongoing management issues President Carlos Salinas (1989-1994) initiated a paradigm shift in the national municipal water policy in 1989. Since then, the national government promotes the corporatization of municipal water administration. Outsourcing municipal water service provision from the general municipal administration to semi-independent public water utilities (*Organismos Operadores de Agua* in Spanish) has aimed at fostering entrepreneurial orientation and professionalization, and at limiting the influence of politics.

To overcome the chronic lack of funding and administrative and technical deficiencies the public corporations ought to become financially self-sufficient by raising and collecting cost-

---

<sup>25</sup> The following states had transferred systems to the municipal level by 1988: Aguascalientes, Baja California Sur, Colima, Chiapas, Guanajuato, Estado de México, Michoacán, Nayarit, Puebla, Sinaloa, and Tlaxcala. The following state remained in charge of the municipal systems: Baja California, Chihuahua, Coahuila, Campeche, Distrito Federal, Durango, Guerrero, Hidalgo, Jalisco, Morelos, Nuevo León, Oaxaca, Querétaro, Quintana Roo, San Luis Potosí, Sonora, Tabasco, Tamaulipas, Veracruz, Yucatán, Zacatecas (CONAGUA, 1989)

<sup>26</sup> By 1996, the state governments of Baja California, Durango, Jalisco, Nuevo León, Querétaro, Quintana Roo, Tabasco, Veracruz and Yucatan still operated the municipal systems while two other federal states run them in cooperation with municipal administrations (Alcántara Palma, 1996; Pineda Pablos and Salazar Adams, 2008).

covering service fees that allow for the recruitment and decent remuneration of skillful staff and the execution of investments and expenses required for a sound service provision. In contrast, direct political influence of municipal and federal state administrations often generates unprofessional personnel and prevents long-term planning, as the staff of the general municipal bureaucracy is commonly turned over every three years as no possibility of reelection exists for municipal administrations. Political leaders also tend to use their positions in municipal water departments as a stepping stone for their personal political career and distribute political favors, e.g. by establishing not cost-covering, subsidized water fees for particular interest and voter groups (Wilder, 2010; Aguilar Amilpa, 2010, Barkin, 2011). Additionally, the new policy approach intended to democratize municipal water management by allowing for more participation of local water user groups and citizens in the decision making bodies of public water utilities (*consejos administrativos* in Spanish).

In response to the paradigm shift 457 public water utilities<sup>27</sup> had been established until 2014 across Mexico (CONAGUA, 2014b). By their majority, they serve metropolises, state capitals, economic centers, and municipal main towns as smaller settlements usually lack the critical economic and population mass for launching financially self-sufficient public utilities. Small towns often can't afford equipment required for an adequate municipal water service. This holds in particular true for wastewater treatment and sludge disposal as applied methods are energy intensive and require substantial levels of technical expertise and investment (Briceño, 2008).

Overall, the legacy of the corporatization wave has been rather disappointing as only utilities in few municipalities (Monterrey, Tijuana, León and Ciudad Acuña) excelled and achieved levels comparable with international good practice standards (Quadri de la Torre, 2008; Saltiel, 2008; Barkin, 2011). For the majority the situation has not changed much (Dau Flores, 2008). Many municipal service providers are still caught in vicious circles with clients unwilling to pay for poor service which, in consequence, renders the suppliers unable to raise funds to invest in improved service (Briceño, 2008). According to official data, CONAGUA has published on 627 municipalities, the average commercial efficiency is 60%, i.e. only 6 of 10 invoiced liters are paid for. In addition, average physical efficiency is only 50% as only about half of the water supplied into municipal networks reaches household taps. The rest gets lost due to leakages,

---

<sup>27</sup> As of June 16<sup>th</sup>, 2014 according to an inquiry of CONAGUA from June 9<sup>th</sup>, 2014 (CONAGUA, 2014b).

clandestine connections and malfunctioning metering. In consequence total average efficiency amounts to only 30%. That mean only 3 out of 10 produced liters get paid (CONAGUA, 2014a). Frequently levels of collected service fees are also too low to cover operation and maintenance costs, mainly because the establishment of tariff levels is still subject to political discretion and does not orientate on technical criteria (Barkin, 2006; CONAGUA, 2015a).

This political influence reinforces itself as public utilities lacking financial self-sufficiency depend on governmental support and subsidies. In consequence, municipal and even federal state governments continue to intervene regularly e.g.in staffing and pricing decisions (Contreras Zepeda, 2006; Guerrero Reynoso, 2008; OECD, 2013; Salazar Adams and Lutz Ley, 2015). In addition, the short average term of general managers of a public water utility impedes the establishment of a long-term orientation. It is estimated to be as little as 2 years. Furthermore, it continues to be common practice that managerial staff rotates when a general manager is removed. This defeats any attempt for strategic long-term planning, and expertise and capacity building (Contreras, 2008).

As a further step towards even greater independence from politics, relieve of public budgets, and efficiency and entrepreneurial orientation the national government started in the 1990s to promote the privatization of public utilities (Omaña, 2006; Pineda Pablos and Salazar Adams, 2008; Wilder, 2010; Aguilar Amilpa, 2010, Barkin, 2011). However, in practice privatization is only of marginal relevance in Mexico as less than a dozen of municipalities have experimented with privatizing municipal water systems. In several municipalities privatization failed and municipal governments either canceled private industry contracts (e.g. the cities of Puebla, Navojoa) or respective agreements never entered into force (e.g. the cities of Hermosillo, Acapulco, Nogales) (Barkin, 2011). At large, 4 metropolitan areas achieved to sustain permanent private involvement: Aguascalientes, Cancun, Saltillo, and Mexico-City (D.F.). In 1993, Aguascalientes and Cancun privatized their municipal water management while in Saltillo a public-private joint venture assumed responsibilities. On the other hand, the local water authorities of Mexico-City outsourced only subordinated management areas like the installation and reading of meters, elaboration of customer directories, invoicing, and restoration and expansion of water infrastructure. With overall service quality improved in all 4 cases they are considered as relative success stories (Contreras, 2008). Though some critic has been voiced

due to steep increases in tariffs and persistent shortcomings in water delivery in qualitative and quantitative terms (Barkin, 2011).

## **3.2. Municipal water governance legislation**

As a result of past developments described in subchapter 3.1, a complex regulatory web of interacting stakeholders emerged to form the current legislative framework of Mexican municipal water supply and sanitation administration. Laws and regulations of all three governmental levels – national, federal state, and municipal – apply. Generally, legislation of superior government tiers oversees inferior tiers and sets the scene in which legislative bodies of secondary governmental tiers may act (Aguilar Amilpa, 2010).

### **3.2.1. National Legislation**

As to the case of general water legislation, the National Mexican Constitution is the most elementary legislation body for municipal water legislation. Since the major decentralization reform of the constitution in 1983, subparagraph III of Article 115 assigns the responsibility for the public services of municipal water supply, drainage, sanitation, treatment and disposal of wastewater to municipal governments (Pineda Pablos and Salazar Adams, 2008; Barkin, 2011). The original amendment of 1983 lapidary details “the service of water supply” to municipal levels, without any further specification. Only a decree from 22 of December 1999 refines the term “service” to: “The municipalities are charged with the following public functions and services: a) municipal water supply, drainage, sanitation, treatment and disposal of wastewater” (DOF, 2016; Garza, 2008).<sup>28</sup> At the same time, article 115 III states that the service of water supply is still subject to federal and state legislation though the actual task of service provision falls into the domain of municipal administrations (Abedrop López and Reyes Morales, 2008).<sup>29</sup>

---

<sup>28</sup> The original text in Spanish is: “Los Municipios tendrán a su cargo las funciones y servicios públicos siguientes: a) Agua potable, drenaje, alcantarillado, tratamiento y disposición de sus aguas residuales” (DOF, 2016).

<sup>29</sup> Art. 115 Section III Subparagraph i) stresses explicitly: “Without impairment of their constitutional competence, in regard of the configuration of the functions or delivery of the services a municipality is charged with, the municipalities will comply with the prescript by federal and state laws” (in the original Spanish version:

In this regard, the specifications of the National Water Law (LAN) are of peculiar importance. Generally, it confirms the delegation to municipal levels and acknowledges the possible involvement of federal states (Cámara de Diputados, 1992a; Cámara de Diputados, 1992b; LAN, 1992, Art. 44-45; De la Garca, 2008; Rolland and Vega Cárdenas, 2010). At the same time, articles 85 ff. and 119 ff. establish that the Mexican National Water Commission CONAGUA is as a national authority in charge of monitoring the compliance of issued water use volumes and wastewater discharge limits and of sanctioning violating municipalities (LAN, 1992). Articles 46 in combination with 99 and 101 provides further binding guidelines concerning extent and quality of the support of the national government that subnational entities may receive in the service of municipal water supply and sanitation, e.g. in terms of financial and technical assistance (LAN; 1992; Aguilar Amilpa, 2010).

Several national laws complement the National Water Law (LAN) stipulations. The General Health Law (*Ley General de Salud* in Spanish) forbids in Article 122 the discharge of untreated wastewater into water bodies destined for human consumption unless quality standards of the Mexican National Health Ministry are met. The General Law for Environmental Protection (*The Ley General del Equilibrio Ecológico y la Protección al Ambiente* in Spanish) stipulates competences of different government tiers with respect to environmental protection. According to Article 8, municipal administrations are, for instance, responsible for the preservation and restoration of the ecological equilibrium and the protection of the environment in urban settlements. They are also ordered to follow legal instructions for preventing and controlling the contamination of water released into municipal sewage networks (Aguilar Amilpa, 2010).

Of secondary relevance are the National Laws on 1) Sustainable Rural Development (*Ley de Desarrollo Rural Sustentable* in Spanish), 2) Contributions for Improvement in Public Federal Water Infrastructure Works (*Ley de Contribución de Mejoras por Obras Públicas Federales de Infraestructura Hidráulica* in Spanish), and 3) Fiscal Coordination (*Ley de Coordinación Fiscal* in Spanish).

1) deals with the satisfaction of fundamental material and cultural needs of rural and marginalized populations, like access to basic infrastructure, e.g. in form of municipal water service

---

“Sin perjuicio de su competencia constitucional, en el desempeño de las funciones o la prestación de los servicios a su cargo, los municipios observarán lo dispuesto por las leyes federales y estatales”) (DOF, 2016).

provision, though not mentioned *expressis verbis* by the law. 2) regulates the scope of (financial) contributions and commitments of the different government tiers and specifies beneficiary groups of public works. Though theoretically of importance as it establishes a funding mechanism for municipal (waste)water infrastructure, the law hardly finds application. Lastly, 3) provides a legal framework for the fiscal and administrative cooperation of national, state, and municipal tiers. This law is rather relevant as different government levels join frequently forces to construct, expand, and improve municipal (waste)water infrastructure (Aguilar Amilpa, 2010).<sup>30</sup>

### **3.2.2. Legislation of federal states**

Complementary to the national level, also federal states legislate on municipal water service. In consequence of the municipalisation of the service in 1983 federal states adjusted their respective State Constitutions (Pineda Pablos and Salazar Adams, 2008).<sup>31</sup> Though Article 115 of the Federal Constitution constitutes Mexican municipalities as free and sovereign, they are strictly subject to state legislation in regard of budgetary matters. Thus, reforms had to warrant municipalities sufficient fiscal autonomy to administer municipal water supply and sanitation. In particular, municipalities need to be endowed with the legal authority to charge and collect municipal water service fees and to issue and incur debts. The ability to borrow is considered a vital prerequisite to enable municipal administrations to invest in municipal water infrastructure as respective expenditures are likely to transcend the regular municipal budget (Aguilar Amilpa, 2010).

In addition, the federal states reformed their water laws whereby one of the most important feature has been the regulation of the subsidiary role of the state executive authority. Article 115, section III, i) of the Federal Constitution allows municipalities to transfer the service of municipal water supply to state authorities if they lack required financial, administrative, and technical capacities (DOF, 2015). For this case, state water laws detail rules and mechanism for the support provided by state authorities to empower municipalities to deliver their constitutional duties in the long run. With the aim of improving the financial, administrative, and

---

<sup>30</sup> Cf. also subchapter 3.3. of this thesis.

<sup>31</sup> Generally, federal states Constitutions complement the Federal Constitution.

technical capacities of municipal water service providers, states reform their municipal water legislation continuously, e.g. by granting service providers legal autonomy in pricing and charging water fees, by enshrining into state law the right to disconnect water connections of defaulting costumers, by mandating municipal administrations to earmark revenues originating from the municipal water sector for the very same sector, and by conceding water consumption debt the legal status of tax liabilities (see for a detailed discussion of the topic Pineda Pablos and Salazar Adams, 2008; Aguilar Amilpa, 2010).

### 3.2.3. Municipal legislation

At the municipal level, mainly two laws regulate the administration of urban water and sanitation: 1) The Municipal Organic Law (*Ley Orgánica Municipal* in Spanish), and 2) The Municipal Finance Law (*Ley Hacendaria Municipal* in Spanish).<sup>32</sup> 1) is the legislative basis for the administration of Mexican municipalities. Inter alia, it mandates municipal governments to prepare annual revenue reports, including municipal water service revenues, and submit them to state congress for approval. In addition, 2) specifies general rules and procedures of operation for the municipal budget. It incorporates relevant regulations of the state water laws like the autonomy of water service providers in pricing and the conversion of debt into tax liabilities (Aguilar Amilpa, 2010). In addition, few municipal administrations issue within the limits of national and state legislation municipal water decrees to specify goals, targets and management procedures for municipal water service.<sup>33</sup>

---

<sup>32</sup> State parliaments provide the general framework of the Municipal Organic Law and the Municipal Finance Law as Mexican municipalities do not possess the competence to pass laws in particular. Though state laws by nature I discuss them at the municipal level as they are applied there.

<sup>33</sup> No comprehensive data is available on the number of Mexican municipalities which enacted municipal water regulation. According to the judgement of the expert Anabel Palacios Moreno supposedly not more than a few hundred of the 2,456 municipalities. She is a researcher of the institute 'El Colegio de México' (contact: [apalacios@colmex.mx](mailto:apalacios@colmex.mx)) I talked to her at the National Conference of Water Culture in May 2014 in Durango, Mexico.



### 3.3. Organizational landscape of municipal water governance

As a result of the historic developments described in subchapter 3.1, also a broad spectrum of national, federal state, and municipal governmental organizations<sup>34</sup> are involved in the current administration of municipal water supply and sanitation in Mexico. They act either as normative-regulating or financing-administrating authorities, or on both counts. The involvement of plenty of public agencies of all three governmental tiers has generally led to a rather fragmented management of the Mexican municipal water sector (Barkin and Klooster, 2006; OECD, 2013). The most important key players of the three government tiers are presented in the following subchapters.

#### 3.3.1. The national level

##### The National Water Commission “CONAGUA”

The National Water commission (CONAGUA or CNA; *Comisión Nacional de Agua* in Spanish; literal translation of “CON AGUA” is “with water”) acts as the most important national key player in the field of municipal water governance in Mexico. It was established as a deconcentrated agency of the national government in 1989 during the Presidency of Salinas de Gortari (1988-1994). According to its founding charter, it is supposed to be the sole national water authority that bundles the effort of the national government to foster an efficient management of the Mexican water sector. Its mission is the preservation, administration, and organization of national water resources. Its major tasks are 1) the design of national water policies,<sup>35</sup> 2) the granting of water concessions, 3) the establishment of water quality norms, and

---

<sup>34</sup> I use in the thesis the term ‘organization’ to refer to governmental agencies and do not use the term ‘institution’ in this regard. Thus, I follow the well-known definition of ‘institution’ and ‘organization’ of Douglas C. North. According to this author ‘Institutions’ are defined as: “... the humanly devised constraints that structure political, economic and social interaction. They consist of both informal constraints (sanctions, taboos, customs, traditions, and codes of conduct), and formal rules (constitutions, laws, property rights)” (North, 1991, p. 97). In contrast, organizations are defined as “groups of individuals bound by a common purpose” (North, 1990). I.e. while institutions are defined as the rules of the game a society plays organizations are the entities that play the game (Wallis, 2015).

<sup>35</sup> Since 1976, it elaborates at the beginning of each presidency the so called “Plan Nacional de Hídrico”, the National Water Plan, which entails the political water agenda of the current term. It is part of the National Development Plan (PND; Plan Nacional de Desarrollo in Spanish) which specifies the general policy priorities of a presidential term. Usually it identifies 5 strategic fields political action focuses on during a presidency. In this

4) the coordination of regional and national water plans (Biswas, 2003; Molle et al., 2009; Rolland and Vega Cárdenas, 2010).

With respect to municipal water governance, CONAGUA acts according to article 119 of the National Water Law as a regulatory authority (LAN, 2014). As such it imposes sanctions for unauthorized discharge of untreated (municipal) wastewater and addresses structural shortcomings of municipal water systems in order to empower them to meet national regulations and legal provisions (Olivares, 2008; Salazar Adams and Lutz Ley, 2012). It further designs the municipal water politics of the national government and cooperates with subnational levels – particularly with municipal administrations and municipal water utilities – in order to implement the municipal water agenda of the national government.<sup>36</sup> Typical fields of its engagement are the modernization of the municipal water sector, the increase of municipal water system efficiency, and the augmentation of the national coverage of municipal water service provision. In particular, it engages in capacity building measures, the provision of technical and administrative guidelines and assistance, and in the setup of funding programs for municipal water infrastructure (CONAGUA, 2005; Rolland and Vega Cárdenas, 2010; Barkin, 2011). The Mexican National Water Commission is the most important funding source of municipal

---

context, the PNH details the measures in the water sector to push for the attainment of the general policy priorities in the Mexican national agenda.

Since the 1990s federal policy agendas pursue a concept of integrated and sustainable water management. In consequence of this more holistic view, more attention has been paid to sanitation and treatment of municipal wastewater as untreated sewage threatens the soundness of natural water cycles. Though already the first PNH (1976) formulated the establishment of wastewater treatment facilities in localities of more than 2,500 inhabitants as objective, wastewater treatment started to kick in only with the launch of the National Program of Municipal Water, Sewage and Wastewater Treatment (Programa Nacional de Agua Potable, Alcantarrillado y Saneamiento in Spanish) which was part of the PNH 1990-1995 (Omaña, 2006). In 2006, with the national treatment rate reaching 30%, the PNH of the presidency of Felipe Calderon (2006- 2012) established the ambitious target to increase treatment rates of collected municipal wastewater to 60% by 2012 (PNH, 2008). Though only 47.5% were actually achieved by the end of 2012 official sources considered the improvement still as significant (CONAGUA; 2013b).

In contrast to its predecessor, the current PNH (2014-2018) of ruling President Enrique Peña Nieto (2012-2018) highlights only in general terms the necessity of continued improvement of municipal wastewater treatment performance and expansion of respective infrastructure without providing concrete target figures for the wastewater treatment rate. Instead, it announces as measurable objective an increase in the Global Indicator of Access to Basic Water Services (IGASA; Índice global de acceso a los servicios básicos de agua in Spanish) from 0.652 (2012) to 0.761 (2018). Municipal wastewater treatment is thereby only one out of nine weighted indicator components which divide into 2 groups: a) access to municipal drinking water supply, b) access to sanitation service. B) contains, inter alia, the percentage of treated municipal wastewater (PNH, 2014).

<sup>36</sup> In this context it is important to note that national authorities, notably the Mexican National Water Commission CONAGUA, set the scene for the design and implementation of municipal wastewater treatment policies in spite of the fact that the service of municipal wastewater treatment falls officially and according to the letter of the law into the municipal domain. Prevailing administrative, technical and financial incapacities at the municipal tier cause superior levels to intervene (Barkin, 2011).

water infrastructure in Mexico.<sup>37</sup> In 2014, it made, for instance, about 50% of all public and private investment (US\$ 2.6 billion) into the municipal water sector. 82% of the investment of the national government came from CONAGUA in this year.

To finance municipal water infrastructure CONAGUA has launched several support programs. As a general rule, most of these programs require the financial commitment of the beneficiaries. In most cases, the municipal water supply and sanitation systems are only eligible for the participation in the support and funding programs of the Mexican National Water Commission if they and/or the municipal or state administrations of the entities they are located in agree to contribute financially to the project too. This prerequisite explains to a large extent investments federal states and municipal administrations make into urban wastewater infrastructure. They usually join forces with the national government level to advance the municipal water service sector (Olivares and Sandoval, 2008; Aguilar Amilpa; 2010; Peña et al., 2013; CONAGUA, 2015a).

---

<sup>37</sup> The existing Mexican municipal water infrastructure is predominantly funded by public investment. Table A.5 in the appendix lists the expenses of the three governmental tiers from 2002 to 2014 in millions of Mexican Pesos (Mex\$) at current prices. During this period overall spending almost tripled from 10.5 to 34.2 billion Pesos, peaking in 2012 with 40.5 billion Pesos. In US Dollars (US\$) at current prices investments increased from approximately 1.1 to which is equivalent to an increase of about 140% (in 2002 on average: 1 US\$ = 9.75 Mex\$; in 2014: 1 US\$ = 13.30 Mex\$; Mexican Federal Reserve Board, 2016). Simultaneously, investments of the national government almost increased tenfold. Figure A.5 in the appendix visualizes the increasingly dominant position of the national level. In 2014, 60% of the total funding originated from national, 16% from federal states, and 10% from municipal public sources. Another 14% come from alternative sources. This position aggregates investments from private initiatives, e.g. real estate developers that develop entire quarters of growing cities or private companies that participate in private-public-partnerships, and loans from international banks like the World Bank or commercial banks. It also includes funding from developing aid agencies of foreign countries or international organisations (Olivares and Sandoval, 2008; Peña et al., 2013; CONAGUA, 2015a).

However, only a fraction of total investments in the municipal water sector has been spent on the municipal wastewater treatment. As Table A.6 in the appendix details, 30.3% (10.4 billion Mex\$) of the total budget (34.2 billion Mex\$) was allocated to the potable water supply, 29.3% (10.0 billion Mex\$) to sewerage, 18.5% (6.3 billion Mex\$) to efficiency improvements and only the smallest share of 16.3% (5.6 billion Mex\$) to wastewater treatment in 2014 (CONAGUA, 2015a). Figure A.4 in the appendix depicts the development in investment volumes into the Mexican municipal water supply and sanitation sector from 2002 to 2014. With 15.9 billion pesos, 2012 has been the only year investments into the municipal wastewater sector took the lion's share of 39%. This high figure is partly explained by final efforts of the national government to fall less short of the goal to reach a 60% treatment rate by the end of 2012 (PNH, 2008). About a third of funding was earmarked for building wastewater infrastructure in the greater metropolitan region of Mexico-City (Valley de México) where about 20 million people reside and the wastewater treatment rate was as low as 10% before 2012. The construction of the treatment plant of Atotonilco is the most important project. After several delays it is scheduled to enter in full operation in mid-2016. As one of the biggest plants in Latin America it is supposed to treat about 60% of Mexican Valley's wastewater (Peña et al., 2013; CONAGUA, 2015a).

As prime financier, the National Water Commission has also launched several funding programs to support municipal wastewater treatment projects in particular. Two programs are of particular importance: PROTAR and PROMAGUA.<sup>38</sup>

PROTAR, standing for Program of Wastewater Treatment (*Programa de Tratamiento de Aguas Residuales* in Spanish), allocates resources to municipal public water utilities for designing, constructing, extending, rehabilitating, and operating wastewater treatment plants with the aim to increase treated volumes and/or enhance treatment quality.

PROMAGUA, standing for Modernization Program for Water Utilities (*Programa para la Modernización de los Organismos Operadores de Agua* in Spanish) supports since 2001 water utilities in form of non-recoverable credits for the provision of potable water, sewage networks and wastewater treatment, preferably in localities of more than 50,000 inhabitants.<sup>39</sup>

---

<sup>38</sup> In addition, CONAGUA operates the APAZU, PROSSAPYS, PROSANEAR, and PRODDER program. These programs provide states, municipal administrations, and water utilities financial and technical assistance to establish and improve, inter alia, municipal wastewater treatment infrastructure. However, their financial contribution to the establishment of municipal wastewater treatment infrastructure is only of secondary importance (see for details figures in Table A.7 in the appendix).

APAZU, standing for Program of Municipal Water Supply and Sanitation in Urban Areas (*Programa de Agua Potable, Alcantarillado y Saneamiento en Zonas Urbanas* in Spanish) targets localities with a population of more than 2,500 inhabitants. Overall, APAZU is CONAGUA's most potent program which it runs already since 1990. However, it spends the bulk of resources on the improvement and expansion of water supply and sewerage networks. Its counterpart for rural areas, though financially less endowed, is PROSSAPYS, standing for Program for the Construction and Rehabilitation of Municipal Water Supply and Sanitation Systems in Rural Areas (*Programa para la Construcción y Rehabilitación de Sistemas de Agua Potable y Saneamiento en Zonas Rurales* in Spanish). PROSANEAR, standing for Federal Program of Wastewater Treatment (*Programa Federal de Saneamiento de Aguas Residuales* in Spanish), has as single objective to promote measures to increase the share of treated wastewater. Finally, PRODDER – Water Rights Refund Program (*Programa de Devolución de Derechos* in Spanish) – reimburses municipal service providers the water use fees they paid to CONAGUA provided that they invest the money in municipal water infrastructure or efficiency improvements and match the reimbursed amount with own investments.

Table A.7 in the appendix attributes the municipal wastewater treatment service investments in 2014 to different CONAGUA programs. In total, they channelled investments of 4.617 billion Pesos (US\$ 350 million) into the wastewater treatment sector out of a total of Mex\$ 5.576 billion (US\$ 420 million). With 2.225 and 1.819 billion Pesos PROMAGUA and PROTAR contributed almost 73% of total investments (cf. column 2 of Table A.7 in the appendix). In contrast, the shares of APAZU and PRODDER remain marginally. Investments of 959 million Pesos (17%) originated from Non-CONAGUA sources, mainly from other entities of the national government like SEDESOL and CDI (cf. lower part of column 1 of Table A.7 in the appendix) (CONAGUA, 2015a).

Insofar data is available columns 3-6 of Table A.7 detail, in addition, the financial contributions of CONAGUA, the federal states, municipalities, and other entities like private capital to respective CONAGUA programs. In PROMAGUA investments of the state governments (806.5 million Pesos) matched almost the commitment of the national government (974.4 million Pesos) while the private sector contributed 504.2 million Pesos. This indicates that the funding that federal state governments provide plays generally an important complementary role in the funding of the municipal wastewater sector. Private capital funded at least 9% of overall investments.

<sup>39</sup> A particular prerequisite of the program is the participation of private capital. Its objective is to provide funding for restructuring water utilities to increase system efficiency, facilitate access to state-of-the-art technology, and trigger sustainable solutions like the reuse of treated municipal wastewater (CONAGUA, 2015a and 2015b). In

As Table A.7 in the appendix depicts, these two CONAGUA programs contributed almost 73% of the total investments of US\$ 420 million in the municipal wastewater treatment sector in 2014 (CONAGUA, 2015a).

### The Ministry of Environment “SEMARNAT”

The Ministry of Environment and Natural Resources (SEMARNAT; *Secretaría de Medio Ambiente y Recursos Naturales* in Spanish) designs the environmental policies of the national government. Its area of competence includes all natural resources no other department is explicitly in charge of (SEMARNAT, 2012). In coordination with other responsible governmental authorities SEMARNAT designs national policies in the fields of ecology, environmental restoration, water, environmental regulation of urban development and fishing industry. Particularly with CONAGUA, it collaborates to specify regulations and standards for wastewater discharge, and in monitoring compliances of water users with the help of national, state, and municipal authorities (OECD, 2013).

Together, SEMARNAT and CONAGUA provide the Official Mexican Standards for The Water Sector (*Normas Oficiales Mexicanas del Sector Agua* in Spanish). The SEMARNAT-norms NOM-001 to NOM-004 establish maximum contamination limits for a) wastewater discharged into national water bodies and municipal sewage systems, b) the reuse of treated wastewater in the public domain, and c) wastewater sludge for final disposal or reuse. Complementary, the CONAGUA-norms NOM-001 to NOM-013 cover technical regulations on the construction, operation and maintenance of municipal water infrastructure in order to protect the environment and reduce human health risks (CONAGUA, 2006; SEMARNAT, 2014b).

---

recent years, PROMAGUA has gained also in importance as facilitator of public-private-partnerships in the construction and operation of wastewater treatment plants. In this context, the BOT scheme is of particular relevance: Concession are given out to private businesses to build (B), operate (O), and transfer (T) wastewater treatment facilities after a certain period of time elapsed. For example, the consortium of Aguas Tratadas del Valle de México won the DBOT bid in 2009 for the wastewater treatment plant of Atotonilco. It has to design (D), build (B) and operate (O) the facility for 20 years, and transfer (T) it afterwards to the public sector. While the federal government paid 45.89% of total investment costs of 10.022 billion Pesos (approx. US\$ 789 million) in form of non-recoverable funds the private contracting party contributed the remaining amount. The consortium is supposed to reclaim its investment by charging service fees to municipal water users and municipal administrations in coming years (Barkin, 2011; Peña et al., 2013).

### Other national authorities

Further governmental entities with regulatory power on municipal wastewater treatment are at the national government level the Ministry of Health (SALUD; *Secretaría de Salud* in Spanish) which stipulates quality standards for municipal water supply and domestic water use, and the Federal Attorney for Environmental Protection (PROFEBA; *Procuraduría Federal de Protección al Ambiente* in Spanish) which elaborates environmental studies, monitors the water quality of groundwater and surface water bodies and applies sanctions if environmental standards are violated (LAN, 2014, Art. 14 BIS 4). As a decentralized entity of SEMARNAT, the Mexican Institute for Water Technology (IMTA; *Instituto Mexicano de Tecnología de Aguas* in Spanish) provides (scientific) knowledge, technological standards and innovation to the Mexican municipal water sector (OECD, 2013).

As funding agency the Ministry of Finance (SHCP; *Secretaría de Hacienda y Crédito Público* in Spanish) plays a crucial role as it earmarks the public water sector budget, takes part as coordinator in the financial planning of (water related) governmental programs and authorizes and (co)finances multi-annual investment programs. Supplementary, the General Congress has to approve respective water policies and allocated budgets. Additional funding institutions are the National Infrastructure Fund (FONADIN; *Fondo Nacional de Infraestructura* in Spanish), the Federal Electricity Commission (CFE; *Comisión Federal de Electricidad* in Spanish), the National Commission of Housing (CONAVI; *Comisión Nacional de Vivienda*), the National Commission for the Development of Indigenous Peoples (CDI; *Comisión Nacional para el Desarrollo de los Pueblos Indígenas* in Spanish), and the Ministry of Social Development (SEDESOL; *Secretaría de Desarrollo Social* in Spanish). FONADIN funds the planning, design, construction, operation and maintenance of infrastructure, in general, and of sanitation projects, in particular. CFE is only marginally involved in municipal wastewater treatment funding as it constructs and operates multi-use dams including the provision of municipal drinking water and serving as receiving bodies. While CDI supports the development of infrastructure in settlement of 15,000 to 50,000 dwellers with a marginalized indigenous population of at least 40%, SEDESOL provides funding for rural settlements in general (CONAGUA, 2010a; OECD, 2013).<sup>40</sup>

---

<sup>40</sup> Table A.7 in the appendix provides investment volumes made by these national public entities in 2014 (see section 'Non-CONAGUA Investment').

### 3.3.2. The federal state level

#### Governments of federal states

Complementary to the national government, the governors of the Mexican federal states also elaborate so called 'State Water Programs' (PEH; *Programas Estatales Hídricos* in Spanish) for their respective six-year terms. The programs comply with the National Development Plan (PND; *Plan Nacional de Desarrollo* in Spanish) and National Water Program (PNH; *Programa Nacional Hídrico* in Spanish) of the Mexican national government as well as with respective State Developing Plans of the governments of federal states.<sup>41</sup> Obviously, the 32 federal state entities differ in their commitment to the municipal sanitation sector. Some federal states have put particular focus on wastewater treatment issues in recent years. For instance, the latest Water Program of the Federal State of Morelos (2014-2018), includes the target to increase municipal wastewater treatment from 27.7% (2011) to 60% (2018). In addition, utilization of installed treatment capacity shall be improved from 38% (2012) to 80% (2018) (PEH de Morelos, 2014).

Generally, governments of federal states participate in the regulation, funding, and administration of municipal water service provision. By and large, they have followed the example of the national government and established so called State Water Commissions (*Comisiones Estatales de Agua* in Spanish) which bundle efforts to govern water at the state level. Similar to CONAGUA at the national level, these state commissions elaborate and implement water policies of the federal states, often with a particular focus on municipal water service provision. However, since neither the Mexican Constitution nor the Mexican National Water Law specify binding roles for the executive power in the federal states the design of the water governance vary to some extent among the Mexican federal states. Instead of binding legal provisions, CONAGUA promoted in the 1990s only a so called Blue Print Law (*Ley Tipo* in Spanish) for the design of a modern municipal water governance with corporatization, and later privatization, of municipal water service provision as main features. Since nonbinding, federal states adopted the CONAGUA's guideline to varying degrees (Garza, 2008; Pineda Pablos and Salazar Adams, 2008). Generally, the governments of federal states acquired more political

---

<sup>41</sup> Like the Mexican president at the national level, elaborates every governor of a Mexican federal state at the beginning of his or her term in office a development plan which contains the priorities and goals of his or her term.

and fiscal autonomy due to a second decentralization wave in the political system of Mexico in the second half of the 1990s. Since then, they gradually started to pursue own local water agendas with substantial investments in some states into the municipal water sector (Wester and Vargas-Velázquez, 2009).

### Water Commissions of Federal States

Similar to the executive authority at the national level, governments of federal states bundle increasingly their efforts in water governance in deconcentrated so called 'State Water Commissions' (*Comisiones Estatales de Agua* in Spanish). Although stipulations differ to some extent among federal states State Water Commissions tend to be charged with 1) the elaboration of the water policy of a federal state, 3) the design, coordination and implementation of (municipal) water infrastructure construction, 4) the provision of technical, administrative, and financial assistance to the municipal water service providers, and 5) the supervision of municipal performance (Olivares and Sandoval, 2008).<sup>42</sup>

Additionally, State Water Commissions act as go-between for the municipal and national level. According to the National Water Law and the CONAGUA Regulation of Funding Programs for Municipal Water Supply and Sanitation (*Reglas de Operación para los Programas de Infraestructura Hidroagrícola y de Agua Potable, Alcantarillado y Saneamiento a cargo de la Comisión Nacional del Agua* in Spanish) municipal entities are only eligible for support of the national government if the national government and the government of the federal state the municipality belongs to sign respective agreements (Aguilar Amilpa; OECD, LAN, 2014, Art. 9 XXV; 2013; SEMARNAT, 2014a). Furthermore, several programs of the Mexican national government require explicitly contributions of the governments of federal states in terms of funding (Aguilar Amilpa, 2010).

In a substantial number of cases, State Water Commissions also operate directly municipal water service systems. Lacking capacities, municipal governments, particularly in rural areas, make frequently use the provisions of Art. 115 of the Mexican Constitution and transfer the

---

<sup>42</sup> See for examples: LAEAC – Water Law of Aguascalientes, 2007, Art. 5, and LCEA – Inauguration Law of the State Water Commission of Morelos, 2012, Art. 3.



administration of municipal water systems to federal state authorities (Pineda Pablos and Salazar Adams, 2008; Garza, 2008, Abedrop López and Reyes Morales, 2008).

### State Congresses

As the legislative authority of federal states, State Congresses (*Congresos Estatales* in Spanish) approve in most federal states tariffs for the service of municipal water supply, sanitation, and wastewater treatment. In addition, public water sector budgets and water agendas of federal state governments require parliamentary approval (Briceño, 2008; CONAGUA, 2010a; OECD, 2013).

### **3.3.3. The municipal level**

#### Municipal Administration

In the majority of municipalities municipal water service provision is part of the general municipal administration. Usually, the task is allocated to a small department in the city hall. No general legal provisions of national or state laws exist that stipulate the organizational structures of such a department.

Alternatively to the direct administration, the National and State Water Laws allow municipalities to either 1) outsource the service provision to deconcentrated municipal public utilities, 2) to create inter-municipal public water entities, or 3) to grant concessions to private enterprises to run either the municipal water service holistically or components of it like wastewater treatment or administrative tasks like metering or invoicing (Barkin and Klooster, 2006). Commonly, State Water Laws detail the organizational structure of municipal public water utilities. Features, common to entities in all federal states, are briefly described in the next paragraph.

## Municipal Public Water Utilities

457 municipalities<sup>43</sup> outsourced the municipal water administration to municipal public water utilities (*Organismos Operadores de Agua* in Spanish). Disposing to varying degrees of technical, administrative and financial competences, these entities are, in theory, semi-independent from municipal governments.<sup>44</sup> However, although endowed with legal personality and operating assets they maintain, de facto, close structural and personnel ties to the municipal administration (Barkin, 2011).

Respective State Water Laws specify the organizational structure of water utilities. Consequently, it varies to some extent across federal states. Commonly, a water utility disposes of an executive or administrative board (*Consejo Directivo* or *Consejo de Administración* in Spanish), a general manager (*Director General* in Spanish), an advisory council (*Consejo Consultivo* in Spanish), and a commissar (*Comisario* in Spanish). The law in some federal states stipulates further that technical and administrative staff is required for sound municipal water administration, for instance, Article 76 of Sonora's State Water Law (Congreso del Estado de Sonora, 2011).

The executive board of a water utility is composed of a chairman (*Presidente* in Spanish), a position the municipal president assumes, a secretary (*Secretario* in Spanish), usually assumed by the general manager of the water utility, and assessors (*Vocales* in Spanish) which commonly include representatives of the municipal administration – e.g. aldermen, head of the urban development or health department –, the state government or state water commission, and different local water user associations – e.g. delegates from agricultural, industrial, commercial, civic and neighborhood associations. The main responsibilities of the executive board is to 1) outline general policies, standards and criteria for municipal water service provision, 2) determine service fees, 3) appoint and dismiss the general manager, and 4) authorize the general manager's working agenda, the budget, and infrastructure investments and associated borrowing.

---

<sup>43</sup> As of June 16<sup>th</sup>, 2014 according to an inquiry of CONAGUA from June 9<sup>th</sup>, 2014 (see for details CONAGUA, 2014b).

<sup>44</sup> There are considered only semi-independent and not completely independent because they still have to report to the general municipal administration.

The general manager 1) sets goals and targets, 2) elaborates implementation agendas, 3) organizes day-to-day operations, and 4) reports periodically to the executive board and the municipal administration. The advisory council comments the utility's performance and gives advices in financial, technical, and administrative matters. The commissioner is appointed by the municipal administration and acts as auditor who scrutinizes proceedings' legality.<sup>45</sup>

### **3.4. Summary of chapter 3**

Chapter 3 of the thesis has given a detailed overview over the institutional environment within which municipal wastewater treatment takes place or not in Mexico. Having a federalist political system that consists of the national, federal state and municipal governmental level, Mexico is described as a country that has a complex municipal water supply and sanitation governance that includes the interaction of all three governmental tiers (OECD, 2013). While the Mexican constitution assigns the task to treat municipal wastewater to the municipal government, it endows the national and federal state government level with legislative and regulating competences in the administration of municipal water supply and sanitation (DOF, 2016). In practise, superior government levels are heavily involved in the actual management of municipal water due to historic developments and the lack of administrative, financial and technical capacities of municipal governments. Municipal administrations apply generally for federal state and national funding and rarely pursue municipal wastewater treatment projects without the co-investment and co-management of superior tiers (Peña et al., 2013; CONAGUA, 2015a). In particular the funding and support programs of the National Water Commission CONAGUA are of importance making the commission to the central player in the governance of sanitation (Molle et al., 2009, Peña et al., 2013). Since the late 1990s, the governments of federal states gradually started to pursue own local water agendas with substantial investments in some states into the municipal wastewater sector (Wester and Wester, 2009). During this period, the institutional landscape has been further diversified as a substantial number of Mexican municipalities created public water utilities in their jurisdictions and outsourced the

---

<sup>45</sup> See e.g. Articles 27 ff. of the Water Law of the Federal States of Aguascalientes (LAEAC, 2007), and Articles 47 ff. of the Water Law of the Federal States of Michoacan (Congreso del Estado de Michoacan, 2007).

management of municipal water supply and sanitation from water departments in the general municipal administration to these new public enterprises (CONAGUA, 2014b and 2014c).

Potentially, this observed heterogeneity in the institutional structure of municipal water supply and sanitation management across Mexican municipalities may explain to some extent differences in the treatment of municipal wastewater across Mexican municipalities. Thus, the description of the institutional landscape of municipal water governance in chapter 3 lays the foundations for the development of hypotheses in chapter 4 of the thesis.

## **4. Literature review: Economic features of wastewater and social drivers of municipal wastewater treatment**

As illustrated in chapter 2, Mexican municipalities differ substantially in their performance of municipal wastewater treatment. By 2010, 846 of the 2,456 Mexican municipalities treated a share of their municipal wastewater that ranged from single-digit percentages to full coverage, while the remaining municipalities did not engage in municipal wastewater treatment (CONAGUA, 2013b). In addition, chapter 2 and chapter 3 elaborated that Mexican municipalities are also diverse in socioeconomic, demographic and institutional aspects and in terms of water availability. From there, the question arises to what extent heterogeneity in social factors explain the variance in municipal wastewater treatment performance in a developing country.

Accordingly, chapter 4 of the thesis develops hypotheses on socioeconomic, demographic, geographic, and institutional factors and characteristics of a municipality that may explain why treatment of municipal wastewater takes place or not. To do so, subchapter 4.1 discusses briefly the economic features of municipal wastewater. It classifies untreated wastewater as a negative environmental externality and treated wastewater as a (local) public good and recaps why the identified features may impair a society to treat municipal wastewater and provoke environmental pollution. Subsequently, subchapter 4.2 reviews economic research on the causal link between social characteristics and environmental performance. It discusses the mechanisms, economic literature theorizes on and scrutinizes empirically, how certain social characteristics foster the internalization of negative environmental externalities and facilitate the provision of public goods like environmental protection. Based on these insights and on the information provided in chapters 2 and 3 on the social structure of the Mexican society and the Mexican municipal water governance, the thesis derives 10 hypotheses on social factors and characteristics of municipalities possibly affecting municipal wastewater treatment performance in a developing country. Subchapter 4.3 summarizes the chapter's findings and states the 10 hypotheses.

#### 4.1. Economic features of wastewater

Its solvent properties and relatively plentiful supply turn water into a medium capable of assimilating and absorbing wastes and pollutants (Young and Haveman, 1985). In addition, water tends to be highly mobile. These physical features predestine it to serve as a perfect “solution” to remove waste which is particularly made use of in the industrial and residential housing domain (Hanemann, 2006).

However liquidizing waste and flushing the wastewater away is often not so much a final solution to a pollution issue but just a relatively easy and cheap way to get rid of it in a certain place by shifting the very same pollution simply to somewhere else. In such a situation, the costs of environmental pollution may be externalized to a third party which may suffer the negative effects instead of the polluter. Therefore untreated municipal wastewater can be classified as a negative environmental externality.<sup>46</sup> Its negative externality character materialize in form of reduced water quality of receiving water bodies. As a consequence, the usability as a water source for drinking water, irrigation, fishing, recreational or other environmental purposes might be at risk as untreated wastewater provides beneficial living conditions for a wide range of potentially harmful organisms to humans like bacteria, virus, and protozoans, and give rise to eutrophication, algae proliferation and, in turn, fish die-offs (Livingston, 1995; Molinos-Senante et al., 2010; Molinos-Senante and Sala-Garrido, 2015; WHO, 2011; Malik et al., 2015).

The phenomenon of socializing pollution costs results from an underlying incentive dilemma due to the asymmetrical distribution of associated costs and benefits. A paragon are communities located along a river. On the one hand, upstream communities have an incentive to discharge municipal wastewater into the river instead of treating it as this is an easy solution to get rid of unwanted polluted water since pollution affects primarily downstream communities. On the other hand, the upstream communities would have to bear the costs for

---

<sup>46</sup> Generally, negative externalities are defined as the costs a third party has to bear from an economic activity of others and which are not translated through market prices. (Jaeger, 2005).

wastewater treatment while downstream communities would derive the benefit of this activity. Consequently, upstream communities lack the incentive to treat municipal wastewater to avoid environmental pollution (Zetland, 2011).<sup>47</sup>

To eliminate or at least reduce losses in welfare resulting from negative externalities of untreated municipal wastewater a mechanism needs to be established that internalize the costs originally inflicted on third parties into the decision making of individuals engaged in the polluting activity. Economic research identifies mainly two mechanism types that may incentivise polluters to internalize the cost of pollution: 1) extrinsic or 2) intrinsic motivation mechanisms (Epstein, 2017).

Extrinsic motivation is characterised as a mechanism that imposes external punishment to compel compliance of environmental rules that have been enacted by a society to protect the environment. Typically, this mechanism imposes sanctions to increase the costs of environmental misbehaviour incentivizing the polluter to curb pollution accordingly (Deci and Ryan, 2000). As opposed to extrinsic motivation, internal factors or characteristics of the polluting entity trigger intrinsic motivation. I.e. a polluter may comply with environmental standards and internalize externalities of environmental pollution because he or she personally wants to do so due to his or her particular characteristics and regardless of the presence or absence of external forces that enforce compliance extrinsically (Kerr et al., 1997; Epstein, 2017).

In Mexico, for instance, the national water legislation enacted the “Polluter pays” principle<sup>48</sup> as an extrinsic motivation mechanism. It mandates municipal administrations to pay the Mexican national government for the right to discharge wastewater into national water bodies. In

---

<sup>47</sup> The same holds true for positive externalities (and other types of market failure like monopoly markets etc.). In contrast to negative externalities, positive externalities are benefits a third party derives from an economic activity of others (Jaeger, 2005). However they are neglected in this research context as untreated wastewater poses primarily a negative externality in form of environmental pollution and health risk. Nevertheless, untreated wastewater may also feature positive externalities under certain circumstances. For instance, if it is applied to agricultural fields for irrigation it may serve as a cheap fertilizer.

<sup>48</sup> The “polluter pays” principle was developed by the Organisation for Economic Co-Operation and Development (OECD, 1992). It stipulates that the polluting entity shall pay the costs that arise in order to prevent or implement measures against the caused pollution. Measures are determined by public authorities with the aim to keep the environment in an acceptable state (Jephcote et al., 2016).

In addition, other principles have been implemented in practice in order to give polluters extrinsic motivation to internalize externalities and eliminate pollution (Epstein, 2017). According to the Coase theorem, for instance, issuing the right to pollute either to the polluter or pollutee suffices to internalize negative or positive externalities and to reach welfare maximizing pollution levels. At least this holds true as long as both parties are able to negotiate the pollution level at negligible transaction costs, no information asymmetries are present, and property rights are enforceable (Coase, 1960).

addition, it fines the illicit release of untreated wastewater that does not meet national standards of water quality (CONAGUA, 2012a; Wilder, 2010; OECD, 2013). Thus, Mexican municipalities should be, in principle, incentivized extrinsically to avoid environmental pollution. However, as it is rather typical for a developing country, compliance of discharge limits of municipal wastewater is, in reality, rarely monitored, and detected violations frequently not punished in Mexico (Barkin, 2011). Obviously, this defective environmental policy reduces the incentives for Mexican municipalities to treat municipal wastewater. In addition, it is doubtful whether fee and fine levels give sufficient extrinsic incentives to municipal administrations to treat municipal wastewater as fees are rather low in Mexico (Barkin, 2011).<sup>49</sup> As a consequence negative externalities may not get internalized as intended by the installed mechanism.

In consequence, intrinsic motivation is of particular importance to cause Mexican municipalities to treat their wastewater and comply with environmental rules. I.e. the presence or absence of certain socioeconomic, demographic, and institutional characteristics of Mexican municipalities may motivate municipalities intrinsically to internalize negative externalities by treating municipal wastewater.

In addition, treated municipal wastewater display to some extent the features of a (local) public good<sup>50</sup> as treated and untreated municipal wastewater is frequently discharged into local water bodies and the environment. The population of a municipality may enjoy an intact local environment in a non-rivalry and non-excludable manner if water bodies are not polluted by untreated wastewater. Thus, treating municipal wastewater conserves a safe and healthy environment that does not pose health risks to anyone and can be used for recreational purposes by everyone (Molinos-Senante et al., 2010; Molinos-Senante and Sala-Garrido, 2015).

---

<sup>49</sup> Generally, one may also dispute whether respective discharge fees and quality standards of discharged municipal wastewater are set at marginal pollution costs as one would expect that caused marginal environmental harm varies, most likely, across Mexican municipalities. To some extent, the levels of charges account for this as they depend on the relative availability of water resources in a municipality. The scarcer water in an area the higher the fees. Whether the level of these tariffs gives the right incentives to treat wastewater is questionable though.

<sup>50</sup> Generally, a public good is defined as a good whose consumptions is non-excludable and non-rivalry. I.e. no market participant can neither be excluded from consuming it nor does his or her consumption make it impossible that other market participants consume the good (Samuelson, 1954; Mankiw and Taylor, 2014). A local public good is a good whose consumptions is only non-excludable and non-rivalry within a certain location or area and not for all market participants (Tiebout, 1956).



Generally, the provision of public goods requires collective action and cooperation due to freeriding behaviour at the individual level. Rational behaving individuals are prone to freeride on other's decision to provide public goods because they can't be excluded once the good is provided. In addition, a public good requires joint funding as providing it is commonly beyond the means of an individual (Samuelson, 1954; Hanemann, 2006). I.e. in order to provide a clean environment as a (local) public good, a municipal government usually has to pursue a sound municipal water policy on behalf of the entire community that includes the proper treatment of municipal wastewater. However, the success of this endeavour may depend largely on the socioeconomic, demographic and institutional environment within which the municipal government has to take action.

## **4.2. Social drivers of municipal wastewater treatment**

Economic research has investigated at large the connexion between factors and characteristics of a society that may facilitate or impede public goods provision and the internalization of external effects (e.g. Oates, 1972; Easterly and Levine, 1997; Hoxby, 2000; Alesina et al., 2003; Jaeger, 2005; Glaeser and Saks, 2006; Witte and Geys, 2011). Within this broad field, a particular research string scrutinizes explicitly the link between social characteristics of a society and its environmental performance (e.g. Dinda, 2004; Hosseini and Kaneko, 2013; Wong and Lewis, 2013; Sundström and Mc Right, 2013; Berthe and Elie, 2015). The thesis draws mainly on this latter research to derive 10 hypotheses on social characteristics and their importance for municipal wastewater treatment. In the following, a detailed overview of these social characteristics and factors is given and their potential relevance for municipal wastewater treatment discussed.

### **4.2.1. Per capita income**

#### The general nexus with environmental performance

The economic-development-environmental-degradation nexus is lively discussed in economic literature. Within this debate the Environmental Kuznets Curve (EKC) hypothesis features prominently since Grossman and Krueger brought it up in 1991 (Grossman and Krueger, 1991).

It postulates an inverted U-shaped relationship between per capita income and pollution (e.g. Shafik and Bandyopadhyay, 1992; Grossman and Krueger, 1993 and 1995; Panayotou, 1993).<sup>51</sup> At very low income levels, marked by no economic development, environmental deterioration remains at very low levels. This changes when incomes start to increase in the take-off phase of an economy. Environmental deterioration is assumed to accelerate disproportionately in this period. However, with incomes further growing the positive relation is expected to flatten out until a tipping point is reached beyond which higher per capita incomes trigger lower pollution levels.

Mainly, two rationales are given for the existence of the ECK (Dinda, 2004; Bo, 2011). First, the relationship may sketch the development from agrarian societies with relatively low pollution levels to industrial societies with severe degrees of environmental degradation to service societies which, again, have low degradation levels. Secondly, the EKC may express higher preferences of people with higher incomes to live in a cleaner environment having therefore a higher willingness to pay for a cleaner environment.

In their seminal work, Grossman and Krueger (1991) identify economic scale, structure and technology as three features of economic growth that impact the environment. If an economy scales up, more resources are consumed which is assumed to lead, *ceteris paribus*, to higher emissions of pollution. On the other hand, structural changes of an economy and technological advances underlie rising incomes. While structural changes may trigger either more or less pollution depending on the nature of the change, technological improvements may translate into more environment-friendly production methods and less resource consumption. Hence, increasing pollution levels in the transition phase from an agrarian to an industrial society is due to the fact that the scale effect together with a negative structural effect<sup>52</sup> outweighs the

---

<sup>51</sup> The Inverted-U hypothesis was originally developed by Kuznets in 1955 to describe the relationship between the development of per capita income and income inequality. He assumed that income inequality increases in the first phases of economic development until a certain income level is reached from which on the relationship is reversed and income inequality starts to decrease with increasing per capita income (Kuznets, 1955). He explained the concave shape of a per-capita-income-income-inequality-curve – later in literature labelled Kuznets Curve (KC) – in the context of the economic trajectory from an agrarian to an industrial society. In an agrarian society, almost all of the working population is employed in the agrarian sector earning there approximately same wages. However, this changes when a society starts to industrialize. At the beginning, relatively few workers migrate to the industrial sector where they get paid higher wages. This causes a spread in income distribution which is only reduced after more and more workers have shifted from the agrarian to the industrial sector. Eventually, the big majority of the working population ends up working in the industry sector earning again similar wages. Likewise, the wages of the few workers remaining in agriculture also have increased as agricultural labor has become scarcer and corresponding reservation wages have been raising due to higher opportunity costs.

<sup>52</sup> The structural effect is negative in the sense that pollution increases.

technological effect. In contrast, the structural effect reduces in the transition phase from an industrial to a service society to alleviate pollution levels and triggers together with the technological effect a negative relationship between per capita income and environmental degradation (Arrow et al., 1995).

While the first explanation of the EKC received some criticism since it implicitly suggests the existence of a single pathway of economic development (Dinda, 2004), the second argument's classification of clean environment as a normal good or even as a superior good for which demand increases disproportionately with increasing per capita income is less controversial (Scruggs, 1998). For people with lower income levels, opportunity costs are prohibitive high to mitigate or abate environmental pollution or restore environmental quality. Alternatively, they spend their income on the consumption of goods and services that yield higher utilities than the protection of the environment. Consequently, only higher income economies observe the negative relationship between environmental pollution and economic development. (Beckerman, 1992; Shafik, 1994; Carson et al., 1997; McConnell, 1997).

In this context, scholars annotated (e.g. Heerink et al., 2001) that it is unlikely that increasing incomes will realize automatically higher environmental standards. Richer people do not simply switch their consumption to more environmentally friendly goods and services. Instead they rather increase pressure on politicians to establish and enforce stricter environmental regulation (Grossman and Krueger, 1995; De Bruyn and Heintz, 1999).

### Empirical validation

Over the last decades a vast number of studies on a wide range of pollution types tested the empirical validity of EKC. Since overall results are mixed a controversial debate is ongoing both on empirical issues – e.g. with respect to the application of estimation techniques, econometric models, statistical strategies, geographic areas, inclusion of control variables and which type of data to use (Stern, 2004; Carson, 2010; Wong and Lewis, 2013) – and on theories about channels that link per capita income growth and changes in environmental pollution levels – e.g. policy regulation, diffusion of eco-friendly technologies via international trade, foreign

direct investment, institutional settings, etc. (Wong and Lewis, 2013; López-Menéndez et al., 2014)<sup>53</sup>

Several studies found an inverted U-shaped relationship between environmental degradation and per capita income particularly for local air pollutants like sulphur (Halkos, 2003), sulphur dioxide (SO<sub>2</sub>) (Shafik, 1994; Selden and Song, 1994; Grossman and Krueger, 1995; Panayotou, 1997; Cole et al., 1997; List and Gallet, 1999; Deacon and Norman, 2006; Farzanegan and Markwardt, 2012), suspended particulate matter (Shafik, 1994; Selden and Song, 1994; Grossman and Krueger, 1995; Cole et al., 1997), oxides of nitrogen (Selden and Song, 1994; Cole et al., 1997; List and Gallet, 1999), and carbon monoxide CO (Selden and Song, 1994; Cole et al., 1997).

Fewer studies confirmed the existence of a EKC for water pollution types like nitrate (Grossman and Krueger, 1995; Cole et al., 1997), volumes of wastewater (Liu et al., 2007; Song and Tong., 2008; Shua et al., 2012), and faecal coliform and heavy metal contamination (Grossman and Krueger, 1995).

For other types of environmental degradation (e.g. deforestation), several studies show evidence of an inverted U-shape correlation (Panayotou, 1993; Culas, 2007; Choumert et al., 2013). However, plenty of studies do not confirm the ECK hypothesis. Instead, they find rather monotonically increasing or decreasing, U-shaped or (inverted) N-shaped relations or no significant correlation at all (Hettige et al., 1999; Dinda et al., 2000; Harbaugh et al., 2002; Groot et al., 2004; Wagner, 2008; Wong and Lewis, 2013). A no significant relations is particularly observed for pollutants with a more global impact like carbon dioxide (CO<sub>2</sub>) and methane (CH<sub>4</sub>). With few exceptions (e.g. López-Menéndez et al., 2014), studies identified a positive linear relationship of greenhouse gases emission and per capita income, if any at all (Shafik, 1994, Cole et al., 1997; Ansuategi and Perrings, 2000; Plassmann and Khanna, 2006; Azomahou et al., 2006; Wagner, 2008; Paudel and Schafer, 2009). An explanation for this may be that national actors face less incentives to abate emissions of global pollutants as damage is (partially) externalized to other world regions.

---

<sup>53</sup> For a comprehensive overview of empirical issues see (Stern, 2004); for a summary of theoretical explanations (Cole, 2003) and (Dinda, 2004).

## Hypothesis

Applying the general EKC argumentation to the particular field of municipal wastewater treatment, I hypothesize a positive relation between per capita income and treatment performance in Mexican municipalities. Since demand for a cleaner environment is expected to increase with people becoming richer, efforts, put into municipal wastewater treatment, presumably augment accordingly. Richer citizens might be more willing to vote for local politicians campaigning for the establishment of wastewater treatment infrastructure and its proper management. In contrast, constituents disposing of lower incomes might rather prefer tax revenues to be spent on other social issues they perceive as even more pressing than water pollution. This could be, for instance, the establishment of a public health and education system, the construction of a public electricity grid, direct measures for poverty alleviation, and so forth. From there it follows that municipalities with a population that has a higher average per capita income at its disposal should have a better record of wastewater treatment performance.

Moreover, municipalities with a richer population have not only higher preferences but also a higher ability to pay for municipal wastewater treatment service on average. Commonly, little incomes generate little revenues for public administrations. This might forestall public investments in expensive wastewater treatment infrastructure since they would blow the local public budget. As it is typically the case for an emerging and developing country municipal financial resources are relatively tight in Mexico (Barkin, 2011, Peña et al., 2013).

Economic research links economic activity and related higher per capita income levels also with better governance performance, notably, because institutions become affordable that provide public goods like sanitation more efficiently. In addition, institutions of improved quality are better able to internalize negative externalities by duly monitoring compliance and rigorously fining misbehaviour (North, 1981).

Finally, I also expect a positive impact of per capita incomes on municipal wastewater treatment performance based on the scale, structural and technological effect argumentation of the EKC. Provided the expansion of production and a switch to a more polluting production scheme cause per capita incomes to rise in the industrialization phase, higher pollution discharge loads into municipal sewerage systems are likely to be, *ceteris paribus*, observed. Hence, there is more pressure to treat municipal wastewater. In consequence, it should be

also more likely that it gets actually treated. In addition, technological standards are supposed to advance with economic development. This increases prospects that wastewater treatment technologies become readily available once population develops further economically and produces higher per capita incomes.

In conclusion and in consideration of all argumentations provided in this subchapter, I derive the first hypothesis:

Hypothesis 1: Per capita income has a significant positive net impact on municipal wastewater treatment performance (+).<sup>54</sup>

#### **4.2.2. Income inequality**

##### The general nexus with environmental performance

Beside the amount of a society's average per capita income, the distribution of income within a society may matter too with respect to environmental performance (Berthe and Elie, 2015). In economic research, it is controversial whether more pronounced income inequalities have a positive or negative impact. Two main strings exist in literature. One focuses on the political economy aspect of environmental pollution and investigates how income inequality affects the determination of environmental policies (Roemer, 1993; Boyce 2003 and 2007; Wisman, 2011; Berthe and Elie, 2015). The other discusses the nexus between income inequality and environmental degradation based on the economic behaviours of households. I.e. it investigates environmental degradation as the result of households' consumption decisions (Scruggs, 1998; Heerink et al., 2001; Berthe and Elie, 2015).

Within the political economy string, it has been argued that a more equal income distribution remedies environmental pollution as pollutees have more political influence in such an environment (Roemer, 1993). The argument bases on the assumption that the rich part in a society tend to be the polluter, and the poor part the pollutee. In consequence, the rich do not have the incentive to share in abatement costs. The line of argument originates from the insight that being rich makes it generally more likely to engage in (polluting) production processes and derive related producer surplus. In addition, higher financial endowment allows for a

---

<sup>54</sup> "+" stands for the expectation of a positive net effect of the explanatory factor.

higher consumption level. Thus, the rich enjoy a higher share in the consumer surplus derived from polluting activities than the poor. On the other hand, associated pollution costs are socialized as the poor suffers from negative externalities (Boyce, 2003 and 2007).

In order to internalize the pollution costs the poor part of society needs to become active in the political arena and demand stricter regulation and the implementation of abatement measures (Wisman, 2011; Berthe and Elie, 2015). At the same time, the poor in an unequal society tend to have limited political power. In comparison with the richer parts, their lower incomes render them less able to influence the political agenda and decision making in their favour as they lack necessary financial means. Apart from that the relatively small number of rich people in unequal societies makes it more feasible for them to coordinate to pursue their political interests. In contrast, the poor face high transaction costs of coordination due to their large number. In consequence, the political process in unequal societies favours the rich which may imply higher pollution levels (Roemer, 1993; Torras and Boyce, 1998; Boyce, 1994, 2003, 2007; Wisman, 2011; Berthe and Elie, 2015).

Moreover, regardless of who caused the pollution, it might be a more cost-effective and therefore a more rational strategy for affluent people to isolate themselves geographically from pollution by settling in pollution free areas instead of joining abatement efforts that benefit all of society (Torras & Boyce, 1998; Roca, 2003). Empirical studies confirm that local residents cluster according to their ability and willingness to pay to settle in locations with e.g. higher or lower air quality (Hamilton and Phaneuf, 2015).

In addition, Magnani (2000) hypothesizes that the focus of public policy in unequal societies is on economic development and growth as the respective median voter is relatively poor in comparison to the mean voter. Environmental issues rank, therefore, less high on the median voter's agenda. She bases her argument on the assumption that the perception of personal well-being depends largely on social standing which is the more humble for the median voter the more unequal a society is, i.e. the bigger the gap between mean and median income. As a consequence, the median voter in unequal societies prefers politics that narrow this gap over environmental protection policy.

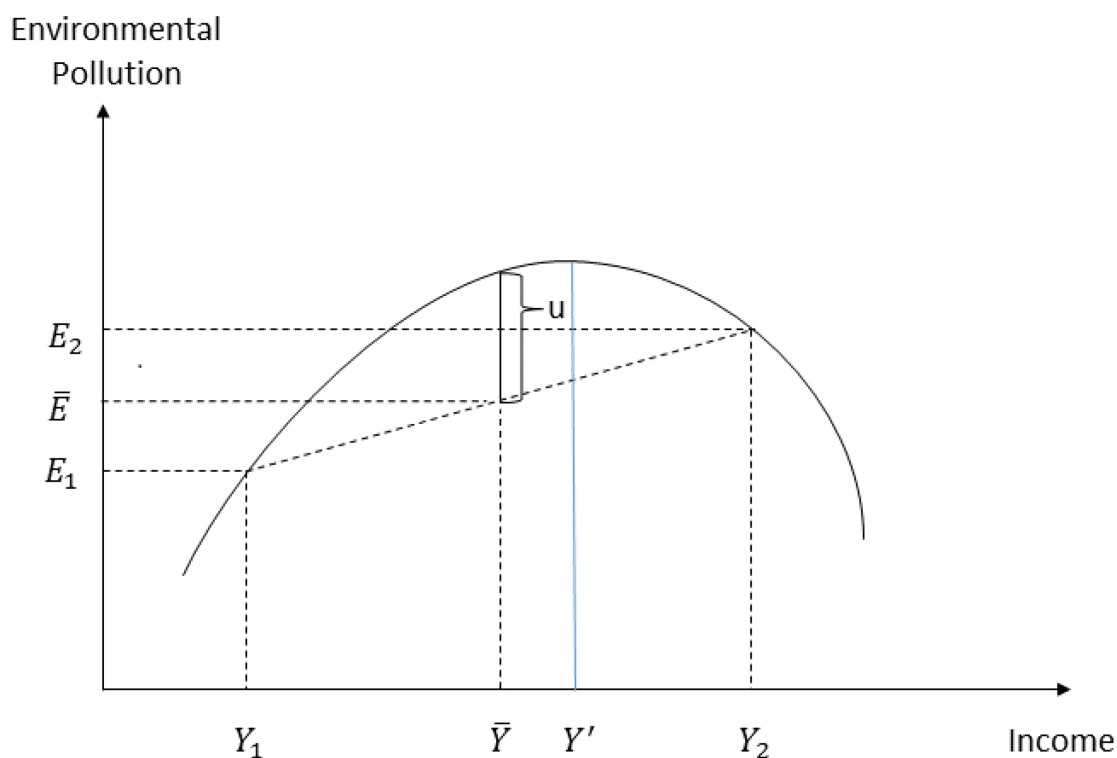
On the other hand, authors like Scruggs (1998) caution against concluding indiscriminately from a higher individual's income share to an increased marginal demand for environmental

degradation. Contrarily, he highlights empirical evidence for the prevalence of higher preferences for environmental quality among affluent people in comparison to less fortunate population strata and argues the case for a negative relation between income inequality and environmental degradation. As richer people turn out to be more powerful player in the political arena who are able to impose their political opinion on weaker parts of society by influencing and manipulating their values (Roemer, 1993) stricter environmental policies might be the political outcome of less equal societies.

The second string of the discussion on the income-inequality-environmental-quality nexus derives its hypotheses from the economic behaviour of households. According to Berthe and Elie (2015), this discussion is not less controversial than the debate based on political economy considerations.

Under the assumption that a nation's EKC is the sum of EKC's of individual households Heerink et al., (2001) conclude that from the general validity of the Environmental Kutznets Curve necessarily a negative relationship of income inequality and environmental improvement follows. As Figure 9 illustrates, the concave shape of the EKC implies that the aggregated pollution ( $E_2 + E_1$  or  $2 * \bar{E}$ ) of two households with unequal incomes ( $Y_1$  and  $Y_2$ ) falls necessarily short (by  $u$ ) of the aggregated pollution ( $2 * (\bar{E} + u)$ ) of two households that have the average income ( $\bar{Y}$ ) of the two households with the unequal incomes ( $Y_1$  and  $Y_2$ ).





**Figure 9: Household incomes and average environmental pollution**

Source: Heerink et al., (2001), *Income inequality and the environment: aggregation bias in environmental Kuznets curves*, p. 361, modified by the author.

To put it another way, a marginal redistribution of income from higher to lower income households always results within the ECK framework in higher overall pollution levels as a marginal increase in a poorer household income triggers a marginal change in its pollution that does not compensate the marginal changes in the pollution levels of richer households that experience a marginal decrease in their incomes. This can be seen again in Figure 9 of Heerink et al., (2001). If, on the one hand, all households are located to the left of the tipping point  $Y'$ , where the ECK is positively sloped, the marginal reduction in pollution levels of the rich households caused by a marginal redistribution is lower than the marginal increase in pollution levels of the poor households. If, on the other hand, poor households are located to the left of the tipping point  $Y'$  and rich households to the right, where the ECK slope is negative, both types of households increase their pollution levels after a marginal redistribution. Lastly, if all households are located to the right of the tipping point marginal redistribution from the richer households to the poor households triggers poorer households to reduce their pollution levels and richer households to increase their pollution levels. However, the marginal reduction in

pollution of the poorer households is lower than the marginal increase in the pollution of richer households.<sup>55</sup>

Heerink et al.'s approach has been criticized mainly on the basis of lacking unambiguous empirical evidence for the existence of a concave shaped ECK (Baiocchi et al., 2010; Berthe and Elie, 2015). Drawing on empirical findings of a positive relation between per capita income and environmental degradation, it is argued that richer individuals might indeed value clean environment higher and have, principally, a more pro environmentalism attitude than poorer individuals. However, this general preference does not translate into lower pollution levels of more affluent households as their consumption levels of environmentally degrading goods and service remain nevertheless above the ones of poorer individuals. Being ecological crusaders by heart does not prevent the rich to consume higher quantities of polluting goods and luxurious goods that are environmentally more harmful. According to statistical insights affluent car owners, for instance, tend to drive longer distances in their cars than their poorer counterparts. Moreover, rich people tend to use more energy intensive transportation means than poor people – e.g. one's own car instead of public transportation. Hence, there is no guarantee that more unequal societies trigger less aggregated pollution levels (Cox et al., 2012; Fleurbaey et al., 2014; Berthe and Elie, 2015).

Complementary, some authors highlight the role of social norms to argue for a positive correlation of income inequality and environmental degradation (Berthe and Elie, 2015). In their views, different degrees of income inequality might lead to differences in social behaviour which are, in turn, associated with particular conducts towards the environment. The argumentation is based on the traditional insights from Veblen (1899) that individuals do not only consume for the sake of maximizing their personal utility but also for demonstrational purposes. From this it follows that in more unequal societies affluent people have higher incentives to engage in conspicuous consumption in order to distinguish themselves. Simultaneously, poorer population strata might augment conspicuous consumption levels as they com-

---

<sup>55</sup> In addition, combining the original Kuznets Curve (KC) and ECK argumentation allows also for assuming a positive correlation between income inequality and environmental degradation. On the one hand, the take-off phase of an economy is characterized by high levels of income inequality and pollution levels alike. On the other hand, income tend to be more equally distributed and environmental degradation generally lower in the initial phase and in later phases of higher economic development. Thus, income inequality and environmental degradation exhibit a positive correlation (see also footnote 51).

monly mimic the behaviour of dominant social groups. In addition, as social stability and cohesion tend to lessen in more unequal societies, their members might assume a more short-term perspective. Thus, they may prefer to spend incomes rather on individual consumption which usually pays off instantly instead of environmental protection which frequently pays off only long-term. As a result, overall consumption increases in less egalitarian societies putting higher pressure on the environment even in cases where a concave EKC exists (Putnam, 2000; Wilkinson and Pickett, 2010).

### Empirical validation

As there is no consensus about the theories how inequality may influence environmental performance of a society, not surprisingly empirical studies executed on the topic also do not produce unambiguous results. The conclusions from econometric models vary highly depending on which dependent variable has been tried to be explained (Berthe and Elie, 2015).

Studies find, for instance, a positive relation between inequality and biodiversity loss (Heenrik et al., 2001; Mikkelsen et al., 2007; Holland et al., 2009) and a negative relation between inequality and environmental policy levels (Magnani, 2000; Bimonte, 2002; ). On the other hand, empirical investigations performed on the relation between inequality and CO<sub>2</sub> emissions (Heerink et al., 2001; Clément and Meunié, 2010; Baek and Gweisah (2013), water (Scruggs, 1998; Torras and Boyce, 1998; Clément and Meunié, 2010) and air pollution (Torras and Boyce, 1998; Heerink et al., 2001) produced mixed results – sometimes finding a positive or negative or no correlation at all. In consequence, it remains an open issue which of the theoretical explanations, presented previously, describes reality most adequately (Berthe and Elie, 2015).

### Hypothesis

Applied to the particular context of municipal wastewater treatment performance in Mexico, the general debate on the nexus between income-inequality and environmental performance accordingly does not suggest an unambiguous relationship between income inequality and municipal wastewater treatment performance.

On the one hand, municipal wastewater treatment service may be poorer in municipalities with more unequal income distributions. Richer households generate presumably more wastewater than poorer ones as higher incomes trigger higher consumption levels of water

polluting goods. According to theory, the rich are also assumed to derive higher producer surpluses from polluting goods and services (Torras & Boyce, 1998; Boyce, 1994, 2003 and 2007; Berthe and Elie, 2015). Hence, affluent members of a community might have incentives to externalize the negative effects of water pollution instead of treating municipal wastewater. This is all the more likely to happen as municipal wastewater is rather a localized form of environmental pollution. Usually, rich population shields itself effectively from contact of polluted water by settling in unpolluted areas (Roca, 2003). Poor people, on the other hand, are often forced to locate in polluted areas, the poorest frequently next to open sewers (Ringquist 1997; Evans and Kantrowitz, 2002; Germani et al., 2014; Berthe and Elie, 2015). Consequently, one would expect the rich's willingness to support the provision of municipal wastewater treatment facilities to erode. Instead they may spend more money on private and club goods consumption (Wisman, 2011). At the same time, the municipality might rely necessarily on their financial contribution for the funding of treatment infrastructure.

The negative relationship between income inequality and wastewater treatment might be reinforced by the fact that the median voter is relatively poor in municipalities with unequal income distribution. He or she might, therefore, prefer politics reducing the gap between median and mean voter over public spending on municipal wastewater treatment (Magnani, 2000). In addition, trust levels might be deteriorated in inegalitarian municipalities. This may impair a holistic long-term perspective and, in turn, cooperative action on the establishment of treatment facilities (Alesina and La Ferrara 2000; Papyrakis, 2013).<sup>56</sup>

On the other hand, a poor median voter might vote in favour of increased public expenditure (Meltzer and Richard, 1981; Anderson et al., 2008). He or she might opt for elevated levels of local public good provision like clean local environment in form of municipal wastewater treatment. The low share in tax revenues of the median voter implies that more well-heeled community members have to shoulder, to a large extent, the funding of municipal wastewater treatment. Hence, the median voter's marginal costs of wastewater treatment are relatively low which should result in a relatively high demand for the service. In addition, his or her preferences might be reinforced if the affluent stratum of the municipal population displays a

---

<sup>56</sup> See also subchapter 4.8.

pro environmentalism attitude and pushes for municipal wastewater treatment to provide a clean local environment.

In conclusion and in consideration of the contrary argumentations presented previously in this subchapter, I derive the second hypothesis:

Hypothesis 2: Income inequality impacts municipal wastewater treatment performance significantly. However, the sign of its net effect is ambiguous (/).<sup>57</sup>

### **4.2.3. Institutional quality**

#### The general nexus with environmental performance

Cooperative action to provide environmental quality as a public good and to overcome environmental pollution in form of negative externalities requires institutions (Grossman and Krueger, 1995) as “the humanly devised constraints that structure political, economic and social interaction”<sup>58</sup>. According to North (1991), institutions consist of formal rules like property rights, laws, and regulation, and informal requirements like codes of conduct, customs, and so on. Following Coase (1960), the establishment of a comprehensive property right system is a crucial prerequisite of a market institution to internalize effectively environmental externalities. In addition, the effective realisation of a community’s demand for improved environmental quality depends on the existence of sound environmental regulations (Grossman and Krueger, 1995; De Bruyn and Heintz, 1999).

The quality of institutions matters for the preservation of the environment. Literature discusses the quality aspect mainly in two perspectives. On the one hand, it highlights structural features of institutional settings such as democracy and decentralization. On the other hand, the topic of corruption is addressed as a phenomenon that impairs the sound and efficient functioning of institutions.

The effects of democratic institutions on environmental quality is controversially debated in literature. Four main argumentations have been brought up suggesting a positive influence of

---

<sup>57</sup> “/” means that it is, from a theoretical standpoint, unclear whether the expected net effect is positive or negative as several contradicting explanations are provided.

<sup>58</sup> North, Douglass C. (1991). Institutions, *Journal of Economic Perspectives*, Volume 5, Number 1, p. 97.

democracy (Li and Reuveny, 2006; Bernauer and Koubi, 2009; Hosseini and Kaneko, 2013). First, as democracies uphold political rights and freedom they provide a better operating environment for environmental interest groups than autocracies to inform and sensitize the wider public on environmental concerns and trigger cooperation that brings about desired behavioural change (Hosseini and Kaneko, 2013).

Secondly, being electorally accountable, democratic governments and administrations are more amenable to influence of interest groups representing broader classes of population and therefore more likely to pursue policies orientated towards the environmental needs of the general public (Kotov and Nikitina, 1995). In contrast, non-democratic regimes provide inferior levels of public goods, including clean environment, as their policies cater predominantly the interests of the small group of ruling elites in order to consolidate their positions and stay in power. Environmental protection might not attract the elites' support if they are the major beneficiaries of polluting activities and had to bear the bulk of the costs of pro-environment measures (Olson, 1993; McGuire and Olson, 1996; Deacon, 1999; Bernauer and Koubi, 2009).

Thirdly, within democratic societies the rule of law is respected to higher extents than in autocracies. Consequently, environmental agreements are more likely to be enforced in democratic settings resulting in higher levels of environmental quality (Weiss and Jacobsen, 1999). In addition, democracies tend to grant more economic freedom and establish market economies. Markets, in turn, improve environmental quality inasmuch their build-in mechanisms facilitate and promote the spreading of more resource-efficient and, therefore, less polluting technologies. Generally, they allow for a more efficient satisfaction of consumers' demand, e.g. for a clean environment (Berge, 1994).

The fourth argument builds on the observation that environmental degradation develops gradually in time while leaders in autocratic regimes assume a more short-term perspective than in democracies. Presumably, democratic governments align their policy with the preferences of the masses who value an intact environment in the future higher than the beneficiaries in autocratic regimes. Supposedly, the beneficiaries in autocratic have a higher discount rate as their privileges will fade away if the autocratic regime loses its grip on power. Hence, instead of environment protection, they give priority to policies that strengthen the government's position like oppressing the political opposition (Congleton, 1992; Li and Reuveny, 2006).

By contrast, some authors suggest that the democratic organisation of a society causes environmental degradation. Again, the argumentation is based on four main narratives (Li and Reuveny, 2006; Hosseini and Kaneko, 2013). First, democracies are more likely to experience Hardin's "Tragedy of the Commons" (1968) as they concede more political and economic freedom. Unconstrained individuals or interest groups might overexploit the environment when it is a common or public good. Secondly, while environmental issues and the economy that causes them are nowadays often global or international in nature and require therefore a global political answer, the sphere of influence of democratic governments remains restricted to local or national levels (Paehlke, 1996). Though this holds true for autocratic regimes as well it is argued that autocrats have to respect personal liberty rights to a lesser extent. This gives them more effective means at hand to restrict population growth as a major threat to the global environment (Heilbrunner, 1974). Thirdly, though universal suffrage is a crucial characteristic of a modern democratic government system it produces often outcomes which resemble political decisions of systems with a census voting right. Democratic governments tend to pursue the interests of more affluent groups. Since democracies are frequently market economies financially powerful business interest groups often influence societal policy in their favour. Being profit-maximizing entities, businesses might oppose environmental protection as respective measures would be disproportionately at their expenses (Dryzek, 1987). The fourth argument stresses that the economic concerns of the median voter in a democracy might overwrite environmental concerns. Consequently, democratic governments concentrate on solving economic issues instead of saving the environment (Midlarsky, 1998; Hosseini and Kaneko, 2013).

Another string of the debate on the nexus between institutional and environmental quality centers on how decentralism and decentralization of environmental policymaking to lower government tiers affects environmental quality (Oates and Portney, 2003; Dijkstra and Fredriksson, 2010; Alm and Banzhaf, 2012; Millimet, 2013; Woods, 2013; Fredriksson and Wollscheid, 2014; Sigman, 2014).<sup>59</sup> The theoretical literature identifies environmental centralisms and environmental federalism as the two general institutional designs to frame environmental

---

<sup>59</sup> As already discussed in subchapter 2.1.4 of this thesis, a tier is generally defined as a governmental layer that disposes of a political executive (Treisman, 2002). In Mexico, three different governmental tiers exist: the national, state, and municipal level (cf. subchapter 2.1.4 of this thesis).

policy. While the centralistic framework concentrates executive competences at the national level, the federalist system allocates political decision power according to the subsidiarity principle. However, none of the two approaches classifies in theoretical literature as a one size fits all solution with clear-cut advantages to govern environmental quality (Fredriksson and Wollscheid, 2014; Sigman, 2014).

Some authors argue that decentralized institutional designs generate too high pollution levels if negative externalities are present in form of transboundary pollution spillovers (Fredriksson and Wollscheid, 2014). In this case, local decision makers face incentives to scope with environmental issues by pursuing a polluting-thy-neighbour policy (Oates, 1972; Silva and Caplan, 1997; Lipscomb and Mobarak, 2013; Caia et al., 2016). In addition, local government entities might enter a race to the bottom with respect to environmental standards in order to attract businesses and capital investments to their respective locations (Oates, 1972; Kunce and Shogren, 2005a; Kunce and Shogren, 2005b; Sigman, 2014). However, they may also engage, under certain circumstances, in a race to the top while competing with each other in providing a too clean environment to attract residents (Levinson, 2003; Millimet, 2002; Münch, 2011).

In contrast, Oates (1972, 2002) argues that environmental federalism excels in providing environmental quality at optimal levels if it is a local public good. In this case, local executive authorities are incentivized to deal with environmental degradation efficiently as generated harms remain internalized. Potentially, decentral systems are also more flexible than central systems in setting locally optimal pollution levels. While decentral systems are able to adjust environmental standards to respective local conditions and demands, a central regulator may only be able to provide a one size fits all regulation which turns inefficient if lower-tier jurisdictions are heterogeneous and require customized regulations. Due to local proximity decentral administrations might also have an information advantage as knowledge of costs and benefits of environmental pollution and regulation are more readily available to them than to a remote central bureaucracy. On the other hand, central institutions might be more competent as they may realise economies of scale in the acquisition of knowledge on environmental issues, respective solutions, and regulatory capabilities. Competence aside, decentral policy-makers might be steeped in higher motivation as they are generally closer to and more accessible for local voters. Thus, they may be subject to more scrutiny and held more accountable (Oates, 1972; Seabright, 1996; Oates, 1999; Sigman, 2003).



In terms of lobbying efforts of special interest groups, Esty (1996) stresses that business and industry lobby associations are financially better off than environmental lobby groups and therefore better capable to advance their interests in decentralized systems. His argumentation is based on the assumption that lobbyists are required to maintain subsidiaries in each lower-tier jurisdiction in order to promote their interests successfully. This requirement might be frequently beyond the means of environmentalist associations. On the other hand, Revesz (2001) considers central policymaking systems rather unlikely to systematically favour environmental over business interests. According to his view, advocacy at the national level requires a minimum spending which, again, benefits affluent interest groups. In contrast, grassroots environmental organization have more leeway at local levels where political engagement is less conditioned on financial resources (Fredriksson and Wollscheid, 2014).

A third string of the discussion on the relationship of institutional quality and environmental degradation focuses on corruption as a phenomenon that affects the quality of institutions and their sound and effective functioning. Economic literature identifies two different ways corruption may impact environmental quality (Hosseini and Kaneko, 2013). First, the direct impact of corruption is assumed to be negative as corruption, in a strict sense, materializes in all situations where involved stakeholders pursue particular interests at the expense of the general public interest. Based on this definition, corruption is then the behaviour of actors that, in order to maximize their own economic welfare, circumvent environmental regulations whose compliance would result in socially optimal pollution levels. According to the common view in literature, public servants in a corrupt system specialize in taking bribes instead of enforcing and monitoring environmental standards (Hosseini and Kaneko, 2013; Fredriksson and Wollscheid, 2014). In addition, economic actors prefer to pay them a fraction of their noncompliance dividend instead of implementing environmental regulation. The result is a deterioration in environmental quality.

Secondly, corruption potentially impacts environmental quality indirectly via the Environmental Kuznets Curve (EKC) mechanisms. This view bases its argumentation on the assumption that corruption relates to economic prosperity variables like per capita income and economic growth (Cole, 2007; Hosseini and Kaneko, 2013). In this context, some authors argue that corruption may improve economic development under the circumstance of government failure.

Provided that governmental regulations hinder economic development, paying bribes may help to overcome inefficient regulations that hinder economic growth. For example, bribes may shorten undue delays in economic activities due to bureaucratic customs (e.g. Huntington, 1968). However, compared to the situation without government failure bribing officials results always in inferior economic development. In the absence of government failure, market participants would not need to spend scarce resources on bribing activities and could use their money and time on welfare increasing ventures instead. Public officials, in turn, would perform an efficient job in pursuing the general public interest instead of specializing in receiving bribes. I.e. economic development is per se better in a world without corruption than in a world with it. With this in mind, authors argue that corruption hinders economic development as in corrupt economies market participants spend on average more resources on unproductive rent seeking activities than their counterparts in sound systems without corruption (Murphy et al., 1991, Kaufman and Wei, 1999; Hosseini and Kaneko, 2013).

Though the common view is in economic research that corruption has a direct negative influence on environmental quality, it remains, at least within the theoretical framework of the Environmental Kuznets Curve an open issue whether corruption has an indirect positive or negative effect on environmental quality. On the one hand, in cases where the ECK hypothesis is valid, the ECK tipping point would be indeed reached faster if, ceteris paribus, paying bribes may help to overcome inefficient regulations that hinder economic growth in a situation of government failure. However, in a situation without government failure, corruption generally slows down economic development and retards, thus, the passing of the tipping point. On the other hand, in cases where the ECK hypothesis does not hold because, for instance, economic development correlates positively with pollution levels corruption may improve environmental quality if it slows down economic development. Generally, multiple combinations with different outcomes can be thought of.

Complementary, the existence of a shadow economy may also impair the efficient and well-functioning of government institutions. According to its definition, the informal economy is beyond the reach of formal regulations of official institutions. Thus, also environmental regulation cannot be enforced efficiently on them (Mazhar and Elgin, 2013). The issue of a negative link between environmental performance of a society and the existence of an informal economy seems to be of particular relevance for developing countries as the informal sector tend

to be big in these countries compared to the overall economic activity. Accordingly, Blackman and Bannister (1998) identify the shadow economy as a major polluter in developing countries. Moreover, it has been argued, and to some extent empirically validated, that a strict enforcement of environmental regulation might be even counterproductive as this may trigger the migration of economic players from the formal into the informal sector to avoid compliance costs (Blackman and Banister, 1998; Chaudhuri 2005; Baksi and Bose, 2010; Elgin and Oztunali, 2012; Mazhar and Elgin, 2013). In consequence, the existence of an informal economy may impede the efficient functioning of environmental regulations and institutions.

### Empirical validation

Though theoretical explanations predict that democracy has contradicting effects on the environmental quality most of the empirical studies find democracy having a positive net effect. According to Li and Reuveny (2006), democracy reduces carbon dioxide emissions, nitrogen dioxide emissions, deforestation, land degradation, and organic pollution in water. In addition, Bernauer and Koubi (2009) identifies the degree of democracy as having a positive effect on air quality (sulphur dioxide concentrations) in 107 cities in 42 countries. Moreover, Farzin and Bond (2006) successfully correlate democratic governments with decreased concentrations and emissions of local and global air pollution in comparison with autocratic regimes. However, some studies also limit the positive relation between democracy and environmental quality. E.g. You et al., (2015) confirm only for the 20% most emitting nations in their sample that more democratic institutions lead to reduced CO<sub>2</sub> emissions.

A relatively scant number of empirical studies on the outcome of environmental federalism and decentralization on various local and global types of pollutants produce mixed results in verifying which of the aforementioned explanations dominates in reality. List and Gerking (2000) and Millimet (2003) find no empirical support for a change in air pollution levels in the US in the aftermath of Reagan's decentralization policy in the 1980s. According to Sigman (2008), decentralization of environmental expenditure is negatively correlated with access to sanitation, positively with habitat protection, and shows no correlation with wastewater treatment and sulphur dioxide concentration in water in a sample of up to 34 countries. Sigman (2014) finds support for a significant positive effect of budget decentralization and the adop-

tion of a federalist constitution for biochemical oxygen demand (BOD) but not for faecal coliforms concentrations in water bodies in 47 countries. In addition, her findings seem to support the hypothesis that constitutional federalism leads to higher variability in water pollution though this is not the case for budget decentralization. Complementary, a study of Cutter and Deshazo (2007) finds high degrees of heterogeneity in environmental policies across local jurisdictions in California resulting from decentralization. To varying degrees, Helland and Whitford (2003), Kahn (2004), Gray and Shadbegian (2004), and Caia et al., (2016) present empirical evidence for the practise of externalizing environmental damages and the phenomenon of environmental spillovers by adopting a polluting-thy-neighbour strategy in settings with decentralized environmental governance. From there, they conclude that environmental federalism and decentralization may lead to elevated pollution levels and will, hence, result in reduced environmental quality.

Though theoretical economic argumentation is to some extent ambiguous about the net effect of corruption on environmental degradation there is substantial empirical support that corruption has a negative net effect on environmental quality. According to Damania et al., (2003), Fredriksson and Svensson (2003), and Cole et al., (2006) high degrees of government's corruptibility result in less stringent environmental policy, and vice versa. Leitão (2010), using cross-country panel data, confirms empirically the existence of an EKC for sulphur. In addition, she finds that the higher the corruption level in a country the higher the income at the turning point of the ECK suggesting a negative correlation between corruption and environmental quality. To the contrary, she finds that institutional quality affects positively environmental quality. Results of several other empirical studies affirm her view (e.g., Panayotou, 1997; Torras and Boyce, 1998; Bimonte, 2002).

### Hypothesis

Based on the theoretical discussion of the nexus between institutional and environmental quality and the respective findings of previous empirical studies, I expect a positive net effect of democratic, sound and well-functioning institutions on the wastewater treatment performance in Mexican municipalities. The expected net effect of environmental federalism and decentralization seems to be ambiguous though.

The presence of democratic institutions and the absence of corruption may prompt municipal administration to assume a perspective that considers to a greater extent the costs of untreated municipal wastewater to the entire municipal population and the benefits it derives from a local environment that is unpolluted by untreated municipal wastewater. In addition, democratic, sound and well-functioning municipal institutions may be more accessible to local environmental interest groups lobbying, inter alia, for wastewater treatment. They might also use available financial, technical and administrative resources more efficiently and professionally which allows for the implementation of sophisticated projects like building and operating municipal wastewater treatment infrastructure.

In contrast, the effect of environmental federalism and decentralization is presumably not that unambiguous. On the one hand, decentralized institutional settings may give incentives to the decentralized governmental entities to externalize water pollution by adopting polluting-thy-neighbour policy – for instance, by discharging untreated municipal wastewater to downstream or neighbouring municipalities. On the other hand, municipal wastewater treatment performance may improve or, at least, diversify across decentralized jurisdictions in Mexico. Decentralized governmental administrations may be more able to provide environmental quality standards that meet varying local conditions and demands for a clean local environment, e.g. because they possess information advantages concerning the optimal level of municipal wastewater treatment. On the other hand, decentralized institutions might be less competent than centralized ones as they may be less able to realise economies of scale in the acquisition of knowledge on environmental issues caused by untreated municipal wastewater and in the implementation of respective solutions and regulatory capabilities. In addition, being closer to the constituencies, decentralized governmental authorities might be more scrutinized by the people and be more exposed to the influence of local grassroots environmental groups that lobby for the treatment of municipal wastewater.

Overall, I derive from the above presented argumentations two hypotheses:

Hypothesis 3: The sound and well-functioning of municipal institutions has a significant positive net impact on municipal wastewater treatment performance (+).

Hypothesis 4: The net effect of environmental federalism and decentralization is significant, though ambiguous (/).

#### **4.2.4. Spatial environmental spillovers and proximity**

##### The general nexus with environmental performance

Spatial proximity and spatial spillovers might matter for a location's environmental performance (Maddison, 2006 and 2007; Verdolinia and Marzio, 2011; Costantini et al., 2013; Hosseini and Kaneko, 2015). These terms describe the phenomenon of the spreading of particular environmental settings across locations. Neighbouring countries might, for instance, copy particular environmental policies, regulations, and institutional settings from each other. Proximity matters in this context as physical closeness reduces presumably the costs of diffusion. Simmons et al., (2006) provide four different mechanisms how political ideas diffuse spatially: by 1) Competition 2) Learning 3) Emulation, and 4) Coercion.

1) According to Tiebout's insight (1956), neighbouring jurisdictions compete for residents, tax payers, private investment, and the establishment of business by providing public goods and services in different quantities and qualities. Citizens might be inclined to "vote with their feet" and move to another location which meets better their demands, e.g. by providing good environmental quality. Hence, public administrations have the incentive to follow suit successful policies in order to keep their constituency from moving.

2) Public policy actors can also learn from their counterparts in neighbouring localities. According to Simmons et al., (2006), three main theories exist to explain the mechanism of social learning which is defined as generation of knowledge and beliefs based on data and information other people's choice provide.

From a political science perspective, public authorities and civil servants learn from each other as they draw their beliefs from a common knowledge pool they access as elites. Members of this circle feed in new experiences, information, and convictions. Once new ideas are accepted as common knowledge, they are spread spatially. This mechanism triggers then the diffusion of policy innovation (Haas, 1980).

The economic science perspective assumes, in its most fundamental form, that civil servants are rational behaving individuals. Accordingly, they adopt or change their beliefs and behaviours once they have learned from others new information, insights, and experiences which are more likely to be true and produce better results (Banerjee, 1992; Simmons et al., 2006).

Finally, the sociological perspective developed the idea of channel-learning (March and Simon, 1993). Like the economic science perspective, this model assumes rational behaving individuals – however, under information uncertainty. This view considers availability of information as limited since acquiring information is costly and requires resources. Hence, perfect knowledge on every possible action alternative is not feasible in reality and political actors have to rely on shortcuts, so called channels, to gather information. For instance, they might use already established communication networks or consider only the most successful cases to inform themselves on policy alternatives. Unavoidably, outcomes become biased (Kahneman et al., 1982; Simmons et al., 2006).

3) Unlike learning where policy action is based on a rational choice, emulation describes a behaviour whereby political actors only mimic others' activities without understanding the true context. According to this theory, politicians might be inclined to copy measures of success stories in order to avoid to appear, for instance, old-fashioned. They dispose of no judgment on the real value of the policy measure though (Drezner, 2001; Perkins and Neumayer, 2009).

4) Finally, coercion explains the phenomenon of geographical spillovers as the imposed adoption of particular policies due to power asymmetries. Though against its actual will and preferences a relatively powerless jurisdiction might be compelled to change its policy or institutional setting because a powerful external political force demands it. To achieve the coercive diffusion several mechanisms are employed, e.g. the threat or use of physical force, the manipulation of economic costs and benefits, or the monopolization of information and expertise (Simmons et al., 2006).

## Empirical validation

Several previous empirical studies confirm the relevance of spatial proximity in the context of environmental performance. Maddison (2006, 2007) finds evidence for a significant positive correlation of per capita emission of air pollutants in neighbouring countries, worldwide and for European countries. He employs emulation as explanation and argues that governments mimic environmental policies of neighbouring countries while producers and consumers take up neighbours' technologies, products and lifestyles. In addition, a study of Verdolinia and Marzio (2011) on 38 countries provides evidence that the probability of the flow of knowledge on energy-efficient and environmentally friendly technologies decreases between countries with increasing geographic distance. In the Italian context, Costantini et al., (2013) identify the environmental performance of a region's neighbours as a factor that has substantial influence on the region's own environmental performance. Based on their estimation results, they conclude that a region's emissions of greenhouse gases and air pollutants, responsible for acidification, increase significantly when respective emissions in neighbouring regions increase. Moreover, their results suggest that abatement technologies applied in a region diffuse to neighbouring regions. At the transnational level, Hosseini and Kaneko (2015) test whether institutional spillovers catalyse the spreading of a country's environmental quality to neighbouring countries. Using the Civil liberties index, the Political rights index, and the democracy level as proxies for institutional quality, and CO<sub>2</sub> emission intensity for environmental quality their empirical results support a positive coherence.

Complementary, some scholars include variables other than spatial proximity in order to explain the phenomenon of spillovers. It has been pointed out that the intensity of the relation and interaction among localities might not only depend on spatial proximity. Factors like trade and communication links, and cultural exchange may also constitute channels through which ideas spill over (Hosseini and Kaneko, 2013).

Accordingly, empirical research of Peri (2005) and Verdolinia and Marzio (2011) finds cultural factors like a common language significant in promoting knowledge spillovers. Regarding environmental performance, Perkins and Neumayer (2009) identify transnational linkages in form of import ties to CO<sub>2</sub> and SO<sub>2</sub> efficient economies helping to diffuse environmentally superior innovations. However, they do not find this particular link for exports, inward foreign direct investment (FDI), and transnational connectivity in form of telecommunication (phone



calls). Overall, results of empirical studies on the impact of transnational interlinkages on environmental performance are mixed (e.g. Heil and Selden, 2001; Mielnik and Goldemberg, 2002; Grimes and Kentor, 2003; Jorgenson, 2007; Perkins and Neumayer, 2008; for a summary see Perkins and Neumayer, 2009 and 2012; Garrone et al., 2014).

### Hypothesis

Based on the insights gained from the overview of the literature on the nexus between environmental performance and spatial environmental spillovers, I conclude that spatial proximity of municipalities with a successful wastewater treatment policy may influence positively wastewater treatment performance in a Mexican municipality.

On the one hand, municipal administrations might compete for residents by providing clean environment as a local public good in order to meet respective demands from local population. On the other hand, learning spillovers might be present. Insofar municipal politicians and public servants belong to the same regional elitist circles they share expertise and knowledge they acquired, for instance, in the field of municipal sanitation and wastewater treatment. In addition, public officials may inform themselves individually about success cases in the neighbourhood and follow suit. In this context, the availability of knowledge on municipal wastewater treatment from nearby locations might be indispensable as gathering information from information sources further away might be too costly. Particularly, for local government tiers in developing country where capabilities tend to be restricted the effective communication and information exchange with entities located further away, or even abroad, might not be feasible. Hence they might have to rely on using already established communication channels within the immediate surrounding to acquire information.

In addition, mimicking local counterparts may also play a role. The successful engagement of a particular municipal administration in municipal wastewater treatment might trigger a domino effect in its region. Administrations of nearby municipalities may simply want to avoid to look backwards orientated in comparison and copy the efforts in municipal wastewater treatment.

On the other hand, coercion among municipal governments seems to be rather unlikely as the power difference among them is supposedly rather weak. Commonly, a nation's constitution

does not endow municipalities with legislative, judicative, and executive discretion over their counterparts (e.g. DOF, 2016). On the other hand, superior national and state government tiers may put some pressure on inferior tiers to provide wastewater treatment service e.g. by respective legislation and its strict enforcement.

In consideration of all argumentations discussed previously in this subchapter, I derive the fifth hypothesis:

Hypothesis 5: Municipal wastewater treatment performance spills over spatially (+).

#### **4.2.5. Population density and urbanization**

##### The general nexus with environmental performance

According to theoretical literature, population density and urbanization are also factors that explain pollution levels of an economy (e.g. Selden and Song, 1994; Grossmann and Krueger, 1995; Panayotou, 1997; Cole and Neumayer, 2004; Stern, 2005; Wong and Lewis, 2013).

On the one hand, higher population density and urbanization may lead to higher environmental degradation as more population, in a given area, emits, *ceteris paribus*, higher volumes of pollution (Cole and Neumayer, 2004; Stern, 2005). On the other hand, environmental performance may improve in densely populated and urbanized areas if economies of scale are present in the abatement process due a high share of fixed costs (Panayotou, 1997). With affordability being often a key bottleneck for the implementation of abatement measures, high population densities and degrees of urbanization might be crucial in terms of funding. In urbanized or densely populated areas, more individuals may share in the associated fixed costs of abatement reducing thus the per capita financial burden (Massoud et al., 2009). In addition, the pressure to abate might be higher as more people are negatively affected by the pollution (Panayotou, 1997; Stern, 2005).

##### Empirical validation

On empirical grounds, studies on several pollutant types have found mixed results with respect to the significance and magnitude of the impact of population density and urbanization on environmental performance. Grossmann and Krueger (1995) and Cole and Neumayer (2004) do not detect significant correlations for several air pollutants. In contrast, Stern (2005)

finds support for a positive correlation of population density and applied sulphur-emission-abating technologies. Panayotou (1997), on the other hand, finds more support for a U-shape relationship of SO<sub>2</sub> air concentration and population density. He identifies areas with low and high population density as having high concentration levels, whereas correlations are negative in areas with medium population density. He explains the positive correlation in sparsely inhabited areas with lower pressure to take abatement measures. Pollution in this area affects only few people and abatement costs might be too high. With increasing population density, the correlation turns negative due to abatement measures. As more and more people suffer from pollution the pressure to implement abatement increases. Also economies of scale might be realized beyond a certain threshold. However, with an ongoing increase in the population density, scale effects outweigh abatement efforts from a certain threshold on, resulting in a positive correlation of population density and SO<sub>2</sub> air concentration in densely inhabited areas (Panayotou, 1997).

### Hypothesis

In the field of municipal wastewater treatment, I expect that denser population causes, *ceteris paribus*, higher volumes of generated municipal wastewater and, thus, higher pollution levels in a given area. Therefore, intensified treatment efforts might become necessary to offset pressing pollution and deterioration of environmental quality. In addition, economies of scale may be more likely to be realized the higher the number of people served within a given area. As the construction, operation and maintenance of wastewater treatment systems contain a substantial fraction of fix costs – like the establishment and operation of a sewerage networks, pumping stations, central treatment plants, and the like – per capita costs diminish with increasing population density (Parkinson & Tayler, 2003; Massoud et al., 2009).

In consequence, I derive as sixth hypothesis:

Hypothesis 6: Urbanization has a significant positive net impact on municipal wastewater treatment performance (+)

#### **4.2.6. Education**

##### The general nexus with environmental performance

The theoretical literature considers education as having a positive effect on environmental performance of a society. The basic argumentation is rather straightforward. Generally, more educated individuals possess more information and knowledge on the negative consequences of the deterioration of environmental quality and have, in consequence, higher preferences for an intact environment (Munasinghe, 1999; Bimonte, 2002).

From a behavioural economics standpoint, these advanced levels of knowledge may trigger environmentally-friendly behaviour and practises at the personal level like garbage recycling, water and energy saving, and purchase of organic food (Danielson et al., 1995; Torgler and García-Valiñas, 2007; Meyer, 2015).

In addition, the general debate on the Environmental Kuznets Curve discusses whether higher education levels trigger, *ceteris paribus*, higher demand for environmental quality and eco-friendly policies. Therefore, empirical studies on the EKC include frequently education as control variable to validate the robustness of the inverted-U-shape relationship of per capita income and environmental quality.

##### Empirical validation

Results of empirical studies on changes in an individual's behaviour towards the environment induced by more education are mixed. Several studies confirm a higher likelihood and willingness of higher educated individuals to engage in more eco-friendly practises (e.g. Israel and Levinson, 2004; Veisten et al., 2004; Ferrara and Missios, 2005; Hidano et al., 2005; Callan and Thomas, 2006; Zepeda and Li, 2007; Bellows et al., 2008, Monier et al., 2009; Mundaca et al., 2010). Other studies are not affirmative though (e.g. Ek and Soderholm, 2008; Ayalon et al., 2013; Millock and Nauges, 2013; Grafton, 2013; for an overview see Torgler and García-Valiñas, 2007; and Meyer, 2015).

In addition, a good many of conducted EKC studies confirm a positive correlation of environmental quality and various education indicators like average school attendance in years, share of graduated population and literacy rates, etc. (e.g. Torras and Boyce, 1998).

## Hypothesis

As for municipal wastewater treatment performance in Mexican municipalities, I expect more educated people to be better informed about health risks and environmental hazards originating from polluted water sources. Hence, educated constituencies should be open to the idea of municipal wastewater treatment and support respective public policies.

Moreover, a higher education level of average population increases chances that the staff of local public administration is also well educated. This fact might help the municipal government to perform a better job on municipal water service management. Particularly in developing countries, educational deficits in this field are often an issue. Studies acknowledge (Bar-kin, 2011) that public municipal water managers lack necessary expertise.

In conclusion, I derive as the seventh hypothesis:

Hypothesis 7: Education has a significant positive net impact on municipal wastewater treatment performance (+).

### **4.2.7. Gender**

#### The general nexus with environmental performance

On theoretical grounds, a discussion is ongoing if women and men differ in their preferences and attitudes towards the environment. The view in literature hypothesises that women are more concerned with environmental conservation as they are generally more socially orientated than men. As possible explanation for the gender differentiation traditional gender socialization is given. Cultural and social norms trigger a certain gender expectation towards both genders which shapes the behaviour of a female or male individual respectively (Zelezny et al., 2000; Hunter and Hatch, 2004). Concretely, women are encouraged to be more cooperative and compassionate and to assume the role of caregivers and nurturers in the family and society (Blocker and Eckberg, 1989; McStay and Dunlap, 1983; Mohai, 1992; Hunter and Hatch, 2004; Torgler and García-Valiñas, 2007). As such, they are considered to assume a view on the world that focuses more on relationships in society and maintenance of life in general which includes the conservation of environment (McStay and Dunlap, 1983). In addition, they are supposed to embrace more the ideal of altruism (Dietz et al., 2002). This mind setting may

prompt women to be more affected by environmental concerns (Hunter and Hatch, 2004). Complementary, it has been argued that their parenting role at home may induce them to display also a protecting behaviour against nature (Blocker and Eckberg, 1997; Hunter and Hatch, 2004).

Based on the general argumentation regarding women's behaviour towards environmental matters, a nascent string in the scientific debate investigates if women, once elected as political officials, pursue as political decision makers more eco-friendly policies than their male counterparts (Ergas and York, 2012; Svaleryd, 2009; Sundström and Mc Right, 2013). Generally, the existence of a positive nexus between female influence in politics and environmental performance has been objected with the argument that the preferences of elected politicians may not correspond with the preferences of the general population as politicians may have to behave strategically in order to get elected or to stay in power. To some extent, this line of argumentation has been validated empirically (Pierce and Lovrich, 1980 and 2005; Pierce et al., 1987). Nonetheless, authors like Sundström and Mc Right (2013) argue that female politicians may still be more pro-environmental than male politicians as they keep on worrying as women more about the safety and well-being of other members of society than men. Accordingly, they may continue to be more aware of environmental issues and concerns (Carroll et al., 1991; Blocker and Eckberg, 1997; Reingold, 2000). Furthermore, they still may display a value orientation that embeds values like "ecocentrism, altruism, openness to change"<sup>60</sup> that generally favour environment protection (Dietz et al., 2002; Stern et al., 1993). Finally, they may also continue to be more risk sensitive than men and perceive therefore risks emerging from environmental pollution to a higher extent. This may motivate them to put more efforts on protecting the environment as public officers in charge (Xiao and Mc Cright 2012; Sundström and Mc Right, 2013).

### Empirical validation

On empirical grounds, a relatively large number of scientific studies and surveys among women and men in North America and European countries have identified females as having moderately stronger pro-environmentalist attitudes, beliefs, value orientations, and concerns

---

<sup>60</sup> See Sundström and McCright (2013). Examining Gender Differences in Environmental Concern across Four Levels of the Swedish Polity, QoG Working Paper Series 2013:10, p. 6.

(Stern et al., 1993; Stern and Dietz, 1994; Flynn et al., 1994; Bord and O'Connor, 1997; Hunter et al., 2004; Dietz et al., 2007; Mc Cright, 2010; Sundström and McCRight, 2013). This holds particularly true for environmental issues that occur locally and pose a significant health risk to the local population (Mohai, 1992; Greenbaum, 1995; Klineberg et al., 1998). Accordingly, women are more prone to vote for more environmentally friendly policies and display a more eco-friendly personal behaviour (Zelezny et al., 2000; Sundström and Mc Right, 2013).

Based on this empirical insight, a nascent string in the scientific debate investigates environmental attitudes and actions of women as political leaders (Ergas and York, 2012; Svaleryd, 2009; Sundström and McCRight, 2013). Mainly due to lack of data, only few empirical case studies have been performed on whether women pursue as political decision makers more eco-friendly policies than their male counterparts. Overall, they produced mixed results (Sundström and Mc Right, 2013). Several studies do not find any empirical evidence for a more pro-environmental attitude of female officials (Jones, 1997; Tremblay, 1998; Reingold, 2000; Papavero 2010; Fielding et al., 2012). On the other hand, some research articles support the thesis of a positive relationship (Kahn, 1993; Iwanaga 1998; Fredriksson and Wang 2011; Sundström and Mc Right, 2013).

### Hypothesis

Translated into the context of municipal wastewater treatment performance in Mexico, I expect female participation in the politics of a Mexican municipality to influence positively its treatment performance. As constituencies and politicians, women likely favour and enact public measures benefiting the entire community and the environment. In this context, female politicians may also execute a stricter municipal sanitation and wastewater treatment policy than male public official in order to reduce human health risks from waterborne diseases or to conserve the environment.

Overall, I derive as eighth hypothesis:

Hypothesis 8: Female participation in local politics has a significant positive net impact on municipal wastewater treatment performance (+).

#### 4.2.8. Ethnic heterogeneity

##### The general nexus with environmental performance

Generally, theoretical literature associates ethnic fractionalization of a society with reduced levels of public good provision. Mainly two explanations are given for the negative correlation: 1) heterogeneity in individuals' preferences and 2) rent seeking behaviour in social interaction (Easterly and Levine, 1997; Alesina et al., 1999 and 2003; Alesina and La Ferrara 2005; Habyarimana et al., 2007; Lieberman and McClendon, 2013; Gerring et al., 2015).<sup>61</sup>

First, ethnic diversity implies differences in the preferences for public goods across social groups according to the type of the provided public good, its amount, and the time and place of provision. Increased transaction costs in form of required negotiation efforts make it more difficult to reach an agreement in diverse societies (Easterly and Levine, 1997; Alesina et al., 1999 and 2003; Alesina and La Ferrara 2005). Consequently, public goods like environmental conservation and protection may be underprovided, particularly in situations where individuals perceive respective provisions only as beneficial as long as they benefit members of their own ethnicity and benefits provided to other ethnic groups as neutral or even as negative. In such a situation, ethnic groups may also have higher incentives to externalize pollution costs on other parts of society as they disregard harm inflicted on other ethnicities (Alesina and La Ferrara 2000; Papyrakis, 2013). Moreover, cooperation among groups and individuals requires trust and understanding which might be undermined due to language barriers, different cultural customs and habits prevalent in diverse societies (Papyrakis, 2013).

Secondly, lower levels of social coherence may trigger rent seeking behaviour and corruption among public servants and officials. Instead of pursuing policies that maximize welfare, politicians might implement policies that maximize the utility of their respective ethnic group at the expense of other parts of society (Alesina et al., 1999 and 2003; Gerring et al., 2015). Due to a feeling of solidarity, local public administrators may make common cause with local polluters of their own ethnicity to circumvent environmental regulations and share the non-compliance-dividend as bribes (Videras and Bordoni, 2006). Politicians and bureaucrats might also allocate public resources to their own ethnic group in order to buy their consent and acceptance for corrupt administration practises (Glaeser and Saks, 2006). Moreover, public good

---

<sup>61</sup> For a detailed overview of the literature see Papyrakis (2013) and Gisselquist et al., (2016).



provision requires cooperation and the punishment of free riding behaviour. However, information asymmetries existing due to cultural disparities across ethnical boundaries might impair the detection of free riding behaviour. In consequence, politicians have more incentives to be corruptible in social settings with higher degrees of ethnic fractionalisation (Papyrakis, 2013).

### Empirical validation

On empirical grounds, many studies confirm a negative influence of ethnic fractionalisation on the provision of public goods at cross-country and subnational levels (e.g. Easterly and Levine, 1997; Alesina et al., 1999, Baldwin and Huber, 2010; Jackson, 2013; Gerring et al., 2015). In contrast, relatively few studies investigate the particular relationship between ethnic diversity and environmental performance. Some studies confirm a negative relationship (Grafton et al., 2004; Papyrakis, 2013). On the other hand, Das and DiRienzo (2010) find a non-linear, and Gisselquist et al., (2016) a positive relationship, at the subnational level. Das and DiRienzo (2010) identify municipalities with moderate levels of ethnic diversity as having the best environmental performance in Colombia while municipalities with high degrees of ethnic fractionalization perform worst. According to their explanation, municipalities with moderate levels of ethnic diversity benefit from high levels of social engagements of their citizens while municipalities with a high degree of ethnic heterogeneity suffer from the effects of poor communication and the lack of social cohesion among ethnicities. Gisselquist et al., (2016) give only hints for future research to explain a “Diversity Dividend” they find empirical evidence for in their Zambian case study.

### Hypothesis

Based on the theoretical argumentation and empirical findings of the general literature on the nexus between ethnic heterogeneity and environmental performance, I expect a negative impact of ethnic fractionalization on municipal wastewater treatment performance. The administration of treatment service may require a significant level of cooperation among a commu-

nity's population. Hence, ethnic diversity may pose a substantial risk to a successful implementation of such a policy. Different preferences of ethnic groups for the provision of unpolluted water might reduce chances to reach an agreement to treat municipal wastewater.

Instead, local politicians may pursue rent seeking policies that favour their respective ethnicities and externalize associated costs to other ethnic groups in form of untreated municipal wastewater. For instance, instead of establishing municipal wastewater infrastructure, politicians may distribute the financial resources earmarked for a treatment project among their ethnic entourage and make sure that members of other ethnic groups have to suffer the harm caused by untreated wastewater. Alternatively, it may be also imaginably that politicians establish the treatment service in a municipality and make other ethnic groups pay for it. Which of these alternatives is more attractive for them depends on the net benefits they and their constituencies derive from it. I assume that it is more likely that politicians externalize the harm of untreated municipal wastewater instead of the costs of building the wastewater treatment infrastructure. Generally, the treatment service, once established, tend to benefit the entire community as it produces the (local) public good of unpolluted environment. I.e. the ruling politicians and their ethnic group derive only a share of the generated benefit. On the other hand, they can keep all of the benefits if they spend resources on projects only the derive benefit from.

Overall and in consideration of all argumentations discussed previously in this subchapter, I derive the ninth hypothesis:

Hypothesis 9: Ethnic heterogeneity has a significant negative net impact on municipal wastewater treatment performance (-)<sup>62</sup>.

#### **4.2.9. Water availability**

Complementary to demographic, socioeconomic, and institutional factors and characteristics, presented previously in chapter 3 of this thesis, I expect also that the availability of water in Mexican municipalities may explain to some extent municipal wastewater treatment performance. Generally, recycling of already used water might become a viable economic strategy

---

<sup>62</sup> “-“ indicates, from a theoretical standpoint, a negative expected net effect.

if water as a resource becomes scarce in a location (Zetland, 2011). However, reusing municipal wastewater requires treatment to ensure adequate water quality. This procedure might become a viable option in localities experiencing shortages in relative water availability (Devia et al., 2007; Angelakis and Gikas, 2014). Thus, I derive as the tenth and last hypothesis:

Hypothesis 10: Water availability has a significant negative impact on municipal wastewater treatment performance (-).

### **4.3. Summary of chapter 4 and statement of the hypotheses**

Chapter 4 of the thesis has developed 10 hypotheses on cause and effect relationships between social characteristics of a municipality in a developing country and its municipal wastewater treatment performance. It derives these hypotheses from a thorough investigation of the economic literature on social features that may trigger the willingness of a society to protect the environment and that facilitate the expedient manifestation of this willingness in respective political decisions. Chapter 4 classifies treated municipal wastewater as a public good. If treated and released into water bodies or soil, it may be consumed in form of an intact living environment in a non-rivalry and non-excludable way. Untreated wastewater, in turn, is classified as an environmental negative externality (Zetland, 2011). Due to its solvent properties and high mobility water serves as a perfect “solution” to remove waste from one place to another in a relatively cheap way (Hanemann, 2006). In this way, a polluter may have the incentive to externalize the costs of water pollution to a third party which suffers then the negative effects of the pollution instead of the polluter.

Chapter 4 develops the 10 hypotheses on social characteristics and their effect on municipal wastewater treatment performance based on two general insights from economic science: 1) Being a public good, the provision of clean environment presupposes the cooperation within a society, and 2) The internalization of an environmental externality requires the proper incentivisation of the stakeholders of a society. Economic literature has investigated at large the connexion between factors and characteristics of a society that may facilitate or impede public goods provision and the internalization of external effects (e.g. Oates, 1972; Easterly and Levine, 1997; Alesina et al., 2003; Glaeser and Saks, 2006; Hoxby, 2000; Jaeger, 2005; Witte and Geys, 2011). Within this broad field, the chapter draws mainly on the research that scrutinizes

explicitly the link between characteristics of a society and its environmental performance to derive the 10 hypotheses (e.g. Dinda, 2004; Hosseini and Kaneko, 2013; Wong and Lewis, 2013; Sundström and Mc Right, 2013; Berthe and Elie, 2015).

In summary, the 10 hypotheses are:

Hypothesis 1: Per capita income has a significant positive net impact on municipal wastewater treatment performance (+).<sup>63</sup>

Hypothesis 2: Income inequality impacts municipal wastewater treatment performance significantly. However, the sign of its net effect is ambiguous (/).<sup>64</sup>

Hypothesis 3: The sound and well-functioning of municipal institutions has a significant positive net impact on municipal wastewater treatment performance (+).

Hypothesis 4: The net effect of environmental federalism and decentralization is significant, though ambiguous (/).

Hypothesis 5: Municipal wastewater treatment performance spills over spatially (+).

Hypothesis 6: Urbanization has a significant positive net impact on municipal wastewater treatment performance (+).

Hypothesis 7: Education has a significant positive net impact on municipal wastewater treatment performance (+).

Hypothesis 8: Female participation in local politics has a significant positive net impact on municipal wastewater treatment performance (+).

Hypothesis 9: Ethnic heterogeneity has a significant negative net impact on municipal wastewater treatment performance (-)<sup>65</sup>.

---

<sup>63</sup> "+" stands for the expectation of a positive net effect of the explanatory factor.

<sup>64</sup> "/" means that it is, from a theoretical standpoint, unclear whether the expected net effect is positive or negative as several contradicting explanations are provided.

<sup>65</sup> "-" indicates, from a theoretical standpoint, a negative expected net effect.

Hypothesis 10: Water availability has a significant negative impact on municipal wastewater treatment performance (-).

## 5. Methodology

The thesis applies econometrics as research method to scrutinize empirically the validity of the 10 hypotheses chapter 4 has derived from a thorough investigation of economic research on the link between characteristics of a society and its environmental performance. Literally, econometrics means “economic measurement”<sup>66</sup> and “... may be defined as the quantitative analysis of actual economic phenomena based on the concurrent development of theory and observation, related by appropriate methods of inference.”<sup>67</sup>

In order to scrutinize empirically the relationship between the phenomenon of interest and explanatory factors, hypothesized relations have to be expressed in a model function:

$$(5.1) \quad Y = \beta_0 + \sum_{i=1}^n \beta_i X_i + u$$

The left side of the function contains the dependent variable ( $Y$ ), i.e. the variable whose values ought to be explained in dependence – i.e. as a function – of the independent variables ( $X_i$ ) which represent explanatory factors. The independent variables ( $X_i$ ) are contained on the right side of the equation whereby  $i$  represents the included independent variables, i.e.  $i = 1, 2, 3, \dots, n$ , with  $n$  denoting their total number.  $u$  is an error term that absorbs the random fluctuation in the values of the dependent variable that are not explained by changes in the independent variables. It is assumed that the error term  $u$  is on average zero and disposes of normally distributed values.

A major challenge of any quantitative analysis is always the requirement to translate theoretical statements and hypotheses into quantifiable entities. If hypotheses are not verifiable or falsifiable by appeal to empirical evidence, no validation is possible to what extent they are a reasonable good approximations of reality.<sup>68</sup>

Hence, as this thesis aims at explaining wastewater treatment performance in dependence of factors like per capita income, income distribution, institutional quality, spatial spillovers, urbanization, female participation in local politics, ethnic heterogeneity, and availability of water in a Mexican municipality it has to deal with the question how to express these entities in

---

<sup>66</sup>Gujarati (1995). Basic econometrics, 3rd (international) edition, p.1.

<sup>67</sup> Samuelson et al., (1954). Report of the Evaluative Committee for Econometrica, Econometrica, volume 22, no. 2, p. 142.

<sup>68</sup> Cf. Gujarati (1995). Basic econometrics, 3rd (international) edition, p. 9.

measurable terms. In particular, the quantitative specification of municipal wastewater treatment performance is important as the selection of proper econometric models depends, to a large extent, on the characteristics of the dependent variable.

The structure of chapter 5 is as follows: Subchapter 5.1 specifies wastewater treatment performance as a measurable dependent variable. Subsequently, subchapter 5.2 identifies indicators that express in quantitative terms the municipal characteristics and factors that chapter 4 has identified as potentially impacting municipal wastewater treatment performance. Finally, subchapter 5.3 selects the set of econometric models suitable to scrutinize the hypothesized relationships econometrically. Subchapter 5.4 summarizes chapter 5 and reproduces the major findings.

### **5.1. Specification of the dependent variable**

I measure municipal wastewater treatment performance by two quantitative indicators:

- The probability municipal wastewater treatment takes place in a Mexican municipality.
- The estimated percentage of treated municipal wastewater in a Mexican municipality.

Concerning the first measure of wastewater treatment performance, I abstain from treated volumes and share of municipal wastewater and consider only the fact whether municipal wastewater treatment takes either place or not in a Mexican municipality. I.e. I aim at estimating the probability that municipal wastewater treatment takes place in a municipality in dependence of the hypothesized socioeconomic, demographic, and institutional characteristics. The National Inventory of Potabilization and Wastewater treatment Plants of the Mexican National Water Commission CONAGUA (2010b) reports regularly on wastewater treatment plants that exist in Mexican municipalities. Concretely, I consider this information for 2010. For this particular year, respective data is available for 2,452 of the 2,456 Mexican municipalities (CONAGUA, 2010b).

Concerning the second measure of wastewater treatment performance, I rely on estimations of the share of treated municipal wastewater in Mexican municipalities. For a varying selection of Mexican municipalities, the Mexican National Water Commission (CONAGUA) and the Mexican Institute of Water Technologies (IMTA) report regularly, inter alia, on aggregated and per

capita municipal drinking water supply volumes and volumes of treated municipal wastewater (CONAGUA, 2010b; CONAGUA, 2012a; IMTA, 2014b). Based on this data, the estimation of generated municipal wastewater is feasible. IMTA does this by assuming that 70% of drinking water volumes supplied into a municipal water network convert into municipal wastewater (RAS, 2000; CONAGUA, 2007; IMTA, 2014b).<sup>69</sup> I apply this formula to the data CONAGUA provides on municipal drinking water supply and treated wastewater volumes in order to calculate the estimated percentage of treated wastewater volumes. Together, CONAGUA and IMTA provide data on 516 municipalities for the year of 2010 (CONAGUA, 2012a; IMTA, 2014b). I refer to it as the 'estimated percentage' because of the assumption that 70% of municipal water supply is turned into municipal wastewater. The 70%-rule is only an estimation though. Alternatively, the percentage of actual treated municipal wastewater volumes in a Mexican municipality would have been a rather obvious choice for the measurement of municipal wastewater treatment performance.<sup>70</sup> However, although data on treated municipal wastewater volumes and installed municipal wastewater treatment capacities is available across Mexican municipalities (CONAGUA, 2010b),<sup>71</sup> lack of data on municipal wastewater

---

<sup>69</sup> An alternative to estimate the generated municipal wastewater volumes at the municipality level more precisely would be to consider the drinking water supply volumes that are actually delivered to households and buildings in a Mexican municipality. However, delivered volumes of municipal drinking water into households are not known as micro-metering is not comprehensively used in Mexico.

The alternative is to consider volumes of bulk water delivery into municipal water supply systems. However, this approach is also not feasible for the majority of Mexican municipalities. A crucial requirement of this method is that the water volumes are approximately known that are getting lost due to leakage. Generally, loss rates are supposed to be substantial in Mexico – both, on the way from exploitation sources to human settlements and their water supply networks, and, then again, within town limits in water supply and sewerage networks. The main reason for this is outdated or badly designed infrastructure (Barkin, 2006, 2011). Though assumed to be high, loss volumes remain in many places unknown or get, at least, not centrally recorded. To make matters worse, macro-metering of bulk water deliveries is not installed everywhere (Barkin, 2006, 2011).

Finally, another option to estimate generated wastewater volumes would be to rely on data on produced drinking water as a proxy for drinking water volumes supplied into municipal networks. However, this is also not a feasible alternative in the Mexican context as only a fraction of the delivered water receives purification in a limited number of purification plants. According to official data, only 91.7 m<sup>3</sup>/s of a total of 329.3 m<sup>3</sup>/s of water supply was purified in 645 plants in 2010 (CONAGUA, 2010a and 2011a).

<sup>70</sup> Optimally, it takes additionally the quality of the treated wastewater into consideration, i.e. whether wastewater volumes receive primary, secondary, or tertiary treatment.

<sup>71</sup> The 2010 edition of the National Inventory of Municipal Wastewater Treatment Plants (*Inventario nacional de plantas municipales de potabilización y de tratamiento de aguas residuales* in Spanish) contains a list of the 2,186 municipal wastewater treatment plants that were in operation in Mexico in 2010. Furthermore, it provides detailed information on their location in respective municipalities, installed treatment capacities (in m<sup>3</sup>/s) and actual treated municipal wastewater volumes (in m<sup>3</sup>/s) (CONAGUA, 2010b).



volumes generated in each Mexican municipality<sup>72</sup> makes it impossible to calculate the actual percentage of treated volumes at the municipal level.

Consequently, I consider the estimated percentage of treated municipal wastewater as a measure for municipal wastewater treatment performance. However, this data is only available for the relatively small sample of 516 Mexican municipalities. I therefore abstain, in an additional step, from any wastewater volumes and treated percentages of municipal wastewater and consider as a further measure of municipal wastewater treatment performance the probability municipal wastewater treatment takes place in a Mexican municipality. The advantage of this approach is that the big majority of Mexican municipalities can be included in the econometrical analysis as respective data is available on 2,452 Mexican municipalities.

## **5.2. Specification of independent variables and data collection**

Beside the specification of the dependent variable the municipal characteristics of hypotheses 1 to 10 have to be expressed in measurable entities. As data availability is a frequent bottle neck in any quantitative research I am not able to specify measures for which data is available for all Mexican municipalities. Therefore, I follow the strategy to identify quantitative indicators for which data is available for a great number of Mexican municipalities. Municipalities I am not able to gather data are generally left out of the econometric analysis. Except for the availability of water for which data is only available for about half of Mexican municipalities, I am able to gather, in this way, data on the measures of the different social characteristics for 90% or more of Mexican municipalities.<sup>73</sup>

### **5.2.1. Per capita income**

Per capita income is generally measured in gross domestic product (GDP) per capita (Mankiw and Taylor, 2014). It is defined as “the market value of all final goods and services produced

---

<sup>72</sup> Missing information on municipal wastewater generation is not an issue particular to the Mexican case but generally well known around the globe (see e.g. Malik et al., 2015).

<sup>73</sup> An overview of the actual numbers of observations is given in in Table 4 in subchapter 6.1.

within a [given area] in a given period of time”<sup>74</sup>. Usually, the “given period of time” defaults to one year. To calculate per capita figures GDP is “divided by the population”<sup>75</sup> living in a given area in the specified period.

The thesis includes GDP per capita at the municipal level for the year of 2010, denominated in PPP<sup>76</sup> US Dollars at current prices. I use the denomination in US Dollars instead of Mexican Pesos as this may help to facilitate a better understanding of the estimation results for the international reader of the thesis. Data for the year 2010 is selected as the data on the dependent variables is also from 2010.<sup>77</sup> The Mexican National Institution for Federalism and Municipal Development INAFED published respective income data based on the Population and Housing Census (*Censo de Población y Vivienda* in Spanish) of the Mexican National Statistical Bureau INEGI (*Instituto Nacional de Estadística y Geografía* in Spanish) (PNUD, 2014; INAFED, 2015).

In addition, nominal GDP per capita for the year 2005, again denominated in PPP US Dollars at current prices, is considered as an alternative measure for per capita income. The Mexican National System of Municipal Information (SNIM; *Sistema Nacional de Información Municipal* in Spanish) provides corresponding data (SNIM, 2014). Though it is principally reasonable to include data on independent variables of the year the data on the dependent originates from, i.e. 2010, lagging GDP per capita data by 5 years may bear the advantage of avoiding a potential endogeneity issue. According to literature, improved sanitation may affect economic growth positively (Minh and Nguyen-Viet, 2011; Hepworth et al., 2013). To account for this possible link, a second run of the regressions will include 2005 GDP per capita data as GDP numbers in 2005 are less likely affected by the status quo of sanitation in 2010.

### 5.2.2. Income distribution

---

<sup>74</sup> Mankiw and Taylor (2014). Economics, 3rd Edition, p. 439.

<sup>75</sup> Mankiw and Taylor (2014). Economics, 3rd Edition, p. 9.

<sup>76</sup> PPP = purchasing-power-parity.

<sup>77</sup> Cf. subchapter 5.1 of the thesis.

A common indicator to measure inequality in income distribution is the GINI coefficient (Mankiw and Taylor, 2014). It builds on the Lorenz Curve concept which “shows the relationship between the cumulative percentage of households and the cumulative percentage of income.”<sup>78</sup> In this context, the 45 degree line represents perfect income equality. The GINI coefficient measures “the ratio of the area between the 45 degree line of perfect income equality [...] and the Lorenz curve to the entire area under the 45 degree line of perfect income equality.”<sup>79</sup> Ranging from 0 to 1, or from 0% to 100%, higher values of the GINI coefficient indicate higher degrees of income inequality. The two extremes of zero and one or 0% to 100% represent perfect income equality (0) and perfect income inequality (1) which means that all income belongs to one individual. Generally, two types of the GINI coefficient are distinguished: before and after taxes and transfers. While the GINI coefficient before taxes and transfers measures how the income is distributed before the state gets involved in the allocation of the resources of an economy, the GINI coefficient after taxes and transfers indicates the income distribution after the intervention of the state. Throughout, the thesis refers to the GINI coefficient after taxes and transfers.

The Mexican National Evaluation Council of Policies of Social Development provides data on the GINI coefficient after taxes and transfers for 2010 at the municipal level (CONEVAL, 2015). The following econometric analysis will incorporate this data as a measure for income inequality in Mexican municipalities.

### **5.2.3. Institutional quality**

Generally, finding indicators that measure institutional quality in terms of democratic orientation of a society is rather a challenge at the local governmental tier (Li and Reuveny, 2006; Farzin and Bond, 2006; Bernauer and Koubi, 2009). Variables traditionally applied in literature to measure inter-country differences in democratic quality like political freedom and liberty rights are less suitable for an inner-country case study. Commonly, formal constitutional aspects do not differ substantially among lower-tier entities. This holds also true for Mexico

---

<sup>78</sup> Mankiw and Taylor (2014). Economics, 3rd Edition, p. 386.

<sup>79</sup> Mankiw and Taylor (2014). Economics, 3rd Edition, p. 388.

where the National Constitution sets tight limits within which the municipal administration has to operate (DOF, 2016).

Another constraint is data availability. Principally, one may consider the existence of environmentally active interest groups as an informative proxy-indicator for democratic participation in local environmental politics. However, no corresponding data is available at the municipal level in Mexico. Alternatively, accounting for the number of environmental lawsuits filed at court per municipality might be a valid option to measure the quality of local legal institutions and the well-functioning of the judiciary as the third pillar of a democratic system with embedded separation of powers. However, on this subject also no data is available. Alternatively, the National Statistical Bureau INEGI (2015c) reports annual data per municipality on claims of environmental violations filed with the Federal Attorney for Environmental Protection PROFEPA. Concerned and affected citizen are able to complain, *inter alia*, about misconducts against protected species, natural forest flora, terrestrial and maritime wildlife resources, contaminating industries, solid waste dumping, and illegal discharge of wastewater (PROFEPA, 2016). Unfortunately, data is only published in aggregated form for all violation categories and not specific to the field of illegal municipal wastewater discharge. Furthermore, reported numbers are rather low with only few exceptions in the states of Chihuahua, Nuevo León, Quintana Roo and Yucatan. However, complains in these states concentrate on one or two municipalities and are commonly filed against industrial contamination or solid municipal waste generation (INEGI, 2015a). In consequence, claims of environmental violations filed with PROFEPA are not assumed to develop explanatory power in explaining differences in municipal wastewater treatment performance.

The effect of decentralism may be measured by including dummy variables for the belonging of a municipality to one of the 31 federal states or the Federal District of Mexico-City. To some extent, significant differences in state-belongingness may result from state specific idiosyncrasies. Nevertheless, dummies may capture differences in municipal wastewater governance and institutional quality due to regionally varying environmental demands for clean aquatic environment and respective more or less effective public policies on municipal wastewater treatment service.

To consider institutional quality in form of sound institutional settings and absent or, at least, reduced levels of corruption, I include the existence of public municipal water utilities in a

municipality as a dummy variable into the regression model. Outsourcing the administration of municipal water service to semi-independent public utilities was meant to foster the institutional soundness of municipal water administration and, above all, to shield it from corrupting political influence. As mentioned in chapter Historic overview, 457 out of 2,456 municipalities created public municipal water utilities as of 2014 (CONAGUA, 2014b).

In addition, it would be desirable to include additional meaningful indicators like average term in office of general managers and the average frequency of personal turnovers in public water utilities and municipal water departments into the regression models. In doing so, one may measure degrees of managerial soundness and independency from politics with more accuracy. One could argue that a relatively long average term of the general manager leads to a more long-term orientation of the policy of a public water utility which is usually required for a sound management, e.g. due to the necessity of long-term investments (Briceño, 2008). Moreover, only rare turnovers of staff may indicate that a water utility is decoupled from direct political influence to some extent. The influence of municipal and federal state administrations often generates unprofessional personnel and prevents long-term planning, as the staff of the general municipal bureaucracy is commonly turned over (Barkin, 2006 and 2011). Respective data is not available though.

In addition, INAFED (2015 and 2016) provides data on the institutional quality of the general municipal administration (*Desempeño Institucional Municipal* in Spanish). 2012 was the first year, it published the Index of Strategic Planning and Municipal Evaluation (*Índice de Planeación Estratégica y Evaluación municipal* in Spanish) for 2,199 municipalities. As there is no data available for the year of 2010 I use the 2012 data. In addition, I drop the remaining municipalities for which no data is available from the sample. The index aims at measuring the degree public municipal governments incorporate strategic planning and quality control to achieve a more effective and rule-bound municipal administration. Concretely, it factors in whether a municipal administration 1) officially states its mission, vision, objectives and/or targets, 2) elaborates a strategic and operational program, 3) provides indicators on management and goal achievement, 4) uses manuals and/or quality standards for service provision, 5) has established respective control and follow up panels, and 6) has implemented a system for customer complaints and measurement of user satisfaction.

Depending on the performance, the administration receives scores in the 6 management fields whereby maximum scores vary in each field. The highest maximum score (25.00) is assigned to 1), the lowest (3.57) to 4). Maximum scores total to 100. The index classifies municipal administrations achieving scores of  $\geq 80$  as full achievers with only minor shortcomings. In municipalities with  $40 \leq \text{scores} \leq 80$ , strategic planning and evaluation mechanisms are considered to be incomplete while scores of  $< 40$  correspond with low and fragmented institutional quality of municipal administrations (INAFED, 2016). Where available, I include the Index of Strategic Planning and Municipal Evaluation as a measure for institutional quality of municipal administrations in Mexico.

In addition, INAFED (2015) provides data on the degree of implementation of regulations within municipal administration for 2,400 Mexican municipalities for the years of 2008, 2010, and 2012. That means that the remaining 156 municipalities for which no data is available are excluded from the sample and hence not considered in the econometric analysis. The Index of Basic Municipal Regulation Implementation (IRMB; *Índice de Reglamentación Municipal básica* in Spanish) informs whether municipal administrations have implemented 17 regulations the Mexican Constitution mandates to establish. They are as follows:<sup>80</sup>

Decree of police force and good governance (*Bando de policía y buen gobierno*; Art. 115 II),

Interior guidelines for the town hall administration (*Reglamento interior del Ayuntamiento*; Art. 115 fracción II),

Municipal public administration (*Administración pública municipal*; Art. 115 fracción II),

Transparency and access to information (*Transparencia y acceso a la información*; Art. 6),

Civil participation (*Participación ciudadana*; Art. 115 fracción II),

Regulation of public works (*Reglamento de obras públicas*; Art. 115 fracción II),

Scavengery and/or recollection of solid urban waste (*Limpia y/o recolección de residuos sólidos urbanos*; Art. 115 fracción III inciso c),

Public security (*Seguridad pública*; Art. 115 fracción III inciso h),

Civil protection guidelines (*Reglamento de protección civil*; Art. 73 fracción XXIX-I),

Regulation of public street lights (*Regl. de alumbrado público*; Art. 115 frac III inciso b),

Cemetery regulation (*Reglamento de cementerios*; Art. 115 fracción III inciso e),

---

<sup>80</sup> Corresponding articles of the Constitution and the Spanish original designation are kept in brackets.

Regulation of public markets (*Reglamento de Mercados*; Art. 115 fracción III inciso d),  
Regulation of meat markets (*Reglamento de Rastro*; Art. 115 fracción III inciso f),  
Road traffic regulation (*Reglamento de Vialidad y transporte*; Art. 115 frac. V inciso h),  
Spatial planning and development (*Zonificación y uso de suelo*; Art. 115 frac. V inciso a),  
Environmental regulation (*Ordenamiento ecológico*; Art. 115 fracción V inciso g),  
Building regulation (*Reglamento de la construcción*; Art. 115 fracción inciso f).

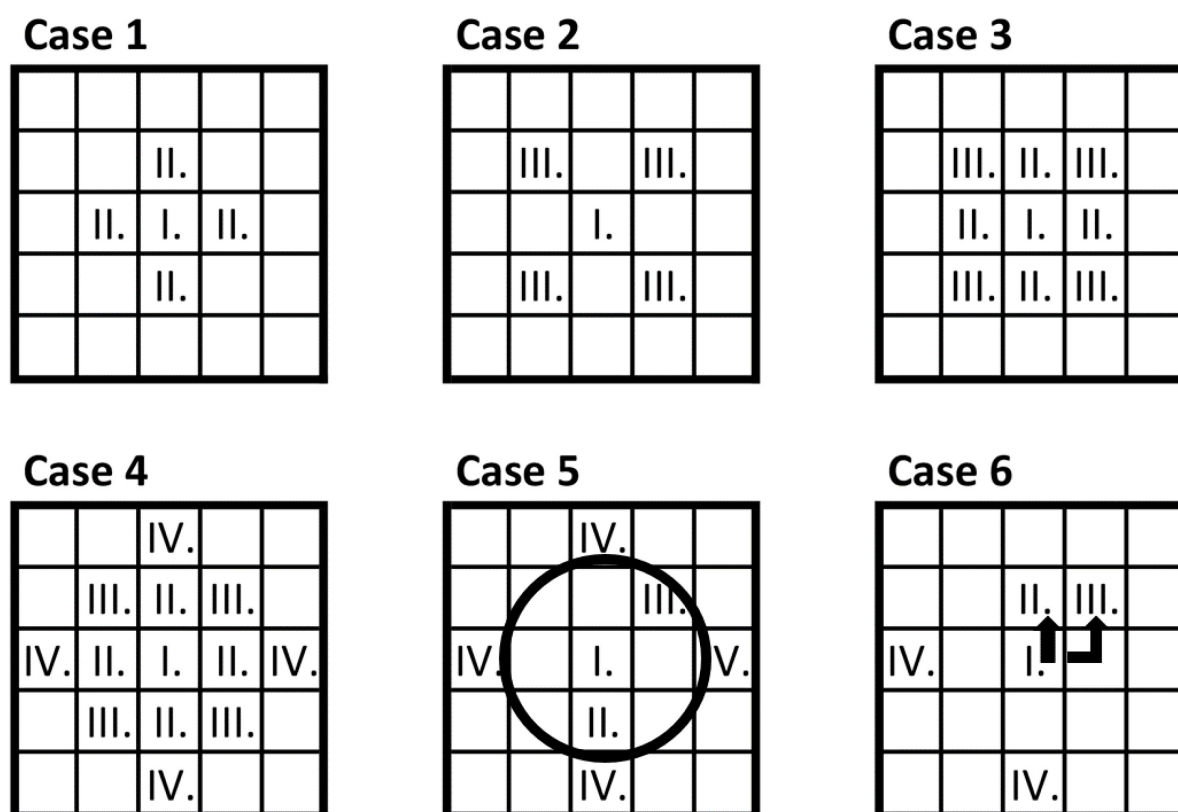
The index assumes that the implementation of regulations fosters transparency, sound administrative mechanisms, and prevents or, at least, restrains the occurrence of corruption in municipal public administrations. Thus, it might serve as a suitable proxy measure for institutional quality. It is calculated as the ratio, multiplied by 100, of the number of implemented regulations to the total number of mandated regulations. Generally, the IRMB considers municipalities with values of 60 to 80 as high, of 40 to 60 as middle, and of below 40 as low performing (INAFED, 2015).

#### **5.2.4. Spatial spillovers and spatial proximity**

In the discipline of spatial econometrics, several methods exist to measure spatial proximity. According to Hosseini and Kaneko (2013), Figure 10 depicts the six most common procedures to measure contiguity.<sup>81</sup>

---

<sup>81</sup> Hosseini and Kaneko (2013) base their insights on Freitas et al., (2013).



**Figure 10: Six measures of contiguity**

Source: Hosseini and Kaneko (2013). Can environmental quality spread through institutions?, p. 315; modified by author.

Case 1 A considers only spatial entities (II.) that boarder directly at the spatial entity (I.) as having potentially influence on (I.).<sup>82</sup> All other entities, represented as blank cells in the spatial matrix, are classified as exerting no influence. Contrasting to that, case 2 defines only localities with a vertex border (III.) to locality (I.) as contiguous, i.e. as of influence. Case 3 illustrates the so called Queen contiguity which is a combination of case 1 and 2. Case 4 extends the area having influence on (I.) to all cells that border (II.) localities. Case 5 and 6, on the other hand, define contiguity or spatial proximity on the basis of distance. They calculate localities' linear distance based on the Euclidian distance method, i.e. by using the longitude and latitude points of the centers of the localities. In this context, case 5 specifies a certain radius within which the centre of a locality has to fall in order to qualify as a contiguous locality (II. and III.). Case 6 F illustrates the K nearest neighbour approach instead, i.e. only a certain number of localities, K, that are nearest to locality (I.), are classified as of having influence. In case 6, for

<sup>82</sup> Influence in the sense that spillovers may take place.



instance,  $K = 2$ ; hence only (II.) and (III.) are considered as contiguous localities (Hosseini and Kaneko, 2013; LeSage and Pace, 2009).

As no comprehensive information is readily available on Mexican municipalities sharing a common border or vertex, the natural choice of this study is to select the distance and radius method, as illustrated in cas 5, to measure spatial proximity or contiguity. The Mexican National System of Municipal Information SNIM publishes latitude and longitude points of the geographic centres of 2,316 municipalities (SNIM, 2015). Based on this information, I calculate a bilateral distance matrix for the municipalities data is available (see Table A.8 in appendix).<sup>83</sup> The remaining municipalities are again dropped from the sample.

In a next step, I identify the overall number of municipalities and the number of municipalities with wastewater treatment activities which are located within the radii of 25, 50, and 100 kilometres of the centre of each municipality. From there, the share of municipalities with municipal wastewater treatment is calculated for each radius. Generally, I consider municipalities within a 25 km distance of the centre of a municipality as being within the natural scope of view of a municipal administration for policy inspiration. However, I also consider alternatively municipalities within the radii of 50 and 100 km as neighbouring localities since 237 of the 2,316 included Mexican municipalities have such a large extension that there is no neighbouring municipality within a 25 km range of the municipality's centre.<sup>84</sup>

Finally, the share of neighbouring municipalities with municipal wastewater treatment is included as independent variable into the regression model. The different radii are then considered in three different model runs. In the first, I include the share of municipalities with municipal wastewater treatment within a radius of 25 km; in the second the share within a radius of 50 km, and thirdly within a radius of 100 km. According to the theoretical narrative, one

---

<sup>83</sup> The Table A.8 in the appendix shows only an expert of the distance matrix as it is not feasible to depict a 2316 x 2316 matrix containing all bilateral distances of the 2,316 Mexican municipalities for which longitude and latitude data is available. The illustrated data set provides the first and last couples of municipalities of the overall sample starting with the municipality of Aguascalientes in the federal state of Aguascalientes and ending with the municipality of Zacatecas in the federal state of Zacatecas. For further information on the distance calculation method, see end note of Table A.8.

<sup>84</sup> This number reduces from 237 to 38 and 9 if radii of 50 and 100 km are considered respectively. As for the 25 km radius, I decided, in order to avoid a significant reduction of the sample size, to include for the 190 municipalities, which have neighboring municipalities within 50 kilometers but none within 25 km of their center, the data on municipalities within the 50 km radius, and for the 38 municipalities which have neighboring municipalities within 100 kilometers but none within 25 km of their center the data on municipalities within the 100 km radius.

would expect a diminishing effect of municipal wastewater treatment performance in magnitude and significance the greater the chosen radius. Supposedly, more remote localities exert less influence on the wastewater treatment policy of a municipal administration. To control for this, I also run additionally a model where I include the share of municipalities with wastewater treatment within a radius of 1,000 km as independent variable. As almost all Mexican municipality are located within a distance of 1,000 km to each other, its parameter should not display any significance.

### **5.2.5. Population density, concentration and urbanization**

Simply including municipal population density into the regression models is rather meaningless as it disregards differences in population concentration. Mexican municipalities are generally composed of several localities of different size and of unsettled areas like agricultural land, forest and wild nature. Taking the average population density of such a heterogeneous amalgamation does not account for higher demand and ability to treat municipal wastewater due to high degrees of population concentration within a municipality. For this reason, I include the share of urbanized population in a municipality instead of municipal population density as independent variable.

Concretely, settlements of 30,000 or more inhabitants within a Mexican municipality are considered as urbanized. I follow in this definition the Mexican National Municipal Information System SNIM who considers a municipality with 50% or more of the population living in localities with one million or more inhabitants as metropolitan, with 100,000 to one million inhabitants as urbanized in large cities, and with 30,000 to 100,000 inhabitants as urbanized in middle sized cities (SNIM, 2010). This classification seems to be reasonable as it coincides approximately with the official recommendation of settlement hierarchization of the United Nations Statistics Division UNSTATS. According to UNSTATS, a metropolis accommodates at least one million people, a large city between 300,000 and less than one million, and a city between 100,000 and less than 300,000 people. The population of a large town aggregates to 20,000 to less than 100,000 people (Doxiadis, 1968; UNSTATS, 2016).

As SNIM (2015) provides data on how many persons live in each municipality in localities with 30,000 to 49,999 and 50,000 to 99,999 inhabitants, but not in localities with 20,000 to 99,999

inhabitants I consider settlements with 30,000 to 99,999 inhabitants approximately as large towns. Consequently, I consider a population as urban if it lives in a settlement of 30,000 inhabitants or more.

### 5.2.6. Education

As a measure of the level of education in Mexican municipalities I rely on the so called Education Index (EI; Índice de Educación in Spanish) which has been developed by the United Nations Development Programme and for which data is available for the years 2005 and 2010 at the municipal level in Mexico (UNDP, 2010, 2014 and 2010).

It measures the relative educational progress of a Mexican municipality. As equation 5.2 details, it is composed of the arithmetic mean of two sub-indexes: a) the Mean Years of Schooling Index (MYSI), and b) the Expected Years of Schooling Index (EYSI). It assumes values between 0 and 1 whereby zero represents the worst and one the best of all possible education levels in a country.

$$(5.2) \quad EI = \frac{MYSI + EYSI}{2}$$

On the one hand, the Mean Years of Schooling Index (MYSI) is calculated as the mean years of schooling of persons aged 24 and above living in a municipality divided by the maximum of mean years of schooling of all Mexican municipalities. The maximum of mean years of schooling happens to be 13.1 years (PNUD, 2014):<sup>85</sup> In the mathematical terms, the MYSI is expressed as:

$$(5.3) \quad \text{Mean years of schooling Index}_m = \frac{\frac{1}{I} \sum_{i=1}^I \text{years of schooling}_{i,m}}{13.1}$$

where  $m$  denotes the municipality,  $I$  the total number of persons living in the municipality  $m$  aged 24 and above. The mean years of schooling is indexed by the maximum of mean years of

---

<sup>85</sup> Generally, the UNPD assumes 15 years to be the maximum value of mean years of schooling in a locality. However, it has been reduced to 13.1 years in the Mexican context as this figure is the actual maximum value observed in Mexican municipalities (UNDP, 2010 and 2013; Barro and Lee, 2010).

schooling in order to generate unit-free MYSI with values between 0 and 1. This procedure allows to sum up the MYSI and EYSI to the Education Index (UNPD, 2010).

On the other hand, the Expected Years of Schooling Index (EYSI) is calculated as the school years individuals aged between 6 and 24 years can expect to attend at their first day at school divided by the general maximum of expected years of schooling which are assumed to be 18 years:<sup>86</sup> The mathematical description of the EYSI is:

$$(5.4) \quad \text{Expected years of schooling Index}_m = \frac{\sum_{e=6}^{24} \text{percentage of enrollment}_{e,m}}{18}$$

whereby

$$(5.5) \quad \text{Percentage of enrollment}_{e,m} = \frac{\text{enrolled individuals}_{e,m}}{\text{individuals}_{e,m}},$$

with  $e$  denoting the age with  $e \in \{6,24\}$ . Again, indexation is applied to generate a unit-free EYSI with values between 0 and 1.

Generally, the INEGI National Population and Housing Census provides data on the MYSI and EYSI. The census is performed every 5 years with 2010 being the most recent year data has been published on. Based on this information, the United Nations Development Programme in Mexico UNDP calculates both sub-indicators and merges them to the Education Index (PNUD, 2014). Complementary, the Mexican National System of Municipal Information SNIM has published data on the Education Index for the year of 2005 (SNIM, 2014). Generally, the Education Index values of Mexican municipalities cover a large part of the possible spectrum between 0 and 1. In 2010, the delegation of Benito Juárez (D.F.) performed with a score of 0.92 best among all municipalities while Cochoapa el Grande (Guerrero) was at the bottom of the list with a score of 0.41.

Analogous to GDP per capita, I perform two different regression runs, one with data on the Education Index of 2010, and one with the 2005 Education Index data. Lagging the causal relation between independent and dependent variable by five years might be, again, indicated in order to control for potential endogeneity problems between municipal wastewater treat-

---

<sup>86</sup> This follows from 18 being the difference of 24 and 6 years. 18 years are set to be the term one needs to acquire a Master degree in most countries, likewise in Mexico (UNDP, 2010; PNUD, 2014).

ment performance and the education level in a municipality. Possibly, not only elevated education levels trigger improved performances in wastewater treatment, but, reciprocally, better municipal sanitation may also result in higher education levels as school absence rates may decrease due to a reduced prevalence of waterborne diseases (Hepworth et al., 2013).<sup>87</sup>

### 5.2.7. Female participation in local politics

To measure female participation in local politics I include as independent variable the female share in the members of the municipal government consisting of the municipal president (*presidente municipal*), the aldermen (*regidores*), and the receiver(s) (*síndico(s)*).<sup>88</sup> In 2005, the United Nations Development Programme in Mexico (UNDP; *Programa de las Naciones Unidas para el Desarrollo* in Spanish) published corresponding data for the preceding legislative period based on updated information from the Mexican National Municipal Information System SNIM (INAFED 2000; PNUD, 2005; SNIM, 2014). More recent data on the gender composition of the entire municipal government is not available.

Alternatively, the Investigation Centre for Development CIDAC (*Centro de Investigación para el Desarrollo* in Spanish) publishes recent and comprehensive information on the gender of municipal presidents. Principally, this information is of interest as the office of the municipal president is the most influential in municipal politics in Mexico. However, considering the mayor's gender in a particular term of office or year as an alternative independent variable is nonetheless an unfeasible option in my view. Supposedly, the mayor's gender is subject to more fluctuations over terms of office than the respective female share in the compositions of the entire municipal government. Hence selecting female presidencies in municipalities in a particular term of office or year as explanatory variable is an inferior approach. Due to higher variations, the selected indicator is less representative for female participation in local politics. Instead, one would have to consider the share of female presidencies over a period of the last

---

<sup>87</sup> In terms of comparability, one might consider that the United Nations Development Programme changed the calculation method and the composition of the Education Index in 2010. Before 2010, the EI was composed of the weighted sum of the adult literacy rate index (ALI; 2/3 weight) and the Combined Primary, Secondary, and Tertiary Gross Enrollment Rate Index (GEI; 1/3 weight). Partly due to data constraints, partly due to a relatively overall high literacy rate in Mexico, the Mexican Education Index of 2005 contains only the GEI. Since the focus and scope of GEI, and MYSI and EYSI appear to be rather similar, I assume that the old and new Education Index are roughly comparable in the Mexican context. For a more detailed discussion of the topic see e.g. Majerová (2012).

<sup>88</sup> See subchapter 2.1.4 for a detailed discussion of the structure of municipal governments in Mexico.

20 or 25 years to cover the recent positive developments in municipal wastewater treatment and create a more representative explanatory variable. However, gathering this data comprehensively has not been feasible within this research project.<sup>89</sup>

### 5.2.8. Ethnic heterogeneity

A popular measure of ethnic heterogeneity in a society is the so called Fractionalization Index (Papyrakis, 2013). Its formal presentation is:

$$(5.6) \quad \textit{Fractionalisation} = 1 - \sum_{i=1}^N \pi_i^2$$

where  $\pi_i$  denotes the share of total population that belongs to the  $i^{\text{th}}$  ethnic group of a society. The sum of the shares of ethnic groups is then subtracted from 1. Values close to zero indicate then ethnic homogeneity while values approaching one indicate higher degrees of ethnic fractionalisation in the population.

As already mentioned in subchapter 2.1.2 of this thesis, the Mexican society comprises several ethnicities as it is the nation with the 11<sup>th</sup> biggest indigenous population worldwide (CIA, 2015a). 60% of the Mexican population are mestizos, 10% indigenes while 29% are of European and about 1% of African descent. According to official data, 6.9% of the population speak indigenous languages (INEGI, 2010). Most of indigenous people live in rural municipalities of the central federal states of Puebla, Veracruz, Hidalgo, San Luis Potosí, and Guerrero, or of the southern federal states of Oaxaca, Yucatán and Chiapas. In addition, also some northern states like Sonora and Sinaloa home islands of ethnic minorities. At the municipal level, the percentage of indigenous population in total municipal population vary from 0% or single digit percentages in most municipalities to up to 100% in few cases (INEGI, 2010). Overall, 63 indigenous languages are officially recognized by the Mexican law (DOF, 2003). According to official estimates, Nahuatl is with 1.45 million speakers the most spoken indigenous language (INEGI, 2005). It is followed by Yukatek Maya which is spoken by about 750,000 people (CDI, 2017).

---

<sup>89</sup> Principally, CIDAC provides respective data for the last decades. However, one would need to gather the information from plenty of excel sheets and pdf documents which is unfeasible for 2,456 municipalities and several election periods. On request formulated by the author of this thesis via email on 2015/10/23, no overall table was available at CIDAC.

Other main indigenous languages are Mixtec and Zapotec. About 400,000 people speak each of these languages (INALI, 2017).

For the population aged 3 and above, the INEGI National Population and Housing Census provides for the year of 2010 at the municipal level data on the number of only Spanish speaking people and people who speak, in addition or instead of Spanish, at least one indigenous language (SNIM, 2014). Based on those skills, I fragment the municipal population into two ethnic groups: a) Only Spanish speaking Mexicans and b) Mexicans with indigenous language skills.<sup>90</sup> The computed Fractionalization Index is then included into the econometric regression models as independent variable.

In addition, I include as independent variable also the percentage of Mexicans with indigenous language skills in the municipal population as a measure of municipal ethnic fractionalization against the national and state level. Generally, the national and state government tiers are dominated by non-indigenous Mexicans. Since the national and state governmental tiers play an important role in the governance of municipal water supply and sanitation a high indigenous proportion in a municipal population may impede the cooperation across governmental tiers and, hence, result in a degraded municipal wastewater treatment service (CONAGUA, 2015a).

For technical reasons and lack of data, I do not further differentiate the ethnic group b) 'Mexicans with indigenous language skills' into different indigenous groups based on skills of different indigenous languages. Respective data would have to be computed manually which is beyond the scope of this thesis. Moreover, the population of the majority of the Mexican municipalities does not seem to be fragmented into several indigenous population strata as the main four indigenous languages are spoken in different parts of Mexico. Nahuatl is spoken in areas located in the centre of Mexico, Yukatek Maya in areas in the southeast, Mixtec and Zapotec in different areas in the southwest of Mexico (INEGI, 2005; INALI, 2017). Hence ethnic fragmentation should emerge approximately along the line of "Only Spanish speaking Mexi-

---

<sup>90</sup> In almost all Mexican municipalities a small proportion of the population does not specify whether it speaks an indigenous language. Within this study, I assume that this small part of the municipal population has no indigenous language skills and is only Spanish speaking.

cans” and “Mexicans with indigenous language skills”. Furthermore, I also refrain from considering other ethnic characteristics beside language skills due to lack of data availability at the municipal level.

### **5.2.9. Water availability**

To obtain comprehensive data on the status quo of water availability in a Mexican municipality is rather difficult. In general, the measurement of water supply and consumption is subject to some fluctuations and uncertainties.

CONAGUA provides a rough approximation of net water availability at the local scale. It publishes regularly data on the mean annual net availability of surface water at the hydrological watershed level. Mean annual net availability of surface water is defined as the difference between annual gross water availability and annual water demand. Mean annual gross water availability, in turn, is defined as the sum of mean annual precipitation, mean annual inflow from upstream watersheds,<sup>91</sup> annual volumes imported from other countries, and annual volumes returned by water users after consumption into the hydrological watershed. Furthermore, annual water demand is specified as the total of annual extracted volumes of surface water, annual volumes exported to other countries, annual volumes of evaporated water, annual variation in water reservoirs volumes, mean annual outflows and volumes committed to downstream watersheds (CONAGUA, 2008a).

Overall, Mexico is divided into 731 hydrological watersheds (CONAGUA, 2013a and 2013b; DOF, 2016). In most cases, their limits do not correspond with the borders of the 2,456 Mexican municipalities, mainly because watersheds are geographical and municipalities political entities. In some cases, a municipality belongs to several watersheds. In others, a single watershed comprises the entire areas of various municipalities, and vice versa. Thus, using watershed data at the municipal level requires adjustment. I consider therefore the data of a watershed representative for a municipality if a watershed comprises an entire municipality. If a municipality comprises, on the other hand, several watersheds I consider the average of

---

<sup>91</sup> Water inflows into a watershed are possible since a hydrological watershed in the Mexican definition does not necessarily correspond 1:1 to the natural watershed of rivers, streams, and creeks. Particularly bigger natural watersheds are commonly divided into smaller sub-units as considering entire natural watersheds would produce rather meaningless results in terms of local net water availability.



net availability of surface water of these watersheds as representative for the municipality. In cases where a municipality belongs to several watersheds, I assume that annual net availability of surface water in a watershed is representative for a municipality if either its capital or more than 50% of the municipal territory is located within the boundaries of a watershed. In cases where the capital of a municipality is located in another watershed than 50% of its territory I consider the average of both watersheds as representative for the municipality provided data is available for both watersheds. In cases where data is only available for one of the two watersheds I consider its data as representative.

Based on this assumptions, I am able to gather manually data on annual net availability of surface water for 1,446 municipalities for the year of 2007. Out of the 1,446 municipalities 400 disposed of a negative annual net water availability, i.e. water demand surmounted gross water availability. Commonly, this excess demand is met by tapping into surface water reservoirs and/or groundwater resources.

Following the official CONAGUA classification (CONAGUA, 2008a) which defines localities with negative mean annual net water availability as suffering from water scarcity and localities with a positive mean annual net water availability as water abundant I include a dummy variable for the mean annual net availability of surface water into the regression models for a sample of 1,446 municipalities. In this context, zero-values of the dummy variable indicate water scarcity.<sup>92</sup> Municipalities I was not able to gather data on are dropped from the sample. However, as this leads to a significant reduction of the overall sample size I include the dummy variable for the mean annual net water availability only in a separate run of the regression models. The results of this model shall mainly serve for the verification of the empirical findings of the main regression models that do not include the dummy variable for net water availability but therefore a much higher number of Mexican municipalities.

---

<sup>92</sup> Instead of the dummy variable one may directly include annual net availability of surface water as continuous independent variable into the regression model. However, I do not consider this as a feasible option due to the modest data quality caused by the necessity to adjust the hydrological watershed data to municipal settings manually. Moreover, considering exclusively surface water data may only produce a biased picture of the true degree of relative water availability in municipalities as relative groundwater availability is not included. Particularly in drier regions groundwater is frequently an important water abstraction source. However, including relative availability of groundwater is not feasible due to lack of data. Generally, CONAGUA reports only on the 653 groundwater reservoirs that exist in Mexico which is too large a scale to break it down to the municipal level (DOF, 2001; CONAGUA, 2013a and 2013b).

### 5.3. Econometric models selection

In order to select fitting econometric models, one needs to consider the particularities of chosen dependent variables. As discussed in detail in subchapter 5.1, the thesis specifies the dependent variable in two different ways:

- The probability municipal wastewater treatment takes place in a Mexican municipality.
- The estimated percentage of treated municipal wastewater in a Mexican municipality.

Commonly, the conditional estimation of probabilities relies on binary outcome regression models. The conditional estimation of percentage of treated municipal wastewater may default to selection models, like the Tobit model, or extended binary outcome models, like the Fractional Logit model. The following subchapters 5.3.1 and 5.3.2 detail the particular characteristics of the econometric models that will be applied in the case study part of the thesis in chapter 6 and chapter 7.

#### 5.3.1. Binary outcome models

If the aim is to estimate the probability that municipal wastewater treatment takes place in a Mexican municipality a particular feature of the dependent variable  $y$  is its discreteness as it assumes only two values:

$$(5.7) \quad y = \begin{cases} 1 & \text{if wastewater treatment takes places,} \\ 0 & \text{if wastewater treatment does not take place,} \end{cases}$$

whereby municipal wastewater treatment takes place in municipality  $i$ , i.e.  $y_i = 1$ , with probability  $p_i$ . From there it follows that the probability of municipal wastewater treatment not taking place, i.e.  $y_i = 0$ , equals to  $(1 - p_i)$ . Generally,  $p_i$  assumes values  $[0; 1]$  whereby  $p_i = 0$  represent 0% and  $p_i = 1$  stands for 100%.

Binary outcome regression models parameterize the probability  $p$  as a function of independent variables or regressors  $x$ . In mathematical terms, the binary outcome model is expressed as:

$$(5.8) \quad p_i \equiv \Pr(y_i = 1|x) = F(x'_i\beta),$$

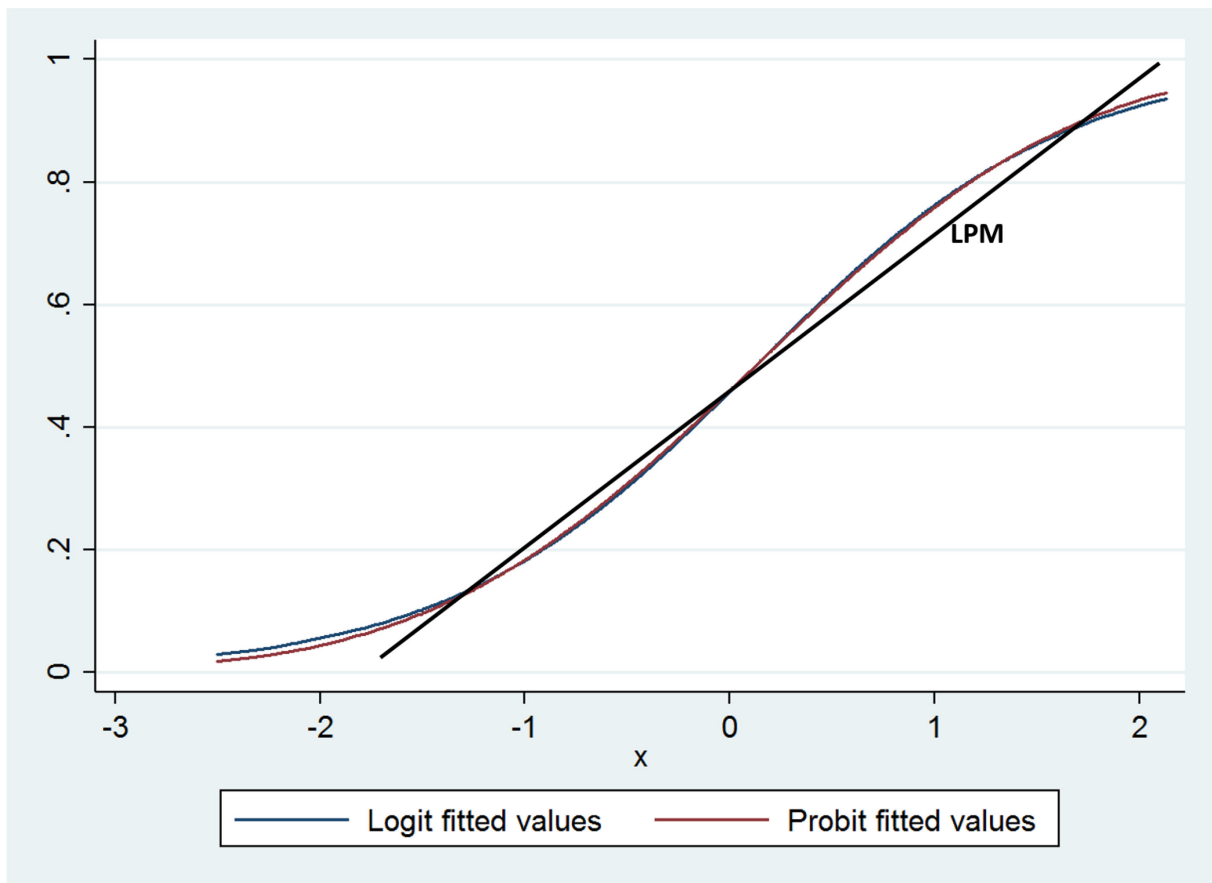
whereby  $F(\cdot)$  is a function which specifies the link by which  $p_i$  depends on the regressors  $x$  and their parameters  $\beta$ . The term  $Pr$  denotes probability. Naturally, the probability municipal wastewater treatment taking place ranges between 0 and 100%. To guarantee that  $0 \leq p \leq 1$  a standardized cumulative distribution function (c.d.f.) is generally selected since  $F(\cdot)$  gives the area under the probability density function of  $y = 1$  for  $x$  values varying from  $(-\infty, \infty)$  if it is specified as c.d.f.<sup>93</sup>

Basically, four binary outcome models are used in econometrics: the logit model, probit model, complementary log-log model (clog-log), and linear probability model (LPM) (Cameron and Trivedi, 2005 and 2009). They differ in their respective specification of  $F(\cdot)$ , particular the LPM model against the other models as the logit, probit, and the clog-log model select a cumulative distribution function and postulate implicitly a S-shaped relationship between independent variables  $x$  and  $\Pr(y_i = 1)$ . In contrast, the linear probability model (LPM) does not use a c.d.f and specifies instead  $p_i = x'_i\beta$  assuming a linear slope (Cameron and Trivedi, 2005 and 2009, Greene, 2012).

Figure 11 illustrates the standardized logit, probit, and the linear probability function whereby the  $x$ -axis depicts the independent variable  $x$ . The  $y$ -axis shows the probability  $p$  that  $y = 1$  with values ranging from 0 to 1 in dependence of  $x_i$ . As Figure 11 illustrates, the logit and probit function are symmetric around the normalized mean of the independent variable,  $\bar{x} = 0$ . Alternatively, one can also specify, for instance,  $\bar{x} = 0.5$ . Then symmetry around the mean means that a one-unit change in the independent variable at  $p$  levels of 0.2 and 0.8 have the same effect on  $\Pr(y_i = 1)$ . At the same time, Figure 11 reveals that effects vary in magnitude across different  $x$  levels for the logit and probit function. At low and high  $x$  values, which correspond to  $p$  values close to zero or 100%, a one-unit change in  $x$  has significantly less impact than at values closer to the population mean. Based on theoretical grounds, one may consider this parametric feature of the logit and probit model as a realistic description of municipal wastewater treatment performance.

---

<sup>93</sup> For a more detailed discussion, see (Cameron and Trivedi, 2005 and 2009).



**Figure 11: Cumulative distribution functions of the logit, probit, and LPM**

Source: own creation, using Stata 13 and Powerpoint 2013.

Take, for instance, per capita income as independent variable  $x$ . One may argue that, at low income levels, marginal increases in  $x$  improve the probability of municipal wastewater treatment relatively little as available financial means for investments into treatment facilities remain insignificant. However, chances might disproportionately increase with an ongoing increase in per capita income as funding means may become more readily available and public demand for a clean environment may also augment disproportionately. At high income levels, probabilities might, again, increase only at diminishing rates as it is rather likely that treatment takes already place.

In contrast, the function of the linear probability model assumes a linear slope. As seen in Figure 11, this has the disadvantage that estimated probabilities may become negative or exceed 100%. Obviously, this does not make sense in reality. Furthermore, LPM assumes the marginal effect on probability  $p$  of a one-unit change in a  $x$  variable to be equal across all  $x$  values. In contrast to that, the cloglog model<sup>94</sup> underlies a c.d.f that again restricts estimated probabilities to values between 0 and 1, like in logit and probit. However, the particular cloglog

<sup>94</sup> The cloglog curve is not included into Figure 11 as the statistical software Stata does not support this feature.

c.d.f. does not imply a symmetric conditional distribution of  $\Pr(y_i = 1)$  around the normalized mean of independent variables.

Generally, the logit, probit, and clog models rely on the maximum likelihood estimation method (MLE) to estimate the most likely parameter index  $\hat{\beta}$ , given  $y$  observations of the used data sample and the applied model. According to literature, MLE is the most natural estimator for probabilities as the distribution of  $y$  values is Bernoulli.<sup>95</sup> The linear probability model defaults on ordinary least square (OLS) as estimation method instead. Using OLS regression, the LMP can provide consistent estimation results nonetheless if the assumption of normally distributed error terms  $u_i$  is met.<sup>96</sup>

In the following, subchapters 5.3.1.1 to 5.3.1.4 discuss the particular features and characteristics of the logit, probit, cloglog, and LPM model in more detail.

### 5.3.1.1. Logit model

The logit model assumes  $F(\cdot) = \Lambda(\cdot)$ , i.e. the c.d.f. of the logistic distribution of probability  $p$ . In general terms, this leads to the specification of equation 5.8 as follows:

$$(5.9) \quad p = \Lambda(x'\beta) = \frac{e^{x'\beta}}{1+e^{x'\beta}}$$

The logistic distribution resembles the standard normal distribution, i.e. it is symmetric around zero. At the same time, it has a leptokurtic kurtosis, i.e. a kurtosis higher than 3. In consequence, it features heavier tails than the normal distribution. The logistic distribution is therefore considered to increase the robustness of analysis results (Amemiya, 1981; Mc Fadden, 1984; Balakrishnan, 1992).

For logit being a nonlinear model, the marginal effect of a unit change in an independent variable  $x_i$  on  $\Pr(y_i = 1)$  varies according to selected  $x_{ij}$  values<sup>97</sup>, i.e. the marginal effect of an

---

<sup>95</sup> Compare (Cameron and Trivedi, 2009).

<sup>96</sup> Compare (Gujarati, 1995).

<sup>97</sup>  $i$  and  $j$  refer to the different independent variables included into the estimation equation.

independent variable  $x_i$  does not only vary if its values change but also if values of other included independent variables  $x_j$  change. In mathematical terms, the marginal effect of an independent variable  $x_i$  is in the logit model:

$$(5.10) \quad \frac{\partial \Pr[y_i=1|x_i]}{\partial x_{ij}} = F'(x_i'\beta)\beta_j = p_i(1 - p_i)\beta_j = \Lambda(x_i'\beta)(1 - \Lambda(x_i'\beta))\beta_j$$

It is common practice to interpret estimated logit parameters with regards to their marginal effect on odds ratios instead of probabilities, i.e. how a marginal change in an independent variable  $x_i$  affects  $\frac{p_{ij}}{1-p_{ij}}$  rather than  $p_{ij}$ . If,

$$(5.11) \quad p = \frac{e^{x'\beta}}{1+e^{x'\beta}}$$

is rearranged as:

$$(5.12) \quad \frac{p}{1-p} = e^{x'\beta},$$

and transformed into:

$$(5.13) \quad \ln \frac{p}{1-p} = x'\beta,$$

an economic perspective may interpret  $\beta$  as a semi-elasticity. It indicates that a unit increase in the independent variable triggers a percentage increase in the odds ratio of a multiple of the coefficient value.<sup>98</sup>

### 5.3.1.2. Probit model

The probit model assumes  $F(\cdot) = \Phi(\cdot)$ , i.e. the standard normal c.d.f. of probability  $p$ . Hence,

$$(5.14) \quad p = \Phi(x'\beta) = \int_{-\infty}^{x'\beta} \phi(z) dz,$$

---

<sup>98</sup> For a detailed discussion see (Cameron and Trivedi, 2005) and (Ramsey and Schafer, 2013).

with  $z = \frac{x-\mu}{\sigma}$  since  $\Phi(\cdot)$  being the standard normal c.d.f. The corresponding probability density function is symmetric around zero.

The marginal effect of an independent variable  $x_i$  is in the probit model:

$$(5.15) \quad \frac{\partial p_i}{\partial x_{ij}} = \phi(x'_i \beta) \beta_j = \phi(\Phi^{-1}(p_i)) \beta_j,$$

whereby  $p_i = \Phi(x'_i \beta)$ . In the probit model, the marginal effect is interpreted as the marginal impact of a one-unit change in the independent variable on  $PR(y_i = 1)$  (Amemiya, 1981; Cameron and Trivedi, 2005).

The underlying standard normal distribution of the probit function has thinner tails than the logistic distribution of the logit function. Due to a lower kurtosis, the Probit model is considered to be less robust than the logit model. Nonetheless, it is widely used in microeconometrics (Cameron and Trivedi, 2005; Ramsey and Schafer, 2013, Balakrishnan, 1992). Which of the two models suits better as a model functions depends, theoretically, on the data-generating process (dgp) of the empirical case under investigation. If the true dgp corresponds to  $p = \Lambda(x' \beta)$  as functional form of the parameter specification of the probability distribution, logit is the correct choice while probit would yield inconsistent results. Empirically though, there is commonly little difference in choosing one over the other model as logit and probit produce rather similar probability estimates with greatest differences in the tails.<sup>99</sup>

### 5.3.1.3. Complementary log-log model (clog-log)

The complementary cloglog model assumes  $F(\cdot)$  being:

$$(5.16) \quad p = C(x' \beta) = 1 - \exp(-\exp(x' \beta))$$

whereby  $C(\cdot)$  is the c.d.f. of the extreme value distribution.

In difference to the logit and probit function it is asymmetric around zero, i.e. a one-unit increase in an independent variable at probability levels of, e.g.  $p_1 = 0.2$  and  $p_1 = 0.8$ , do not

---

<sup>99</sup> Cf. Cameron and Trivedi (2005).

correspond in the clog-log environment if  $mean = 0.5$ . Due to this asymmetric characteristic, the clog-log function may qualify better as a functional specification of  $F(\cdot)$  when one of the two possible outcomes in the binary outcome model appears relatively seldom. In such circumstances an asymmetric development of the probability  $p_i$  with varying  $x_i$  values may be more likely, and, hence, the use of clog-log possibly recommendable.<sup>100</sup>

The marginal effect of independent variables  $x_j$  is in the clog-log model:

$$(5.17) \quad \frac{\partial p}{\partial x_j} = \exp(-\exp(x'\beta)) \exp(x'\beta) \beta_j.$$

#### 5.3.1.4. Linear probability model (LPM)

The linear probability model does not rely on a c.d.f. and specifies instead:

$$(5.18) \quad p = F(x'\beta) = x'\beta$$

It assumes a linear relationship between probability  $p$  and independent variables  $x_j$ . Thus, the marginal effect of included independent variables  $x_j$  is constant for  $x_j$  values from  $(-\infty, \infty)$ :

$$(5.19) \quad \frac{\partial p}{\partial x_j} = \beta_j$$

As stated in chapter 5.3.1, an obvious shortcoming of the Linear probability model (LPM) which is based on OLS regression is that it doesn't restrict estimated  $p$  values to the interval  $[0, 1]$ . According to literature, the OLS estimator is nevertheless a useful instrument as in empirical practice predicted probabilities ( $\hat{p}$ ) mostly remain within the 0 to 100% range. Furthermore, it provides reasonable estimates of marginal effects at the sample average of included independent variables. However, estimated probabilities of single observations ( $\hat{p}_i$ ) might be off the mark since the linearity assumption is frequently not a reasonable approximation to reality due to the existence of non-constant marginal effects (Cameron and Trivedi, 2005).

---

<sup>100</sup> Cf. Cameron and Trivedi (2005 and 2009).



Also, one has to be aware of that LPM is prone to heteroscedasticity since the sample variance is  $p(1 - p)$  or  $Var(y|x) = (x'\beta)(1 - x'\beta)$ .<sup>101</sup>

### 5.3.2. Tobit and selection models

For the reduced sample of Mexican municipalities the aim is to explain the estimated share of treated municipal wastewater in dependence of a set of independent variables. In this context, a particular feature of the dependent variable might be that it is only incompletely observed due to the presence of censored data.

What this means and why it might be an issue, literature typically illustrates with the example of personal income. Frequently, income levels are reported only below a certain threshold, e.g. US \$ 100,000 per year. Above that threshold incomes are merely reported as exceeding US \$ 100,000 and, consequently, treated as if being equal to US \$ 100,000. Hence, part of the data is incompletely observed. As a result the observation sample does not represent the population. In consequence, parameter estimates of the linear ordinary least-squares (OLS) regression are inconsistent (Maddala, 1983; Gouriéroux, 2000; Cameron and Trivedi, 2005; Greene, 2012).

There is some similarity between the case of interest of this thesis and the general income example. While a significant number of the Mexican municipalities reports a share of municipal wastewater treatment of zero the remainder of the sample has positive treatment rates varying from 1% to 100%. This mixture of zero and positive percentage values suggest that using simple OLS regression would lead to inconsistent estimation results. To solve this issue one needs to specify a new model framework that accounts for the particularities of the dependent variable.

#### 5.3.2.1. Tobit model

The Tobit model is the most basic approach (Tobin, 1958; Cameron and Trivedi, 2009). Traditionally, the Tobit model has been applied to estimate the utility or net benefit consumers

---

<sup>101</sup> Compare (Cameron and Trivedi, 2009).

derive from the consumption of a particular good or service.<sup>102</sup> For that purpose, commonly cross-sectional data on the expenditure of households on a particular good or service is used. Usually, expenditure data contains a significant number of observations with zero expenditure and varying amounts of positive expenditure. Hence, like in the censored income example, OLS yields inconsistent results as the sample does not represent the population (Tobin, 1958; Cameron and Trivedi, 2009). Supposedly, households, reported to have zero expenditure, would derive some benefit from consuming the good or service. However, their demand does not materialize and their actual expenses on the product remain at zero because (opportunity) costs of consumption are prohibitive at given market prizes. The same narrative may also apply to the implementation of municipal wastewater treatment service. Mexican municipalities, reported to treat 0% of municipal wastewater, would basically benefit from the provision of municipal wastewater treatment. However, their actual demand and expenses remain at zero because the costs associated to the service provision outweigh the benefits. In consequence, they would only derive a negative utility or net benefit from the provision of municipal wastewater treatment service.<sup>103</sup>

In the context of the thesis' cases study, the Tobit model corrects for the insufficiency in the observed sample data by giving linear estimates of the share of treated municipal wastewater in Mexican municipalities conditional on the probability that municipal wastewater treatment takes place in a municipality. Pursuing this estimation strategy, the Tobit model is a combination of the probit and linear regression model (Tobin, 1958; Cameron and Trivedi, 2009).

The Tobit model assumes the existence of an underlying latent variable,  $y^*$ , which is partly unobserved.<sup>104</sup> If  $y^*$  is left-censored, it is only observed once a particular threshold,  $L$ , is surpassed whereas the opposite is true if  $y^*$  is right-censored. Within the context of the thesis' case study,  $y^*$  may be the utility for municipal wastewater treatment of a Mexican municipality which may be considered to be left-censored as it is only expressed for cases where municipal wastewater treatment rates are larger than zero. For  $y^* \leq L$ , it defaults to zero. In mathematical terms, this is expressed as:

---

<sup>102</sup> Generally, utility or net benefit is defined as the gross benefit derived from consumption, i.e. the demand for a good, minus the costs of consumption.

<sup>103</sup> See also Footnote 155.

<sup>104</sup> See for a detailed discussion (Cameron and Trivedi, 2009).

$$(5.20) \quad y = \begin{cases} y^* & \text{if } y^* > L \\ L & \text{if } y^* \leq L, \end{cases}$$

whereby  $y$  denotes observed values, e.g. actual percentages of treated municipal wastewater, whereby  $L = 0$ .

The basic procedure estimates the parameters of the regression with the dependent variable specified as latent unobserved variable  $y^*$ :

$$(5.21) \quad y_i^* = x_i' \beta + \varepsilon_i, \quad i = 1, \dots, N$$

whereby  $x_i$  denotes the  $(K \times 1)$  vector of the independent variables which are, in contrast to  $y^*$ , fully observed. Furthermore,  $\varepsilon_i$  denotes the error term which is assumed to be normally distributed and homoscedastic, i.e.  $\varepsilon_i \sim N(0, \sigma^2)$ <sup>105</sup>.

If  $y^*$  were fully observed, one would default on OLS to estimate the parameters  $\beta$ . However, if it is not fully observed, an observation of the dependent variable is censored with a certain probability:

$$(5.22) \quad \Pr(y^* \leq L) = \Pr(x_i' \beta + \varepsilon_i \leq L) = \Phi\{(L - x_i' \beta) / \sigma\}$$

whereby  $Pr$  denotes the probability that the dependent variable is censored. The probability's cumulative distribution function is specified as the standard normal c.d.f.  $\Phi(\cdot)$ <sup>106</sup>. Within this framework, expected values of non-censored observations of the dependent variable are derived as:

$$(5.23) \quad E(y_i | x_i, y_i > L) = x_i' \beta + \sigma \frac{\phi\{(x_i' \beta - L) / \sigma\}}{\Phi\{(L - x_i' \beta) / \sigma\}}$$

where  $\phi(\cdot)$  denotes the standard normal density function. Obviously, the conditional mean of equation 5.3.4 differ from  $x_i' \beta$  and also does not convert to it with  $N \rightarrow \infty$  so that simple OLS regression on  $y^*$  yields inconsistent results.<sup>107</sup>

---

<sup>105</sup> Compare (Cameron and Trivedi, 2009).

<sup>106</sup>  $\Phi(\cdot)$  is the c.d.f. of the probit model.

<sup>107</sup> For a detailed discussion see (Cameron and Trivedi, 2005) and compare (Cameron and Trivedi, 2009).

Marginal effects of a one-unit change in independent variables on the conditional mean of the dependent variable may be estimated in various ways, depending on the particular interest of the analysis. For instance, predicted marginal effects of the latent variable mean,  $\bar{y}^*$ , or the censored mean,  $\bar{y}$ , are derived as:

Latent variable

$$(5.24) \quad \frac{\partial E(y^*|x)}{\partial x} = \beta$$

Left censored (at  $L = 0$ )

$$(5.25) \quad \frac{\partial E(y|x)}{\partial x} = \Phi(w)\beta$$

whereby  $w$  is defined as  $\frac{x'\beta}{\sigma}$  (cf. equation 5.3.3).

### 5.3.2.2. Fractional logit model

As an alternative to the Tobit model one may consider to apply the Fractional Logit model in order to estimate the share of treated municipal wastewater. A general critique of the Tobit model has always been that its underlying theoretical argumentation relies exclusively on the utility concept (Papke and Wooldridge, 1996; Baum, 2008 and 2013). As mentioned, the Tobit model usually aims at predicting the utility for a certain good or service. In consequence, it allows implicitly for the estimation of negative values and values above 1. However, estimating such values may generally not be suitable for the estimation of fractions and proportions, like e.g. the treated share of municipal wastewater. In addition, the concept of utility may be in some cases rather meaningless and not always applicable to explain fitted values of fractions and proportions conditional on certain independent variables (Papke and Wooldridge, 1996; Baum, 2008 and 2013). For instance, there is no guarantee that shares of treated municipal wastewater necessarily depend only on the demand municipalities have for wastewater treatment in order to realize utility. In addition, it might be generally questionable to express a municipality's utility in shares of treated wastewater volumes. Hence it might be indicated to estimate directly the shares of treated municipal wastewater and not the underlying utility.

Against this background, Papke and Wooldridge (1996) developed, on basis of the generalized linear model (GLM) concept<sup>108</sup>, the Fractional Logit model as an extension of the general Logit model. Concretely, they aimed at developing a model that can be readily used to predict the employee participation rates in pension plans. In contrast to general Logit, the Fractional Logit model allows the dependent variable to assume not only the values of one or zero but also other values of the interval  $[0; 1]$ . The prediction of negative values or above one are, on the other hand, excluded. As the formal aspects of the Fractional Logit model do not vary from formal aspects of the general Logit model (Papke and Wooldridge, 1996; Baum 2008; Williams, 2016), I refrain from a repeated presentation of mathematical terms at this point.

However, due to its particular features and characteristics, I will apply the Fractional Logit model complementary to the Tobit model to estimate the share of treated municipal wastewater to validate if estimation results are robust across models and whether a particular model may fit better the data.

#### **5.4. Summary of chapter 5**

Chapter 5 has introduced econometrics as the analytical procedure the thesis applies to scrutinize empirically the validity of the 10 hypotheses developed in chapter 4 on the impact of social characteristics on municipal wastewater treatment performance. A statistical validation of causal relationships requires necessarily the statement of causes and effects as quantifiable indicators. Therefore, chapter 5 specified respective indicators for municipal wastewater treatment performance of a municipality and socioeconomic, demographic and institutional characteristics. Due to lacking data availability, finding suitable indicators is usually a research's bottle neck.

Municipal wastewater treatment performance of Mexican municipalities is measured in two ways: first, as "probability municipal wastewater treatment takes place in a Mexican municipality" and, secondly, as "estimated percentage of treated municipal wastewater in a Mexican municipality". Data limitations impedes to consider the actual share of treated municipal

---

<sup>108</sup> Generally, GLM estimators allow for more flexibility in terms of density and distributional aspects as they do not require necessarily a normal (Gaussian) distribution of the used data. In contrast, the relative strong assumptions of normality and homoscedasticity underlie the Tobit model (see also chapter 7).

wastewater which would have been first choice. In contrast, data on whether municipal wastewater treatment takes place in a municipality is available for almost all of the 2,456 Mexican municipalities that existed in 2010 which is the year of investigation of this thesis. Data on the estimated percentage of treated municipal wastewater is available for 511 Mexican municipalities.

Concerning the social characteristics of a municipality, per capita income is measured as GDP per capita, income distribution with the Gini coefficient after taxes and transfers, the education level with the UNPD education index, urbanization as the percentage of urbanized municipal population, ethnic heterogeneity as the ethnic fractionalization index and as percentage of the indigenous municipal population, female participation in local politics as percentage of female members in the municipal government, spatial spill overs as percentage of neighbouring municipalities with municipal wastewater treatment, environmental federalism with a dummy variable for the belonging of a municipality to a particular federal state, and water availability as dummy variable for net availability of surface water in a municipality. Furthermore, three measures for the soundness and well-functioning of municipal institutions are applied: the Index of Strategic Planning and Municipal Evaluation, the Index of Basic Municipal Regulation Implementation and a dummy variable for the existence of a public municipal water utility in a municipality.

In consideration of the particularities of the dependent variable – i.e. of the indicators for municipal wastewater treatment performance – chapter 5 selects finally the set of econometric models. To estimate the conditional probability that municipal wastewater treatment takes place in a municipality, the thesis relies on binary outcome models, in particular on Standard Logit, Probit, Complementary Log-Log Model (Cloglog) and the Linear Probability Model (LPM). To regress the estimated percentage of treated municipal wastewater, the Tobit and Fractional Logit model will be applied.

## 6. Case 1: Binary outcome models and the probability of municipal wastewater treatment

After the selection of suitable econometric models and the specification of dependent and independent variables in chapter 5, chapter 6 proceeds to the estimation of the binary outcome models on the probability that municipal wastewater treatment takes place in a Mexican municipality. The structure of chapter 6 is the following: Subchapter 6.1 provides a statistical description of the used data. Subchapter 6.2 presents the estimation results while subchapter 6.3 gives an interpretation of the results. Finally, model outcomes are tested in terms of goodness of fit and prediction quality in subchapter 6.4 and in terms of robustness and endogeneity issues in subchapters 6.5. Subchapter 6.6 summarizes the results and conclusions of chapter 6.

### 6.1. Descriptive statistics

Table 3 gives a description of the dependent and independent variables included in the econometric analysis. The first column “**variable name**” lists the abbreviations by which variables enter into the regression models. In addition, the second column “**variable label**” describes the abbreviations’ meaning. For instance, the abbreviation of **WWT** in the first row stands for the dependent Dummy variable of municipal wastewater treatment taking place. It assumes the value of 1 if a municipality treats municipal wastewater; otherwise it is zero. Subsequent rows display included independent variables beginning with GDP per capita (**gdpcap**) and ending with the Dummy variables for the state belongingness of a municipality. For instance, the dummy variable of the state of Aguascalientes (**AguasCalientes**) is 1 if a municipality belongs to this federal state; otherwise 0.

**Table 3 Description of dependent and independent variables**

variable name	variable label
WWT	Dummy for municipal wastewater treatment: if WWT=1 --> yes
gdpcap	GDP per capita in 2010 (in 1,000 PPP US \$)
gini	GINI coefficient in 2010
eduind	Education Index in 2010
urban	Percentage of urbanization in 2010 (>30,000 inhabitants)
fracind	Ethnic fractionalization Index in 2010
ethnic	Percentage of indigenous population in 2010
femadmin	Percentage female members in municipal government in 2005
neighmun	Percentage of neighbouring municipalities with WWT in 2010 (within 25km)
planind	Index of strategic planning and municipal evaluation in 2012
regind	Index of basic municipal regulation implementation in 2010
watavail	Dummy for net availability surface water in 2007: if =0 --> water scarcity
waterutility	Dummy for public municipal water utility/organismo operador: if =1 --> yes
32 State Dummies	Dummies for belonging to a particular federal Mexican State: if =1 --> yes

Source: Own calculations, using Stata 13.

Note: For reasons of clarity, the table does not itemize each Dummy variable for the belonging of a municipality to one of the 32 federal Mexican states.

**Table 4: Summary statistics for dependent and independent variables**

Variable	Obs	Mean	Std. Dev.	Min	Max
WWT	2456	.34	.48	0	1
gdpcap	2456	8.7	4.2	2.4	47
gini	2454	41	3.9	29	59
eduind	2456	79	7.1	40	92
urban	2456	9.1	25	0	100
fracind	2456	12	16	0	50
ethnic	2456	19	31	0	100
femadmin	2440	17	14	0	80
neighmun	2307	33	35	0	100
planind	2199	50	27	0	100
regind	2400	39	38	0	100
watavail	1446	.72	.45	0	1
waterutility	2452	.19	.39	0	1

Source: Own calculations, using Stata 13.

Note: gini, urban, ethnic, femadmin, neighmun expressed in percentage (%). For reasons of clarity, the table does not itemize each Dummy variable for the belonging of a municipality to one of the 32 federal Mexican states.



Table 4 summarizes the basic statistical features of the data sample in view of number of observation (**Obs**), mean values (**Mean**), standard deviation (**Std. Dev.**), and the minimum (**Min**) and maximum (**Max**) values of the dependent and independent variables.<sup>109</sup>

While information on **municipal wastewater treatment**, **GDP per capita**, **GINI coefficient after taxes and transfers**, **Education Index**, **Percentage of urbanized population**, **Fractionalization Index**, **Percentage of indigenous population**, **Public municipal water utility**, and **Belonging to a particular state** is available for almost all Mexican municipalities (>2,450 Obs.), data is missing for some municipalities on the independent variables of **Percentage of female members in municipal government** (2,440 Obs.), **Share of neighbouring municipalities with wastewater treatment** (2,307 Obs.), **Index of strategic planning and municipal evaluation** (2,199 Obs.), **Index of basic municipal regulation implementation** (2,400 Obs.), and information on **Net availability surface water** (1,446 Obs.).

As detailed in subchapter 5.2, municipalities for which no data is available on the independent variables are dropped from the sample. This leads to an overall sample of 1,201 municipalities for which data on all independent variables is available. As the inclusion of the dummy variable for **Net availability surface water** reduces the overall sample size substantially I decided to drop it from the main model. It is only included in a complementary run of the binary outcome model. The respective results are discussed in subchapter 6.5.1. Without the consideration of **Net availability surface water** as independent variable the sample size increases to 1,996 observations. If, in addition, the **Index of strategic planning and municipal evaluation** and the **Index of basic municipal regulation implementation** are left out the number of municipalities increases further to 2,290 observations. As this is again a significant increase in the sample size I decided to specify two alternatives of the general binary outcome model: Model 1 which includes the two indices, and Model 2 which excludes them. The topic of the selection issue is discussed in further detail in subchapter 6.2.

The standard deviation values of the continuous independent variables in Table 4 indicate that there is a good deal of variation in the data set; with maybe the exceptions of the data on the Gini coefficient after taxes and transfers and the Education Index. Though respective minimum

---

<sup>109</sup> For reasons of clarity, the Dummy variables for belonging to a particular federal Mexican state are not included in Table 3

and maximum values are reported to diverge rather widely with values of **28.57** and **59.08** (*gini*) and **0.40** and **0.92** (*eduind*), reported standard deviations of **3.90** (*gini*) and **0.071** (*eduind*) seem to be rather low. This suggests that the majority of Mexican municipalities are relatively similar to each other in terms of income distribution and education levels. Furthermore, GDP per capita is, to some extent, positively skewed, mainly, due to the existence of some positive outliers. 44 municipalities report, for instance, per capita GDPs of above PPP US\$ 20,000 whereas the mean of the sample is PPP US\$ 8,652. Thus, the mean is much closer to the sample’s minimum value of municipal per capita GDP of PPP US\$ 2,404.

**Table 5: Correlation of wastewater treatment and independent variables**  
(obs=2240)

	WWT	gdpcap	gini	eduind	urban	fracind	ethnic	femadmin	neighmun	regind
WWT	1.0000									
gdpcap	0.4120	1.0000								
gini	0.1341	0.1541	1.0000							
eduind	0.3435	0.6928	-0.0120	1.0000						
urban	0.2906	0.6137	0.1504	0.3362	1.0000					
fracind	-0.2473	-0.3257	0.1181	-0.3390	-0.1438	1.0000				
ethnic	-0.2758	-0.4824	0.0113	-0.6353	-0.1799	0.5421	1.0000			
femadmin	0.2489	0.2786	0.0927	0.2575	0.1512	-0.1595	-0.2493	1.0000		
neighmun	0.5016	0.4387	0.0927	0.4025	0.2162	-0.3239	-0.3693	0.3324	1.0000	
regind	0.2500	0.2857	0.1340	0.2382	0.2398	-0.1916	-0.2394	0.2067	0.3003	1.0000

Source: Own calculations, using Stata 13.

Table 5 displays the correlations of continuous independent variables with the positive outcome of the dependent variable, i.e. WWT = 1, for 2,240 municipalities. Table 5 omits the **Index of Strategic Planning and Municipal Evaluation** as its consideration reduces the number of observations significantly to below 2,000 (1,996 Obs.). Alternatively, Table A.9 in the appendix details respective correlations including the **Index of Strategic Planning and Municipal Evaluation**. As seen there, the **Strategic Planning Index** shows neither high correlation with other independent variables nor with the dependent variable (**0.107**). Furthermore, the correlation magnitudes of the other variables do not change significantly compared to values reported in Table 5.

Generally, all independent variables display positive signs except the **Fractionalization Index** and the **Percentage of indigenous population**. The negative signs meet the expect-

tation of the underlying theory as higher values of both ethnic variables represent higher degrees of ethnic heterogeneity. Their correlation magnitudes of **-0.247** and **-0.276** are medium-sized in comparison to other variables. With the exception of the **GINI coefficient after taxes and transfers**, theory predicts positive values of the correlations of other included independent variables with the positive outcome of the dependent variable. **GDP per capita (0.412)**, the **Education Index (0.344)**, and the **Percentage of neighbouring municipalities with municipal wastewater treatment (0.502)** dispose of the largest correlation magnitudes. Interestingly, the correlation of the net effect of unequal income distribution and wastewater treatment is reported to be positive. However, its magnitude is low (**0.124**). The percentages of urbanized population and female members in municipal government range with correlations of **0.291** and **0.249** in the middle field.

As for correlations among included independent variables, it is not surprising to observe, to some extent, relatively high degrees of correlation. Particularly, the correlation between **GDP per capita** and the **Education Index (0.693)** and the **Percentage of urbanized population (0.6137)** is high. Commonly, it is assumed and also empirically largely confirmed that per capita income tend to be higher among educated people and in urbanized areas (Barro, 1997; Gylfason, 2001; Zanden et al., 2014). Furthermore, the **Education Index** and **Percentage of indigenous population** exhibits a high degree of negative correlation (**-0.635**). This may indicate that education is significantly lower among Mexican indigenes. Also not surprising is the relatively high correlation (**0.542**) between the **Fractionalization Index** and the **Percentage of indigenous population**. Both variables have similarities in their composition. To some extent, observed high correlations among independent variables may pose the issue of multicollinearity in the ongoing econometric investigation. However, due to the relatively big sample size (ca. 2,000 observations) its occurrence should be of less concern in terms of estimation outcomes. The topic will be discussed in more detail in chapter 6.5 on model robustness.



**Figure 12: Plot of moving average of wastewater treatment and independent variables**

Source: Own calculations, using Stata 13.

Note: 13 observations of GDP per capita above 19,000 PPP US\$ from sample removed for the sake of better illustration.

Additionally, Figure 12 plots the observations of continuous independent variables against the moving average of the probability that municipal wastewater treatment takes place. This procedure is applied as plotting the actual values of the dependent variable directly against the observations of an independent variable is not very informative. As the dependent variable assumes only values of 0 or 1 plotting its values does not serve to illustrate how changes in the independent variable relate to the probability of municipal wastewater treatment takes place. It produces only a diagram in which the values of an independent variable correspond either with the value of 0 or 1 of municipal wastewater treatment.

To account for this, I arrange the municipalities according to the size of the values of independent variables. Afterwards I create the moving average of 10 succeeding values of the dependent variable and assign it to respective values of the independent variable. For instance, the municipality with the lowest GDP per capita receives the average value of the dependent variable values of the 10 poorest municipalities. For the second poorest municipality the average value is composed of the values of the dependent variable of the 11 poorest municipalities except the poorest, and so on. The advantage of this procedure is that it creates values between 0 and 1. If the probability of municipal wastewater treatment is conditional on the hypothesized independent variables one should see respective correlation patterns in Figure 12.

To some extent, ***GDP per capita***, the ***Education Index***, and ***Percentage of neighbouring municipalities with municipal wastewater treatment*** show, as postulated by the Logit, Probit, and Cloglog model, an S-shape relation with the moving average of the dependent variable. In contrast, the ***GINI coefficient after taxes and transfers*** exhibits a rather positive relation, with a potential heteroscedasticity issue for higher values. The observations of ***Percentage of urbanized population*** seem to be split into two data sets. On the low end, non-urbanized municipalities correlate with moving averages of the dependent variable ranging from 0% to 100%. Contrasting to that, municipalities with an urbanization degree of 20% or higher tend to relate positively with the moving average. On the other hand, no clear pattern is shown for the ***Share of female members in the municipal government***, the ***Fractionalization Index***, ***Percentage of indigenous population***, the ***Index of strategic planning and municipal evaluation***, and the ***Index of basic municipal regulation implementation***. With some imagination, one might detect a slight negative relation between the ***Fractionalization Index*** and the moving average of municipal wastewater

treatment, and a slight positive correlation for the ***Percentage of female members in a municipal government***.

Complementary, Figure A.6 in the appendix plots the natural logarithm of the continuous independent variables against the moving average of municipal wastewater treatment. Zero values of the independent variables are omitted. Generally, taking the natural logarithm may help to smooth used data as this procedure reduces the weight of outliers. Overall, Figure A.6 reproduces the illustration of Figure 12 and confirms detected patterns.

## 6.2. Parameter estimations

In a next step, parameters of the independent variables are estimated with STATA Software Version 13. Table 6 details the results of the OLS, Logit, Probit, and Cloglog regressions for two general model specifications: Model 1 and Model 2.<sup>110</sup>

Model 1 includes all independent variables except the ***Dummy variable for net surface water availability***. As mentioned in subchapter 5.2., considering this variable reduces the sample size significantly to 1,201 observations. Alternatively, Model 1 considers 1,996 municipalities. Outcomes of the model specification that includes net water availability are discussed in subchapter 6.5.1.

A constraint in data availability is also the reason for the specification of Model 2 as a second general model. In contrast to Model 1, it excludes the ***Index of Strategic Planning and Municipal Evaluation*** and the ***Index of Basic Municipal Regulation Implementation***. Omitting these variables allows Model 2 to include 2,290 observations. Since its results are based on a bigger sample size, they may serve as a validation of the findings of Model 1.

---

<sup>110</sup> Table A.13 to Table A.20 contain the complete regression results of the estimations with the STATA software.

**Table 6: Results of binary outcome models, selection**

Dependent Dummy Variable: y=1 --> Wastewater treatment takes place in a Mexican municipality y=0 --> no wastewater treatment										
	OLS	Logit	Probit	Heteroskedastic probit	Cloglog	OLS	Logit	Probit	Heteroskedastic probit	Cloglog
Independent variables	model 1	model 1	model 1	model 1	model 1	model 2	model 2	model 2	model 2	model 2
GDP per capita in 2010 (gdpcap)	.0103** (2.51)	.0900*** (2.80)	.0512*** (2.97)	.0509*** (2.93)	.04249** (2.28)	.0110*** (2.85)	.0917*** (3.08)	.0513*** (3.18)	.0511*** (3.16)	.0424** (2.43)
GINI coefficient in 2010 (gini)	.0042* (1.71)	.0355* (1.94)	.0203* (1.93)	.0205* (1.94)	.0258* (1.95)	.0063*** (2.72)	.0502*** (2.98)	.0286*** (2.95)	.0287*** (2.94)	.0364*** (3.01)
Education Index in 2010 (eduind)	.0017 (0.83)	.0106 (0.60)	.0074 (0.77)	.0073 (0.75)	.0191 (1.37)	.0020 (1.04)	.0139 (0.84)	.0095 (1.06)	.0095 (1.05)	.0237* (1.83)
Percentage of urbanization in 2010 (urban)	.0013*** (2.65)	.0074** (2.15)	.0045** (2.26)	.0045** (2.27)	.0050** (2.41)	.0014*** (3.14)	.0079** (2.51)	.0045*** (2.70)	.0049*** (2.70)	.0056*** (2.89)
Ethnic fractionalization Index in 2010 (fracind)	-.0002 (-0.25)	-.0001 (-0.01)	-.0003 (-0.10)	-.0003 (-0.09)	-.0004 (-0.09)	-.0003 (-0.53)	-.0011 (-0.21)	-.0010 (-0.33)	-.0009 (-0.33)	-.0008 (-0.17)
Percentage of indigenous population in 2010 (ethnic)	.0003 (0.81)	.0020 (0.53)	.0017 (0.64)	.0012 (0.62)	.0003 (0.08)	.0003 (0.75)	.0015 (0.44)	.0011 (0.61)	.0011 (0.60)	.0001 (0.02)
Percentage female members in municipal government 2005 (femadmin)	.0004 (0.51)	.0026 (0.46)	.0012 (0.39)	.0012 (0.38)	-.0016 (-0.40)	.0003 (0.48)	.0020 (0.40)	.0010 (0.35)	.0010 (0.35)	-.0014 (-0.40)
Percentage of neighbouring municipalities with WWT in 2010 (neighmun)	.0016*** (4.33)	.0096*** (3.93)	.0057*** (3.99)	.0057*** (3.98)	.0059*** (3.60)	.0018*** (5.13)	.0104*** (4.70)	.0062*** (4.79)	.0062*** (4.78)	.0067*** (4.52)
Index of strategic planning and municipal evaluation in 2012 (planind)	.0007** (2.07)	.0048** (2.08)	.0028** (2.12)	.0029** (2.12)	.0034** (2.02)					
Index of basic municipal regulation implementation in 2010 (regind)	.0001 (0.29)	.0003 (0.18)	.0003 (0.30)	.0003 (0.31)	.0009 (0.65)					
Dummy for public municipal water utility (waterutility)	.1315*** (4.32)	.6351*** (3.06)	.3639*** (3.03)	.3662*** (3.03)	.3489*** (2.58)	.1194*** (4.24)	.5608*** (2.99)	.3247*** (2.98)	.3258*** (2.97)	.3060** (2.50)
Constant	.1720 (0.90)	-.9851 (-0.54)	-.8934 (-0.96)	-.8839 (-0.94)	-2.6596** (-2.17)	.0735 (0.41)	-2.5527* (-1.67)	-1.6423** (-2.00)	-1.6380** (-1.99)	-3.5456*** (-3.17)
Insigma2: surface				0.0035 (0.22)					0.0058 (0.10)	
LR test of Insigma2=0: Prob > chi2				0.8200					0.916	
Sample size	1,996	1,996	1,996	1,996	1,996	2,290	2,290	2,290	2,290	2,290
Adj R-squared	0.38					0.378				
F( 37, 1958)	34.6					40.8				
Prob > F	0.0000					0.0000				
Pseudo R2		0.346	0.348				0.337	0.339		
Log likelihood		-830.17	-827.55	-827.53	-842.45		-968.45	-965.40	-965.40	-981.29
LR chi2		877.38	882.61		852.82		984.76	990.86		959.08
Wald chi2		(37) 877.38	(37) 882.61	(37) 531.02	(37) 852.82		(35) 984.76	(35) 990.86	(35) 616.00	(35) 959.08
Prob > chi2		0.0000	0.0000	0.0000	0.0000		0.0000	0.0000	0.0000	0.0000
Iterations		5	5	2	5		5	5	2	5

\* significant at 10%, \*\* significant at 5%, \*\*\* significant at 1%, Figures in () = Z-value.

Source: Own calculations, using Stata 13.

Note: For reasons of clarity, Table 6 does not contain the parameter estimates of the 31 included Dummy variable for the belonging of a municipality to federal Mexican states. This information can be found in Table A.12

Overall, most of the parameters show the expected signs in all applied regressions in Model 1. According to estimations of the OLS regression (second column of Table 6), **per capita GDP, Education Index, Percentage of urbanized population, Percentage of female members in the municipal government, Percentage of neighbouring municipalities with municipal wastewater treatment, the Index of Strategic Planning and Municipal Evaluation, the Index of Basic Municipal Regulation Implementation, and the Dummy for the existence of an independent public municipal water utility** exhibit the expected positive signs. The net effect of unequal income distribution (**GINI coefficient**) on the probability of municipal wastewater treatment taking place is positive. On the other hand, the parameter of the **Fractionalization Index** has a negative sign. Accordingly, higher degrees of ethnic homogeneity improve the probability municipal wastewater receives treatment. Somewhat unexpected, the parameter of **Percentage of Indigenous Population** has a positive sign though. However, the magnitudes of the parameter estimates of both variables are fairly small and not significant. Thus, the estimation results confirm, first and foremost, the impression derived from the scatterplots in Figure 12 in the descriptive statistic part of the thesis (subchapter 6.1) that ethnicity may not play a significant role in explaining the municipal wastewater treatment performance of Mexican municipalities.

As to the dummy variables of the **Belonging of a municipality to a particular federal state**, most of them display the expected signs in the OLS regression of Model 1 (second column of Table 6). As reference case the regression omits federal states that contain only municipalities with municipal wastewater treatment. Thus, the parameters of state dummy variables indicate in the regression models how the belonging of a municipality to a particular state impacts the probability of municipal wastewater treatment taking place in comparison to the belongingness of a municipality to one of the omitted states. The reference case comprises 100 municipalities of 6 Mexican federal states: Aguascalientes, Baja California, Baja California Sur, Colima, Nuevo León, and Sinaloa. All municipalities in these states<sup>111</sup> engage in municipal wastewater treatment.

Thus, it is not surprising that the OLS regression of Model 1 reports for the parameters of the vast majority of the **state belonging dummy variables** negative signs (cf. second column

---

<sup>111</sup> In concreto, in Aguascalientes 11, Baja California 5, Baja California Sur 5, Colima 10, Nuevo León 51, and Sinaloa 18.



of Table 6). Only the states of Durango, Nayarit, Queretaro, and Tabasco are exceptions displaying positive signs. However, none of the positive estimates is significant at the 10% level. Apart from that, the more sophisticated Logit and Probit regressions estimate negative parameter signs for all state dummy variables (cf. column 3 and 4 of Table 6 in this thesis). The Cloglog regression reports only a positive sign for the state dummy variable of Nayarit. Like in the OLS regression, it is not significant at the 10% level though (cf. column 6 of Table 6 of this thesis).

For all other independent variables included in Model 1 the Logit, Probit, and Cloglog regression estimate identical signs like OLS. There is only one exception as Cloglog estimates for **Percentage female members in municipal government** a negative parameter.

In terms of significance of parameters, the OLS regression predicts the parameters of **Percentage of urbanized population**, **Percentage of neighbouring municipalities with municipal wastewater treatment**, the **Dummy variable for a public municipal water utility**, and the **Dummy variables for Belonging to the States of Campeche, Coahuila, Chiapas, DF, Guerrero, Hidalgo, Jalisco, Mexico, Michoacán, Morelos, Oaxaca, Puebla, San Luis Potosi, Tlaxcala, Veracruz, Yucatan** as being significant at the 1% level. At the 5% level, **GDP per capita**, the **Index of Strategic Planning and Municipal Evaluation**, and the **Dummy variables for belonging to the States of Guanajuato** and **Tamaulipas** are significant while the **Gini coefficient after taxes and transfers** parameter is reported to be significant at the 10% level.

In comparison to the OLS regression, Logit and Probit report higher significance levels for **GDP per capita** (1% level), the **Dummy variables for belonging to the States of Guanajuato** and **Tamaulipas** (1% level), the **State of Chihuahua** (5% and 1% level), the **States of Sonora** and **Zacatecas** (5% level), and the **States of Queretaro** and **Quintana Roo** (10% level). On the other hand, significance of **Percentage of urbanization** is reduced to 5% in both models. Reported levels of the Cloglog regression fall in between the levels of Logit and Probit, and OLS. None of the regression models attributes any significance to the param-

eter estimates of the *Education Index, Fractionalization Index, Percentage of indigenous population, Percentage of female members in municipal government, and Index of basic municipal regulation implementation.*

By and large, the reduced Model 2 confirms the results of Model 1 (cf. columns 7 to 11 in Table 6). Signs of estimated parameters are identical except for the *Belonging to the states of Durango, Nayarit, and Tabasco.* For *Durango* and *Nayarit*, Logit, Probit and Cloglog report in Model 2 insignificant, positive parameters. For *Tabasco*, Logit predicts in conformity with OLS estimates of Model 1 and 2 a positive sign. In contrast to Model 1, all regressions predict a parameter of the *Gini coefficient after taxes and transfers* that is significant at the 1% level. Apart from that, reported significance levels of included variables match approximately the outcomes of Model 1.

To answer the question which of the econometric regression models may fit best the underlying data, a comparison of the respective log likelihoods may provide some hints. Applied to the same data, a model with higher log likelihood is considered to perform better (Cameron, Trivedi, 2009). As Table 6 illustrates, the Logit model possesses in Model 1 a log likelihood of **-830.16** whereas the log likelihood of Probit and Cloglog is **-827.55** and **-842.45** respectively. Accordingly, Probit is the better choice though the difference between the Logit and Probit regression is with **-2.61** negligible. The Cloglog regression seems to perform significantly worse though. On the other hand, the linear regression of Model 1 has no log likelihood value since it does not use ML as estimation method. The OLS regression is therefore not comparable. However, due to its acknowledged shortcomings in estimating binary outcomes<sup>112</sup> it is considered to be generally a less suitable model. As the most basic regression type it is nonetheless performed as it always provides a good starting point for an investigation with more sophisticated regression models. As a general rule, the results of more sophisticated models should not diverge too much from the estimated trend of the basic linear regression model (Gujarati, 1995; Cameron and Trivedi, 2009; Greene, 2012; Baum, 2013).

The ranking order identified in Model 1 also applies to Model 2 where Logit has a log likelihood of **-968.44**, Probit of **-965.4**, and Cloglog of **-981.28**. A comparison of Model 1 and 2 based on log likelihood values is, on the other hand, not possible as included independent variables

---

<sup>112</sup> It does not restrict fitted values to the interval [0; 1], and estimates only linear parameters (cf. also subchapter 5.3.).

differ. To compare models with different numbers of parameters<sup>113</sup> one may use the Akaike's information criterion (AIC). Generally, smaller AIC values are preferred as they correspond with higher log likelihoods (Cameron and Trivedi, 2009). In the Logit regression, the AIC is **1736.33** for Model 1 and **1736.70** for Model 2. The Probit regression has an AIC of **1731.10** in Model 1, and **1731.66** in Model 2. Hence, the AIC prefers slightly Model 1 over Model 2.<sup>114</sup>

In addition to the Standard Probit regression, columns 5 and 10 of Table 6 report the parameter estimations of the Heteroskedastic Probit regression for Model 1 and Model 2. The outcomes validate the assumption of the Standard Probit model of homoscedasticity in the error terms. Concretely, the Standard Probit and Heteroskedastic Probit regression are tested with the Likelihood-ratio test (LR) to figure out whether there is a statistically significant difference between a regression model that assumes heteroscedasticity and a model that assumes homoscedasticity in the error terms. In mathematical terms, the homoscedastic model is specified as:

$$(6.1) \quad \Pr(y_i = 1|x) = \Phi\left(\frac{x_i'\beta}{\sigma}\right),$$

whereby the variance is standardized, i.e.  $\sigma^2 = 1$ . On the other hand, the heteroskedastic model is specified as:

$$(6.2) \quad \Pr(y_i = 1|x) = \Phi\left(\frac{x_i'\beta}{\sigma_i}\right)$$

Since the error term is considered to be heteroskedastic, the variance is denoted as  $\sigma_i^2 = \exp(z_i'\delta)$  whereby  $z$  is an exogenous variable that is considered to cause variation in the error term. The LR test specifies then as null hypothesis  $\delta = 0$  and verifies whether it is rejected at low significance levels. If this is not the case, applying a regression model that accounts for

---

<sup>113</sup> At the same time, the compared models need to include the same number of observation (Cameron and Trivedi, 2009). To meet this requirement, 294 municipalities have been dropped from Model 2. After that, both models contain 1,996 Mexican municipalities.

<sup>114</sup> Though the difference does not seem to be significant as a complementary Loglikelihood-ratio test (LR-test) for the Logit regression corresponds asymptotically with the Wald test of Model 1 specification. The Wald test does not reject the null hypothesis of [Index of strategic planning and municipal evaluation = Index of basic municipal regulation implementation = 0] with  $p = 0.11$ . In addition, the LR-test does not reject the null hypothesis of Model 2 being nested in Model 1 with  $p = 0.11$  (see Table A.10 and A.11 in appendix for details). Hence, both tests report very similar p-values which is a hint that the difference between Model 1 and 2 is insignificant.

heteroscedasticity, like in columns 5 and 10 in Table 6, is not required for improving and rectifying yielded estimation results of the standard Probit model in columns 4 and 9 in Table 6<sup>115</sup>

As z I specify the **Surface in square kilometres of a municipality (surface)**. It does not show any significant correlation with the dependent binary variable (**WWT**) if included as independent variable into the Standard Probit regression of Model 1 and 2 (see Table A.21 and A.22 in appendix). Hence, it should qualify as a suitable exogenous variable.<sup>116</sup> The results of Heteroskedastic Probit does not indicate heteroscedasticity in the error terms for neither Model 1 nor Model 2. The null hypothesis,  $\delta = 0$ , is not rejected at the 5% level with  $p = 0.82$  in Model 1, and  $p = 0.92$  in Model 2 (cf. in Table 6 LR test of  $\text{Insigma2}=0$ : Prob > chi2, and Tables A.23 and A.24 in the appendix). Hence, there seems to be no need to discard the Standard Logit and Probit model and apply Heteroskedastic Probit instead. In addition, spatial autocorrelation does not seem to be an issue either, since observations enter the regression models in alphabetical order which does not show any spatial pattern in particular.

### 6.3. Interpretation: Marginal effects

Parameter estimates of Logit, Probit, and Cloglog are not suitable to quantify the correlation between dependent and independent variables (Cameron and Trivedi, 2005 and 2009). Being parameters of non-linear models, values vary across different levels of independent variables. In consequence, the estimation of marginal effects is required to get an idea how incremental changes in included independent variables correlate with the probability of municipal wastewater taking place.

Inter alia, the Stata software provides estimates of marginal effects at the mean of continuous independent variables. That means that Stata sets, first, all continuous independent variables at their respective sample means. Secondly, it estimates how the probability of municipal wastewater treatment taking place changes if, ceteris paribus, the independent variable devi-

---

<sup>115</sup> For a detailed discussion see Cameron and Trivedi (2005 and 2009).

<sup>116</sup> According to Cameron and Trivedi (2009), one should avoid to specify z as a variable that is already included in x, "because in a binomial model, a variable that affects  $\text{Pr}(y = 1)$  must necessarily affect the variance of y" (Cameron and Trivedi (2009). *Microeconometrics Using Stata*, p. 469). In this context, one needs to verify that the variable specified as z is not an omitted explanatory variable with explanation power as, in this case, the variance in the error term may result from the omitted explanatory variable instead from heteroscedasticity.

ates by unit from its sample mean. Table 7 details the sample means of the continuous explanatory variables included in Model 1. Furthermore, Stata estimates for the included dummy and discrete independent variables the effect of a discrete change of the base level, i.e. a change from zero to one, on the dependent variable.

**Table 7: Sample means of independent variables (model 1)**

variable name	variable label	Sample mean
gdpcap	GDP per capita in 2010 (in 1,000 PPP US \$)	8.6
gini	GINI coefficient in 2010	41.2
eduind	Education Index in 2010	78.4
urban	Percentage of urbanization in 2010 (>30,000 inhabitants)	8.8
fracind	Ethnic fractionalization Index in 2010	12.2
ethnic	Percentage of indigenous population in 2010	19.6
femadmin	Percentage female members in municipal government in 2005	16.2
neighmun	Percentage of neighbouring municipalities with WWT in 2010 (within 25km)	33.2
planind	Index of strategic planning and municipal evaluation in 2012	50.1
regind	Index of basic municipal regulation implementation in 2010	38.1

Source: Own calculations, using Stata 13.

Table 8 contains the estimated marginal effects for the means of the continuous independent variables. I.e. the parameter of an independent variable indicates by how much the probability of municipal wastewater treatment taking place changes if the respective independent variable deviates from its sample mean by one unit in an otherwise average Mexican municipality. Average Mexican municipality means that all other continuous independent variables remain at their respective sample means. In addition, Table 8 reports the estimated effect of a discrete change in the **Dummy variable for public municipal water utility** for the Logit, Probit, Heteroskedastic Probit, and Cloglog regressions of Model 1 and Model 2. I.e. it indicates the change in the probability of municipal wastewater treatment if a semi-independent public water utility is established in a Mexican municipality.<sup>117</sup>

---

<sup>117</sup> I refrain from the presentation of discrete changes in the Dummy variables for the belongingness of a municipality to a particular federal state in the main text for reasons of clarity and simplicity. Respective values can be found in Tables A.25 to A.30 in the appendix. The Logit model estimates, for instance, in Model 1 negative significant marginal effects of belonging to a particular state other than the 6 reference states that range between -24% (Queretaro) and -57% (Oaxaca).

**Table 8: Marginal effects of binary outcome models, selection**

Dependent Dummy Variable: y=1 --> Wastewater treatment takes place in a Mexican municipality y=0 --> no wastewater treatment								
	Logit	Probit	Heteroskedastic probit	Cloglog	Logit	Probit	Heteroskedastic probit	Cloglog
Independent variables	model 1	model 1	model 1	model 1	model 2	model 2	model 2	model 2
<b>GDP per capita in 2010 (gdpcap)</b>	.0185*** (2.79)	.0176*** (2.98)	.0175*** (2.93)	.0091** (2.28)	.0189*** (3.08)	.0177*** (3.18)	.0176*** (3.15)	.0092** (2.43)
<b>GINI coefficient in 2010 (gini)</b>	.0073* (1.95)	.0070* (1.94)	.0070* (1.95)	.0056* (1.95)	.0103*** (2.99)	.0099*** (2.96)	.0099*** (2.96)	.0079*** (3.02)
<b>Education Index in 2010 (eduind)</b>	.0022 (0.60)	.0026 (0.77)	.0025 (0.75)	.0041 (1.38)	.0029 (0.84)	.0033 (1.06)	.0033 (1.05)	.0051* (1.84)
<b>Percentage of urbanization in 2010 (urban)</b>	.0015** (2.13)	.0015** (2.26)	.0015** (2.26)	.0011** (2.39)	.0016** (2.49)	.0017*** (2.69)	.0017*** (2.69)	.0012*** (2.86)
<b>Ethnic fractionalization Index in 2010 (fracind)</b>	-.0000 (-0.01)	-.0001 (-0.10)	-.0001 (-0.09)	-.0001 (-0.09)	-.0002 (-0.21)	-.0003 (-0.33)	-.0003 (-0.33)	-.0002 (-0.17)
<b>Percentage of indigenous population in 2010 (ethnic)</b>	.0004 (0.53)	.0004 (0.64)	.0004 (0.62)	.0001 (0.08)	.0003 (0.44)	.0004 (0.61)	.0004 (0.60)	.0000 (0.02)
<b>Percentage female members in municipal government 2005 (femadmin)</b>	.0005 (0.46)	.0004 (0.39)	.0004 (0.38)	-.0003 (-0.40)	.0004 (0.40)	.0004 (0.35)	.0004 (0.35)	-.0003 (-0.40)
<b>Percentage of neighbouring municipalities with WWT in 2010 (neighmun)</b>	.0020*** (3.90)	.0020*** (3.97)	.0020*** (3.97)	.0013*** (3.57)	.0021*** (4.67)	.0021*** (4.77)	.0021*** (4.76)	.0015*** (4.49)
<b>Index of strategic planning and municipal evaluation in 2012 (planind)</b>	.0010*** (2.08)	.0010** (2.12)	.0010** (2.13)	.0007** (2.02)				
<b>Index of basic municipal regulation implementation in 2010 (regind)</b>	.0001 (0.18)	.0001 (0.30)	.0001 (0.31)	.0002 (0.65)				
<b>Dummy for public municipal water utility (waterutility)</b>	.1404*** (2.89)	.1320*** (2.91)	.1325*** (2.92)	.0813** (2.39)	.1233*** (2.83)	.1176*** (2.87)	.1179*** (2.87)	.0715** (2.34)

\* significant at 10%, \*\* significant at 5%, \*\*\* significant at 1%, Figures in () = Z-value.

Source: Own calculations, using Stata 13.

Generally, the Logit, Probit and Heteroskedastic Probit regressions provide rather similar estimates, both in terms of the magnitude of marginal effects<sup>118</sup> and significance levels. Like in the general models, **GDP per capita**, **Gini coefficient after taxes and transfers**, **Percentage of urbanized population**, **Percentage of neighbouring municipalities with treatment**, **Index of Strategic Planning and Municipal Evaluation**, **Dummy variable for public municipal water utility** are at least significant at the 10% level. Only respective values of the Cloglog regressions differ to some extent. However, this is somewhat expected as Cloglog assumes an underlying link function that is significantly different. According to log likelihood values the link functions of Logit and Probit fit the data better though. In consequence, they may produce more realistic estimates of marginal effects.

Logit predicts for Model 1 that the probability of municipal wastewater treatment augments by around **0.2%** if GDP per capita increases by an amount equivalent to PPP US\$ 100 in 2010 prices in an otherwise average municipality.<sup>119</sup> A unit increase of the **GINI coefficient after taxes and transfers**, on the other hand, correlates at its mean of 41.1 with an increase of **0.7%** in the probability treatment takes place. Marginal changes in **Percentage of urbanized population** and **Percentage of neighbouring municipalities with treatment** correlate with comparable changes in the treatment probability. If, for instance, the population composition of an averaged urbanized municipality experiences a marginal 5% increase in its urbanized population it becomes about **0.8%** more likely that it treats its wastewater.<sup>120</sup> A 5% increase in the **Share of neighbouring municipalities with municipal wastewater treatment** increases the fitted probability by **1%**.<sup>121</sup> In comparison, treatment probability improves only marginally, by about **0.01%**, if an average municipality ranks 1 or 2

---

The reported Logit values of marginal effects indicate changes in the probability not in odds ratio in Stata (cf. subchapter 5.3.1.1). Hence, results are directly comparable to Probit estimates.

<sup>119</sup> The marginal effect coefficient of **GDP per capita** is **0.019** in the Logit estimation of Model 1 (cf. column 2 of Table 8 of this thesis). Since GDP per capita enters the equation in thousand of PPP US\$ this means that the probability of municipal wastewater treatment increases by about **2%** if **GDP per capita** increases by PPP US\$ 1,000. Thus, a marginal change in **GDP per capita** of PPP US\$ 100 changes the treatment probability by **0.2%**.

<sup>120</sup> As seen in column 2 of Table 8, a **1%** increase in in the **Percentage of urbanized population** increases the treatment probability by about **0.15%**. Hence, an increase of **5%** in urbanization increases the treatment probability by about **0.8%**.

<sup>121</sup> As seen in column 2 of Table 8, a **1%** increase in in **Share of neighbouring municipalities with municipal wastewater treatment** increases the treatment probability by about **0.2%**. Hence, an increase of **5%** in urbanization increases the treatment probability by about **1%**.

points higher in the ***Index of Strategic Planning***. According to Logit, outsourcing the municipal water administration to a ***public municipal water utility*** coincides with a treatment probability increase of **14%**.<sup>122</sup>

Logit estimates of marginal effects in Model 2 reproduce the estimates of Model 1 approximately. Somewhat different changes are observed for the ***Gini coefficient after taxes and transfers*** and the ***Dummy variable for public municipal water utility***. A unit increase in the ***Gini coefficient*** triggers in Model 2 a **1%** increase in the treatment probability in an average municipality, whereas municipalities with water utilities treat municipal wastewater with a **12%** higher probability. Since Probit matches approximately Logit estimates of marginal effects for Model 1 and 2 I abstain from an explicit discussion of its values at this point (see for further details Table 8 and Tables A.25 to A.30 in the appendix).

#### **6.4. Goodness of fit and prediction quality**

After estimating the binary outcome models and interpreting the results, it is required to validate the goodness of fit of applied models. Several test techniques are available to scrutinize how well estimation outcomes fit the regressed data. In the following, the thesis is going to apply popular methods for binary outcome models. Starting with the standard procedure of reviewing Mc Fadden's and adjusted  $R^2$  values (subchapter 6.4.1), it executes in a second step the Hosmer-Lemeshow goodness of fit test and controls for the presence of interaction effects among independent variables (subchapter 6.4.2). Finally, it compares predicted and actual outcomes under the ROC-Curve concept (subchapter 6.4.3).

##### **6.4.1. Mc Fadden's and adjusted $R^2$**

As a standard goodness-of-fit measure, the adjusted R squared applies to linear regression models. Its formula calculates the proportion of the total variability in the dependent variable

---

<sup>122</sup> The marginal effect coefficient of the ***Dummy variable for public municipal water utility*** is **0.14** (cf. column 2 of Table 8 of this thesis).



explained by the variation in independent variables, adjusted by the number of included independent variables.<sup>123</sup> Its values are restricted to the interval [0; 1]. Higher values indicate then a better fit of the model. Overall, OLS regressions on Model 1 and Model 2 do reasonably well with reported values of **0.38** (see columns 2 and 7 of Table 6).

In contrast, non-linear models like Logit and Probit rely on the ML method to estimate parameters. Therefore, they do not minimize the portion of unexplained variance like OLS. For this reason, Stata reports the *McFadden's Pseudo - R<sup>2</sup>* as an alternative goodness-of-fit measure for non-linear models. It is defined as  $1 - L_N(\hat{\beta})/L_N(\bar{y})$ , whereby  $L_N(\hat{\beta})$  denotes the natural logarithm of the likelihood value of the fitted model, and  $L_N(\bar{y})$  the log likelihood of a model that includes only the intercept as explanatory variable.

*McFadden's Pseudo - R<sup>2</sup>* measures then whether the inclusion of additional independent variables improves the explanatory power of the fitted model in comparison with the model that includes only the intercept. Principally, its values can vary between one and zero with values closer to one indicating a better goodness of fit. According to McFadden, a Pseudo-R<sup>2</sup> value between 0.2 and 0.4 represent already a very good model fit (McFadden, 1974; Cameron and Trivedi, 2005). Accordingly, with a value of **0.35** in Model 1, and **0.34** in Model 2, Logit and Probit qualify reasonably well as fitted models (cf. columns 3 and 4, and columns 8 and 9 of Table 6 of this thesis).

#### 6.4.2. Hosmer-Lemeshow goodness of fit test

The Hosmer-Lemeshow (HL) test is a goodness of fit test of the model specification. It is widely used to verify how well the applied model fits the used data. Its basic idea is to compare the

---

<sup>123</sup> The formula is:  $R^2_{adjusted} = 1 - \frac{(1-R^2)(N-1)}{N-p-1}$  where  $N$  denotes the total sample size,  $p$  the number of included independent variables, and  $R^2$  the proportion of the explained variability. It explicitly accounts for the number of included independent variables as the *unadjusted R* might assess too optimistically the model fit. Including more and more independent variables may increase, by chance, the explained proportion of the dependent's variable variability though no true causal relation exists between the dependent and added independent variables.  $R^2_{adjusted}$  corrects for that. The formula of the unadjusted R square is  $R^2 = 1 - \frac{\sum_{i=1}^N (y_i - \hat{y}_i)^2}{\sum_{i=1}^N (y_i - \bar{y})^2}$  with  $y$  being the dependent variable,  $\hat{y}$  the predicted value, and  $\bar{y}$  the mean of  $y$ .

actual sample frequency with the frequency predicted by the applied model within subgroups of the overall sample (Cameron and Trivedi, 2009).

By default, the Stata command of the HL-test divides the entire sample size into 10 subgroups whereby the first group entails the 10% of the observations with the smallest predicted probabilities, i.e. in the thesis' context, the municipalities for which the applied model predict the 10% lowest probability that municipal wastewater treatment takes place. The second group is composed of the municipalities of the second lowest tenth in terms of predicted treatment probability, and so on. In a second step, the HL-test compares then the predicted and the actual probabilities within subgroups. In this way, it verifies whether the model outcomes departure significantly from actual outcomes which may indicate a suboptimal model specification. As null-hypothesis the HL-test assumes that the composition of the fitted and actual subgroups do not differ (Hosmer and Lemeshow, 1980; Cameron and Trivedi, 2009).

If the sample is divided into 10 subgroups the Hosmer-Lemeshow test produces p-values of **0.005** and **0.003** for the Logit regressions of Model 1 and Model 2 (cf. Tables A.31 and A.32 in the appendix). Thus, the null hypothesis is for both models rejected at the 1% level. This might indicate a potential model misspecification. The null hypothesis is also rejected for the Probit regression of Model 1 and Model 2 with similar low p-values (see for details Tables A.33 and A.34 in the appendix).

To remedy potential model misspecification, one might test for the presence of statistically significant interaction effects among independent variables and amplify the Logit and Probit regression models respectively (Cameron and Trivedi, 2009).

According to the Wald test,<sup>124</sup> the estimated parameters of 3 interaction variables are significant at the 5% level if included individually into the Logit and Probit regressions of Model 1 and Model 2:

Per capita GDP x<sup>125</sup> Fractionalization Index (***gdpcapfracind***),

Per capita GDP x Regulation index (***gdpcapregind***),

Percentage of female members in municipal government x Percentage of neighbouring municipalities with wastewater treatment (***femadminneighmun***).

---

<sup>124</sup> The results of the Wald test can be seen in Table A.35 in the appendix.

<sup>125</sup> "x" represents "times", i.e. per capita GDP "times" Fractionalization index

Another 4 interaction variables are significant at the 1% level:

Per capita GDP x per capita GDP (*gdpcap2*),

Per capita GDP x Percentage of indigenous population (*gdpcapethnic*),

Per capita GDP x Percentage female members in municipal government (*gdpcapfemad-*  
*min*),

Per capita GDP x Percentage of neighbouring municipalities with wastewater treatment  
(*gdpcapneighmun*)

Including all 7 interaction variables into extended versions of Model 1 and Model 2, renders the Hosmer-Lemeshow test with 10 subgroups insignificant. Table A.36 reports a p-value of **0.21** for the Logit regression of Model 1, and Table A.37 in the appendix a p-value of **0.15** for Model 2. With **0.37** and **0.47**, p-values of the respective Probit regressions are even higher.<sup>126</sup> The HL-test also does not reject the null hypothesis if the sample data of the extended model is alternatively grouped into 4 subgroups.<sup>127</sup>

Table A.41 and Table A.42 in the appendix contain the Logit estimations of the extended Model 1 and Model 2. As can be seen there, the **Percentage of female members in municipal government** turns interestingly significant at the 1% level if one controls for the interaction effect between **GDP per capita and Percentage of female members in municipal government**. Further, **Percentage of female members in municipal government** seems to have a stronger positive effect on the treatment probability than in the general model.<sup>128</sup> In accordance with economic argumentation, this means that more female participation in municipal politics has, ceteris paribus, a positive influence on municipal wastewater treatment performance.

Simultaneously, the interaction variable of **Per capita GDP and Percentage of female members in municipal government** has a negative parameter which is significant at the 1% level.<sup>129</sup> This means that the interaction between **Per capita GDP** and **Percentage of**

---

<sup>126</sup> See for details Tables A.38 and A.39 in the appendix.

<sup>127</sup> See for details Table A.40 in the appendix.

<sup>128</sup> For example, in the Logit regression of the general Model 1, the estimated parameter for **Percentage of female members in municipal government** is **0.0003** while in Logit regression of the extended Model 1 it is **0.028**.

<sup>129</sup> See for details of regression results for the logit and probit model 1 and model 2 Table A.41 to A.44 in the appendix.

**female members in municipal government** diminishes and counters the positive individual effects of **Per capita GDP** and **Percentage of female members in municipal government**. This outcome of the extended model versions is rather difficult to interpret in economic terms. From an economic perspective, one would expect, on the contrary, that the interaction between **Per capita GDP** and **Percentage of female members in municipal government** would reinforce the positive individual effects of the two variables. E.g. in municipalities with a richer population female politicians may be more effective in implementing a sound municipal water and sanitation policy as they may have there more resources at their disposal to build and operate respective wastewater treatment infrastructure.

As to the estimated parameters of other included interaction variables, none of them are significant at the 1% or 5% level. At the 10% level, the interaction effect between **GDP per capita** and **Percentage of indigenous population (gdpcapethnic)** is significant in the Logit and Probit estimations of Model 2.<sup>130</sup> It shows a positive sign. That may mean that a high GDP per capita may help a municipality which also has a high percentage of indigenous population to overcome more effectively issues in providing municipal wastewater treatment that may result from a high share of indigenous people. For instance, the Mexican national government provides funding programs of municipal wastewater treatment infrastructure that cater particularly municipalities with a high indigenous population share (Peña et al., 2013; CONAGUA, 2015a and 2015b). This funding mechanism may reinforce the positive effect of GDP per capita on the probability of municipal wastewater treatment in a Mexican municipality. Commonly, national programs require co-payment of the municipal level. Thus, a municipality with high GDP per capita may be more able to apply successfully to these national funding programs.

Apart from that, the estimated parameters of **GDP per capita**, **Percentage of urbanization**, **Percentage of neighbouring municipalities with municipal wastewater treatment**, the **Index of strategic planning and municipal evaluation**, and the **Dummy variables for public municipal water utility** and **State belonging of a municipality** have the same signs like in the general Model 1 and Model 2. Furthermore, all of them continue to be significant at least at the 10% significance levels, whereas parameters insignificant

---

<sup>130</sup> See for details of regression results for the logit and probit model 1 and model 2 Table A.41 to A.44 in the appendix.

in the general models remain so in the extended versions. This is an indication of respective parameter estimates being robust over different model specifications.

In contrast to the estimation results of general Model 1 and Model 2, Logit and Probit estimate for the extended versions a negative correlation coefficient for **Percentage of indigenous population (ethnic)** and the **Education Index (eduind)**. The negative sign of the parameter of **Percentage of indigenous population** is backed by theoretical considerations. The reported negative influence of education makes no sense from an economic perspective though. Anyhow, both estimated parameters are not significant. Interestingly, also the Logit and Probit parameter estimates of the **GINI coefficient after taxes and transfers** lose their significance in the extended Model 1. In the general Model 1, the **GINI coefficient after taxes and transfers** is significant at the 10% level.

#### 6.4.3. Predicted vs actual outcomes

Another measure of goodness of fit is the percentage of correctly classified observations by applied models. The predicted vs actual outcomes test assumes that the predicted outcome in a municipality is  $\hat{y} = 1$  if the applied model estimates  $F(x'\beta) > 0.5$ .  $\hat{y} = 1$  means that a municipality is predicted to treat municipal wastewater and  $F(x'\beta) > 0.5$  that the applied model predicts a probability of above 50% that municipal wastewater treatment takes place in a municipality. If, on the other hand, the model estimates that  $F(x'\beta) < 0.5$ .<sup>131</sup> it assumes that  $\hat{y} = 0$ . Consequently,  $\hat{y} = 0$  means that a municipality is predicted not to treat municipal wastewater and  $F(x'\beta) < 0.5$  that the applied model predicts a probability of below 50% that municipal wastewater treatment takes place in a municipality.

---

<sup>131</sup> If  $F(x'\beta) < 0.5$  the applied model predicts a probability of below 50% that municipal wastewater treatment takes place in a municipality.

**Table 9: Predicted vs. actual outcomes for logit model 1**

Classified	True		Total
	D	~D	
+	403	133	536
-	260	1200	1460
Total	663	1333	1996

Classified + if predicted  $\Pr(D) \geq .5$

True D defined as  $WWT \neq 0$

Sensitivity	$\Pr(+ D)$	60.78%
Specificity	$\Pr(- \sim D)$	90.02%
Positive predictive value	$\Pr(D +)$	75.19%
Negative predictive value	$\Pr(\sim D -)$	82.19%
False + rate for true ~D	$\Pr(+ \sim D)$	9.98%
False - rate for true D	$\Pr(- D)$	39.22%
False + rate for classified +	$\Pr(\sim D +)$	24.81%
False - rate for classified -	$\Pr(D -)$	17.81%
Correctly classified		80.31%

Source: Own calculations, using Stata 13.

Table 9 presents the result of the predicted vs actual outcomes test for the Logit regression of Model 1. The term "Classified + if predicted  $\Pr(D) \geq .5$  – True D defined as  $WWT \neq 0$ " in the middle of Table 9 indicates that municipalities are predicted as treating municipal wastewater if the treatment probability is predicted to be above 50%. In the upper part of Table 9, D is defined as municipalities that actually treat municipal wastewater and ~D as municipalities that actually do not treat municipal wastewater. In addition, + and – represent the municipalities the model classifies as treating or not treating municipal wastewater respectively.

As can be seen at the end of Table 9, overall **80.3%** of the 1,996 included Mexican municipalities are classified correctly. This value is considered to be rather good in terms of prediction quality (Metz, 1978; El Khouli et al., 2009; Kohler and Kreuter, 2012; Hosmer et al., 2013).<sup>132</sup> The upper part of Table 9 details furthermore that **403** and **1,200** municipalities are correctly predicted as jurisdictions with and without municipal wastewater treatment respectively. The **19.7%** misclassified municipalities are composed of **260** municipalities wrongly specified as

<sup>132</sup> To assess the prediction quality of a model one needs to compare the precision of its outcome with the outcome of random guessing. Since random guessing yields a 50% rate of correctly specified municipalities the Logit Model increases the prediction quality by 30.3% which is a reasonable improvement.

municipalities without treatment, and **133** municipalities wrongly specified as municipalities with wastewater treatment.

In the lower half of the Table 9, 'sensitivity' measures the percentage of correctly specified municipalities with  $y = 1$ , i.e. with actual wastewater treatment. It is the ratio of 403/663, i.e. the number of municipalities the model predicts correctly as municipalities with wastewater treatment is divided by the number of municipalities that actually treat wastewater. On the other hand, 'specificity' measures the percentage of correctly specified municipalities with  $y = 0$ , i.e. without actual treatment. It is the ratio 1200/1,333, i.e. the number of municipalities the model predicts correctly as municipalities without wastewater treatment is divided by the number of municipalities that actually do not treat wastewater.

With **90%** the 'specificity' of the model prediction is very good as only **10%** of municipalities without actual municipal wastewater treatment are misclassified. In contrast, the 'sensitivity' of the model is significantly lower as only **60.8%** of the municipalities with actual municipal wastewater treatment are correctly fitted. Thus, compared to random guessing the Logit model improves the predicting quality for  $y = 1$  only by **10.8%**.<sup>133</sup>

The classification of the predicted vs actual outcomes test is generally sensitive to the relative sizes of the two included groups. It favors to classify predicted cases as belonging to the larger group (Kohler and Kreuter, 2012; Hosmer et al., 2013). Therefore, one may expect, to some extent, that the specificity of the model is better than the sensitivity as the group of municipalities of non-treating municipalities is significantly larger than the group of treating municipalities.

An additional possible explanation why sensitivity and specificity figures diverge to such a great extent may be due to the heavy involvement of the federal and state governments in the construction and administration of municipal wastewater infrastructure in Mexico. As mentioned previously,<sup>134</sup> municipal administrations apply commonly for federal state and national funding and rarely pursue municipal wastewater treatment projects without the co-investment and co-management of superior tiers. In this context, a high specificity value suggests that the Logit model identifies based on socioeconomic, demographic, and institutional

---

<sup>133</sup> Again, random guessing would predict 50% of the municipalities with municipal wastewater treatment correctly.

<sup>134</sup> E.g. see subchapter 3.3.1.

characteristics very well municipalities that do not apply for federal and state funding. On the other hand, low sensitivity indicates that Logit is not so good in predicting the municipalities that are actually considered by federal and state funding programs. The Logit model is relatively bad in identifying the municipalities that actually treat municipal wastewater. Hence, it might also not a good predictor of municipalities that apply for federal or state funding as usually only municipalities treat wastewater that applied to funding before. Merely based on socioeconomic, demographic and institutional characteristics, Logit underestimates with **511** the total number of municipalities with municipal wastewater treatment which is **663** in the actual sample. Overall, it predicts **260** municipalities wrongly as municipalities without treatment, i.e. as municipalities not applying for federal and state funding, while they supposedly did.

From these observations two conclusions may follow. First, national and state funding programs may support, in addition to municipalities that apply for funding due to their socioeconomic, demographic and institutional characteristics, also municipalities that do not feature characteristics that make municipal wastewater treatment in a municipality per se more likely. This would explain why Logit underestimates the total number of treating municipalities by **127**. Secondly, it might be the case that due to limited resources of national and state programs not all of the applying municipalities are considered. In this case, municipalities may apply that feature respective socioeconomic, demographic, and institutional characteristics. However, the criteria by which the national and state programs select sponsored municipalities out of the application pool may differ from those characteristics. This possibly explains why Logit predicts **260** municipalities wrongly as municipalities without treatment and **133** with treatment. Unfortunately, these hypotheses cannot be tested empirically as no comprehensive information on approved applications and budget utilization is available for municipal water infrastructure funding programs. Alternatively, the focus of launched programs and stated selection criteria for applicants in different funding programs may serve as a hint. As described in subchapter 3.3.1, most CONAGUA programs require co-funding of the sponsored entity (Olivares and Sandoval, 2008; Peña et al., 2013; CONAGUA, 2015a and 2015b). Presumably, this particular requirement favors richer communities. However, in addition several pro-



grams with less strict financial obligations exist that cater exclusively the needs of marginalized and rural population. E.g. the program PROSSAPYS<sup>135</sup> does not require that investments of the national government need to be matched by entities at the municipal level (CONAGUA, 2015a and 2015b). Moreover, general CONAGUA programs like PROMAGUA, APAZU and PROTAR frequently state as one of the selection criteria of municipalities the priority support of marginalized areas (CONAGUA, 2015a and 2015b). In consequence, wastewater treatment patterns may become, to some extent, less related to the socioeconomic, demographic and institutional characteristics of municipalities included into the regression models of this thesis. According to the Predicted vs actual outcomes test, the selected characteristics provide nonetheless a reasonably good explanation why Mexican municipalities do not engage in municipal wastewater treatment. As general conclusion might follow that the selection criteria of national and state funding programs for benefiting municipal entities offset somewhat the “natural” divide among Mexican municipalities. Without the involvement of superior tiers the Logit would probably predict better municipalities with actual municipal wastewater treatment on the basis of municipal characteristics.

Furthermore, the Predicted vs actual outcomes test attests the Logit regression of the general Model 2 and the Probit regression of general Model 1 and Model 2 good prediction quality. All models specify more than **80%** of the Mexican municipalities correctly. Including interaction variables into the Logit regression of Model 1 does not change the overall prediction quality though.<sup>136</sup>

Usually, the ROC-curve concept<sup>137</sup> is applied to confirm the results of the Predicted vs actual outcomes test. Figure 13 specifies the area under the ROC-curve of the Logit regression of Model 1 as **0.87**. This is again a good value in terms of prediction quality according to literature (Metz, 1978; Cleves, 2002; El Khouli et al., 2009).<sup>138</sup>

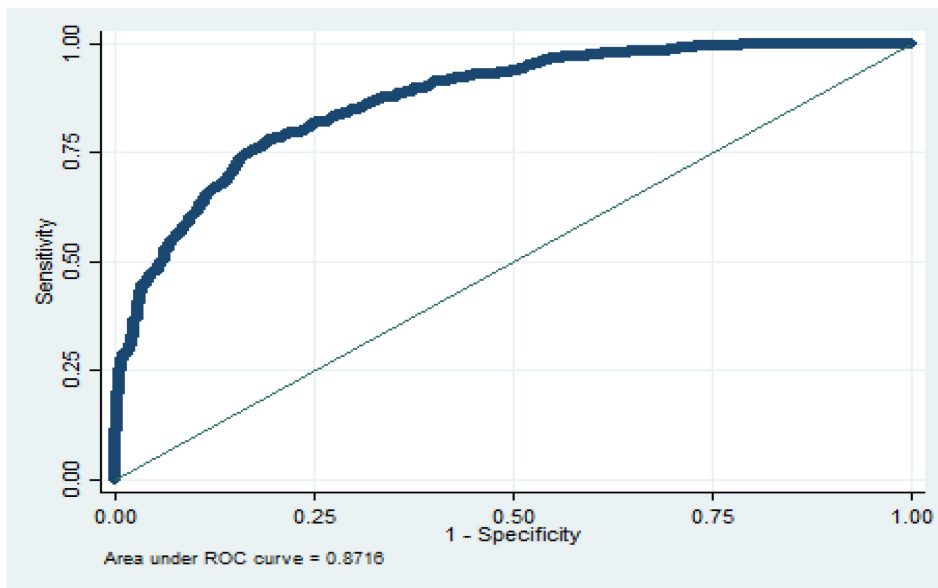
---

<sup>135</sup> PROSSAPYS stands for Program for the Construction and Rehabilitation of Municipal Water Supply and Sanitation Systems in Rural Areas.

<sup>136</sup>See for details Tables A.45 to A.48 in the appendix.

<sup>137</sup> ROC stands for Receiver operating characteristic.

<sup>138</sup>The general classification is as follows: ROC-scores between .90-1 = excellent (A), .80-.90 = good (B), .70-.80 = fair (C), .60-.70 = poor (D), .50-.60 = fail (F) (Cleves, 2002).



**Figure 13: ROC-curve of logit model 1**

Source: Own calculations, using Stata 13.

Generally, the ROC-curve relates to the specificity and sensitivity concept. In the diagram of Figure 13, it depicts  $1 - \text{Specificity}$  at the  $x$ -axis and  $\text{Sensitivity}$  at the  $y$ -axis. It then illustrates the cumulative sensitivity and specificity prediction quality for every cutting point of the probability function  $F(x'\beta)$  between the two extremes 0 and 1. For instance, in the previously applied predicted versus actual outcome tests the cutting point has been 0.5 since  $\hat{y} = 1$  if  $F(x'\beta) > 0.5$  and  $\hat{y} = 0$  otherwise. If the cutting point is 0 instead sensitivity is automatically 100% as all outcomes are predicted as 1 since  $\hat{y} = 1$  for all  $(x'\beta) > 0$ . The most upper right point of the ROC-curve in Figure 13 represent this case. If, on the other hand, the cutting point is 1 specificity is 100% since  $\hat{y} = 0$  for all  $F(x'\beta) < 1$ . This case is represented by the lowest left point of the ROC-curve. The points of the ROC curve in between the two extremes represent the outcomes for all possible cutting points. Generally, the tested model is the better the more the ROC-curve is biased towards the left upper corner. The best ROC-curve is the one for which the area under the curve is 1. In this case, the tested regression model predicts all outcomes correctly. By way of comparison, the 45-degree line in Figure 13 represents the sensitivity and specificity accuracy of random guessing. Consequently, a model with a ROC-curve close to that line is considered as being of poor predicting quality or as having none at all.

In comparison to the 45-degree line, the reported ROC-curve value of **0.87** for the Logit regression of Model 1 is reasonable good. The ROC-curve values of the Logit regression of Model 2 and of the Probit regressions of Model 1 and Model 2 are similar high.<sup>139</sup>

## 6.5. Model robustness

A concluding step of a regression analysis should validate the robustness of the estimation results of applied regression models to changes in the model composition. Accordingly, subchapter 6.5.1 investigates whether the inclusion of a **Dummy variable for net water availability** as additional independent variables changes parameter signs and significance levels significantly in a smaller sample size. In addition, Subchapter 6.5.2 modifies to some extent the definition of **urbanized population** and of **neighbouring municipalities** and examines how the inclusion of modified variables affects estimation results. For the same purpose, a further model run replaces the **Dummy variables for state belonging of a municipality** by **State categories** that group federal states according to their estimated shares of treated municipal wastewater. Finally, subchapter 6.5.3 controls for potential endogeneity issues between municipal wastewater treatment performance and **GDP per capita** and the **Education Index**. In addition it discusses the issue of multicollinearity and its possible effects on regression outcomes.

### 6.5.1. Inclusion of net water availability

As discussed in subchapter 4.2.9, the thesis follows the official CONAGUA classification of water scarcity and water abundance. Localities with a negative net availability of surface water suffer from water scarcity. Localities with a positive net water availability are water abundant. Accordingly, the **Dummy variable of net availability of surface water (watavail)** assumes the value of 0 if net water availability is negative and 1 if it positive.<sup>140</sup>

---

<sup>139</sup> See for details Figures A.7, A.8 and A.9 in the appendix.

<sup>140</sup> See for a detailed discussion subchapter 5.2.9.

Including the ***Dummy variable for net water availability*** as an additional variable into the Logit regression of Model 1 reduces the sample size significantly. As mentioned in subchapter 4.2.9, data on net water availability is only available for 1,446 municipalities. Furthermore, Logit predicts for municipalities belonging to the federal states of Chihuahua, Durango, Morelos, Quintana Roo, and Yucatan outcomes of the dependent variable perfectly. Respective ***Dummy variables for a municipality's state belonging*** have to be therefore omitted in addition to the general 6 reference states. Overall, the sample size is reduced to 1,201 observations.

In order to use the Logit regression which is extended by the ***Dummy variable for net water availability*** as a check of the robustness of the Logit regression of the general Model 1, I need to reduce the sample size of the general Model 1 to 1,201 observations. Only this way, I am able to compare the general model with the extended model. As Tables A.49 and A.50 in the appendix detail, the independent variables display the same coefficient signs in both models. Bigger differences exist in terms of the reported significance levels of ***GDP per capita***, the ***Education Index***, and the ***Percentage of urbanized population*** though. While the ***Education Index*** is now significant at the 10% level, the parameters of ***GDP per capita*** and ***Percentage of urbanized population*** lose their significance. However, this does not seem to be the particular effect of including the ***Dummy variable for net water availability*** into the Logit regression as the reported significance levels of these 3 variables are the same, if the ***Dummy variable for net water availability*** is not included (cf. Table A.50 in the appendix). Hence the changes in the significance levels are rather the result of the reduction in the sample size than of the inclusion of a new independent variable.

Generally, the reported correlation between ***GDP per capita***, the ***Education Index***, and the ***Percentage of urbanized population*** is high ( $>0.65$ ). Thus, multicollinearity among those variables likely explains the observed changes in the significance levels.

To cope with the phenomenon of multicollinearity, I remove ***Percentage of urbanized population (urban)*** from the regressions with the reduced sample size. If ***Percentage of urbanized population*** is omitted the parameter of ***GDP per capita*** is significant at the 5% level – irrespective of whether the ***Dummy variable for net water availability*** is included or not (compare Table A.49 and A.50 in the appendix)

In addition, the estimated parameter of the ***Dummy variable for net water availability*** is, as expected, negative (cf. Table A.51 in the appendix). Generally, a negative sign means that a municipality is less likely to engage in municipal wastewater treatment if water is abundant in a municipality. However, the parameter is far from being significant ( $p = 0.38$ ).

A possible explanation for the low significance of the dummy variable may be that the included dummy variable is only a rough indicator for the actual degree of water scarcity in a municipality. Municipalities may rely on additional water resources the dummy variable does not account for – e.g. groundwater. In addition, since the original data was published on hydrological watersheds and has been only adjusted to municipalities it may not provide a precise description of the actual prevalence of water scarcity in a municipality. However, no better indicator of net water availability has been available to this thesis. Having said that, low significance could also result from that municipalities actually face water scarcity but yet do not have the incentive to treat municipal wastewater. Though water is scarce, externalizing the damage of untreated municipal wastewater to neighbouring entities might, for instance, still be more efficient from their perspective than treating it instead.

### **6.5.2. Modification of independent variables**

An additional mechanism to assess the robustness of the findings of the general Model 1 and Model 2 is to vary the definition of included independent variables in order to investigate how the estimation results of the general models change. I introduce variations in three different ways: 1.) by a change in the definition of nearby municipalities 2.) by a change in the definition of urbanized population, and 3.) by a different classification of federal states in terms of municipal wastewater treatment performance. According to whether the alternative definition of the independent variable is broader or stricter the estimated effect on the dependent variable needs to soften or strengthen in order to confirm the underlying theoretical narrative of cause and effect. At the same time, the inclusion of modified variables should not alter significantly the parameter estimates of other variables.

### 6.5.2.1. Municipal wastewater treatment in nearby municipalities

Instead of defining municipalities located within 25 km of the geographical centre of a municipality as neighbouring entities the radius within which localities are considered as neighbouring is extended to 50, 100, and 1,000 km respectively. Based on these alternative definitions of contiguity, the **Percentage of neighbouring municipalities with municipal wastewater treatment** is calculated and then included as **neighmun50**, **neighmun100**, and **neighmun1000** into separate runs of Logit Model 1. Presumably, spillover effects decrease with increasing distance in-between municipalities. Thus, one should see a decrease in magnitude and significance of the estimated parameters if larger radii are applied. At the same time, changing the definition of nearby municipalities and including alternative **Percentage of neighbouring municipalities with municipal wastewater treatment** should not alter significantly the estimation results of other included variables if outcomes of the general Model 1 are robust.

**Table 10: Parameters of neighmun with radii of 25, 50, 100 and 1,000 km (logit model 1)**

variable name	variable label	Estimated parameter
neighmun	Percentage of neighbouring municipalities with municipal wastewater treatment within a radius of 25km	0.01*** (3.93)
neighmun50	Percentage of neighbouring municipalities with municipal wastewater treatment within a radius of 50km	0.013*** (3.87)
neighmun100	Percentage of neighbouring municipalities with municipal wastewater treatment within a radius of 100km	0.007 (1.28)
neighmun1000	Percentage of neighbouring municipalities with municipal wastewater treatment within a radius of 1,000km	-0.009 (-0.29)

Source: Own calculations, using STATA 13.

Table 10 details the estimation results of the parameters of the independent variables **neighmun50**, **neighmun100**, and **neighmun1000** if they are included as alternatives into the Logit regression of Model 1.<sup>141</sup> As can be seen there, the parameters of **neighmun100** and **neighmun1000** steadily decrease compared to **neighmun25**. Magnitudes drop from **0.01 (neighmun25)** to **0.007 (neighmun100)** to **-0.009 (neighmun1000)**. Simultaneously, significance levels deteriorate as p-values steadily increase from **0.000 (neighmun25)**

<sup>141</sup> Tables A.52 to A.54 in the appendix contain all estimation results of the alternative Logit regressions of Model 1.

to **0.199** (*neighmun100*) and to **0.774** (*neighmun1000*). As expected by theory, it becomes more erroneous to reject the null-hypothesis of  $\beta_{\text{neighmun}} = 0$  if the radius is enlarged to 100km and then to 1,000km. In some contrast, Logit yields a parameter estimate for *neighmun50* that is greater in magnitude than the parameter for *neighmun25* (**0.013** versus **0.01**). Like *neighmun25*, it is significant at the 1% level (cf. Table 10 of this thesis).

A possible explanation for this somewhat unexpected result may be that in Mexico, as a rather large country by extension with a relatively low population density, members of municipal administrations and the general public in a municipality may inform themselves not only about activities in very nearby municipalities (=within a distance of 25km) but also in municipalities that are relatively close (=within 50km). For instance, municipalities within this distance might be still located in the same hydrological watershed or administrative district. In consequence, their municipal governments may access the same local elite circles and have well established communication channels among each other.<sup>142</sup>

In terms of overall model robustness, the inclusion of **Percentage of neighbouring municipalities with municipal wastewater treatment** with modified radii does not alter significantly estimated magnitudes and significance levels of other included independent variable. Thus, estimation results seem to be rather robust against performed changes. In addition, Logit regressions of Model 2 with *neighmun50*, *neighmun100*, and *neighmun1000* confirm generally the previous findings.

### **6.5.2.2. Percentage of urbanized population**

Instead of defining urbanized population as the share of people that reside in localities with 30,000 and more inhabitants, one may alternatively consider only the population as urban that lives in settlements of at least 50,000 inhabitants. Based on theoretical considerations,

---

<sup>142</sup> See also subchapter 4.2.4. for a more detailed discussion of how political ideas and practices spread geographically.

A further caveat against the validity of the general Model 1 findings is that if the radii within which municipalities are considered as neighboring are alternatively extended to 250 km or 500 km, magnitudes of estimated parameters decrease to **-0.024** and **0.056**. Respective p-values are **0.04** and **0.01**. Thus, both parameter estimates are significant at the 5% level. However, to find a theoretical explanation why municipal wastewater treatment in a municipality should relate negatively with treatment activities in municipalities within a distance of 250 or 500 km is rather challenging. Maybe the significant negative parameter estimates need to be considered as mere coincidence (see for further details Tables A.55 and A.56 in the appendix).

higher degrees of population concentration impact municipal wastewater treatment performance positively. Hence, the estimated parameter of the **Percentage of the population urbanized in localities of at least 50,000 inhabitants (urbanII)** should be more significant and exhibit a greater magnitude than **Percentage of the population urbanized in localities of at least 30,000 inhabitants (urban)**.

**Table 11: Parameters of urban and urbanII for logit model 1 and 2**

model	variable name	variable label	Estimated parameter
model 1	urban	Percentage of the population urbanized in localities of at least 30,000 inhabitants	0.007** (2.15)
model 1	urbanII	Percentage of the population urbanized in localities of at least 50,000 inhabitants	0.01*** (2.79)
model 2	urban	Percentage of the population urbanized in localities of at least 30,000 inhabitants	0.008** (2.51)
model 2	urbanII	Percentage of the population urbanized in localities of at least 50,000 inhabitants	0.01*** (2.97)

Source: Own calculations, using STATA 13.

Table 11 details the estimation results of the parameters of the independent variables **urban** and **urbanII** if they are included as alternatives into the Logit regression of Model 1 and Model 2.<sup>143</sup> As can be seen there, respective estimation results are affirmative. With **0.010** in Model 1 and Model 2, the correlation coefficients of **urbanII** are higher than the coefficients of **urban** which are **0.007** and **0.008** respectively. Moreover, reported p-values of **0.005** (Model 1) and **0.003** (Model 2) are significantly lower than the p-values of urban of **0.032** (Model 1) and **0.012** (Model 2).

Moreover, the modification of the Percentage of urbanized population does also not change significantly parameter estimates and significance levels of other included independent variable. Like previous model runs with alternative independent variables the **urbanII** model confirms the robustness of the main model findings.

<sup>143</sup> Tables A.57 and A.58 in the appendix contain all estimation results of the alternative Logit regressions of Model 1 and Model 2.



### 6.5.2.3. Classification of federal states

Instead of including dummy variables for the belonging of a municipality to a particular state into the regression models, another possibility is to classify the 31 Mexican federal states and the Federal District of Mexico-City in different categories according to their estimated share of treated municipal wastewater volumes. Dummy variables for the belonging of a municipality to one of those state categories are then alternatively included into the regression.

The advantage of this approach is that it reduces the number of included independent variables into the regression. In addition, the percentage of estimated treated volumes at the state level might be a valuable alternative indicator of municipal wastewater treatment performance of a state. In contrast, the general Model 1 and 2 measure the treatment performance of a state as the share of municipalities with municipal wastewater treatment in the overall number of municipalities of a state. Accordingly, the states of Aguascalientes, Baja California, Baja California Sur, Colima, Nuevo León, and Sinaloa qualify as best performing states because all municipalities belonging to those states engage, to some extent, in wastewater treatment. Actual shares of treated volumes are neglected though.

Including state categories that consider estimated treatment shares instead allows to investigate whether the belonging of a municipality to a particular state remains robust if states are classified by an alternative indicator of municipal wastewater treatment performance. Based on CONAGUA information (2012a), I create 5 categories and classify states according to their estimated treatment rate in 2010. In this context, state category 1 contains the municipalities of states with estimated treatment rates between 80% and 100% (**StateCategory1**), category 2 municipalities of states with rates between 60% and 80% (**StateCategory2**), category 3 municipalities of states with rates between 40% and 60% (**StateCategory3**), category 4 municipalities of states with rates between 20% and 40% (**StateCategory4**), and category 5 municipalities of states with rates between 0% and 20% (**StateCategory5**).<sup>144</sup> To

---

<sup>144</sup> StateCategory1 includes Aguascalientes, Nuevo León, Baja California, Nayarit, Tlaxcala; StateCategory2 Chihuahua, Sinaloa, Guerrero, Durango, Baja California Sur, Quintana Roo; StateCategory3 San Luis Potosí, Guanajuato, Colima, Tlaxcala, Puebla, Coahuila, Jalisco, Querétaro, Veracruz; StateCategory4 Oaxaca, Sonora, Michuacan, México, Morelos, Zacatecas, Chiapas, Tlaxcala; and StateCategory5 DF, Hidalgo, Campeche, Yucatan. Note that there is some variance in the definition of best performing federal states since the composition of StateCategory1 differs to some extent from the reference case of the general model (which includes the states of Aguascalientes, Baja California, Baja California Sur, Colima, Nuevo León, and Sinaloa).

validate the robustness of Model 1 and 2 results the regression model with state categories should yield similar results.

Tables A.59 and A.60 contain the Logit estimates of the altered Model 1 and 2. **StateCategory1** is removed from the regression as reference case. Thus, the correlation coefficients of included state categories indicate how the belonging of a municipality to a state category that comprises states with estimated treatment rates of below 80% affects the probability wastewater treatment takes place in a municipality. Overall, parameter signs and significance levels correspond reasonable well with the estimates of the general model. The probability that municipal wastewater treatment takes place depends again significantly from its belonging to a particular state. Parameters of all state categories are highly significant and display the expected negative signs. In addition, the negative impact on treatment probability increases if municipalities belong to states with lower overall treatment rates. For instance, the negative parameter of the **StateCategory4** is more than double than the parameter of **StateCategory2** (**-4.022** versus **-1.948**). On the other hand, the inclusion of state categories does not affect significantly the parameter estimates of other independent variables.<sup>145</sup>

### 6.5.3. Endogeneity

As mentioned in subchapter 4.2.1 and 4.2.6, there might be a potential endogeneity issue since municipal wastewater treatment may reversely affect **GDP per capita** and the **Education Index** positively. To account for this, 2010 data is replaced by **GDP per capita (gdp-cap2005)** and **Education Index (eduind2005)** data of the year 2005.

Table 12 details the estimation results of the parameters of the independent variables **GDP per capita** and **Education Index** of the years 2005 and 2010 if they are included alternatively into the Logit regression of Model 1 and Model 2.<sup>146</sup> With **0.006**, the regression estimate of the **2005 GDP per capita** parameter in Model 1 is about one third smaller than the estimate of the **2010 GDP per capita** parameter (**0.09**). In addition, with a p-value of **0.14** it is not significant. In comparison, the 2010 coefficient is significant at the 5% level. At the same

---

<sup>145</sup> See for details Tables A.59 and A.60 in the appendix.

<sup>146</sup> Tables A.61 and A.62 in the appendix contain all estimation results of the alternative Logit regressions of Model 1 and Model 2 with lagged **GDP per capita** and **Education Index**.

time, Logit estimates a magnitude of the **2005 Education Index** parameter about double the size of the **2010 Education Index** parameters (**0.02** versus **0.01**). With **0.10**, it exhibits also a p-value which is much lower than the p-value of the 2010 coefficient (**0.54**).

**Table 12: gdpicap and eduind parameters of 2005 and 2010 (logit model 1 and 2)**

model	variable name	variable label	Estimated parameter
Model 1	gdpcap2005	GDP per capita for the year 2005	0.06 (1.48)
Model 1	eduind2005	Education Index for the year 2005	0.02* (1.65)
Model 1	gdpcap	GDP per capita for the year 2010	0.09*** (2.80)
Model 1	eduind	Education Index for the year 2010	0.01 (0.60)
Model 2	gdpcap2005	GDP per capita for the year 2005	0.08** (2.38)
Model 2	eduind2005	Education Index for the year 2005	0.02 (1.63)
Model 2	gdpcap	GDP per capita for the year 2010	0.09*** (3.08)
Model 2	eduind	Education Index for the year 2010	0.01 (0.84)

Source: Own calculations, using STATA 13.

To infer from that findings in Model 1 a general reduced causal effect of GDP per capita on municipal wastewater treatment might be too hastily though. First of all, an additional Logit regression of Model 2 produces an estimate of the **2005 per capita GDP** parameter whose magnitude is only about 10% below the size of the 2010 coefficient (**0.08** versus **0.09**). Furthermore, it remains significant at the 5% level. In addition, it estimates a **2005 Education Index** parameter that has again twice the magnitude of the **2010 Education Index** parameters (**0.02** versus **0.01**). However, this time it is not significant at the 10% level. One may therefore interpret the insignificant and smaller **GDP per capita** parameter in Logit Model 1 as a result of the relatively high correlation between **per capita GDP** and **Education Index**.<sup>147</sup> The presence of multicollinearity may prevent the consistent and unbiased estimation of respective parameters as the regression model cannot decide to attribute to which of the two independent variables the effects on the dependent variable. As the sample size of Model 1 is significantly smaller than the sample size of Model 2 (1,996 versus 2,290 observations) the issue of multicollinearity may be more pronounced in Model 1. An indication for the presence of multicollinearity is also that the estimated **2005 per capita GDP** comes again close to the

<sup>147</sup>The correlation between **per capita GDP** and **Education Index** is **0.63** in the 2005 and **0.69** in the 2010 data.

estimated parameter of **2010 per capita GDP (0.08** versus **0.09**) once the **2005 Education Index** is omitted in the Logit regression of Model 1. Moreover, it is again significant at the 5% level.<sup>148</sup>

Furthermore, the Wald test of Exogeneity does not reject for the Probit regression of the general Model 1 the null hypothesis that **2010 per capita GDP** is exogenous. In consequence, reverse causality of municipal wastewater treatment and per capita GDP becomes less likely. Generally, the Wald test of Exogeneity tests whether an included independent variable may be endogenous. It does this by substituting the independent variable which is in question of being endogenous by a so called instrument variable. This instrument variable should display, on the one hand, a high correlation with the independent variable in question. On the other hand, there should not exist any obvious causal link between the instrument variable and the dependent variable of the model. The Wald test then validates whether the estimation results of the model with the instrument variable differs significantly from the outcomes of the model that includes the independent variable that is potentially endogenous. If the null hypothesis that both models do not differ can't be rejected endogeneity is excluded (Cameron and Trivedi, 2009).

As instrument variable (IV) I specify **Registered cars per 1,000 inhabitants in a municipality in 2010 (regcar)** and include it in the endogenous Probit model. Regcar apparently qualifies as a fitting IV due to its high correlation with **2010 GDP per capita (0.76)**. Unsurprisingly, richer people tend to possess on average more cars. At the same time, there is no obvious reason to assume the existence of a causal link between the number of registered cars and municipal wastewater treatment performance in a municipality. Overall, the endogenous Probit model includes 1,905 municipalities. Table A.64 in the appendix contains respective estimation results. As can be seen there, the endogenous Probit model predicts a positive **2010 GDP per capita** parameter which is significant at the 10% level. At the same time, it does not reject the null hypothesis of exogeneity for **2010 GDP per capita** with a very high p-value of **0.84** (cf. last row of Table A.64).

---

<sup>148</sup> See for details Table A.63 in the appendix.

In conclusion, there seems to be no need to invalidate the general finding of a strong impact of per capita GDP on municipal wastewater treatment due to reversed causation. Complementary, one may interpret the greater magnitude and higher significance levels of the **2005 Education index** in the Logit regressions of Model 1 and Model 2 as a vague sign of the existence of a lagged impact of the education level on municipal wastewater treatment performance. It may simply take some time until better educated people prompt local politics to improve wastewater treatment. A narrative for this empirical observation that also fits the reduced magnitude and significance level of the **GDP per capita** parameter in Logit Model 1 might be that more educated people demand municipal wastewater treatment from local politics once their higher education pays off in terms of higher incomes. However, caution is needed with this interpretation. The increased size and significance of the **2005 Education Index** may rather be the result of multicollinearity between **GDP per capita** and **Education Index** triggering more arbitrary Logit estimates of affected parameters.

## 6.6. Summary of chapter 6

Chapter 6 has scrutinized empirically the influence of social characteristics of Mexican municipalities on the probability municipal wastewater treatment takes place in a municipality. The binary outcome models and the linear probability model found empirical evidence for a significant positive impact of the indicators for

per capita income

unequal income distribution

soundness and well-functioning of municipal institutions

urbanization and

spillovers from neighbouring municipalities.

In addition, the effects of environmental federalism are significant as the belonging of a municipality to a particular federal state highly matters for the treatment of municipal wastewater. In contrast, no empirical support is lent to a significant influence of the

level of education

ethnic heterogeneity

female participation in municipal politics and water availability.

The results for GDP per capita, the soundness and well-functioning of municipal institutions, urbanization and geographical spillovers correspond with the expectations of the hypotheses. With regard to the soundness and well-functioning of municipal institutions, two of the three included indicators display the expected positive parameter signs: The dummy variable for the existence of a public municipal water utility and the Index of Strategic Planning and Municipal Evaluation. The parameter estimate of the Index of Basic Municipal Regulation Implementation is not significant though. That may be explained by the fact that it may not be a perfect measure of institutional quality.<sup>149</sup>

The insignificant parameters of education, ethnic heterogeneity, female participation in municipal politics and water availability contradict the expectations of the hypotheses. A possible reason for the insignificance of education and ethnic heterogeneity is their high correlation with GDP per capita in the sample. Their influence on municipal wastewater treatment might be indirect as a less educated and indigenous population is on average poorer in Mexico (Santibañez, 2016; Hernandez-Trillo, 2016). Another explanation for the insignificance of education could be its low standard deviation in the sample. Interestingly, female participation in local politics is also interrelated with per capita income according to the model results. Once an interaction term for GDP per capita and female participation is included into the Logit regression the positive parameter estimate of female participation in local politics turns significant. Finally, unequal income distribution is reported to have a significant positive net effect on the treatment probability.

Overall, the goodness of fit of the models is reasonable as the variance of socioeconomic, demographic, and institutional characteristics explain a good deal of the observed variation in municipal wastewater treatment performance. The prediction quality of the models is also

---

<sup>149</sup> The Index of Basic Municipal Regulation Implementation simply measures whether a Mexican municipality has incorporated regulations the Mexican Constitution stipulates to implement into the set of municipal regulations. Therefore, it might not inform too much about the actual quality of the municipal administration as good institutional quality requires not only the forced adoption of regulations but also the implementation of concrete politics and the establishment of a sound operative institutional infrastructure. The adoption of the regulations may be only a necessary but not sufficient base for this.

good. In addition, estimation results seem to be robust as the alteration of included independent variables does not produce contradicting outcomes. Finally, the existence of endogeneity between GDP per capita and municipal wastewater treatment performance is not confirmed.

## **7. Case 2: Tobit and Fractional logit and the percentage of treated wastewater**

In addition to the estimation of the probability that municipal wastewater treatment takes place in chapter 6, chapter 7 performs a Tobit and Fractional Logit regression on a smaller sample of 425 Mexican municipalities in order to explain the 'estimated percentage of treated municipal wastewater' conditional on a set of independent variables.

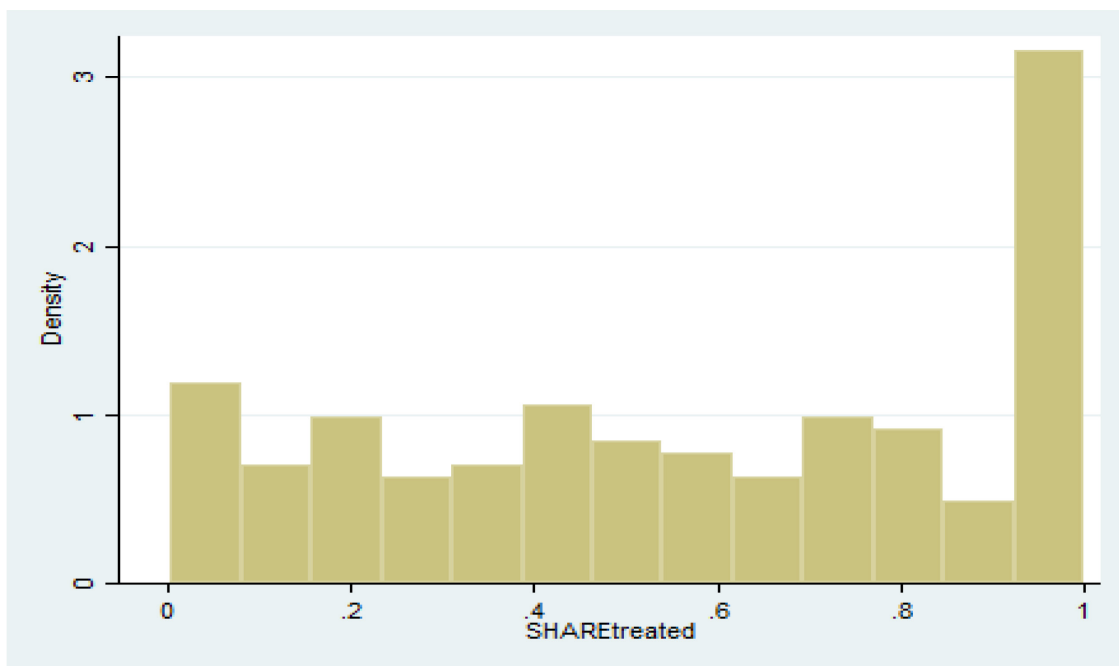
The aim of regressing the additional models is to scrutinize the findings of the binary outcome models in chapter 6 for a different measure of municipal treatment performance. The regression findings in chapter 7 should confirm approximately previous estimation results to corroborate the robustness of the observed correlation pattern of municipal wastewater treatment performance and socioeconomic, demographic and institutional characteristics.

The structure of chapter 7 is as follows: subchapter 7.1 gives a statistical description of the underlying data. Subchapter 7.2 estimates and interprets the results of the Tobit model. Following, subchapters 7.3 investigates the goodness of fit and prediction quality of the Tobit model. Subchapter 7.4 estimates the Tobit model for lognormal data. Finally, subchapter 7.5 presents the Fractional Logit model and its estimation results as an alternative to the Tobit model. Subchapter 7.6 summarizes the results and conclusions of chapter 7.

### **7.1. Descriptive statistics**

Of the 425 included municipalities 239 or 56.3% are reported to treat zero percent of municipal wastewater by 2010 (CONAGUA, 2012a, IMTA, 2014b). The remaining 186 municipalities treated shares varying from 1% to 100%. With 43.7% treating municipalities the sample reproduces only approximately the distribution of treating and not treating municipalities in Mexico. In reality, 65.5% of Mexican municipalities did not treat municipal wastewater in 2010 (CONAGUA, 2012a). Figure 14 depicts the distribution of positive treated shares of municipal wastewater. 34 of the treating 186 municipalities purified 100% of wastewater in 2010 while the remaining municipalities spread almost evenly over the rest of the positive spectrum.





**Figure 14: Distribution of share of treated wastewater (186 municipalities), 2010**

Source: Own calculations, using Stata 13.

Principally, the same socioeconomic, demographic and institutional characteristics are of interest like in the binary outcome models of chapter 6. However, the relatively small sample size of 425 observations requires to reduce the number of independent variables. Instead of including **Dummy variables for the belonging of a municipality to a particular state** the 5 **State categories** introduced in chapter 6.5.2.3 are used. In addition, the **Education Index, Percentage of urbanized population**, and **Percentage of indigenous population** are omitted.

**Table 13: Correlation of omitted variables with gdpicap and fracind**

	gdpicap	eduind	urban	fracind	ethnic
gdpicap	1.0000				
eduind	0.6681	1.0000			
urban	0.6758	0.4933	1.0000		
fracind	-0.2889	-0.4325	-0.1583	1.0000	
ethnic	-0.3093	-0.4981	-0.1759	0.8587	1.0000

Source: Own calculations, using Stata 13.

As Table 13 details, the **Education Index** and **Percentage of urbanized population** exhibit high correlations with **GDP per capita (0.67 and 0.68)** and the **Percentage of indigenous population** with the **Fractionalization Index (0.86)**. Due to lack of data, the **Index of strategic planning and municipal evaluation** and the **Index of basic municipal regulation** are not incorporated into the Tobit and the Fractional Logit regression. Their inclusion would substantially reduce the sample size.

**Table 14: Summary statistics tobit model**

Variable	Obs	Mean	Std. Dev.	Min	Max
Share_WWT	511	.27	.36	0	1
gdpcap	509	7.8	3.3	2.7	26
gini	511	43	3.9	33	55
fracind	511	9.2	15	.12	50
femadmin	509	21	14	0	80
neighmun	426	43	36	0	100
waterutility	509	.5	.5	0	1
StateCat1	511	.13	.33	0	1
StateCat2	511	.18	.38	0	1
StateCat3	511	.19	.39	0	1
StateCat4	511	.32	.47	0	1
StateCat5	511	.18	.38	0	1

Source: Own calculations, using Stata 13.

Note: gdpcap in thousands of PPP US\$, and gini, fracind, femadmin neighmun in %.

Table 14 summarizes the dependent variable **Share of treated municipal wastewater (Share\_WWT)** and the included independent variables. **gdpcap** represents **GDP per capita** in thousand PPP US \$ in 2010 prices, **gini** the **GINI coefficient after taxes and transfers** in 2010, **fracind** the **Fractionalization Index** of 2010, **femadmin** the **Percentage of female members in municipal government** in 2005, **neighmun** the **Percentage of neighbouring municipalities with wastewater treatment** (within a distance of 25km), **waterutil** the **dummy variable for the existence of a municipal public water utility**,

and **StateCat1** to **StateCat5** the **Dummy variables for the belonging of a municipality to a federal state** that falls in one of the five wastewater treatment categories.<sup>150</sup>

Mainly due to **neighmun** the sample size reduces to 425 observations. While data on all other variables is available for 509 to 511 municipalities, the **Percentage of neighbouring municipalities with wastewater treatment** is only available for 426 municipalities. Like in the data of the binary outcome models, the observations of the **GINI coefficient after taxes and transfers** do not exhibit a good deal of variance. In contrast, the standard deviation of other variables is reasonable though. With a per capita GDP equivalent to about 26,000 PPP US\$ the municipality of Playa del Carmen in the federal state of Quintana Roo constitutes an outlier. The GDP per capita of other municipalities vary with values between PPP US\$ 2,700 and 18,000 much less around the sample mean of about PPP US\$ 7,800. With a mean share of treated municipal wastewater of around 27% the sample has a lower average treatment rate than the national average which was about 39% in 2010.<sup>151</sup>

## 7.2. Tobit model estimation and interpretation

A next step applies the Tobit regression on the data sample. Table 15 contains respective results if the lower boundary is specified as 0. Basically, the signs of estimated parameters correspond with the outcomes of the binary outcomes models. **GDP per capita**, the **GINI coefficient after taxes and transfers**, the **Percentage of neighbouring municipalities with municipal wastewater treatment**, and the **Dummy variable for a municipal public water utility** correlate positively with the **estimated share of treated municipal wastewater**. In addition, the parameter of the **Fractionalization Index** is, as expected, negative. In contrast to the outcomes of the binary outcome models, the parameter of **Percentage of female members in municipal government** exhibits a negative sign though. However, with a p-value of **(0.29)** it is far from being significant.

---

<sup>150</sup> Concretely, **StateCat1** includes federal states with estimated treatment shares between 80% and 100%, **StateCat2** states with rates of 60% to 80%, and so on (see for a detailed discussion subchapter 6.5.2.3).

<sup>151</sup> If only the mean rate of the 425 municipalities that are included in the regression model are considered the sample average reduces further to ca. 25%.

Moreover, the Tobit model attributes significance levels to **GDP per capita** ( $p = 0.035$ ), **Percentage of neighbouring municipalities with wastewater treatment** ( $p = 0.003$ ), the **Dummy variable for a municipal public water utility** ( $p = 0.001$ ), and the **Belonging of a municipality to a particular state category**  $p$ -value between **0.078** and **0.000** that are rather similar to levels reported in Logit and Probit. In addition, it also does not diagnose a significant impact of the **Fractionalization Index**. Contrasting to the binary outcome models, the **Gini coefficient after taxes and transfers** is not significant in the Tobit model though.

**Table 15: Tobit on share of treated municipal wastewater**

```
Tobit regression                                Number of obs =          425
                                                F( 10,    415) =          22.27
                                                Prob > F      =           0.0000
Log pseudolikelihood = -276.26932              Pseudo R2      =           0.2132
```

Share_WWT	Coef.	Robust Std. Err.	t	P> t	[95% Conf. Interval]	
gdpcap	.0266607	.0104227	2.56	0.011	.0061728	.0471486
gini	.0012448	.0090696	0.14	0.891	-.0165832	.0190728
fracind	-.0012717	.0032832	-0.39	0.699	-.0077255	.0051822
femadmin	-.0027012	.0025444	-1.06	0.289	-.0077027	.0023003
neighmun	.0036714	.0013015	2.82	0.005	.0011113	.0062298
1.waterutility	.2623343	.0742261	3.53	0.000	.1164284	.4082403
1.StateCategory2	-.2183366	.0985368	-2.22	0.027	-.4120301	-.024643
1.StateCategory3	-.2663608	.107582	-2.48	0.014	-.4778343	-.0548873
1.StateCategory4	-.5083912	.1219972	-4.17	0.000	-.7482007	-.2685816
1.StateCategory5	-.6368515	.1587902	-4.01	0.000	-.9489849	-.3247181
_cons	-.1606147	.4040932	-0.40	0.691	-.9549392	.6337099
/sigma	.5636669	.0246047			.5153016	.6120323

```
Obs. summary:      239 left-censored observations at Share_WWT<=0
                   186 uncensored observations
                   0 right-censored observations
```

Source: Own calculations, using Stata 13.

A next step estimates the marginal effects. Due to the non-linearity of the Tobit model, estimated parameters cannot be used to quantify directly the effects of included regressors on the dependent variable.

Table 16 gives respective estimates of marginal effects for the censored sample mean. As can be seen there, the Tobit regression predicts an augmentation of about 0.1% in the **treatment share** for an otherwise average municipality if **GDP per capita** increases marginally by an

amount of 100 PPP US\$. If, on the other hand, the **Percentage of neighbouring municipalities with wastewater treatment** experiences an incremental change of 5% at mean the dependent variables changes by around 0.8%. In terms of institutional quality, **outsourcing the administration of municipal water to a municipal public water utility** correlates with an 11.7% higher share of treated wastewater. The belonging of an average municipality to another **State Category** than **State Category 1** worsens treatment shares by 8.5% (**StateCategory2**) to 20.6% (**StateCategory5**). In accordance with parameter estimates, the marginal effects of the **GINI coefficient after taxes and transfers**, **Fractionalization Index**, and **Percentage of female members in municipal government** are not significant.

**Table 16: Marginal effects of tobit model**

```

Conditional marginal effects          Number of obs   =          425
Model VCE      : Robust

Expression      : E(Share_WWT*|Share_WWT>0), predict(ystar(0,.))
dy/dx w.r.t.   : gdpicap gini fracind femadmin neighmun 1.waterutility 1.StateCategory2
                1.StateCategory5 1.StateCategory3 1.StateCategory4

```

	Delta-method					[95% Conf. Interval]	
	dy/dx	Std. Err.	z	P> z			
gdpicap	.0117698	.0045331	2.60	0.009	.0028851	.0206544	
gini	.0005495	.0040038	0.14	0.891	-.0072977	.0083967	
fracind	-.0005614	.0014472	-0.39	0.698	-.0033979	.002275	
femadmin	-.0011925	.0011224	-1.06	0.288	-.0033924	.0010075	
neighmun	.0016208	.0005703	2.84	0.004	.000503	.0027386	
1.waterutility	.1176921	.0339729	3.46	0.001	.0511063	.1842778	
1.StateCategory2	-.0852514	.0336124	-2.54	0.011	-.1511305	-.0193722	
1.StateCategory3	-.102377	.0354302	-2.89	0.004	-.171819	-.032935	
1.StateCategory4	-.1987546	.0425871	-4.67	0.000	-.2822237	-.1152854	
1.StateCategory5	-.20634	.0379086	-5.44	0.000	-.2806395	-.1320405	

Note: dy/dx for factor levels is the discrete change from the base level.

Source: Own calculations, using Stata 13.

### 7.3. Goodness of fit and prediction quality

Like in the case of binary outcome models, the goodness of fit of the Tobit model needs to be validated. In this regard, subchapters 7.3.1 examines the reported Pseudo R<sup>2</sup> value and applies

the Linktest to the Tobit model. In addition, subchapter 7.3.2 compares actual with fitted values.

### 7.3.1. Pseudo R2 and Linktest

With a Pseudo R<sup>2</sup> of **0.21**, the goodness of fit of the model is still reasonable.<sup>152</sup> For further scrutiny, I apply the Linktest in order to validate Tobit as correct model specification. Generally, a model passes the Linktest if the actual values of the dependent variable of a model are regressed on the predicted values of the model and their squares, and the squares of the predicted values do not exhibit significant power in explaining the actual values of the dependent variable (Hardin and Hilbe, 2012).

Table 17 details the respective result of the Linktest on the Tobit model. Since ( $p = 0.12$ ) for the squares of the predicted values (***\_hatsq***), they have no significant power in explaining the dependent variable (***Share\_WWT***). Thus, the hypothesis of correct model specification is not rejected.

**Table 17: Linktest on the tobit model**

```
Tobit regression                                Number of obs =          425
                                                LR chi2(2)         =          152.28
                                                Prob > chi2        =           0.0000
Log likelihood = -275.00684                    Pseudo R2         =           0.2168
```

Share_WWT	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
_hat	1.043199	.095494	10.92	0.000	.8554968	1.230901
_hatsq	-.2914242	.1860932	-1.57	0.118	-.6572068	.0743583
_cons	.0437385	.0457295	0.96	0.339	-.0461469	.1336238
/sigma	.5645854	.0325497			.500606	.6285647

```
Obs. summary:      239 left-censored observations at Share_WWT<=0
                   186 uncensored observations
                   0 right-censored observations
```

Source: Own calculations, using Stata 13.

<sup>152</sup> See Table 15 for the PseudoR<sup>2</sup> value and subchapter 6.4.1 for the general discussion of the PseudoR<sup>2</sup> concept. As stated there, values between 0.2 and 0.4 indicate a reasonable model fit according to literature.

### 7.3.2. Fitted vs. actual shares of treated wastewater

A standard measure to assess the prediction quality of a model is to compare fitted values with actual values of the dependent variable. Accordingly, Table 18 gives a detailed summary of the characteristics of the distribution of actual treatment shares (**Share\_WWT**) and fitted values (**Linear Prediction**) of municipalities for which the Tobit model predicts a positive treatment share.

Overall, the Tobit model predicts **155** of the **425** included municipalities as having a positive treatment rate. Thus, the Tobit model underestimates the number of treating municipalities which is actually **186**.<sup>153</sup> On the other hand, with respective values of **0.47** and **0.36** the actual and fitted sample mean differ significantly. This is also true for the sample's standard deviation. While the actual standard deviation aggregates to **0.38**, the fitted is only **0.24**. Furthermore, the percentile distribution of municipalities according to predicted treatment rates indicate that the Tobit model overpredicts the treatment shares of municipalities at the lower tail. While Tobit estimates that municipalities of the tenth lowest percentile treat shares of municipal wastewater ranging from **0.1**, i.e. **1%**, to **0.6**, i.e. **6%**, none of those entities actually treat wastewater. On the other hand, it underrates treated shares of municipalities in the middle and at the upper tail of the sample distribution. The median municipality, for instance, is predicted to treat **32.6%** (cf. **Linear Prediction** part of Table 18), whereas it's actual treatment rate is **45.8%** (cf. **Share\_WWT** part of Table 18). Likewise, municipalities included in the 10<sup>th</sup> highest percentile are predicted to treat **72.9%** to **92%** of municipal wastewater while in reality all of them treat **100%**. Finally, with a fitted rate of **105.3%** the estimate for one municipality overshoots the logically maximum possible treatment rate of **100%**. The reason for this is that the Tobit model does not restrict the estimated value to range between zero and hundred percent (Papke and Wooldridge, 1996; Baum, 2008 and 2013).<sup>154</sup>

---

<sup>153</sup> Cf. Table 15. The term 'uncensored observations' at the bottom of the table refers to the number of municipalities that have a positive percentage of treated municipal wastewater. The term "left-censored observations at  $\text{Share\_WWT} \leq 0$ " states the number of non-treating municipalities (**239**) that are included in the Tobit model regression.

<sup>154</sup> See for a more detailed discussion of the topic subchapter 5.3.2.

**Table 18: Distribution of fitted and actual treatment shares, if  $\widehat{\text{Share\_WWT}} > 0$**   
Share\_WWT

Percentiles		Smallest		
1%	0	0		
5%	0	0		
10%	0	0	Obs	155
25%	.0289	0	Sum of Wgt.	155
50%	.4584222		Mean	.4721632
		Largest	Std. Dev.	.3841736
75%	.855432	1	Variance	.1475894
90%	1	1	Skewness	.0766466
95%	1	1	Kurtosis	1.455739
99%	1	1		
Linear prediction				
Percentiles		Smallest		
1%	.0122282	.0100722		
5%	.0294794	.0122282		
10%	.05549	.0143919	Obs	155
25%	.1485352	.0170502	Sum of Wgt.	155
50%	.328551		Mean	.3605738
		Largest	Std. Dev.	.2424815
75%	.5022088	.8586147	Variance	.0587973
90%	.7290419	.9200673	Skewness	.5351699
95%	.7844051	.9721783	Kurtosis	2.573012
99%	.9721783	1.05295		

Source: Own calculations, using Stata 13.

Additionally, Table 19 summarizes the percentile distribution of actual treatment shares (*Share\_WWT*) and fitted values (*Linear Prediction*) of municipalities for which the Tobit model predicts negative treatment shares.

Based on the general framework of the Tobit model, entities with a predicted negative share may be considered to correspond with municipalities that treat **0%** of wastewater in reality.<sup>155</sup> According to Table 19, fitted values match actual treatment rates reasonably well for

<sup>155</sup> Originally, the Tobit model was developed to estimate the utility or net benefit consumers derive from a certain product. In this context it has been argued that consumers with observed positive expenditures on a product derive a positive utility or net benefit from consuming it. Generally, utility or net benefit is defined as the gross benefit derived from consumption, i.e. the demand for a good, minus the costs of consumption. In contrast, consumers with zero expenditure derive only a negative utility or net benefit from buying and consuming the good because their derived (gross) benefit falls short of the market price of the good. In consequence, their actual expenses on (and demand for) the good are zero as their net utility is negative. Accordingly, the Tobit model estimates negative fitted values for consumers with no observed expenditure. In consequence, negative fitted values are also estimated for municipalities with an observed municipal wastewater treatment rate of zero. The framework of the Tobit model implicitly assumes for these entities that treating municipal wastewater



municipalities below the median. For instance, all municipalities predicted to be in the 25<sup>th</sup> lowest percentile actually do not treat any municipal wastewater in reality. However, matching rates are rather poor for municipalities for which the Tobit model estimates only slightly negative values. For instance, all municipalities predicted to belong to the 1<sup>th</sup> highest percentile of not treating municipalities treat **100%** of their municipal wastewater in reality. In total, the Tobit model predicts **63** municipalities as not treating municipal wastewater while they actually do.

**Table 19: Distribution of fitted and actual treatment shares, if  $\widehat{\text{Share\_WWT}} < 0$**

Share_WWT					
	Percentiles	Smallest			
1%	0	0			
5%	0	0			
10%	0	0	Obs		270
25%	0	0	Sum of Wgt.		270
50%	0		Mean		.1234089
		Largest	Std. Dev.		.2730949
75%	0	1			
90%	.5500278	1	Variance		.0745809
95%	.8307	1	Skewness		2.168074
99%	1	1	Kurtosis		6.409055
Linear prediction					
	Percentiles	Smallest			
1%	-.7436195	-.7698303			
5%	-.6852946	-.7508167			
10%	-.6509809	-.7436195	Obs		270
25%	-.5367853	-.7392699	Sum of Wgt.		270
50%	-.3123219		Mean		-.3376472
		Largest	Std. Dev.		.2219561
75%	-.1369351	-.0124447			
90%	-.0566187	-.0108363	Variance		.0492645
95%	-.0298801	-.0079115	Skewness		-.2061345
99%	-.0108363	-.0040858	Kurtosis		1.711411

Source: Own calculations, using Stata 13.

causes them a negative utility or net benefit, e.g. because treatment costs surpass the benefits of having clean water (see also subchapter 5.3.2.). This negative utility is then explicitly estimated in the Tobit regression.

## 7.4. Tobit model estimation for lognormal data

A reason for the limitations of the Tobit model in predicting treatment shares correctly may be that it crucially relies on the normality assumption (Cameron and Trivedi, 2009). Overall, the used data sample of 425 observations contains 239 municipalities with a treatment rate of zero. Not surprisingly, the histogram in A.10 in the appendix shows therefore a significantly unsymmetrical and heavy-tailed distribution of shares of municipal wastewater treatment. This is a strong indication for the violation of the normality assumption which likely affects estimation results. Thus, it might be advisable to apply procedures to remedy the observed shortcomings and see whether applied measures improve the prediction quality of the Tobit model.

**Table 20: Tobit on the logarithm of share of treated municipal wastewater**

Tobit regression	Number of obs	=	425
	F( 10, 415)	=	26.09
	Prob > F	=	0.0000
Log pseudolikelihood = -601.77883	Pseudo R2	=	0.1170

lnShare_WWT100	Coef.	Robust Std. Err.	t	P> t	[95% Conf. Interval]	
gdpcap	.17385	.0587516	2.96	0.003	.0583622	.2893378
gini	.0137135	.050759	0.27	0.787	-.0860633	.1134903
fracind	-.0136118	.0183058	-0.74	0.458	-.0495956	.0223719
femadmin	-.0155201	.0149332	-1.04	0.299	-.0448743	.0138341
neighmun	.0242564	.0070483	3.44	0.001	.0104016	.0381112
1.waterutility	1.344143	.4122489	3.26	0.001	.5337871	2.1545
1.StateCategory2	-1.08686	.4982214	-2.18	0.030	-2.066212	-.1075079
1.StateCategory3	-1.388289	.538733	-2.58	0.010	-2.447275	-.3293035
1.StateCategory4	-2.587631	.6499486	-3.98	0.000	-3.865233	-1.310029
1.StateCategory5	-3.069816	.8609438	-3.57	0.000	-4.762171	-1.377462
_cons	-1.284128	2.215481	-0.58	0.562	-5.639093	3.070837
/sigma	3.099155	.1390267			2.82587	3.372439

Obs. summary: 239 left-censored observations at lnShare\_~100<=0  
 186 uncensored observations  
 0 right-censored observations

Source: Own calculations, using Stata 13.

A common approach to approximate a sample's distribution to normality is to take the natural logarithm of the dependent variable (Cameron and Trivedi, 2009). However, to perform this exercise the particularities of the data underlying this case study require data transformation. If not accounted for, the majority of observations is lost since the natural logarithm of zero is

not defined.<sup>156</sup> I therefore multiply, in a first step, the percentage of treated wastewater by 100 to express values in %. Subsequently, I add up the values of all observations with 1 since  $\ln(1) = 0$ . The second step ensures that the lognormal Tobit model identifies municipalities with a treatment rate of 0% correctly as censored data.

Table 20 shows the Tobit model estimations for the natural logarithm of the transformed dependent variable (*lnShare\_WWT*) if the lower boundary is again specified as 0. In terms of parameter signs and significance levels outcomes of the general Tobit model are approximately matched. However, the reduced Pseudo R<sup>2</sup> of about **0.12** does not indicate any improvement of goodness of fit of the model. Furthermore, the value of Log Pseudolikelihood drops from around **-276** to around **-602** which is also not affirmative for a better model fit.<sup>157</sup> However, those findings may not come as such a surprise. In the particular case of this thesis, taking the logarithm does not remedy the non-normal distribution of the underlying data of the dependent variable. As the histogram in Figure A.11 in the appendix illustrates, the distribution of the log data seem to be even more unsymmetrical and heavy-tailed than the density of the normal data. Since  $\ln(1) = 0$  the majority of included observations continue to be zero. In addition, also the upper tail becomes more pronounced. In consequence, taking logarithm is of no help to remedy the violation of the normality assumption in the Tobit model.

## 7.5. Fractional logit model estimation

Due to the limitations of the underlying data in fulfilling the normality assumption of the Tobit model and to deal with the issue of fitted treatment rates that are negative or overshoot the 100% mark I apply alternatively the Fractional Logit model on the data. An alternative model may help to improve the prediction quality and/or validate the robustness of the results of the Tobit model.

---

<sup>156</sup> As the logarithm of 0 is not defined, Stata would treat all the observations for municipalities with a treatment rate of zero percent as missing and, consequently, drop from the sample size. To avoid zero values of the observation I add 1 to the value of each observation. Thus, municipalities with no wastewater treatment have now the value of 1. The advantage of this procedure is that the logarithm of 1 is zero so that as lower boundary is specified as 0.

<sup>157</sup> Generally, higher Log Pseudolikelihood values are considered to represent better model fits (Cameron and Trivedi, 2009).

As already mentioned in subchapter 5.3.2.2, Papke and Wooldridge (1996) developed the Fractional Logit model as an extension of the Logit model. In contrast to general Logit, it allows the dependent variable to assume not only the values of one and zero but also other values of the interval [0; 1]. In addition, it excludes the estimation of fitted values below 0 and above 1. In consequence, it may suit well for the estimation of fractional data like the share of treated municipal wastewater. Respective estimation results are given in Table 21.

**Table 21: Fractional logit on percentage of treated wastewater**

Generalized linear models		No. of obs	=	425
Optimization	: ML	Residual df	=	414
		Scale parameter	=	1
Deviance	= 251.8698943	(1/df) Deviance	=	.6083814
Pearson	= 252.825602	(1/df) Pearson	=	.6106899
Variance function:	$V(u) = u*(1-u/1)$	[Binomial]		
Link function	: $g(u) = \ln(u/(1-u))$	[Logit]		
		<u>AIC</u>	=	.8831265
Log pseudolikelihood = -176.6643905		<u>BIC</u>	=	-2253.695

Share_WWT	Coef.	Robust Std. Err.	z	P> z	[95% Conf. Interval]	
gdpcap	.049045	.0346556	1.42	0.157	-.0188787	.1169686
gini	-.0042473	.0280992	-0.15	0.880	-.0593206	.0508261
fracind	.0007215	.0106901	0.07	0.946	-.0202306	.0216736
femadmin	-.007453	.0073453	-1.01	0.310	-.0218494	.0069435
neighmun	.0075475	.0039083	1.93	0.053	-.0001127	.0152077
1.waterutility	.7197784	.212743	3.38	0.001	.3028097	1.136747
1.StateCategory2	-.6649236	.3138913	-2.12	0.034	-1.280139	-.0497079
1.StateCategory3	-.8428318	.3487409	-2.42	0.016	-1.526351	-.1593121
1.StateCategory4	-1.54018	.3798699	-4.05	0.000	-2.284712	-.7956492
1.StateCategory5	-2.091412	.5302729	-3.94	0.000	-3.130727	-1.052096
_cons	-.8200656	1.261399	-0.65	0.516	-3.292362	1.652231

Source: Own calculations, using Stata 13.

As to estimated signs of parameters and significance levels, two major differences are observed in comparison to the Tobit model results. First, the parameters of the **Gini coefficient after taxes and transfers** and the **Fractionalization Index** reverse signs. However, both remain insignificant like in the Tobit model. Secondly, the positive parameter estimate for **GDP per capita** is not significant anymore, not even at the 10% level since  $p = 0.157$ .<sup>158</sup>

In line with the outcomes of the Tobit model, the Fractional Logit model assigns **Percentage of neighbouring municipalities with wastewater treatment**, the **Dummy variable**

<sup>158</sup> Excluding the outlier of the municipality with a per capita GDP of 25,945 US\$ (cf. subchapter 7.1) reduces the significance level even further to  $p = 0.27$  in the Fractional Logit model. In contrast, the results of the Tobit model are not significantly altered if the per capita GDP outlier is removed (see for details Tables A.68 and A.69 in the appendix).

**for a municipal public water utility, and the Dummy variable for the belonging of a municipality to a particular State Category** significance levels of at least 10%.

Like the Tobit model, the Fractional Logit model passes the Linktest. As Table A.65 in the appendix details, squares of predicted values (*\_hatsq*) have no significant power in explaining the actual values of the dependent variable (*Share\_WWT*). However, the Fractional Logit model displays also flaws in the prediction quality. As Table 22 illustrates, fitted values deviate substantially from actual values. For the overall sample median, for instance, it predicts a treatment rate of **19.8%** whereas the actual rate is **0%**. In addition, treatment rates are over-predicted at the lower tail of the percentile distribution while the reverse is true at the upper tail. For instance, municipalities included in the highest 1<sup>th</sup> percentile are predicted to treat only **74.4%** to **79.9%** of municipal wastewaters. In reality these municipalities treat **100%**.

**Table 22: Distribution of fitted and actual treatment shares, fractional logit**  
Share of treated municipal wastewater

Share of treated municipal wastewater					
	Percentiles	Smallest			
1%	0	0			
5%	0	0			
10%	0	0	Obs		425
25%	0	0	Sum of Wgt.		425
50%	0		Mean		.2506017
		Largest	Std. Dev.		.3594018
75%	.4882813	1			
90%	.9417989	1	Variance		.1291697
95%	1	1	Skewness		1.073528
99%	1	1	Kurtosis		2.557606
Predicted mean Share_WWT					
	Percentiles	Smallest			
1%	.0463058	.0418529			
5%	.0533687	.0426562			
10%	.0617443	.0441337	Obs		425
25%	.0996762	.0451741	Sum of Wgt.		425
50%	.1983396		Mean		.2506017
		Largest	Std. Dev.		.1860154
75%	.3677586	.7497057			
90%	.510321	.7638292	Variance		.0346017
95%	.6783623	.7840386	Skewness		1.043014
99%	.7473941	.7992281	Kurtosis		3.192364

Source: Own calculations, using Stata 13.

A direct inter-model comparison by means of Log Pseudolikelihood values suggests that the Fractional Logit model may fit better the data as the Tobit model. With **-176** the Fractional

Logit model possesses of a Log Pseudolikelihood that is significantly lower than the Tobit model **-276**.

The Akaike's information criterion (AIC) also favours the Fractional Logit model **(0.88)** over the Tobit model **(1.35)**.<sup>159</sup> Generally, smaller AIC values are preferred as they correspond with higher log likelihoods (Cameron and Trivedi, 2009).

A general explanation why both the Tobit and the Fractional Logit model exhibit some flaws in terms of prediction quality may be that the quality of the underlying data is rather poor. As mentioned previously,<sup>160</sup> actual volumes of generated municipal wastewater are unknown and have to be therefore uniformly estimated. As such, they may only roughly correspond with actual values though. Once a more accurate description of generated volumes of municipal wastewater is available, regression estimations on the percentage of treated municipal wastewater may yield improved results.

## **7.6. Summary of chapter 7**

In chapter 7, the Tobit and Fractional Logit model have regressed the 'estimated percentage of treated municipal wastewater' conditional on socioeconomic, demographic and institutional characteristics of Mexican municipalities. The aim of regressing the 'estimated percentage of treated municipal wastewater' has been to scrutinize the findings of the binary outcome models in chapter 6 for a different measure of municipal treatment performance.

Lack of data allows the inclusion of only 425 Mexican municipalities into the Tobit and Fractional Logit regressions. Due to multicollinearity the number of included independent variables have been also reduced. The indicators of education and urbanization are omitted due to multicollinearity with GDP per capita. Due to limitations in data availability, the Index of Strategic Planning and Municipal Evaluation and Index of Basic Municipal Regulation Implementation have been dropped. Instead of including dummy variables for the belonging of a municipi-

---

<sup>159</sup> See Table A.67 for the AIC value of the Fractional Logit model and Table A.66 in the appendix for the AIC value of the Tobit model. In addition, the related Bayesian information criterion BIC also favors the Fractional Logit model over the Tobit model as its reported value is again smaller for the Fractional Logit model (cf. values in Table A.66 and A.67).

<sup>160</sup> Cf. subchapter 5.1.

pality to one of the 32 federal states in Mexico, the model has considered only 5 state categories. I.e. municipalities belong now to one of those five groups of federal states. This measure helped to reduce the number of included variables further which is recommendable due to the relatively small size of the sample.

Like the binary outcome models in chapter 6, the Tobit and Fractional Logit model find empirical evidence that the soundness and well-functioning of municipal institutions and spillover effects from neighboring municipalities have a significant positive impact on municipal wastewater treatment performance. In addition, the impact of environmental federalism is again significant as the belonging of a municipality to a particular state category matters. Both, Tobit and Fractional Logit, estimate a positive per capita income parameter though it is not significant in the Fractional Logit model. In accordance with the estimation results of the binary outcome models in chapter 6, the Tobit and Fractional Logit model do also not estimate significant parameters for ethnic heterogeneity and female participation in municipal politics. In contrast, both models estimate a non-significant negative parameter of the GINI coefficient after taxes and transfers though. An explanation for that could be the low standard deviation of the GINI coefficient in the sample.

Overall, the goodness of fit and the prediction quality of the Tobit and Fractional Logit models are reasonable. To some extent, limitations in the quality of the underlying data might be the reason that the applied models do not explain more of the variance of the dependent variable. Generally, the estimated percentage of treated municipal wastewater is not a perfect measure as it constitutes only a rough approximation. For its calculation, it is uniformly assumed that 70% of the water supplied to municipal water networks turn into wastewater (RAS, 2000; CONAGUA, 2007; IMTA, 2014a). In reality, the percentage of supplied water turning into wastewater varies substantially across municipalities in Mexico, e.g. due to different degrees of leakages and clandestine abstraction (Barkin, 2006 and 2011). With regard to the Tobit model, the distribution of the underlying data also does not fit perfectly general model assumptions as the assumptions of normality and homoscedasticity might be violated due to the inclusion of many municipalities with a treatment rate of zero. Notwithstanding these limitations, the results of the Tobit and Fractional Logit model may allow to draw similar conclusions like in the binary outcome models with regard to what factors drive municipal wastewater treatment performance in a municipality of a developing country.





## 8. Summary and discussion of results

Water pollution is a major threat to human health and the environment in developing countries (Jalan and Ravallion, 2003; Azizullah et al., 2011; Wang and Yang, 2016). A major source of this contamination is the discharge of untreated municipal wastewater (Glibert et al., 2008; Nyenje et al., 2010; Azizullah et al., 2011; Malik et al., 2015). Therefore, the aim of this thesis has been to explain what drives and what impairs municipal wastewater treatment in a developing country like Mexico.

In this concluding discussion, the thesis summarizes the empirical findings of the preceding analysis. Subchapter 8.1 condenses the empirical findings of the thesis. Following, subchapter 8.2 discusses to what extent the findings of the thesis support or contradict the expectations of the hypotheses. From there, it derives what can be learnt in theoretical terms and links the thesis' findings with the economic research on environmental performance. In subchapter 8.3, shortcomings and limitations of the thesis' research approach are discussed and a brief outlook on promising further research is given. Finally, subchapter 8.4 develops policy recommendations.

### 8.1. Empirical findings of the case study

Based on economic literature, the thesis has developed 10 hypotheses on how socioeconomic, demographic, institutional factors may impact the performance of municipal wastewater treatment in a developing country:<sup>161</sup>

Hypothesis 1: Per capita income has a significant positive net impact on municipal wastewater treatment performance (+).<sup>162</sup>

Hypothesis 2: Income inequality impacts municipal wastewater treatment performance significantly. However, the sign of its net effect is ambiguous (/).<sup>163</sup>

---

<sup>161</sup> See chapter 4 for a detailed discussion.

<sup>162</sup> "+" stands for the expectation of a positive net effect of the explanatory factor.

<sup>163</sup> "/" means that it is, from a theoretical standpoint, unclear whether the expected net effect is positive or negative as several contradicting explanations are provided.

Hypothesis 3: The sound and well-functioning of municipal institutions has a significant positive net impact on municipal wastewater treatment performance (+).

Hypothesis 4: The net effect of environmental federalism and decentralization is significant, though ambiguous (/).

Hypothesis 5: Municipal wastewater treatment performance spills over spatially (+).

Hypothesis 6: Urbanization has a significant positive net impact on municipal wastewater treatment performance (+).

Hypothesis 7: Education has a significant positive net impact on municipal wastewater treatment performance (+).

Hypothesis 8: Female participation in local politics has a significant positive net impact on municipal wastewater treatment performance (+).

Hypothesis 9: Ethnic heterogeneity has a significant negative net impact on municipal wastewater treatment performance (-)<sup>164</sup>.

Hypothesis 10: Water availability has a significant negative impact on municipal wastewater treatment performance (-).

To scrutinize the validity of these hypotheses the thesis relied on econometric models. Municipal wastewater treatment performance of a Mexican municipalities has been measured in two different ways: 1) As the probability municipal wastewater treatment takes place in a Mexican municipality, and 2) as the estimated percentage of treated municipal wastewater in a Mexican municipality. Data limitations impeded to consider the actual share of treated municipal wastewater. In contrast, data on whether municipal wastewater treatment takes place in a municipality is available for almost all of the 2,456 Mexican municipalities that existed in 2010 which is the year of investigation of this thesis. Data on the estimated percentage of treated municipal wastewater was available for 511 Mexican municipalities.

To estimate the conditional treatment probability of municipal wastewater treatment the thesis relies on binary outcome models, in particular on Standard Logit and Probit as validation of model outcomes suggests that those models fit best underlying data. Supplementary runs

---

<sup>164</sup> “-“ indicates, from a theoretical standpoint, a negative expected net effect.

use Linear Probability Model (LPM), Complementary Log-Log Model (Cloglog), and Heteroskedastic Probit. To regress the estimated percentage of treated municipal wastewater on a selection of explanatory variables, the Tobit and Fractional Logit model were applied. Due to multicollinearity and partially lack of data, the Tobit and Fractional Logit model omit urbanization, education, ethnic heterogeneity, and two of the four indicators that measure the soundness and well-functioning of municipal institutions.<sup>165</sup> Less rich in independent variables and applied to a much smaller sample than the binary outcome models, the outcomes of the Tobit and Fractional Logit model should be considered as of less precision. This applies all the more as the values of the applied dependent variable – the percentage of treated municipal wastewater – are only rough estimates and therefore of suboptimal quality.<sup>166</sup> In consequence, outcomes of the Tobit and Fractional Logit model mainly serve as an approximate validation of the results of binary outcome models.

Overall, the binary outcome models find empirical evidence for a significant positive impact of

per capita income,  
unequal income distribution,  
soundness and well-functioning of municipal institutions,  
urbanization, and  
spillovers from neighbouring municipalities

on the probability that municipal wastewater treatment takes place in a municipality. In addition, environmental federalism is found to be significant as the belonging of a municipality to a particular federal state highly matters for the treatment of municipal wastewater. In contrast, no empirical support is lent to a significant influence of the

level of education,

---

<sup>165</sup> Additionally, instead of including dummy variables for the belonging of a municipality to a particular federal Mexican state into the regression models, the 31 Mexican federal states and the Federal District of Mexico-City have been classified in 5 different categories according to their estimated share of treated municipal wastewater volumes. Dummy variables for the belonging of a municipality to one of those 5 state categories have been then included into the regression in order to reduce the number of included independent variables as a response to the limited data availability (see for a detailed discussion subchapter 6.5.2.3.)

<sup>166</sup> Generally, generated volumes of municipal wastewater are not known at the municipal level and only uniformly estimated by assuming that 70% of the water supplied to the drinking water supply networks turn into wastewater. Therefore, it is not possible to calculate exactly the percentage of treated municipal wastewater in a municipality. In consequence, the percentage of treated wastewater is only an approximate estimate official government sources provide (see for detailed discussion subchapter 5.1).

ethnic heterogeneity,  
female participation in municipal politics, and  
water availability.

Complementary, the reduced Tobit and Fractional Logit models on the estimated percentage of treated municipal wastewater confirm approximately a significant positive impact of per capita income, soundness and well-functioning of municipal institutions, spillovers from neighbouring municipalities.

The impact of environmental federalism is again significant. Overall, the results of the empirical analysis supports the thesis that socioeconomic, demographic, and institutional characteristics matter as differences in the social structure of a Mexican municipality explain a good deal of the observed variation in municipal wastewater treatment performance.

## **8.2. Interpretation of the empirical findings**

In the following, it is discussed to what extent the empirical results of the thesis meet the expectations of the thesis' hypotheses and what can be generally learnt in terms of the link between social characteristics of a municipality in a developing country and its municipal wastewater treatment performance. In cases where empirical results contradict theoretical expectations, possible explanations are provided. In addition, the thesis' findings are linked with the general economic research on environmental performance of a society.

### Per capita income

The estimated positive impact of GDP per capita on the probability and estimated percentage of treated municipal wastewater meets the hypothesized expectation. The empirical findings of the thesis give credit to the view, widely held in economic research, that richer people, on average, demand and afford more environmental quality in form of unpolluted water as a normal or luxury (public) good (Beckerman, 1992; Shafik, 1994; Carson et al., 1997; McConnell, 1997, Scruggs, 1998, Dinda, 2004; Bo, 2011). In consequence, they seem to urge municipal

administrations to implement environmental regulations to internalize more effectively the negative external effects of untreated municipal wastewater and to treat it in order to provide a clean municipal environment (Grossman and Krueger, 1995; De Bruyn and Heintz, 1999, Heerink et al., 2001). Moreover, richer populations may be more able and willing to contribute financially to the implementation of public and private municipal water infrastructure projects that increase the local environmental quality. On average, tax payments to the municipal administration should be higher and public water utilities should be able to cover higher service fees. This gives those entities more leeway to provide an improved service of municipal wastewater treatment.

Beyond that, one has to be aware that it is commonly beyond the economic, institutional and demographic capacity of municipalities and their administrations in a developing country to establish and operate municipal wastewater infrastructure by themselves. For this reason, they apply frequently for funding the national government or the governments of other superior governmental layers provide in a developing country (Briceño, 2008; Peña et al., 2013). Likewise, municipal administrations in Mexico apply for federal state and national funding and rarely pursue municipal wastewater treatment projects without the co-investment and co-management of superior tiers. However, most of these programs require co-funding of the sponsored entity (Olivares and Sandoval, 2008; Aguilar Amilpa, 2010; Peña et al., 2013; CONAGUA, 2011b, 2012b, 2013c, 2014e, 2015a and 2015b; SEMARNAT, 2014a). Accordingly, this particular requirement favours richer Mexican municipalities as they are more able to afford the financial obligations.

Generally, plenty of previous empirical studies have tested the nexus between per capita income and environmental performance of a society. Results have been mixed. Some studies found an inverted u-shaped relationship between economic performance and environmental pollution confirming the hypothesis of the Environmental Kuznets Curve (EKC) (Grossman and Krueger, 1991).<sup>167</sup> Other studies found rather monotonically increasing or decreasing, U-

---

<sup>167</sup> An inverted U-shaped relationship between environmental degradation and per capita income have been found in particular for local air pollutants like sulphur (Halkos, 2003), sulphur dioxide (SO<sub>2</sub>) (Shafik, 1994; Selden and Song, 1994; Grossman and Krueger, 1995; Panayotou, 1997; Cole et al., 1997; List and Gallet, 1999; Deacon and Norman, 2006), suspended particulate matter (Shafik, 1994; Selden and Song, 1994; Grossman and Krueger, 1995; Cole et al., 1997), oxides of nitrogen (Selden and Song, 1994; Cole et al., 1997; List and Gallet, 1999), and carbon monoxide CO (Selden and Song, 1994; Cole et al., 1997). Some studies confirm also the existence of a EKC for water pollution types like nitrate (Grossman and Krueger, 1995; Cole et al., 1997), volumes of wastewater

shaped or (inverted) N-shaped relations or no significant correlation at all (Hettige et al., 1999; Dinda et al., 2000; Harbaugh et al., 2002; Groot et al., 2004; Wagner, 2008; Wong and Lewis, 2013). In consequence of mixed empirical results, the true relation between economic and environmental performance remains unclear. In this context, the thesis is able to relate per capita income positively with efforts to protect the environment. To my best knowledge, none of the previous studies has scrutinized yet the validity of this relationship in the field of municipal wastewater treatment at the municipal level in a developing country.

### Unequal income distribution

Regarding unequal income distribution, economic research is generally undecided about its net effect on environmental quality. On the one hand, one may expect more environmental degradation in more unequal societies. As far as richer population strata benefit both as producers and consumers more from polluting economic activities and poorer strata suffer more from negative externalities of these polluting activities, richer people should not have the incentive to support public policies in favour of environmental protection. However, their political and financial support may be crucial for the successful implementation of respective policies (Roemer, 1993; Torras & Boyce, 1998; Boyce, 1994, 2003, 2007; Wisman, 2011; Berthe and Elie, 2015). In addition, if social standing is decisive for personal well-being the median voter in more unequal societies may be in favour of public policies that improve his or her economic situation over supporting policies that mitigate environmental degradation. These preferences may result from his or her being relatively poor in comparison with the mean voter in unequal societies (Magnani, 2000).

On the other hand, stricter environmental policies might be the political outcome of less equal societies if richer strata have higher preferences for environmental quality than poorer parts of population. In this context, the rich people may exert the greater political influence they tend to have in political systems of unequal societies to assure the implementation of policies that meet their preferences (Roemer, 1993, Scruggs, 1998, Berthe and Elie, 2015). Inter alia,

---

(Liu et al, 2007; Song et al., 2008; Shua et al., 2012), and faecal coliform and heavy metal contamination (Grossman and Krueger, 1995). Several studies produce evidence of the existence of an inverted U-shape correlation for other forms of environmental degradation (e.g. deforestation) (Panayotou, 1993; Culas, 2007; Choumert et al., 2014).

due to their overall tendency to copy attitudes and behaviour of dominant parts of society (Roemer, 1993; Berthe and Elie, 2015), poor parts of a municipal society may follow suit the suggestions made by the rich. In addition, the relatively poor median voter in unequal societies may vote generally in favour of increased public expenditure in unequal societies (Meltzer and Richard, 1981). He or she might have a genuine incentive to do so as the low share of the median voter in tax revenues may imply that richer community members fund environmental policies largely. In consequence, he or she may opt for elevated levels of local public good provision like clean local environment and municipal wastewater treatment (Anderson et al., 2008).

The results of the applied binary outcome models of this thesis suggest a positive net effect of unequal income distribution on the probability that municipal wastewater treatment takes place in a Mexican municipality. That may mean that rich population strata indeed favour municipal wastewater treatment to satisfy their increased demand for a clean local environment. Consequently, they exert their political influence on poorer strata to prompt them to adopt a pro-treatment view to gain a majority in the political arena. With their financial and political means, affluent people may also lobby successfully for municipal wastewater treatment within political administrations. Moreover, the interests of the rich may coincide with the preference of a relative poor median voter in unequal societies for more expenditures on public goods like a clean living environment. Thus, he or she may also support municipal policies that envisage municipal wastewater treatment.

In addition, the heavy involvement of superior governmental tiers in the funding of municipal water and sanitation infrastructure in developing countries may again explain the observed pattern to some extent. For instance, several aid programs of the Mexican national government state as one of the selection criteria of benefiting municipalities the priority support of marginalized municipal populations (Olivares and Sandoval, 2008; CONAGUA, 2015b and 2016). I.e., municipalities that have an unequal income distribution seem to be, *ceteris paribus*, prioritized by national programs.

Previous empirical studies on the impact of income distribution on water pollution produced mixed results (Scruggs, 1998; Torras and Boyce, 1998; Clément and Meunié, 2010). Some of the investigations found a significant positive, some a negative relationship or no correlation. In this context, the results of this thesis may lend empirical credibility to the argumentation

that income inequality reduces water pollution. Data-wise, one may exercise some caution with this interpretation as in the used data the standard deviation around the sample mean of the GINI coefficient after taxes and transfers is rather low.<sup>168</sup> This rather suggests that the majority of Mexican municipality do not differ much in terms of income distribution. In consequence, income distribution may not have a great power in explaining differences in treatment performance across Mexican municipalities. In line with this objection is also the fact that the Tobit and Fractional Logit models do not estimate a significant influence of income distribution on the estimated percentage of treated municipal wastewater for the reduced sample of Mexican municipalities.<sup>169</sup>

### Institutional quality

The empirical findings of the thesis also confirm that institutional factors foster municipal wastewater treatment performance. First, the significant positive parameter estimates of the Index of strategic planning and municipal evaluation indicate that the soundness and well-functioning of the general administration of a municipality seem to matter. A rule bound, transparent organization of the municipal administration that reduces discretionary power and controls for corruption seem to help local environmental interest groups and the concerned general public in a municipality to access better policy makers to lobby, inter alia, for wastewater treatment. In addition, municipal administrations with a better institutional quality use available financial, technical and administrative resources more efficiently and professionally which may allow the implementation of sophisticated projects like building and operating municipal wastewater treatment infrastructure.

Secondly, the empirical findings of the thesis give credit to the hypothesis that outsourcing municipal water service provision from the general municipal administration to a municipal public water utility improves, *ceteris paribus*, substantially municipal wastewater treatment performance. In the last two decades, 457 of 2,456 of the Mexican municipalities have out-

---

<sup>168</sup> Compare Table 4 in subchapter 6.1.

<sup>169</sup> For details consult estimation results in Table 6 in subchapter 6.2, Table 15 in subchapter 7.2, and Table 21 in subchapter 7.5.



sourced the administration of municipal water service from the general municipal administration to semi-independent public water utilities (*Organismos operadores de Agua* in Spanish; CONAGUA, 2014b).

The aim of this measure has been to foster the institutional soundness of municipal water administration by creating a more managerial and professional orientation, by facilitating long-term planning, and, above all, by shielding it from corrupting political influence (Barkin, 2011; Herrera and Post, 2014). Municipal administrations in developing countries chronically lack funding and display administrative and technical deficiencies. The direct political influence often generates unprofessional personnel and prevents long-term planning, as the staff of the general municipal bureaucracy is commonly turned over after every election. Political leaders also tend to use their positions in municipal water departments as a stepping stone for their personal political career and distribute political favors, e.g. by establishing not cost-covering, subsidized water fees for particular interest and voter groups (Wilder, 2010; Aguilar Amilpa, 2010; Barkin, 2011). In contrast, public water utilities ought to be financially self-sufficient by raising and collecting cost-covering service fees that allow for the recruitment and decent remuneration of skillful staff and the execution of long-term investments and expenses required for a sound service provision in municipal water supply and sanitation. Its semi-independence and managerial orientation was meant to reduce political influence (Olivares and Sandoval, 2008). However, one has to keep in mind that many structural deficiencies in the efficient management of the municipal water service continue to exist after corporatization was initiated in the early 1990s in Mexico. Only few utilities have excelled and achieved levels comparable with international good practice standards since then in Mexico (Quadri de la Torre, 2008; Saltiel, 2008; Dau Flores, 2008; Barkin, 2011). Nonetheless, semi-independent public water utilities seem to be able to perform better in municipal wastewater treatment than non-outsourced municipal water supply departments in the general municipal administration.

The affirmative empirical finding of the thesis for a significant positive impact of the establishment of public water utilities might be of particular interest for a nascent scientific debate on the corporatization of public services (Herrera and Post, 2014). Recent decades have seen huge waves of corporatization in which many tasks of the public sector have been outsourced to newly created public enterprises in many countries. According to the few empirical studies

performed on the topic, reforms produced worldwide mixed results (Granados and Sánchez, 2014). The Mexican case may be identified as a relative success story that gives credit to the view that corporatization has the potential to improve the quality of a public service.

Last but not least, the empirical outcomes of the thesis suggest, thirdly, that the belonging of a municipality to a particular federal state in Mexico influences largely its performance in municipal wastewater treatment. Observed differences may serve as a proxy for the institutional quality of respective state water governances. In cases where the belonging of a municipality to a particular state correlates positively with its wastewater treatment performance this may be a sign of the soundness and good quality of state water institutions.

The empirical outcome of the thesis lend empirical support for the hypothesis that environmental federalism diversifies environmental performances. This hypothesis features prominently in the scientific debate on decentralization and its effect on environmental performance (List and Gerking, 2000; Millimet, 2003; Sigman 2003, Herrera and Post, 2014). However, relatively few empirical studies have investigated so far whether decentralized systems lead in fact to higher variability in environmental quality across jurisdictions finding affirmative results (Cutter and DeShazo, 2007; Sigman, 2014). To my best knowledge, no study has investigated yet the particular effect of decentralism on the service provision of municipal wastewater treatment and the sanitation sector at the subnational level in a developing country.

#### Spatial spillovers from neighbouring municipalities

According to the results of all applied regression models, municipal wastewater treatment performance spills over among neighbouring municipalities. I.e. municipalities whose neighbours treat municipal wastewater are more prone to treat also their wastewater. Proximity may matter as physical closeness supposedly reduces the costs of diffusion.

Three mechanisms may explain the phenomenon of geographical spillovers. 1) Municipal administrations compete for residents with the provision of public goods (Tiebout, 1956). In consequence, they have the incentive to treat municipal wastewater and provide clean environment as a local public good if neighbouring municipalities do this as well. 2) Neighbouring

municipalities learn from each other (Banerjee, 1992; Simmons et al., 2006). As municipal politicians and public servants belong to the same regional elitist circles they share expertise and knowledge they acquired, for instance, in the field of municipal sanitation. The availability of knowledge on municipal wastewater treatment from nearby locations might be indispensable as gathering information from information sources further away might be too costly. Particularly, for local governmental tiers in developing or emerging countries like Mexico where capabilities tend to be restricted (Briceño, 2008) the effective communication and information exchange with entities located further away, or even abroad, seem to be less feasible. Hence they have to rely on using already established communication channels within the immediate surrounding to acquire relevant information and knowhow. In addition, if the population of a municipality learn that wastewater treatment works in neighbouring municipalities they might demand their municipal politicians to follow suit. 3) Municipalities mimicking each other (Drezner, 2001; Simmons et al., 2006; Perkins and Neumayer, 2009). Administrations of municipalities may simply want to avoid to look backwards orientated or old-fashioned in comparison to their counterparts in neighbouring jurisdictions and copy therefore success stories in their neighbourhood.

The validity of the hypothesis of the existence of positive spatial spillover effects among neighbouring municipalities is further strengthened by empirical evidence that magnitude and significance of spatial spillovers fade away with increasing distance between municipalities. This is what one exactly expects if spatial proximity is the decisive trigger for spill overs to occur among Mexican municipalities.<sup>170</sup>

Several previous studies have scrutinized the existence of geographical spill overs of environmental performance (Maddison, 2006 and 2007; Verdolinia and Marzio, 2011; Costantini et al., 2013). However, to my best knowledge, no other study has investigated yet the phenomenon of the geographical spillover of successful environmental policies and municipal wastewater treatment in developing countries at the local level. The findings of the study may serve as an interesting starting point of further research that reveal the exact mechanisms

---

<sup>170</sup> The effect of neighbouring municipalities with wastewater treatment fade away, once, the thesis extends the distance within which a municipality is considered to be a neighbouring municipality from 25 and 50 kilometres to 100 and 1,000 kilometres respectively. Somewhat puzzling though, underlying data suggests in addition a significant negative correlation of municipal wastewater treatment performance and the percentage of treating municipalities within a distance of 500 kilometers of the municipality. This phenomenon is rather unexplainable by theory and might need to be considered as mere coincidence. See for a detailed discussion subchapter 6.5.2.1.

how innovation in the sanitation sector spills over across municipal jurisdictions clarifying to what extent competition, learning and mimicking behaviour are of relevance.

### Urbanization

According to the thesis' findings, urbanization is positively correlated with the probability that wastewater treatment takes place in a Mexican municipality.<sup>171</sup> An explanation for that seem to be that urbanization and related higher population density cause, *ceteris paribus*, higher pollution levels in a given area. Therefore, intensified treatment efforts become necessary to offset increased pollution (Selden and Song, 1994; Grossmann and Krueger, 1995; Panayotou, 1997; Cole and Neumayer, 2004; Stern, 2005; Wong and Lewis, 2013). Like in the rest of Latin America which is worldwide the most urbanized region, population concentration is particularly high in Mexico. In 2010, 76.8% of the Mexican population lived in urban areas (INEGI, 2011; SEMARNAT, 2013). The majority of urban population concentrates in 59 metropolitan areas. While metropolitan areas occupy only 8.7% of the national territory they harbour 56.8% – i.e. 63.8 million people – of total population (SEMARNAT, 2013). That means that vast volumes of Mexican municipal wastewater volumes accrue in closely confined areas within the national territory of Mexico. This spatial concentration may require treatment to avoid or, at least, reduce major risks to the human health and the environment.

In addition, economies of scale are likely to be present in the abatement or mitigation of water pollution in form of municipal wastewater treatment. The construction, operation and maintenance of wastewater treatment systems contain a substantial fraction of fix costs – like the establishment and operation of a sewerage networks, pumping stations, central treatment plants, and the like. Thus, per capita costs tend to diminish with increasing population density (Parkinson and Tayler, 2003; Massoud et al., 2009). With affordability being often a key bottleneck for the implementation of municipal wastewater treatment infrastructure, high population density is seemingly a crucial funding requirement. The realization of economies of scale is the more likely the higher the number of people served within a given area. In

---

<sup>171</sup> The Tobit and Fractional Logit regression models on the estimated share of treated volumes of municipal wastewater do not include urbanization as independent variable due to a high observed correlation (68%) with GDP per capita in the sample. Typically per capita income is higher in urban areas. Since the sample contains only 425 observations including both terms as independent variables is econometrically not feasible. See for a detailed discussion of the topic subchapter 7.1.

this case, more individuals may share in the associated costs reducing in this way the per capita financial burden. A major obstacle that frequently impairs the realization of economies of scale in developing countries is that municipal sanitation regulations are too lax and without effect. Often, the general obligation to connect to the public sewage system is not enacted or enforced. However, in many cases it is indispensable that almost all household are connected to the system and share in the costs. Otherwise, the critical mass for the realization of economies of scales may not be reached even in densely populated areas. This issue is also common to many urbanized areas in Mexico (Olivares and Sandoval, 2008) and may reduce the magnitude and significance of urbanization as an explanatory factor of municipal wastewater treatment in the underlying data.

Previous empirical studies on several pollutant types produced mixed results. Some researchers did not find a significant correlation between population density and the degree of urbanization and environmental pollutants (e.g. Grossmann and Krueger, 1995; Cole and Neumayer, 2004). Others identify different types of significant correlations, e.g. a positive correlation (Stern, 2005) or an U-shape relationship (Panayotou, 1997). The empirical findings of this thesis may back the camp of proponents of a positive relation between urbanization and environmental performance.

### Level of education

In contrast to expectations, the underlying data does not lend empirical support to the hypothesis that a more educated municipal population advances municipal wastewater treatment performance. Theoretically, economic research considers education as having a positive effect on environmental performance. More educated individuals possess more information and knowledge on the negative consequence of environmental degradation and have, in consequence, higher preferences for an intact environment (Munasinghe, 1999; Bimonte, 2002). Likewise, more educated people should be better informed about health risks and environmental hazards originating from polluted water sources. Hence, educated constituencies should demand municipal wastewater treatment and support respective public policies. In addition, a higher education level of average population may increase the chance that the staff of the local public administration is better educated. This fact should help the municipal government to perform a better job on municipal water management, including municipal

wastewater treatment. Deficits in education and vocational training in this field are often an issue, particularly in developing countries (Barkin, 2011).

In contrast to the findings of this thesis, a good many of previous empirical studies confirm a positive correlation of environmental performance and various education indicators like average school attendance in years, share of graduated population and literacy rates (e.g. Torras and Boyce, 1998; Bhattarai and Hammig, 2004). However, instead of concluding without further ado a general absence of a causal relationship in the Mexican case, one may alternatively consider the high correlation between the indicators of education and per capita income in the underlying data as a possible explanation for the insignificance of the estimated education parameter.<sup>172</sup> On average, higher educated people thrive better in life economically (Barro, 1997; Gylfason, 2001; Zanden et al., 2014). This causal relation makes it difficult to differentiate effects on treatment performance resulting merely from education or income. A plausible explanation of the observed insignificance in the Mexican data could be that education affects municipal wastewater treatment performance indirectly through its interrelation with per capita income. More educated people may demand municipal wastewater treatment from municipal politics once their higher education pays off in terms of higher incomes as only then sufficient funding for municipal water infrastructure is available in a municipality. Regression models of this thesis that include lagged data on education and per capita income support this hypothesis to some extent. While the magnitude and significance of the parameter of the lagged education indicator increases, the reverse is true for the parameter of per capita income. Data-wise, a caveat against this interpretation is, however, that the standard deviation around the sample mean of education is rather low in the used data.<sup>173</sup> This rather suggests that the majority of Mexican municipality do not differ much in terms of education. In consequence, education may not have a great power in explaining differences in treatment performance across Mexican municipalities. This is, at least, the case if the UNDP Education Index is relied on as a measure for education. Future research that apply other measures for the quality of education in Mexican municipalities may produce different results.

---

<sup>172</sup> Compare Table 5 in subchapter 6.1.

<sup>173</sup> Compare Table 5 in subchapter 6.1.

### Female participation

The thesis also does not find empirical support for a significant positive influence of female participation in municipal politics on the municipal wastewater treatment performance.

Economic research has hypothesised on whether women are principally more concerned with environmental conservation arguing that they are more socially orientated due to the different socialization of both genders. Social norms may encourage women to be more cooperative and to assume the role of caregivers and nurturers, in particular for coming generations. As such, their views and perspectives may also include concerns on environmental degradation that potentially pose a risk to human health or a clean living environment (Stern et al., 1993; Stern and Dietz, 1994; Flynn et al., 1994; Greenbaum, 1995; Hunter et al., 2004; Torgler and García-Valiñas, 2007). Scientific surveys among women and men in North America and European countries have identified females as having generally fairly stronger pro-environmentalist attitudes, beliefs, value orientations, and concerns. This holds particularly true for environmental issues that occur locally and pose a significant health risk to the local and young population (Bord and O'Connor, 1997; Zelezny et al., 2000; Dietz et al., 2007; McCright, 2010; Sundström and McCright, 2013). Based on these empirical findings, a nascent string in the scientific debate investigates if women, once elected into political institutions, pursue as political decision makers more eco-friendly policies than their male counterparts (Svaleryd, 2009; Ergas and York, 2012; Sundström and McCright, 2013). So far, this research has produced mixed results (Papavero 2010, Fredriksson and Wang 2011, Gupta and Manish, 2012; Fielding et al., 2012; Sundström and McCright, 2013).

Based on this line of argumentation, one may expect female participation in local politics to have a positive influence on municipal wastewater treatment performance. Female politicians may generally pursue to a greater extent a policy that benefits the entire population and the environment than their male counterparts. It may include the execution of a stricter municipal sanitation and wastewater treatment policy in order to reduce health risks from waterborne diseases and to protect the local environment.

Though this hypothesis finds no empirical support in the general regression model, this changes when one controls for the interrelation between female participation and per capita income in the regression. Interestingly, a significant positive correlation between female par-

ticipation in municipal politics and the municipal wastewater treatment probability is observed once an interaction term between GDP per capita and the indicator of female participation is included in the regression model. At the same time, the interaction term affects the wastewater treatment probability significantly negatively. I.e. the main effect of female participation is positive – as expected by theory, but its interaction effect with GDP per capita exerts a negative impact – which is hard to explain by economic theory, if at all.<sup>174</sup>

### Ethnic heterogeneity

According to the thesis' empirical findings, ethnic heterogeneity has no impact on municipal wastewater treatment performance. The Mexican nation comprises several ethnicities. According to the official population census of 2010 (INEGI, 2010), 60% of the Mexican population are mestizos, 10% indigenes, 29% of European and about 1% of African descent. Worldwide, Mexico has the 11<sup>th</sup> biggest indigenous population (CIA, 2015a). At the municipal level, the percentage of indigenous population in total population vary from 0% or single digit percentages in most municipalities to up to 100% in few cases (INEGI, 2010).

Economic research associates ethnic fractionalization of a society with reduced levels of public good provision like clean environment. Possible reasons for that are the existence of heterogeneity in individuals' preferences, and rent seeking behaviour and corruption in social interaction (Easterly and Levine, 1997; Alesina et al., 1999 and 2003; Alesina and La Ferrara 2005; Habyarimana et al., 2007; Lieberman and McClendon, 2013; Gerring et al., 2015). On the one hand, ethnic diversity may imply differences in the preferences for public goods across social groups in regards to the type of the provided public good, its amount, and the time and place of provision. This increases transaction costs as more negotiation is required to reach an agreement in ethnically diverse societies. From there the underprovision of public goods like environmental protection may follow (Alesina and La Ferrara 2005; Habyarimana et al., 2007; Gerring et al., 2015). On the other hand, lower levels of social coherence may trigger rent seeking behaviour and corruption among public servants and officials. Instead of pursuing policies that maximize welfare, politicians might implement policies that maximize the utility of

---

<sup>174</sup> See for a detailed discussion subchapter 6.4.2.



their respective ethnic group at the expense of other parts of society (Videras and Bordoni, 2006; Glaeser and Saks, 2006; Papyrakis, 2013).

Accordingly, I would have expected a negative impact of ethnic heterogeneity on municipal wastewater treatment performance. Commonly, the administration of treatment service requires cooperation and political consensus among the municipal population. Hence, ethnic diversity may impair the implementation of such a policy, for instance, because ethnic groups differ in their preferences for unpolluted water and clean environment. To reach a political agreement to treat municipal wastewater might be difficult in such circumstances. Instead, local politicians may pursue rent seeking policies that favour their respective ethnicities and externalize associated costs to other ethnic groups in form of untreated municipal wastewater.

A possible explanation of the rather unexpected insignificance of ethnic heterogeneity in the Mexican case is that superior Mexican government tiers pursue policies that aim at levelling out to some extent disparities among different ethnicities. Generally, the national and federal state governmental tiers are dominated by non-indigenous Mexicans (Santibañez, 2016; Hernandez-Trillo, 2016). However, instead of cultivating an ethnic divide along governmental tiers some of their support programs for municipal water supply and sanitation target exclusively municipalities with increased shares of indigenous populations. The aim of this policy is to reduce or eliminate a perceived backwardness of communities with high shares of indigenous populations (Olivares and Sandoval, 2008; Peña et al., 2013; CONAGUA, 2011b, 2012b, 2013c, 2014e, 2015a and 2015b; SEMARNAT, 2014a). As mentioned previously, the national and state governmental tiers play an important role in the governance of municipal water supply and sanitation.

Furthermore, the correlation between the percentage of indigenous population and education and per capita income is relatively high in the underlying data.<sup>175</sup> From there it may follow that their effects on wastewater treatment performance are somewhat intermingled and may not be clearly attributable to one of these factors. Generally, indigenous population strata are less educated and poorer in Mexico (Hall and Patrinos, 2006; Santibañez, 2016; Hernandez-Trillo, 2016). This may mean that ethnic heterogeneity or an increased share of the indigenous

---

<sup>175</sup> Compare Table 5 in subchapter 6.1.

population in a municipality impact indirectly access to clean environment and municipal wastewater treatment via lower levels of per capita income. Public administrations in these municipalities might not have sufficient economic resources at their disposal to provide the service of municipal wastewater treatment. Future research may investigate this topic in further detail to scrutinize a causal relationship pattern of this kind.

Alternatively, one may argue that rent-seeking public servants that belong to a particular ethnic group may also have an incentive to establish the service of municipal wastewater treatment for their own ethnic groups and make other ethnicities in the municipality pay for it. In contrast to the explanations provided above, this rationale supports a positive relationship between ethnic heterogeneity and municipal wastewater treatment performance. Thus, the net effect of ethnic heterogeneity on municipal wastewater treatment may become unclear. The insignificance of estimated parameters for the indicators for ethnic heterogeneity in the thesis may reflect this ambiguity.

Generally, several empirical studies have confirmed a negative influence of ethnic fractionalisation on the provision of public goods (e.g. Easterly and Levine, 1997; Alesina et al., 1999, Baldwin and Huber, 2010; Jackson, 2013; Gerring et al., 2015). However, only few articles have investigated the relationship between ethnic diversity and environmental performance, finding different results. While Grafton et al., (2004) and Papyrakis (2013) confirm a negative relationship, Das and DiRienzo (2010) find a non-linear, and Gisselquist et al., (2016) even a positive relationship. The empirical findings of this thesis informs the ongoing debate further.

### Net water availability

Finally, the thesis does not find empirical evidence that reduced water availability incentivizes municipal administrations to perform better in municipal wastewater treatment. One may generally argue that recycling used water might become a viable economic strategy if water availability is limited (Zetland, 2011). Reusing municipal wastewater requires prior treatment to ensure adequate water quality though (Devia et al., 2007; Angelakis and Gikas, 2014).

Mainly two explanations might be given for the unexpected insignificant estimation result. On the one hand, a municipality may not have the incentive to treat municipal wastewater alt-

though it faces water scarcity. In the Mexican context, it might be still more efficient to externalize the damage of untreated municipal wastewater to neighbouring entities. Generally, the Mexican national water legislation stipulates that the nation owns the national water resources. Therefore, the national government is in charge of assigning use rights to different water user types. It mandates municipalities to pay for the right to discharge municipal wastewater. In addition, it fines illicit discharge (CONAGUA, 2006 and 2012a; Garza, 2008; Wester et al., 2009; OECD, 2013). However, fines for the discharge of untreated municipal wastewater are rather low. Furthermore, compliance of discharge limits of municipal wastewater is rarely monitored, and detected violations frequently not punished (Olivares and Sandoval, 2008; Wilder, 2010; Barkin, 2011; OECD, 2013; Peña et al., 2013). Likely, this defective charging, monitoring and enforcement policy reduces the incentives for municipalities to treat and reuse municipal wastewater even if water scarcity is prevailing.

On the other hand, one has to consider that the measure for net water availability, the thesis relies on, is only a rough indicator for the actual degree of water availability in a Mexican municipality. Net water availability is defined as the difference between available and consumed surface water in an area (CONAGUA, 2008a and 2013a; DOF, 2016). Municipalities with a negative net water availability are considered as suffering from surface water scarcity, and municipalities with a positive net water availability as surface water abundant localities. However, municipalities frequently rely on additional water resources, like groundwater (CONAGUA, 2013b). This holds in particular true in drier regions. Thus, relying only on surface net water availability may produce only a biased picture of the actual degree of water availability in an area. In addition, the data on net water availability is originally published on hydrological watersheds (CONAGUA, 2008a and 2013a; DOF, 2016). However, in most cases the geographic limits of hydrological watersheds do not correspond with the limits of municipalities. The data had to be adjusted therefore to the municipal level. This could have been done only in an approximate way. Therefore, it may provide only a rough indicator for the actual water availability in a municipality. However, no better indicator of water availability has been available to this thesis. Once available in the future, it is not excluded that the application of data of better quality cause the estimation result to turn significant and confirm the expected positive impact of water scarcity on municipal wastewater treatment performance.

### Equalisation and the corrective role of superior government tiers

Another interesting finding of the quantitative analysis of the Mexican municipal wastewater treatment sector is that it lends empirical support to the view that the action of superior governmental tiers is crucial to align developments in municipal sanitation among lower tier jurisdictions. One may conclude this from the goodness of fit of the binary outcome models. Overall, the goodness of fit is reasonable as these models predict more than 80% of the included Mexican municipalities correctly. However, social characteristics of municipalities do not explain all of the variance.

Frequently, it is beyond the economic, institutional and demographic capacity of municipalities and their administrations in a developing country to establish and operate municipal wastewater infrastructure by themselves. For this reason, they apply for funding the national government or the governments of other superior governmental layers provide to them to compensate for incapacities at the municipal level (Briceño, 2008; Peña et al., 2013). Accordingly, municipalities in Mexico rarely pursue municipal wastewater treatment projects without the co-investment and co-management of the national or federal state government tiers (Olivares and Sandoval, 2008; Aguilar Amilpa, 2010; SEMARNAT, 2014a; CONAGUA, 2015a).

This involvement of national or federal state governments may be a major reason why socio-economic, demographic and institutional characteristics do not explain all of the observed variance among Mexican municipalities. To some extent, the selection criteria of national and federal state funding programs for benefiting municipal entities differ from social characteristic that predestine, according to the model findings of this thesis, municipalities to treat municipal wastewater or not. For instance, some programs cater exclusively or partly the needs of marginalized or rural populations. Other programs support municipalities with increased percentages of indigenous population (Olivares and Sandoval, 2008; Peña et al., 2013; CONAGUA, 2011b, 2012b, 2013c, 2014e, 2015a and 2015b; SEMARNAT, 2014a). The existence of these programs may explain why the thesis does not find, for instance, empirical support for a significant negative influence of ethnic heterogeneity on municipal wastewater treatment performance. I.e. the empirical outcome of this thesis may support the hypothesis that the aid programs of the Mexican national government and the federal state governments help municipalities to provide municipal wastewater treatment that struggle to do so due to their social characteristics.

In line with this argumentation is also the observation that the applied binary outcome models are very good in predicting correctly non-treating municipalities conditional on socioeconomic, demographic and institutional factors. At the same time, they are less good in predicting correctly municipalities that actually treat wastewater. Generally, the models underpredict the number of treating municipalities. This may mean that municipalities that do not apply for funding of the national and state governments can be identified very well based on their socioeconomic, demographic and institutional characteristics. At the same time, municipalities that apply successfully for national and state funding are identified less well. A reason for this may be that the selection criteria of the national and federal state programs invite other municipalities to apply for funding in addition to the municipalities the models predict to apply due to their socioeconomic, demographic and institutional characteristics. A caveat against this interpretation is, however, that the classification of the applied goodness of fit test is generally sensitive to the relative sizes of the two included groups of treating and non-treating municipalities. It tends to underpredict the number of cases belonging to the smaller group (Kohler and Kreuter, 2012; Hosmer et al., 2013). Thus, the number of treating municipalities might be underpredicted anyway as the group of treating municipalities is significantly smaller in the used sample (ca. one-third vs. two-thirds).

Having said that, the findings of this thesis may lend nonetheless empirical support to the hypothesis that fiscal equalisation and financial compensation from superior governmental layers are important mechanisms to overcome or, at least, mitigate identified deficiencies at the municipal level. Their support is supposed to empower municipal governments to assume their local public functions, e.g. by providing local public goods and implementing measures that internalize environmental externalities of spatial spillovers (Ring, 2002; Boadway and Shah, 2007; Santos et al., 2012). This hypothesis has been relatively little scrutinized empirically so far (Wunder et al., 2008; Santos et al., 2012).

### 8.3. Shortcomings and future research

To some extent, a shortcoming of the applied research approach is the data. First of all, the thesis considers cross-sectional data at one point in time and not panel data. Supposedly, the status quo of municipal wastewater treatment performance at a certain point in time does not only depend on contemporaneous values of socioeconomic, demographic and institutional characteristics of Mexican municipalities but also on their past values. Hence, it would have been richer to compare changes in municipal wastewater treatment performance with changes in socioeconomic, demographic and institutional characteristics. A panel-data approach would have accounted for this. However, the collection of data to perform a time sensitive analysis was beyond the thesis' time constraints. It touches the topic only rudimentary by including lagged data of GDP per capita and education into alternative regression model runs. Further research might overcome this shortcoming. In this way, it may scrutinize and deepen the insights gained from the empirical analysis of this thesis.

Furthermore, the thesis' specification of municipal wastewater treatment performance as the probability municipal wastewater treatment takes place in a municipality and as the estimated percentage of treated municipal wastewater may comprise to some extent shortcomings. Alternatively, it would have been richer to specify the actual share of treated wastewater volumes as dependent variable. In addition, one may also consider the water quality of treated municipal wastewater. Lack of data impairs this approach though. For the majority of Mexican municipalities data is only available on whether wastewater treatment takes place or not. In consequence, the thesis investigates only the conditional probability that municipal wastewater treatment takes place. To some extent, this is a rather abstract measurement of wastewater treatment performance. Also the second measure of municipal wastewater treatment performance – the estimated percentage of treated municipal wastewater – is not a perfect measure as it constitutes only a rough approximation. For its calculation, it is uniformly assumed that 70% of the water supplied to municipal networks turn into wastewater (RAS, 2000; CONAGUA, 2007; IMTA, 2014a). In reality, the percentage of supplied water turned into wastewater varies, however, substantially across municipalities, e.g. due to different degrees

of leakages and clandestine abstraction (Barkin, 2006 and 2011). This should be kept in mind while generalizing the models' estimation results to reality.<sup>176</sup>

One may also criticise the interpretation of the empirical finding that the belonging of a municipality to a particular federal state in Mexico influences largely its performance in municipal wastewater treatment. It has been stated that observed differences among federal Mexican states may serve as a proxy for the institutional quality of their respective state water governance. As a caveat against this interpretation, one may point out that observed differences might be to some extent unrelated to institutional quality and due to other state specific characteristics. For instance, a government of a federal state might be urged to practise good water policies because the federal state experience water stress or water scarcity. Therefore water scarcity rather than good institutions might be the cause of good water governance. One may reply to this critic that increased needs and demand for a sound water governance find their expression rather likely in improved institutions.

Unfortunately, formal aspects of state water governance do not differ much across Mexican federal states since all states adopted largely the general water governance framework suggested by the Mexican national government (Garza, 2008; Pineda Pablos and Salazar Adams, 2008).<sup>177</sup> Otherwise the federal pluralism in formal institutional settings would have provided a good starting point to specify more precisely possible institutional causes of observed differences. Instead, differences in institutional quality seem to materialize more in informal or operational features. As such they are hard to detect. As a consequence, their identification in 32 Mexican federal entities has been beyond the scope of this thesis. Future research may perform qualitative interstate comparisons of water governance in Mexico in order to gain further insights.

In addition, future research may also include a qualitative inter-country analysis that investigates the design of formal institutional mechanisms for regulating, monitoring and enforcing

---

<sup>176</sup> For a detailed discussion of the topic see subchapter 5.1. Another reason to exercise some caution in regard of the prediction quality of the applied regression models may be that the underlying data fits not perfectly general model assumptions. This holds true in particular for the Tobit model which requires normality and homoscedasticity of the underlying data. This condition is not fulfilled mainly because the majority of included municipalities has a zero treatment rate. The observed non-normal distribution of the sample cannot be remedied though, e.g. by log-transformation.

<sup>177</sup> For a detailed discussion of the topic see chapter 3.

municipal wastewater discharge standards. As discussed previously, the Mexican water governance scheme tend to fail to monitor and enforce effectively enacted regulations on the discharge of municipal wastewater in national water bodies and the environment. A comparison with a more successful country that features similar societal characteristics may provide valuable insights on institutional factors that foster compliance and help to internalize effectively negative externalities of untreated wastewater.

Finally, the empirical finding of the thesis that municipal wastewater treatment performance spillovers among neighbouring municipalities in Mexico may serve as a starting point for further research. It might be investigated if and how the successful implementation of municipal wastewater treatment in a municipality might trigger a region-wide domino effect. In addition, it might be researched how the implementation of flagship projects at local levels in developing countries may channel regional development and catalyse environmental protection in the field of municipal sanitation and wastewater treatment. A qualitative analysis of selected cases may reveal the exact mechanisms how innovation in the sanitation sector spills over across municipal jurisdictions clarifying in this way to what extent competition, learning and mimicking behaviour are of relevance.

#### **8.4. Policy recommendations**

The overall findings of the thesis may allow to develop some general policy recommendations.

##### The establishment of subnational learning platforms

The thesis' results suggest that the belonging of a municipality to one of the 31 Mexican federal states or the Federal District of Mexico-City impacts substantially its municipal wastewater treatment performance. As reason for that, the thesis identifies differences in water governance. In consequence, it might be helpful to establish closer and more institutionalized links among water administrations of federal states to facilitate or foster learning and knowledge spill overs. Establishing permanent meeting platforms and channels could enable representatives and public officials of the different federal states to exchange their experiences in the management of municipal water supply and sanitation.



In Mexico, for example, representatives of the water administrations of the national, federal state and municipal government level gather regularly at national events – the so called ‘Encuentros Nacionales’. Usually, different Mexican national water associations – like ANEAS (Asociación Nacional de Empresas de Agua y Saneamiento de México), ANNCA (Asociación Nacional por una Nueva Cultura del Agua), ANATEC (Asociación Nacional de Áreas Técnicas), and ACOOA (Asociación Nacional de Áreas Comerciales) – host these events periodically at varying places in Mexico. Topics discussed during these events relate to different fields of municipal water governance, e.g. technical aspects of municipal water management (IIIEENATEC, 2016), integrated management of municipal water (XIIENCA, 2015) or the commercialization of water utility services (XVIIIENAC, 2016). Though water administrations of federal states participate pro-actively in these events (XIIENCA, 2015), the foci of discussion are not systematically put on the institutional role of federal states and on the discussion why municipal water and sanitation governance differ across federal states.

Creating an independent forum for that particular topic may provide an important stepping stone to spread successful municipal water policies and institutional settings across inferior government tiers in developing countries. It is not uncommon to observe institutional rivalry between water administrations of different government tiers within a country. For instance, Wester et al., (2009) diagnose for Mexico a long-lasting conflict of competence between the National Water Commission CONAGUA and State Water Commissions. Thus, it may be of some advantage to establish respective exchange and support channels independently from the national institutional framework. This may help to avoid political capture of the established institution and its misuse as an arena for turf wars between different governmental tiers.

To some extent, the water policy the Mexican national government pursues in the international arena may serve as a blue print. Particularly within Latin-America, the Mexican National Water Commission CONAGUA forms actively part of several development co-operations. Mexico is generally considered as a primus in the region when it comes to good practise in national water governance (Wester et al., 2009; GIZ, 2017). In consequence, CONAGUA supports several development projects in the region, e.g. in the Dominican Republic, Central America, Ecuador, and Bolivia. Frequently, it provides expertise that has been gained from its own experience to other nations (CONAGUA, 2012c; GIZ, 2017). Such a type of relationship may also be

established among Mexican federal states to advance their municipal water sectors. Furthermore, it may be also conceivable to generalize from the case of municipal wastewater treatment and water pollution to other environmental issues. In the future, authorities of inferior governmental tiers may also exchange their views and knowledge on other policies that have been proven to tackle successfully environmental issues in an institutionalized framework.

### Fine-tuning of aid programs

To facilitate a more even development across municipalities, superior governmental tiers of a developing country could cater their support programs better towards the needs of deficient and weak municipalities. This may require the fine-tuning of the selection criteria for benefiting municipalities and the provision of better technical assistance to enable those municipalities to participate successfully in support programs (Bird and Smart, 2002). Aid programs of the Mexican National Water Commission CONAGUA require, for instance, municipal administrations or public water utilities to bear a share of the investment costs (Olivares and Sandoval, 2008; Peña et al., 2013; SEMARNAT, 2014a; CONAGUA, 2015a and 2015b). However, it is not uncommon to see municipal administrations to run chronic deficits in municipal infrastructure investments which renders them unable to keep up with required investments in projects that, inter alia, sustain population health and preserve environmental quality (Mirza, 2007). Program designs should account better for these potential obstacles. If administrations or public water utilities are unable to raise sufficient own funds, for instance, because they are located in municipalities with low per capita incomes, national funding mechanisms should provide an alternative access to support programs. Aid programs may also consider that some municipalities are small with low rates of urbanization or have institutions of low quality that are administratively overstained to design or implement complicated infrastructure projects like municipal wastewater treatment service systems (FCM, 2008; Mehriiz, 2016).

Partially, CONAGUA has taken these shortcomings into consideration by launching programs of technical assistance with the aim to eliminate institutional deficiencies, or programs that cater towards municipalities with e.g. high rates of marginalization, rural or indigenous population (CONAGUA, 2011b; 2012b, 2013c, 2014e, 2016; SEMARNAT, 2014a). However, according to academic analysis the undertaken efforts have produced suboptimal results (Martinez Omaña, 2006; Contreras Zepeda, 2006; Barkin, 2011). Also, additional efforts may be required

to interlock water infrastructure programs of different national and federal state institutions more effectively. To pursue their genuine missions, other national government institutions like the Ministry of Social Development (SEDESOL), National Commission for the Development of Indigenous Peoples (CDI), and the National Commission of Housing (CONAVI) engage also partly in the funding of the Mexican municipal water and sanitation sector. Tighter coordination among these entities might produce improved results, particularly in municipalities with social characteristics that disfavour the well-functioning of municipal wastewater treatment.

#### Establishment of flagship projects

From the spillover of municipal wastewater treatment performance among neighbouring municipalities, it may follow to implement so called flagship or pilot projects in regions where no municipal wastewater treatment takes place. The establishment of a municipal wastewater treatment system in a particular municipality may disseminate as a good practise region-wide and motivate surrounding municipalities to engage in treatment activities as well. As an exemplary project it may help to demonstrate the feasibility of municipal wastewater treatment in the social and geographic settings of a region. In consequence, the innovation may diffuse spatially (Myers, 1978; Magill and Rogers, 1981; Klitkou et al., 2013; Huguenin and Jeannerat, 2017). To exploit this leverage effect, national and federal state funding agencies may consider the location and the potential for producing spatial spillover effects of municipalities they select to benefit from their support programs.

## 9. Appendix

### 9.1. Appendix tables

**Table A.1: Country ranking of renewable water availability per capita, 2011**

No.	Country	Total population (1000 inhabitants)	Total renewable water resources (km <sup>3</sup> /year)	Total renewable water resources per capita (m <sup>3</sup> /inhabitant/year)
1	Iceland	324	170	524.7
2	Guyana	756	241	318.8
3	Suriname	529	122	230.6
4	Congo	4,140	832	201
5	Papua New Guinea	7,014	801	114.2
6	Gabon	1,534	164	106.9
7	Bhutan	738	78	105.7
8	Canada	34,350	2,902	84.5
9	Salomon Islands	552	45	81
10	Norway	4,925	382	77.6
11	New Zealand	4,415	327	74.1
12	Peru	29,400	1,913	65.1
13	Bolivia	10,088	623	61.7
14	Belize	318	19	58.3
15	Liberia	4,129	232	56.2
16	Chile	17,270	922	53.4
17	People's Democratic Republic of Lao	6,288	334	53.0
18	Paraguay	6,568	336	51.2
19	Colombia	46,927	2,132	45.4
20	Venezuela	29,437	1,233	41.8
21	Brazil	196,655	8,233	41.9
59	United States of America	313,085	3,069	9.8
<b>89</b>	<b>Mexico</b>	<b>115,683</b>	<b>471</b>	<b>4.1</b>
97	France	63,126	211	3.3
107	Turkey	73,640	212	2.9
147	South Africa	50,460	51	1.0

Source: CONAGUA (2014). Estadísticas del Agua en México 2013, p. 138, modified by author.

Note: 1 km<sup>3</sup> = 1.000 hm<sup>3</sup> = 1 billion of m<sup>3</sup>.

**Table A.2: Country ranking of annual water withdrawal per capita, 2003-2013**

No.	Country	Total water withdrawal (km <sup>3</sup> /year)	Total water withdrawal per capita (m <sup>3</sup> /inhabitant/year)
1	Turkmenistan	27.95	5,753
2	Chile	35.43	2,126
3	Uzbekistan	56.00	2,100
4	Guyana	1.45	1,818
5	Tajikistan	11.49	1,616
6	United States of America	478.40	1,575
7	Kyrgyzstan	8.01	1,560
8	Iran	93.30	1,299
9	Kazakhstan	21.14	1,299
10	Azerbaijan	11.97	1,286
12	Suriname	0.62	1,208
17	Argentina	37.78	920
23	Venezuela	22.63	818
26	Dominican Republic	7.16	696
27	Ecuador	9.92	695
29	<b>Mexico</b>	<b>80.30</b>	<b>665</b>
32	Cuba	6.96	618
33	India	761.00	615
34	Turkey	40.10	577
36	France	33.11	518
38	Costa Rica	2.35	476
40	Peru	13.66	456
44	Germany	33.04	399
45	Brazil	74.83	377
46	Paraguay	2.41	361
47	El Salvador	2.12	346
52	Jamaica	0.81	300
54	Trinidad and Tobago	0.38	287
57	Panama	1.04	273
58	Puerto Rico	1.00	266
60	Nicaragua	1.55	258
61	Guatemala	3.32	250
63	Colombia	11.77	247
65	Honduras	1.61	224
66	Bolivia	2.09	199
69	United Kingdom	10.83	172
73	Haiti	1.45	143

Source: FAO (2015). AQUASTAT database, consulted on 2015/10/09.

Note: 1 km<sup>3</sup> = 1.000 hm<sup>3</sup> = 1 billion of m<sup>3</sup>

**Table A.3: Country ranking Criticality Ratio, 2003-2013**

No.	Country	Freshwater withdrawal as % of total renewable water resources (%)
1	United Arab Emirates	1,867%
2	Saudi Arabia	943%
3	Qatar	374%
4	Bahrain	206%
5	Yemen	167%
6	Turkmenistan	113%
7	Uzbekistan	101%
8	Jordan	92%
9	Barbados	88%
10	Oman	85%
27	Dominican Republic	30%
35	Germany	21%
<b>43</b>	<b>Mexico</b>	<b>17%</b>
47	United States of America	16%
48	France	16%
51	Puerto Rico	14%
62	Haiti	10%
67	Trinidad and Tobago	9%
69	El Salvador	8%
84	Argentina	4%
86	Chile	4%
93	Guatemala	3%
95	Ecuador	2%
96	Costa Rica	2%
100	Honduras	2%
101	Venezuela	2%
112	Nicaragua	1%
114	Brazil	1%
116	Panama	0.7%
117	Peru	0.7%
118	Paraguay	0.6%
119	Suriname	0.6%
121	Guyana	0,5%
122	Colombia	0,5%
126	Bolivia	0,4%

Source: FAO (2015). AQUASTAT database, consulted on 2015/10/09

**Table A.4: Wastewater treatment in federal states, 2011**

Federal State	In operation			
	N° of plants	Capacity installed (l/s)	Volumes treated (l/s)	Treatment cover-age in %(l/s)
Aguascalientes	132	4,783.5	3,351.7	100.0
Baja California	36	7,568.6	5,732.9	99.7
Baja California Sur	23	1,447.5	1,062.8	60.9
Campeche	26	174.5	147.3	7.8
Chiapas	31	1,543.5	856.0	21.5
Chihuahua	156	9,207.3	6,459.2	74.2
Coahuila de Zaragoza	20	4,956.5	3,858.0	47.4
Colima	59	1,773.5	1,349.1	52.5
Distrito Federal	28	6,770.5	3,329.8	15.1
Durango	173	4,351.9	3,345.7	71.2
Guanajuato	62	5,990.4	4,443.6	53.2
Guerrero	58	3,890.8	3,147.0	82.4
Hidalgo	17	377.5	367.2	14.5
Jalisco	151	7,016.3	5,256.3	36.8
México	139	8,743.0	6,493.9	27.4
Michoacán de Ocampo	32	3,654.5	2,845.6	31.0
Morelos	50	2,777.7	1,810.6	27.7
Nayarit	64	2,393.6	1,628.4	79.1
Nuevo León	60	1,7494.0	1,0250.1	100.0
Oaxaca	69	1,520.5	995.1	41.0
Puebla	70	3,213.9	2,767.8	55.2
Querétaro de Arteaga	84	2,293.4	1,500.3	46.0
Quintana Roo	34	2,350.5	1,724.2	67.1
San Luis Potosí	38	2,509.9	2,115.2	60.5
Sinaloa	210	5,794.6	5,004.1	76.6
Sonora	81	4,932.5	3,027.2	35.9
Tabasco	77	2,077.9	1,613.9	21.8
Tamaulipas	45	7,782.8	5,876.1	84.6
Tlaxcala	63	1,117.2	818.5	53.0
Veracruz de Ignacio de la Llave	105	6,911.9	5,359.4	41.7
Yucatán	28	491.4	99.1	2.7
Zacatecas	68	1,170.8	1,004.3	24.3
<b>Total national</b>	<b>2,289</b>	<b>137,082</b>	<b>97,640</b>	<b>46.5</b>

Source: CONAGUA (2012), Situación del Subsector Agua Potable, Alcantarillado y Saneamiento, p.50, modified by the author.

**Table A.5: Investment in municipal water (Mex\$ MN), 2002-14**

<b>Year</b>	<b>National</b>	<b>State</b>	<b>Municipal</b>	<b>Other</b>	<b>Total</b>
2002	2,293.0	1,146.0	695.0	6,285.0	10,419.0
2003	4,237.7	2,147.5	1,926.8	4,121.5	12,433.5
2004	4,071.4	3,035.4	1,386.5	4,996.0	13,489.4
2005	7,085.3	4,988.4	2,917.8	6,615.9	21,607.3
2006	5,771.4	2,699.2	2,817.4	4,440.5	15,728.5
2007	9,432.6	4,140.4	2,714.2	5,230.2	21,517.4
2008	12,318.7	6,279.2	3,237.2	4,484.7	26,319.8
2009	14,815.3	5,596.3	3,642.6	6,192.8	30,247.0
2010	16,965.9	5,318.1	3,729.2	5,487.8	31,501.0
2011	20,197.8	7,187.7	3,975.3	6,114.2	37,474.9
2012	24,661.6	6,861.9	2,913.7	6,065.1	40,502.2
2013	22,984.4	5,880.5	3,296.1	4,952.0	37,113.1
2014	20,512.4	5,620.3	3,248.4	4,825.1	34,206.2

Source: CONAGUA (2015). Situación del Subsector Agua Potable, Alcantarillado y Saneamiento, p. 8, modified by the author.



**Table A.6: Investment by field of application (Mex\$ MN), 2002–14**

Year	Potable Water Supply	Sewerage	Wastewater Treatment	Efficiency Improvement	Other	Total
2002	3.567,5	4.041,6	1.531,6	1.196,7	81,8	10.419,2
2003	5.180,6	4.932,5	1.209,3	935,2	175,8	12.433,5
2004	5.352,8	5.442,5	1.539,0	1.084,4	70,7	13.489,4
2005	8.392,2	8.237,8	3.266,8	1.592,9	117,7	21.607,3
2006	5.445,0	5.823,2	1.821,3	2.392,7	246,4	15.728,5
2007	9.345,3	7.420,7	1.735,2	2.449,5	566,6	21.517,4
2008	10.497,0	9.356,9	2.312,2	3.050,1	1.103,6	26.319,8
2009	9.960,9	10.847,9	2.277,6	5.427,7	1.732,8	30.247,0
2010	9.159,0	12.373,2	2.855,4	4.863,3	2.250,1	31.501,0
2011	9.044,1	13.961,4	7.707,2	4.587,5	2.174,6	37.474,9
2012	10.880,9	7.401,3	15.913,2	3.777,9	2.529,0	40.502,2
2013	10.624,3	12.785,1	7.421,0	4.606,8	1.675,9	37.113,1
<b>2014</b>	<b>10.355,9</b>	<b>10.018,4</b>	<b>5.576,3</b>	<b>6.335,1</b>	<b>1.920,5</b>	<b>34.206,2</b>

Source: CONAGUA (2015). Situación del Subsector Agua Potable, Alcantarillado y Saneamiento, p. 11, modified by the author.

**Table A.7: CONAGUA programs wastewater treatment (Mex\$ mn), 2014**

Investment Program	Total Amount	Federal Investment	State Investment	Municipal Investment	Other Sources (e.g. Private Capital)
PROVAGUA	2,224.7	974.4	806.5	-	504.5
PROTAR	1,818.7	1,170.0	492.1	102.8	53.9
APAZU	171.0	n.a.	n.a.	n.a.	n.a.
PRODDER	373.9	187.0	-	187.0	-
PROSSAPYS	0.0	-	-	-	-
Other Projects	28.6	n.a.	n.a.	n.a.	n.a.
Non-CONAGUA Investment	959.4	n.a.	n.a.	n.a.	n.a.
<b>Sum</b>	<b>5,576.3</b>	<b>n.a.</b>	<b>n.a.</b>	<b>n.a.</b>	<b>n.a.</b>

Source: CONAGUA (2015). Situación del Subsector Agua Potable, Alcantarillado y Saneamiento, p. 15, modified by the author.

**Table A.8: Distance matrix of Mexican municipalities (km)**

**Info:** The distances have been calculated approximately by using the Pythagoras formula:  $Distance = \sqrt{[dx]^2 + [dy]^2}$  where dx and dy denominate the distances between the longitudes and latitudes of 2 localities respectively. To calculate the distances in kilometres it has been assumed:  $dx = 111.3 * \cos(lat) * (lon1 - lon2)$  and  $dy = 111.3 * (lat1 - lat2)$  whereby lon1 and lon2 represent the longitudes of locality 1 and locality 2, and lat1 and lat2 the latitudes of locality 1 and locality 2 respectively. Moreover, as the distance between two longitudes vary from 111.3 km at the Equator to 0 km at the North Pole dx has to be adjusted according to the latitudes of locality 1 and 2. This is commonly done by multiplying the cosine of the average latitude of locality 1 and 2 ( $\cos(lat)$ ) with the distance between two latitudes at the Equator (ca. 111.3 km). Hence  $lat = (lat1 + lat2) / 2 * \pi / 180$ . In addition, the average latitude has to be multiplied by  $\pi / 180$  for technical reasons since  $(lat1 + lat2) / 2$  is expressed in degrees while the software to calculate the distances frequently requires Radian values. Generally, calculated distances are only approximations as the formula does not consider earth's curvature. However, as this study is merely interested in estimating the impact of the behaviour of nearby municipalities the applied formula suits well enough its purpose as at near distances the earth may be considered to be rather flat.

Source: Own calculation based on information from SNIM – Mexican National System of Municipal Information (2015).

**Table A.9: Correlation of variables (WWT=1)**

(obs=1996)

	WWT	gdpcap	gini	eduind	urban	fracind	ethnic	femadmin	neighmun	regind	planind
WWT	1.0000										
gdpcap	0.4143	1.0000									
gini	0.1265	0.1710	1.0000								
eduind	0.3450	0.6923	-0.0029	1.0000							
urban	0.3053	0.6221	0.1669	0.3471	1.0000						
fracind	-0.2444	-0.3293	0.1182	-0.3473	-0.1582	1.0000					
ethnic	-0.2698	-0.4814	0.0144	-0.6303	-0.1876	0.5479	1.0000				
femadmin	0.2488	0.2753	0.0921	0.2508	0.1589	-0.1572	-0.2486	1.0000			
neighmun	0.5035	0.4452	0.0864	0.4023	0.2339	-0.3196	-0.3602	0.3287	1.0000		
regind	0.2612	0.2889	0.1510	0.2349	0.2499	-0.1880	-0.2392	0.2204	0.3040	1.0000	
planind	0.1071	0.1214	0.0604	0.0718	0.1064	-0.0533	-0.0675	0.0892	0.0856	0.0581	1.0000

Source: Own calculations, using Stata 13.

**Table A.10: Wald test for planind and regind**

```
. quietly logit WWT gdpcap gini eduind urban fracind ethnic femadmin neighmun planind regind i.waterutility i.Campeche i
> .Coahuila i.Chiapas i.Chihuahua i.DF i.Durango i.Guanajuato i.Guerrero i.Hidalgo i.Jalisco i.Mexico i.Michoacan i.Mo
> relos i.Nayarit i.Oaxaca i.Puebla i.Queretaro i.QuintanaRoo i.SanLuisPotosi i.Sonora i.Tabasco i.Tamaulipas i.Tlaxcala
> i.Veracruz i.Yucatan i.Zacatecas

. test planind regind

( 1) [WWT]planind = 0
( 2) [WWT]regind = 0

      chi2( 2) =      4.35
      Prob > chi2 =     0.1135
```

Source: Own calculations, using Stata 13.

**Table A.11: LR-test logit model 1 and 2**

```
. quietly logit WWT gdpcap gini eduind urban fracind ethnic femadmin neighmun planind regind i.waterutility i.Campeche i
> .Coahuila i.Chiapas i.Chihuahua i.DF i.Durango i.Guanajuato i.Guerrero i.Hidalgo i.Jalisco i.Mexico i.Michoacan i.Mo
> relos i.Nayarit i.Oaxaca i.Puebla i.Queretaro i.QuintanaRoo i.SanLuisPotosi i.Sonora i.Tabasco i.Tamaulipas i.Tlaxcala
> i.Veracruz i.Yucatan i.Zacatecas

. estimates store B

. quietly logit WWT gdpcap gini eduind urban fracind ethnic femadmin neighmun i.waterutility i.Campeche i.Coahuila i.Chi
> apas i.Chihuahua i.DF i.Durango i.Guanajuato i.Guerrero i.Hidalgo i.Jalisco i.Mexico i.Michoacan i.Morelos i.Nayarit
> i.Oaxaca i.Puebla i.Queretaro i.QuintanaRoo i.SanLuisPotosi i.Sonora i.Tabasco i.Tamaulipas i.Tlaxcala i.Veracruz i.Yu
> catan i.Zacatecas

. lrtest B

Likelihood-ratio test                                LR chi2(2) =      4.37
(Assumption:  nested in B)                          Prob > chi2 =     0.1125
```

Source: Own calculations, using Stata 13.

**Table A.12: Complete results of binary outcome models**

Dependent Dummy Variable: y=1 → Wastewater treatment takes place in a Mexican municipality y=0 → no wastewater treatment	OLS		Logit		Probit		Heteroskedastic probit		Cloglog		OLS		Logit		Probit		Heteroskedastic probit		Cloglog						
	model 1		model 1		model 1		model 1		model 1		model 2		model 2		model 2		model 2		model 2						
	parameter	t-stat	parameter	t-stat	parameter	t-stat	parameter	t-stat	parameter	t-stat	parameter	t-stat	parameter	t-stat	parameter	t-stat	parameter	t-stat	parameter	t-stat	parameter	t-stat			
GDP per capita in 2010 (gdp pcap)	.01026683**	(2.51)	.08993587***	(2.80)	.05119265***	(2.97)	.05085236***	(2.93)	.04249363**	(2.28)	.01100312***	(2.85)	.09171633***	(3.08)	.05126211***	(3.18)	.05112366***	(3.16)	.04236529***	(2.43)					
GINI coefficient in 2010 (gini)	.00421189*	(1.71)	.03551542*	(1.94)	.0202597*	(1.93)	.02049164*	(1.94)	.02582877*	(1.95)	.00627144***	(2.72)	.05017621***	(2.98)	.02855942***	(2.95)	.0286518***	(2.94)	.03636824***	(3.01)					
Education Index in 2010 (eduind)	.00171042	(0.83)	.01064213	(0.60)	.00742754	(0.77)	.00725622	(0.75)	.01909528	(1.37)	.00202984	(1.04)	.01389629	(0.84)	.00952999	(1.06)	.00945896	(1.05)	.0236954*	(1.83)					
Percentage of urbanization in 2010 (urban)	.00129605***	(2.65)	.00737178**	(2.15)	.00446716**	(2.26)	.00449868**	(2.27)	.00504103**	(2.41)	.00143534***	(3.14)	.00787089**	(2.51)	.00489525***	(2.70)	.00490721***	(2.70)	.0055828***	(2.89)					
Ethnic fractionalization Index in 2010 (fracind)	-.00016906	(-0.25)	-.00008234	(-0.01)	-.00030448	(-0.10)	-.00028223	(-0.09)	-.00043286	(-0.09)	-.00033366	(-0.53)	-.00113647	(-0.21)	-.00096036	(-0.33)	-.00094615	(-0.33)	-.00075349	(-0.17)					
Percentage of indigenous population in 2010 (ethnic)	.00032819	(0.81)	.00195814	(0.53)	.00126377	(0.64)	.00122686	(0.62)	.00027491	(0.08)	.00028754	(0.75)	.00154467	(0.44)	.00112484	(0.61)	.00110425	(0.60)	.00006245	(0.02)					
Percentage female members in municipal government 2005 (femadmin)	.00038063	(0.51)	.00256459	(0.46)	.00122645	(0.39)	.00119613	(0.38)	.00156399	(0.40)	.00033425	(0.48)	.0020407	(0.40)	.00102581	(0.35)	.00101626	(0.35)	.00141363	(0.40)					
Percentage of neighbouring municipalities with WWT in 2010 (neighmun)	.00163827***	(4.33)	.00959789***	(3.93)	.00572811***	(3.99)	.00573318***	(3.98)	.00594002***	(3.60)	.00177985***	(5.13)	.01040749***	(4.70)	.006205***	(4.79)	.00620931***	(4.78)	.00674847***	(4.52)					
Index of strategic planning and municipal evaluation in 2012 (planind)	.00065102**	(2.07)	.00482344**	(2.08)	.00282215**	(2.12)	.00285325**	(2.12)	.00341508**	(2.02)															
Index of basic municipal regulation implementation in 2010 (regind)	.00007521	(0.29)	.00034802	(0.18)	.00032497	(0.30)	.00033438	(0.31)	.00085496	(0.65)															
Dummy for public municipal water utility (waterutility)	.1314915***	(4.32)	.63506326***	(3.06)	.36388049***	(3.03)	.36615256***	(3.03)	.3489319***	(2.58)	.11936375***	(4.24)	.56083797***	(2.99)	.32473812***	(2.98)	.32581743***	(2.97)	.30603829**	(2.50)					
Dummy for belonging to the State of Campeche	-.49999869***	(-3.88)	-.4563772***	(-3.56)	-.2442782***	(-3.92)	-.24535487***	(-3.91)	-.2378615***	(-3.34)	-.47802881***	(-3.73)	-.35510937***	(-3.62)	-.20143433***	(-3.74)	-.2018358***	(-3.72)	-.19222762***	(-3.00)					
Dummy for belonging to the State of Coahuila	-.38479744***	(-4.42)	-.39750028***	(-3.56)	-.20887708***	(-4.16)	-.20977052***	(-4.15)	-.18509454***	(-4.22)	-.41270753***	(-5.31)	-.31990118***	(-4.44)	-.18000809***	(-4.85)	-.18303122***	(-4.84)	-.17299056***	(-4.70)					
Dummy for belonging to the State of Chiapas	-.47689228***	(-6.61)	-.43416563***	(-3.96)	-.2840776***	(-4.79)	-.2916847***	(-4.78)	-.23605522***	(-5.28)	-.45218741***	(-6.90)	-.3118196***	(-5.46)	-.18480974***	(-6.36)	-.18507281***	(-6.36)	-.20252003***	(-5.64)					
Dummy for belonging to the State of Chihuahua	-.08453973	(-1.20)	-.25703547**	(-2.38)	-.12479185***	(-2.67)	-.12494276***	(-2.73)	-.96244328***	(-2.73)	-.05036823	(-0.76)	-.15001606**	(-2.16)	-.7784158**	(-2.16)	-.77817048**	(-2.16)	-.610714**	(-2.15)					
Dummy for belonging to the State of DF	-.41523279***	(-3.52)	-.6882589***	(-3.69)	-.2613483***	(-4.43)	-.26168923***	(-4.43)	-.2582492***	(-4.70)	-.4151108***	(-3.64)	-.37817922***	(-3.95)	-.2501727***	(-4.57)	-.2511835***	(-4.57)	-.2377607***	(-4.85)					
Dummy for belonging to the State of Durango	.12709727	(1.51)	-.13950019	(-1.10)	-.0427395	(-0.07)	-.03580115	(-0.06)	-.11990065	(-0.29)	.15773044**	(2.08)	1.0899343	(0.92)	.47968142	(0.94)	.48350666	(0.95)	.23336121	(0.67)					
Dummy for belonging to the State of Guanajuato	-.1688809**	(-2.18)	-.28469611***	(-2.62)	-.14047038***	(-2.94)	-.14103355***	(-2.95)	-.10894659***	(-2.92)	-.16174782**	(-2.23)	-.19522437***	(-2.80)	-.10434642***	(-2.94)	-.10454263***	(-2.94)	-.84692272***	(-2.76)					
Dummy for belonging to the State of Guerrero	-.30579792***	(-3.87)	-.3157228***	(-3.04)	-.16919259***	(-3.52)	-.16992917***	(-3.52)	-.14199129***	(-3.44)	-.30915843***	(-4.53)	-.25007706***	(-3.67)	-.13760509***	(-4.02)	-.13788032***	(-4.02)	-.12670257***	(-3.93)					
Dummy for belonging to the State of Hidalgo	-.53381957***	(-7.75)	-.46812319***	(-4.33)	-.24763834***	(-5.33)	-.24810236***	(-5.33)	-.25331724***	(-5.98)	-.51804298***	(-7.92)	-.37482726***	(-6.09)	-.20951686***	(-6.09)	-.20965796***	(-6.12)	-.29252579***	(-6.12)					
Dummy for belonging to the State of Jalisco	-.21698142***	(-3.55)	-.1364825***	(-3.00)	-.15830323***	(-3.58)	-.15860265***	(-3.58)	-.12991226***	(-3.93)	-.18557437***	(-3.32)	-.2124886***	(-3.32)	-.1498075***	(-3.32)	-.1505532***	(-3.32)	-.98607971***	(-3.75)					
Dummy for belonging to the State of Mexico	-.32889217***	(-5.40)	-.36751433***	(-3.52)	-.19087722***	(-4.32)	-.19143637***	(-4.32)	-.16637761***	(-4.97)	-.31294535***	(-5.46)	-.26934828***	(-4.21)	-.14974827***	(-4.79)	-.14989894***	(-4.78)	-.13932994***	(-5.17)					
Dummy for belonging to the State of Michoacan	-.52749074***	(-8.05)	-.45988701***	(-4.31)	-.24694554***	(-5.40)	-.24755534***	(-5.40)	-.23964094***	(-6.11)	-.50991636***	(-19.19)	-.36413025***	(-6.21)	-.20721087***	(-6.20)	-.20741211***	(-6.20)	-.21260447***	(-6.30)					
Dummy for belonging to the State of Morelos	-.33053459***	(-3.13)	-.36261417***	(-3.13)	-.1883738***	(-3.47)	-.18876758***	(-3.47)	-.15960073***	(-3.17)	-.26910378***	(-3.26)	-.24973602***	(-3.44)	-.13758292***	(-3.63)	-.13769419***	(-3.63)	-.12036975***	(-3.34)					
Dummy for belonging to the State of Nayarit	.09760383	(0.99)	-.76884858	(-0.53)	-.21260217	(-0.32)	-.20854845	(-0.31)	.04811087	(0.09)	.11324586	(1.15)	.1920882	(0.16)	.18092631	(0.30)	.18338214	(0.31)	.29928082	(0.61)					
Dummy for belonging to the State of Oaxaca	-.50094345***	(-8.00)	-.46087292***	(-4.36)	-.24467373***	(-5.45)	-.24555763***	(-5.44)	-.26753452***	(-7.32)	-.47691694***	(-8.21)	-.36262728***	(-6.39)	-.20357309***	(-6.36)	-.20391468***	(-6.36)	-.23752923***	(-7.96)					
Dummy for belonging to the State of Puebla	-.39844205***	(-6.55)	-.37283939***	(-3.57)	-.19389525***	(-4.39)	-.19469723***	(-4.39)	-.18120831***	(-5.29)	-.37565209***	(-6.55)	-.27308999***	(-4.85)	-.15215456***	(-4.85)	-.15244082***	(-4.85)	-.15204026***	(-5.43)					
Dummy for belonging to the State of Queretaro	.00434742	(0.04)	-.19809625*	(-1.66)	-.91877982*	(-1.68)	-.92269834*	(-1.68)	-.66019762	(-1.48)	.00946424	(0.09)	-.1056831	(-1.23)	-.53866473	(-1.19)	-.5398031	(-1.20)	-.40655953	(-1.01)					
Dummy for belonging to the State of QuintanaRoo	-.18421205	(-0.96)	-.3030499*	(-1.90)	-.14551671*	(-1.69)	-.14559013*	(-1.68)	-.10347074	(-1.31)	-.1616101	(-0.94)	-.1949234	(-1.44)	-.98313403	(-1.26)	-.98232146	(-1.25)	-.70199437	(-0.96)					
Dummy for belonging to the State of SanLuisPotosi	-.40543243***	(-5.21)	-.38860762***	(-3.56)	-.20497503***	(-4.29)	-.20550029***	(-4.29)	-.19046513***	(-4.54)	-.39556772***	(-5.44)	-.29606416***	(-4.21)	-.16751438***	(-4.71)	-.16768427***	(-4.71)	-.16568781***	(-4.63)					
Dummy for belonging to the State of Sonora	-.0642515	(-0.96)	-.24331065**	(-2.26)	-.11583861**	(-2.50)	-.11566437**	(-2.49)	-.90547184***	(-2.63)	-.05506585	(-0.86)	-.15351193**	(-2.23)	-.79049325**	(-2.31)	-.79027954**	(-2.30)	-.67846587**	(-2.41)					
Dummy for belonging to the State of Tabasco	.12174351	(1.07)	-.93696718	(-0.64)	-.39326066	(-0.60)	-.3927951	(-0.60)	-.28392537	(-0.59)	.12091465	(1.14)	.0007057	(0.00)	-.03897409	(-0.07)	-.03833723	(-0.07)	-.14268341	(-0.34)					
Dummy for belonging to the State of Tamaulipas	-.19121776**	(-2.23)	-.28947187***	(-2.60)	-.14627193***	(-2.94)	-.14677059***	(-2.95)	-.12617215***	(-3.15)	-.21976465***	(-2.66)	-.21892536***	(-2.97)	-.12054738***	(-3.17)	-.12072613***	(-3.17)	-.11263969***	(-3.25)					
Dummy for belonging to the State of Tlaxcala	-.2347111***	(-3.18)	-.30774062***	(-2.88)	-.15626526***	(-3.37)	-.15596972***	(-3.35)	-.13747886***	(-3.63)	-.24340827***	(-3.43)	-.2359728***	(-3.28)	-.1233468***	(-3.59)	-.12321344***	(-3.58)	-.11923489***	(-3.69)					
Dummy for belonging to the State of Veracruz	-.4884177***	(-7.67)	-.43757254***	(-4.13)	-.23276087***	(-5.16)	-.23341825***	(-5.15)	-.23291596***	(-6.20)	-.44965377***	(-7.75)	-.32687172***	(-5.03)	-.18469349***	(-5.82)	-.18489922***	(-5.81)	-.18978202***	(-6.51)					
Dummy for belonging to the State of Yucatan	-.5841202***	(-7.87)	-.6283073***	(-4.90)	-.3589875***	(-5.83)	-.3638901***	(-5.83)	-.41164646***	(-5.20)	-.55264931***	(-8.06)	-.5052967***	(-5.72)	-.28296404***	(-6.47)	-.28311495***	(-6.47)	-.36073698***	(-5.59)					
Dummy for belonging to the State of Zacatecas	-.07962405	(-1.07)	-.23194707**	(-2.15)	-.1113866**	(-2.37)	-.11178108**	(-2.37)	-.90587869**	(-2.48)	-.05929982	(-0.82)	-.1362581**	(-1.96)	-.71324727**	(-2.03)	-.71429946**	(-2.03)	-.62556201**	(-2.06)					
Constant	.17200636	(0.90)	-.98512829	(-0.54)	-.89340889	(-0.96)	-.88388914	(-0.94)	-.26596435**	(-2.17)	.07353382	(0.41)	-.25527029*	(-1.67)	-.16422955**	(-2.00)	-.16380385**	(-1.99)	-.34555804***	(-3.17)					
Insigma2: surface							0.0035371											0.00583969							
LR test of Insigma2=0: Prob > chi2							(0.22)											(0.10)							
Sample size	1,996	1,996	1,996	1,996	1,996	1,996	1,996	1,996	1,996	2,290	2,290	2,290	2,290												

**Table A.13: OLS of model 1**

Source	SS	df	MS	Number of obs = 1996		
Model	175.154639	37	4.73390917	F( 37, 1958) = 34.63		
Residual	267.620411	1958	.136680496	Prob > F = 0.0000		
Total	442.77505	1995	.221942381	R-squared = 0.3956		
				Adj R-squared = 0.3842		
				Root MSE = .3697		

WWT	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
gdpcap	.0102668	.0040971	2.51	0.012	.0022317	.018302
gini	.0042119	.002466	1.71	0.088	-.0006244	.0090482
eduind	.0017104	.0020543	0.83	0.405	-.0023185	.0057393
urban	.001296	.000489	2.65	0.008	.000337	.0022551
fracind	-.0001691	.0006661	-0.25	0.800	-.0014753	.0011372
ethnic	.0003282	.0004075	0.81	0.421	-.000471	.0011274
femadmin	.0003806	.0007473	0.51	0.611	-.0010849	.0018462
neighmun	.0016383	.0003785	4.33	0.000	.000896	.0023805
planind	.000651	.000315	2.07	0.039	.0000332	.0012689
regind	.0000752	.0002624	0.29	0.774	-.0004393	.0005898
1.waterutility	.1314915	.030452	4.32	0.000	.0717697	.1912133
1.Campeche	-.4999987	.1289563	-3.88	0.000	-.7529047	-.2470926
1.Coahuila	-.3847974	.0870185	-4.42	0.000	-.555456	-.2141389
1.Chiapas	-.4768923	.072169	-6.61	0.000	-.6184284	-.3353562
1.Chihuahua	-.0845397	.0706808	-1.20	0.232	-.2231572	.0540777
1.DF	-.4152328	.1180904	-3.52	0.000	-.6468289	-.1836367
1.Durango	.1270973	.0844275	1.51	0.132	-.0384799	.2926744
1.Guanajuato	-.1688809	.077642	-2.18	0.030	-.3211506	-.0166112
1.Guerrero	-.3057979	.0789387	-3.87	0.000	-.4606106	-.1509853
1.Hidalgo	-.5338196	.0688845	-7.75	0.000	-.6689142	-.3987249
1.Jalisco	-.2169814	.0611428	-3.55	0.000	-.3368932	-.0970696
1.Mexico	-.3288922	.0608985	-5.40	0.000	-.4483249	-.2094594
1.Michoacan	-.5274907	.0655222	-8.05	0.000	-.6559914	-.3989901
1.Morelos	-.3305346	.1055049	-3.13	0.002	-.5374483	-.1236209
1.Nayarit	.0976038	.0990379	0.99	0.324	-.0966269	.2918346
1.Oaxaca	-.5009434	.0626184	-8.00	0.000	-.6237492	-.3781377
1.Puebla	-.3984421	.0608194	-6.55	0.000	-.5177197	-.2791644
1.Queretaro	.0043474	.1079889	0.04	0.968	-.2074378	.2161327
1.QuintanaRoo	-.184212	.1915738	-0.96	0.336	-.559922	.1914979
1.SanLuisPotosi	-.4054324	.0778809	-5.21	0.000	-.5581707	-.2526942
1.Sonora	-.0642515	.0672451	-0.96	0.339	-.196131	.067628
1.Tabasco	.1217435	.1134832	1.07	0.283	-.1008171	.3443041
1.Tamaulipas	-.1912178	.0857917	-2.23	0.026	-.3594704	-.0229651
1.Tlaxcala	-.2347111	.0738049	-3.18	0.001	-.3794556	-.0899666
1.Veracruz	-.4884177	.0636784	-7.67	0.000	-.6133022	-.3635332
1.Yucatan	-.5841202	.0741866	-7.87	0.000	-.7296133	-.4386271
1.Zacatecas	-.079624	.074633	-1.07	0.286	-.2259926	.0667445
_cons	.1720064	.190482	0.90	0.367	-.2015625	.5455752

Source: Own calculations, using Stata 13.

**Table A.14: Logit of model 1**

Iteration 0: log likelihood = -1268.8588  
 Iteration 1: log likelihood = -846.70216  
 Iteration 2: log likelihood = -830.93721  
 Iteration 3: log likelihood = -830.17508  
 Iteration 4: log likelihood = -830.16891  
 Iteration 5: log likelihood = -830.16891

Logistic regression	Number of obs	=	1996
	LR chi2(37)	=	877.38
	Prob > chi2	=	0.0000
Log likelihood = -830.16891	Pseudo R2	=	0.3457

WWT	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
gdpcap	.0899359	.0321603	2.80	0.005	.0269029	.1529688
gini	.0355154	.0182637	1.94	0.052	-.0002808	.0713117
eduind	.0106421	.0176917	0.60	0.547	-.0240331	.0453173
urban	.0073718	.0034367	2.15	0.032	.0006361	.0141075
fracind	-.0000823	.005678	-0.01	0.988	-.011211	.0110463
ethnic	.0019581	.0037189	0.53	0.599	-.0053307	.009247
femadmin	.0025646	.0055761	0.46	0.646	-.0083645	.0134936
neighmun	.0095979	.0024445	3.93	0.000	.0048068	.014389
planind	.0048234	.0023186	2.08	0.037	.0002791	.0093678
regind	.000348	.0018834	0.18	0.853	-.0033434	.0040394
1.waterutility	.6350633	.2075648	3.06	0.002	.2282436	1.041883
1.Campeche	-4.563777	1.283302	-3.56	0.000	-7.079003	-2.048552
1.Coahuila	-3.975003	1.115177	-3.56	0.000	-6.160709	-1.789297
1.Chiapas	-4.341656	1.097092	-3.96	0.000	-6.491918	-2.191395
1.Chihuahua	-2.570355	1.081168	-2.38	0.017	-4.689406	-.4513037
1.DF	-4.688259	1.2704	-3.69	0.000	-7.178197	-2.198321
1.Durango	-.1395002	1.447552	-0.10	0.923	-2.97665	2.69765
1.Guanajuato	-2.846961	1.085106	-2.62	0.009	-4.97373	-.7201926
1.Guerrero	-3.315728	1.090194	-3.04	0.002	-5.452468	-1.178988
1.Hidalgo	-4.681232	1.080494	-4.33	0.000	-6.798961	-2.563503
1.Jalisco	-3.136483	1.043949	-3.00	0.003	-5.182586	-1.090379
1.Mexico	-3.675143	1.042875	-3.52	0.000	-5.719141	-1.631146
1.Michoacan	-4.59887	1.066993	-4.31	0.000	-6.690139	-2.507601
1.Morelos	-3.626142	1.160106	-3.13	0.002	-5.899908	-1.352375
1.Nayarit	-.7688486	1.457055	-0.53	0.598	-3.624625	2.086927
1.Oaxaca	-4.608729	1.056492	-4.36	0.000	-6.679415	-2.538043
1.Puebla	-3.728394	1.045613	-3.57	0.000	-5.777758	-1.67903
1.Queretaro	-1.980963	1.190044	-1.66	0.096	-4.313405	.3514803
1.QuintanaRoo	-3.030499	1.596379	-1.90	0.058	-6.159345	.0983468
1.SanLuisPotosi	-3.886076	1.091528	-3.56	0.000	-6.025432	-1.746721
1.Sonora	-2.433107	1.074606	-2.26	0.024	-4.539295	-.3269182
1.Tabasco	-.9369672	1.467081	-0.64	0.523	-3.812392	1.938458
1.Tamaulipas	-2.894719	1.113984	-2.60	0.009	-5.078087	-.7113507
1.Tlaxcala	-3.077406	1.068991	-2.88	0.004	-5.17259	-.9822227
1.Veracruz	-4.375725	1.05841	-4.13	0.000	-6.450171	-2.30128
1.Yucatan	-6.283073	1.281603	-4.90	0.000	-8.794968	-3.771178
1.Zacatecas	-2.319471	1.076808	-2.15	0.031	-4.429975	-.2089659
_cons	-.9851283	1.829571	-0.54	0.590	-4.571021	2.600764

Source: Own calculations, using Stata 13.

**Table A.15: Probit of model 1**

Iteration 0: log likelihood = -1268.8588  
 Iteration 1: log likelihood = -838.4445  
 Iteration 2: log likelihood = -827.91442  
 Iteration 3: log likelihood = -827.55647  
 Iteration 4: log likelihood = -827.55403  
 Iteration 5: log likelihood = -827.55403

Probit regression Number of obs = 1996  
LR chi2(37) = 882.61  
Prob > chi2 = 0.0000  
 Log likelihood = -827.55403 Pseudo R2 = 0.3478

WWT	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
gdpcap	.0511927	.0172224	2.97	0.003	.0174374	.0849479
gini	.0202597	.0104754	1.93	0.053	-.0002717	.0407911
eduind	.0074275	.0096153	0.77	0.440	-.0114181	.0262732
urban	.0044672	.0019734	2.26	0.024	.0005993	.008335
fracind	-.0003045	.0030903	-0.10	0.922	-.0063613	.0057524
ethnic	.0012638	.0019632	0.64	0.520	-.0025841	.0051116
femadmin	.0012264	.0031608	0.39	0.698	-.0049687	.0074216
neighmun	.0057281	.0014367	3.99	0.000	.0029123	.0085439
planind	.0028221	.0013333	2.12	0.034	.0002089	.0054354
regind	.000325	.0010839	0.30	0.764	-.0017994	.0024493
1.waterutility	.3638805	.1201235	3.03	0.002	.1284427	.5993183
1.Campeche	-2.442782	.623133	-3.92	0.000	-3.6641	-1.221464
1.Coahuila	-2.088771	.5021136	-4.16	0.000	-3.072895	-1.104646
1.Chiapas	-2.284078	.4771475	-4.79	0.000	-3.219269	-1.348886
1.Chihuahua	-1.247918	.4675247	-2.67	0.008	-2.16425	-.3315869
1.DF	-2.613483	.5895513	-4.43	0.000	-3.768982	-1.457984
1.Durango	-.0427395	.6078628	-0.07	0.944	-1.234129	1.14865
1.Guanajuato	-1.404704	.4773511	-2.94	0.003	-2.340295	-.4691129
1.Guerrero	-1.691926	.4803754	-3.52	0.000	-2.633444	-.7504074
1.Hidalgo	-2.476383	.4646863	-5.33	0.000	-3.387152	-1.565615
1.Jalisco	-1.583032	.4424019	-3.58	0.000	-2.450124	-.7159405
1.Mexico	-1.908772	.4419304	-4.32	0.000	-2.77494	-1.042605
1.Michoacan	-2.469455	.4572824	-5.40	0.000	-3.365712	-1.573198
1.Morelos	-1.883738	.5424214	-3.47	0.001	-2.946864	-.8206116
1.Nayarit	-.2126022	.6701768	-0.32	0.751	-1.526125	1.10092
1.Oaxaca	-2.446737	.4486611	-5.45	0.000	-3.326097	-1.567378
1.Puebla	-1.938952	.441556	-4.39	0.000	-2.804386	-1.073519
1.Queretaro	-.9187798	.5478825	-1.68	0.094	-1.99261	.1550502
1.QuintanaRoo	-1.455167	.8611347	-1.69	0.091	-3.14296	.2326259
1.SanLuisPotosi	-2.04975	.4782138	-4.29	0.000	-2.987032	-1.112469
1.Sonora	-1.158386	.4637342	-2.50	0.012	-2.067288	-.2494838
1.Tabasco	-.3932607	.6581777	-0.60	0.550	-1.683265	.896744
1.Tamaulipas	-1.462719	.4967181	-2.94	0.003	-2.436269	-.4891697
1.Tlaxcala	-1.562653	.4642822	-3.37	0.001	-2.472629	-.6526763
1.Veracruz	-2.327609	.4514617	-5.16	0.000	-3.212457	-1.44276
1.Yucatan	-3.358988	.5761165	-5.83	0.000	-4.488155	-2.22982
1.Zacatecas	-1.113866	.4698034	-2.37	0.018	-2.034664	-.1930683
_cons	-.8934089	.9353912	-0.96	0.340	-2.726742	.9399242

Source: Own calculations, using Stata 13.





**Table A.17: OLS of model 2**

Source	SS	df	MS	Number of obs =	2290
Model	197.965982	35	5.65617091	F( 35, 2254) =	40.80
Residual	312.468953	2254	.138628639	Prob > F =	0.0000
				R-squared =	0.3878
				Adj R-squared =	0.3783
Total	510.434934	2289	.222994729	Root MSE =	.37233

WWT	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
gdpcap	.0110031	.0038648	2.85	0.004	.0034242	.018582
gini	.0062714	.0023039	2.72	0.007	.0017534	.0107895
eduind	.0020298	.0019511	1.04	0.298	-.0017963	.005856
urban	.0014353	.0004578	3.14	0.002	.0005375	.0023331
fracind	-.0003337	.0006289	-0.53	0.596	-.0015669	.0008996
ethnic	.0002875	.0003858	0.75	0.456	-.0004691	.0010441
femadmin	.0003342	.0006945	0.48	0.630	-.0010276	.0016961
neighmun	.0017798	.0003471	5.13	0.000	.0010992	.0024605
1.waterutility	.1193637	.0281796	4.24	0.000	.0641032	.1746243
1.Campeche	-.4780288	.1282579	-3.73	0.000	-.7295447	-.2265129
1.Coahuila	-.4127075	.0777389	-5.31	0.000	-.5651549	-.2602601
1.Chiapas	-.4521874	.0655532	-6.90	0.000	-.5807384	-.3236364
1.Chihuahua	-.0503682	.0660278	-0.76	0.446	-.1798498	.0791133
1.DF	-.4151108	.1139232	-3.64	0.000	-.6385161	-.1917055
1.Durango	.1577304	.0759527	2.08	0.038	.0087859	.3066749
1.Guanajuato	-.1617478	.0726201	-2.23	0.026	-.3041571	-.0193385
1.Guerrero	-.3091584	.0682782	-4.53	0.000	-.4430531	-.1752637
1.Hidalgo	-.518043	.0654278	-7.92	0.000	-.646348	-.389738
1.Jalisco	-.1855744	.0574417	-3.23	0.001	-.2982185	-.0729302
1.Mexico	-.3129454	.0572872	-5.46	0.000	-.4252865	-.2006042
1.Michoacan	-.5099164	.0622921	-8.19	0.000	-.6320722	-.3877605
1.Morelos	-.2691038	.0825823	-3.26	0.001	-.4310491	-.1071584
1.Nayarit	.1132459	.0983676	1.15	0.250	-.0796546	.3061464
1.Oaxaca	-.4769169	.0580813	-8.21	0.000	-.5908153	-.3630186
1.Puebla	-.3756521	.0573549	-6.55	0.000	-.4881261	-.2631781
1.Queretaro	.0094642	.1044391	0.09	0.928	-.1953427	.2142711
1.QuintanaRoo	-.1616101	.1728323	-0.94	0.350	-.5005372	.177317
1.SanLuisPotosi	-.3955677	.0726549	-5.44	0.000	-.5380452	-.2530902
1.Sonora	-.0550659	.0641401	-0.86	0.391	-.1808457	.070714
1.Tabasco	.1209147	.1062736	1.14	0.255	-.0874897	.329319
1.Tamaulipas	-.2197647	.0824731	-2.66	0.008	-.3814959	-.0580334
1.Tlaxcala	-.2434083	.070904	-3.43	0.001	-.3824522	-.1043644
1.Veracruz	-.4496538	.0580281	-7.75	0.000	-.5634478	-.3358597
1.Yucatan	-.5526493	.0686052	-8.06	0.000	-.6871853	-.4181134
1.Zacatecas	-.0592998	.072054	-0.82	0.411	-.200599	.0819994
_cons	.0735338	.1783012	0.41	0.680	-.2761179	.4231856

Source: Own calculations, using Stata 13.







**Table A.21: Probit of model 1 with surface**

Probit regression Number of obs = 1996  
LR chi2(38) = 882.61  
Prob > chi2 = 0.0000  
Log likelihood = -827.55329 Pseudo R2 = 0.3478

WWT	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
surface	2.04e-07	5.29e-06	0.04	0.969	-.0000102	.0000106
gdpcap	.0511439	.0172687	2.96	0.003	.0172978	.08499
gini	.0202576	.0104755	1.93	0.053	-.000274	.0407892
eduind	.007398	.0096454	0.77	0.443	-.0115066	.0263027
urban	.0044724	.001978	2.26	0.024	.0005955	.0083493
fracind	-.0003012	.0030915	-0.10	0.922	-.0063604	.0057581
ethnic	.0012602	.0019655	0.64	0.521	-.0025922	.0051126
femadmin	.0012303	.0031624	0.39	0.697	-.0049679	.0074285
neighmun	.0057283	.0014367	3.99	0.000	.0029124	.0085442
planind	.0028217	.0013333	2.12	0.034	.0002085	.005435
regind	.0003264	.0010845	0.30	0.763	-.0017992	.0024521
1.waterutility	.364048	.1202006	3.03	0.002	.1284591	.5996368
1.Campeche	-2.443623	.6235587	-3.92	0.000	-3.665776	-1.221471
1.Coahuila	-2.089418	.5024195	-4.16	0.000	-3.074142	-1.104694
1.Chiapas	-2.284265	.4771851	-4.79	0.000	-3.21953	-1.348999
1.Chihuahua	-1.248383	.4676961	-2.67	0.008	-2.16505	-.3317151
1.DF	-2.613352	.5895951	-4.43	0.000	-3.768937	-1.457767
1.Durango	-.0432988	.6080213	-0.07	0.943	-1.234999	1.148401
1.Guanajuato	-1.404809	.477376	-2.94	0.003	-2.340449	-.4691691
1.Guerrero	-1.692161	.4804285	-3.52	0.000	-2.633784	-.750539
1.Hidalgo	-2.476188	.4647282	-5.33	0.000	-3.387038	-1.565337
1.Jalisco	-1.582822	.4424505	-3.58	0.000	-2.450009	-.7156349
1.Mexico	-1.90881	.4419468	-4.32	0.000	-2.775009	-1.04261
1.Michoacan	-2.469404	.4572993	-5.40	0.000	-3.365694	-1.573114
1.Morelos	-1.883488	.5424753	-3.47	0.001	-2.94672	-.820256
1.Nayarit	-.2131545	.6702879	-0.32	0.750	-1.526895	1.100586
1.Oaxaca	-2.447152	.4488022	-5.45	0.000	-3.326788	-1.567516
1.Puebla	-1.939301	.4416639	-4.39	0.000	-2.804946	-1.073656
1.Queretaro	-.9186793	.5479039	-1.68	0.094	-1.992551	.1551925
1.QuintanaRoo	-1.456248	.8615608	-1.69	0.091	-3.144877	.2323798
1.SanLuisPotosi	-2.049816	.4782308	-4.29	0.000	-2.987131	-1.112501
1.Sonora	-1.158411	.4637473	-2.50	0.012	-2.067338	-.2494825
1.Tabasco	-.3932445	.6581815	-0.60	0.550	-1.683256	.8967675
1.Tamaulipas	-1.462846	.4967451	-2.94	0.003	-2.436449	-.489244
1.Tlaxcala	-1.56376	.4651723	-3.36	0.001	-2.475481	-.652039
1.Veracruz	-2.327646	.4514762	-5.16	0.000	-3.212524	-1.442769
1.Yucatan	-3.358846	.5761314	-5.83	0.000	-4.488043	-2.229649
1.Zacatecas	-1.11394	.4698215	-2.37	0.018	-2.034774	-.1931072
_cons	-.8909341	.9375705	-0.95	0.342	-2.728538	.9466702

Source: Own calculations, using Stata 13.

**Table A.22: Probit of model 2 with surface**

Probit regression	Number of obs	=	2290
	LR chi2 (36)	=	990.89
	Prob > chi2	=	0.0000
Log likelihood = -965.38568	Pseudo R2	=	0.3392

WWT	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
surface	8.78e-07	5.07e-06	0.17	0.863	-9.07e-06	.0000108
gdpcap	.0510128	.0161832	3.15	0.002	.0192943	.0827312
gini	.0285449	.0096838	2.95	0.003	.0095649	.0475248
eduind	.0094117	.0090288	1.04	0.297	-.0082844	.0271078
urban	.0049169	.0018192	2.70	0.007	.0013514	.0084824
fracind	-.0009501	.0029029	-0.33	0.743	-.0066397	.0047395
ethnic	.0011084	.0018366	0.60	0.546	-.0024913	.0047082
femadmin	.0010451	.002906	0.36	0.719	-.0046506	.0067408
neighmun	.0062042	.0012968	4.78	0.000	.0036626	.0087459
1.waterutility	.3255721	.1092233	2.98	0.003	.1114984	.5396457
1.Campeche	-2.017737	.5398315	-3.74	0.000	-3.075787	-.9596869
1.Coahuila	-1.802359	.3714742	-4.85	0.000	-2.530435	-1.074283
1.Chiapas	-1.848777	.3442964	-5.37	0.000	-2.523586	-1.173968
1.Chihuahua	-.7800193	.3444887	-2.26	0.024	-1.455205	-.1048339
1.DF	-2.248616	.4926252	-4.56	0.000	-3.214144	-1.283089
1.Durango	.4776462	.5087101	0.94	0.348	-.5194073	1.4747
1.Guanajuato	-1.043642	.3546944	-2.94	0.003	-1.73883	-.3484536
1.Guerrero	-1.376859	.3422164	-4.02	0.000	-2.047591	-.7061272
1.Hidalgo	-2.094236	.3440236	-6.09	0.000	-2.76851	-1.419962
1.Jalisco	-1.148597	.3134896	-3.66	0.000	-1.763025	-.5341685
1.Mexico	-1.497465	.3129877	-4.78	0.000	-2.11091	-.8840209
1.Michoacan	-2.07179	.3337203	-6.21	0.000	-2.72587	-1.417711
1.Morelos	-1.374206	.3790268	-3.63	0.000	-2.117084	-.6313266
1.Nayarit	.178694	.5943856	0.30	0.764	-.9862803	1.343668
1.Oaxaca	-2.037764	.319013	-6.39	0.000	-2.663018	-1.41251
1.Puebla	-1.522973	.313114	-4.86	0.000	-2.136666	-.9092814
1.Queretaro	-.5379746	.451145	-1.19	0.233	-1.422203	.3462535
1.QuintanaRoo	-.9871968	.7832931	-1.26	0.208	-2.522423	.5480294
1.SanLuisPotosi	-1.675232	.3554197	-4.71	0.000	-2.371842	-.9786221
1.Sonora	-.7902265	.3424847	-2.31	0.021	-1.461484	-.1189688
1.Tabasco	-.0385358	.566319	-0.07	0.946	-1.148501	1.071429
1.Tamaulipas	-1.205665	.3797374	-3.17	0.001	-1.949936	-.4613929
1.Tlaxcala	-1.237829	.3443035	-3.60	0.000	-1.912651	-.5630065
1.Veracruz	-1.846754	.317321	-5.82	0.000	-2.468692	-1.224817
1.Yucatan	-2.828915	.4370873	-6.47	0.000	-3.68559	-1.97224
1.Zacatecas	-.713383	.3514284	-2.03	0.042	-1.40217	-.0245959
_cons	-1.63168	.8240306	-1.98	0.048	-3.24675	-.0166097

Source: Own calculations, using Stata 13.

**Table A.23: Heteroskedastic probit of model 1**

Heteroskedastic probit model

Number of obs = 1996  
 Zero outcomes = 1333  
 Nonzero outcomes = 663

Log likelihood = -827.5281

Wald chi2(37) = 531.02  
 Prob > chi2 = 0.0000

WWT	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
WWT						
gdpcap	.0508524	.0173358	2.93	0.003	.0168749	.0848299
gini	.0204916	.0105512	1.94	0.052	-.0001883	.0411716
eduind	.0072562	.0096647	0.75	0.453	-.0116861	.0261986
urban	.0044987	.0019825	2.27	0.023	.0006131	.0083843
fracind	-.0002822	.0030982	-0.09	0.927	-.0063547	.0057902
ethnic	.0012269	.001975	0.62	0.534	-.002644	.0050977
femadmin	.0011961	.0031718	0.38	0.706	-.0050205	.0074128
neighmun	.0057332	.0014405	3.98	0.000	.0029099	.0085565
planind	.0028533	.0013439	2.12	0.034	.0002193	.0054872
regind	.0003344	.0010875	0.31	0.758	-.0017971	.0024659
1.waterutility	.3661526	.1207535	3.03	0.002	.12948	.6028251
1.Campeche	-2.453549	.6276071	-3.91	0.000	-3.683636	-1.223461
1.Coahuila	-2.097705	.5050726	-4.15	0.000	-3.087629	-1.107781
1.Chiapas	-2.291685	.478967	-4.78	0.000	-3.230443	-1.352927
1.Chihuahua	-1.249428	.4684064	-2.67	0.008	-2.167487	-.3313679
1.DF	-2.616892	.5909211	-4.43	0.000	-3.775076	-1.458708
1.Durango	-.0358012	.6113863	-0.06	0.953	-1.234096	1.162494
1.Guanajuato	-1.410335	.4785821	-2.95	0.003	-2.348339	-.4723317
1.Guerrero	-1.699292	.4821338	-3.52	0.000	-2.644257	-.7543268
1.Hidalgo	-2.481024	.4656927	-5.33	0.000	-3.393765	-1.568283
1.Jalisco	-1.586027	.4431384	-3.58	0.000	-2.454562	-.7174912
1.Mexico	-1.914364	.4432477	-4.32	0.000	-2.783113	-1.045614
1.Michoacan	-2.475553	.4586464	-5.40	0.000	-3.374484	-1.576623
1.Morelos	-1.887676	.543225	-3.47	0.001	-2.952377	-.8229744
1.Nayarit	-.2085485	.6730076	-0.31	0.757	-1.527619	1.110522
1.Oaxaca	-2.455576	.4510209	-5.44	0.000	-3.339561	-1.571592
1.Puebla	-1.946972	.443578	-4.39	0.000	-2.816369	-1.077575
1.Queretaro	-.9226983	.5487878	-1.68	0.093	-1.998303	.152906
1.QuintanaRoo	-1.459901	.8664773	-1.68	0.092	-3.158166	.2383631
1.SanLuisPotosi	-2.055003	.4794133	-4.29	0.000	-2.994636	-1.11537
1.Sonora	-1.156644	.4645499	-2.49	0.013	-2.067145	-.2461426
1.Tabasco	-.3927951	.6596847	-0.60	0.552	-1.685753	.9001631
1.Tamaulipas	-1.467706	.4980076	-2.95	0.003	-2.443783	-.4916289
1.Tlaxcala	-1.559697	.4655508	-3.35	0.001	-2.47216	-.6472344
1.Veracruz	-2.334182	.4529742	-5.15	0.000	-3.221996	-1.446369
1.Yucatan	-3.36389	.5772269	-5.83	0.000	-4.495234	-2.232546
1.Zacatecas	-1.117811	.4707793	-2.37	0.018	-2.040521	-.1951004
_cons	-.8838891	.9383859	-0.94	0.346	-2.723092	.9553134
lnsigma2						
surface	1.43e-06	6.36e-06	0.22	0.822	-.000011	.0000139

Likelihood-ratio test of lnsigma2=0: chi2(1) = 0.05 Prob > chi2 = 0.8200

Source: Own calculations, using Stata 13.

**Table A.24: Heteroskedastic probit of model 2**

Heteroskedastic probit model

Number of obs = 2290  
 Zero outcomes = 1522  
 Nonzero outcomes = 768

Log likelihood = -965.3951

Wald chi2(35) = 616.00  
 Prob > chi2 = 0.0000

WWT	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
WWT						
gdpcap	.0511237	.0161962	3.16	0.002	.0193796	.0828677
gini	.0286518	.009734	2.94	0.003	.0095736	.04773
eduind	.009459	.009037	1.05	0.295	-.0082532	.0271711
urban	.0049072	.00182	2.70	0.007	.00134	.0084744
fracind	-.0009461	.002908	-0.33	0.745	-.0066458	.0047535
ethnic	.0011043	.0018464	0.60	0.550	-.0025146	.0047231
femadmin	.0010163	.0029086	0.35	0.727	-.0046845	.006717
neighmun	.0062093	.0012988	4.78	0.000	.0036637	.0087549
1.waterutility	.3258174	.1096953	2.97	0.003	.1108186	.5408163
1.Campeche	-2.018358	.5418948	-3.72	0.000	-3.080452	-.9562636
1.Coahuila	-1.803122	.3728292	-4.84	0.000	-2.533854	-1.07239
1.Chiapas	-1.850728	.3453693	-5.36	0.000	-2.527639	-1.173817
1.Chihuahua	-.7781705	.3446648	-2.26	0.024	-1.453701	-.1026399
1.DF	-2.251183	.4930159	-4.57	0.000	-3.217477	-1.28489
1.Durango	.4835067	.5112651	0.95	0.344	-.5185544	1.485568
1.Guanajuato	-1.045426	.3553314	-2.94	0.003	-1.741863	-.3489894
1.Guerrero	-1.378803	.3433621	-4.02	0.000	-2.05178	-.7058259
1.Hidalgo	-2.09658	.3443863	-6.09	0.000	-2.771564	-1.421595
1.Jalisco	-1.150553	.3136308	-3.67	0.000	-1.765258	-.5358482
1.Mexico	-1.498989	.3134987	-4.78	0.000	-2.113436	-.8845433
1.Michoacan	-2.074121	.3344118	-6.20	0.000	-2.729556	-1.418686
1.Morelos	-1.376942	.3791881	-3.63	0.000	-2.120137	-.6337469
1.Nayarit	.1833821	.5961557	0.31	0.758	-.9850616	1.351826
1.Oaxaca	-2.039147	.3206453	-6.36	0.000	-2.6676	-1.410694
1.Puebla	-1.524408	.3143514	-4.85	0.000	-2.140526	-.9082907
1.Queretaro	-.5398031	.4514427	-1.20	0.232	-1.424615	.3450084
1.QuintanaRoo	-.9842315	.7854777	-1.25	0.210	-2.523739	.5552765
1.SanLuisPotosi	-1.676843	.3559759	-4.71	0.000	-2.374543	-.9791428
1.Sonora	-.7892795	.3429475	-2.30	0.021	-1.461444	-.1171149
1.Tabasco	-.0383372	.5670071	-0.07	0.946	-1.149651	1.072976
1.Tamaulipas	-1.207261	.3803804	-3.17	0.002	-1.952793	-.4617293
1.Tlaxcala	-1.232134	.3441074	-3.58	0.000	-1.906572	-.5576963
1.Veracruz	-1.848992	.3180777	-5.81	0.000	-2.472413	-1.225571
1.Yucatan	-2.831149	.4375392	-6.47	0.000	-3.688711	-1.973588
1.Zacatecas	-.7142995	.351776	-2.03	0.042	-1.403768	-.0248312
_cons	-1.638039	.8236276	-1.99	0.047	-3.252319	-.0237581
lnsigma2						
surface	6.40e-07	6.10e-06	0.10	0.916	-.0000113	.0000126

Likelihood-ratio test of lnsigma2=0: chi2(1) = 0.01 Prob > chi2 = 0.9159

Source: Own calculations, using Stata 13.















**Table A.31: HL-test logit model 1, 10 groups**  
**Logistic model for WWT, goodness-of-fit test**

(Table collapsed on quantiles of estimated probabilities)

number of observations =	1996
number of groups =	10
Hosmer-Lemeshow chi2(8) =	21.85
Prob > chi2 =	0.0052

Source: Own calculations, using Stata 13.

**Table A.32: HL-test logit model 2, 10 groups**  
**Logistic model for WWT, goodness-of-fit test**

(Table collapsed on quantiles of estimated probabilities)

number of observations =	2290
number of groups =	10
Hosmer-Lemeshow chi2(8) =	23.05
Prob > chi2 =	0.0033

Source: Own calculations, using Stata 13.

**Table A.33: HL-test probit model 1, 10 groups**  
**Probit model for WWT, goodness-of-fit test**

(Table collapsed on quantiles of estimated probabilities)

number of observations =	1996
number of groups =	10
Hosmer-Lemeshow chi2(8) =	19.24
Prob > chi2 =	0.0137

Source: Own calculations, using Stata 13.

**Table A.34: HL-test probit model 2, 10 groups**  
**Probit model for WWT, goodness-of-fit test**

(Table collapsed on quantiles of estimated probabilities)

number of observations =	2290
number of groups =	10
Hosmer-Lemeshow chi2(8) =	20.42
Prob > chi2 =	0.0089

Source: Own calculations, using Stata 13.

**Table A.35: Wald tests for interaction in logit model 1**

( 1) [WWT]gdpcap2 = 0	( 1) [WWT]gdpcapfracind = 0
chi2( 1) = 8.14	chi2( 1) = 4.05
Prob > chi2 = 0.0043	Prob > chi2 = 0.0442
( 1) [WWT]gdpcapethnic = 0	( 1) [WWT]gdpcapfemadmin = 0
chi2( 1) = 8.33	chi2( 1) = 21.19
Prob > chi2 = 0.0039	Prob > chi2 = 0.0000
( 1) [WWT]gdpcapneighmun = 0	( 1) [WWT]gdpcapregind = 0
chi2( 1) = 6.64	chi2( 1) = 5.78
Prob > chi2 = 0.0100	Prob > chi2 = 0.0163
( 1) [WWT]femadminneighmun = 0	
chi2( 1) = 6.59	
Prob > chi2 = 0.0102	

Source: Own calculations, using Stata 13.

**Table A.36: HL-test logit model 1 with interaction, 10 groups**  
**Logistic model for WWT, goodness-of-fit test**

(Table collapsed on quantiles of estimated probabilities)

number of observations =	1996
number of groups =	10
Hosmer-Lemeshow chi2(8) =	10.80
Prob > chi2 =	0.2131

Source: Own calculations, using Stata 13.

**Table A.37: HL-test logit model 2 with interaction, 10 groups**  
**Logistic model for WWT, goodness-of-fit test**

(Table collapsed on quantiles of estimated probabilities)

number of observations =	2290
number of groups =	10
Hosmer-Lemeshow chi2(8) =	11.94
Prob > chi2 =	0.1538

Source: Own calculations, using Stata 13.



**Table A.38: HL-test probit model 1 with interaction, 10 groups****Probit model for WWT, goodness-of-fit test**

(Table collapsed on quantiles of estimated probabilities)

number of observations =	1996
number of groups =	10
Hosmer-Lemeshow chi2(8) =	8.66
Prob > chi2 =	0.3715

Source: Own calculations, using Stata 13.

**Table A.39: HL-test probit model 2 with interaction, 10 groups****Probit model for WWT, goodness-of-fit test**

(Table collapsed on quantiles of estimated probabilities)

number of observations =	2290
number of groups =	10
Hosmer-Lemeshow chi2(8) =	7.59
Prob > chi2 =	0.4747

Source: Own calculations, using Stata 13.

**Table A.40: HL-test logit model 1 with interaction, 4 groups****Logistic model for WWT, goodness-of-fit test**

(Table collapsed on quantiles of estimated probabilities)

number of observations =	1996
number of groups =	4
Hosmer-Lemeshow chi2(2) =	2.49
Prob > chi2 =	0.2877

Source: Own calculations, using Stata 13.



**Table A.42: Logit of model 2 with interaction terms**

Logistic regression

Number of obs = 2240  
 LR chi2(42) = 1002.54  
 Prob > chi2 = 0.0000  
 Pseudo R2 = 0.3507

Log likelihood = -928.19053

WWT	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]
gdpcap	.2377436	.0646367	3.68	0.000	.111058 .3644292
gini	.040257	.017279	2.33	0.020	.0063907 .0741233
eduind	-.0022611	.0177835	-0.13	0.899	-.0371161 .0325939
urban	.0092654	.0032079	2.89	0.004	.002978 .0155528
fracind	-.0088132	.0142844	-0.62	0.537	-.0368101 .0191836
ethnic	-.0134474	.0105208	-1.28	0.201	-.0340679 .007173
femadmin	.052307	.0124653	4.20	0.000	.0278755 .0767384
neighmun	.015013	.0060939	2.46	0.014	.0030692 .0269569
1.waterutility	.5376952	.1956978	2.75	0.006	.1541345 .9212559
1.Campeche	-3.787349	.9686321	-3.91	0.000	-5.685833 -1.888865
1.Coahuila	-3.222843	.7260593	-4.44	0.000	-4.645893 -1.799793
1.Chiapas	-3.187322	.7072505	-4.51	0.000	-4.573508 -1.801137
1.Chihuahua	-1.451266	.6986208	-2.08	0.038	-2.820537 -.0819939
1.DF	-3.11351	1.022036	-3.05	0.002	-5.116664 -1.110355
1.Durango	.8995535	1.200862	0.75	0.454	-1.454092 3.253199
1.Guanajuato	-2.177713	.7097926	-3.07	0.002	-3.568881 -.7865453
1.Guerrero	-2.615536	.6971785	-3.75	0.000	-3.981981 -1.249091
1.Hidalgo	-3.940742	.7097501	-5.55	0.000	-5.331826 -2.549657
1.Jalisco	-2.251025	.6488818	-3.47	0.001	-3.52281 -.9792403
1.Mexico	-2.836406	.6486206	-4.37	0.000	-4.107679 -1.565133
1.Michoacan	-3.862079	.689662	-5.60	0.000	-5.213792 -2.510366
1.Morelos	-2.586321	.7336681	-3.53	0.000	-4.024284 -1.148358
1.Nayarit	.1453427	1.20974	0.12	0.904	-2.225703 2.516389
1.Oaxaca	-3.680758	.6699194	-5.49	0.000	-4.993776 -2.36774
1.Puebla	-3.010184	.6562119	-4.59	0.000	-4.296336 -1.724033
1.Queretaro	-1.17875	.8621957	-1.37	0.172	-2.868622 .5111225
1.QuintanaRoo	-2.067122	1.342061	-1.54	0.123	-4.697514 .5632698
1.SanLuisPotosi	-3.146039	.7141487	-4.41	0.000	-4.545745 -1.746333
1.Sonora	-1.514433	.6917102	-2.19	0.029	-2.87016 -.1587061
1.Tabasco	-.0453218	1.214071	-0.04	0.970	-2.424857 2.334213
1.Tamaulipas	-2.383819	.7473371	-3.19	0.001	-3.848573 -.9190654
1.Tlaxcala	-2.383746	.695038	-3.43	0.001	-3.745996 -1.021497
1.Veracruz	-3.481261	.6744493	-5.16	0.000	-4.803157 -2.159365
1.Yucatan	-5.622101	.9238854	-6.09	0.000	-7.432883 -3.811319
1.Zacatecas	-1.472948	.7167398	-2.06	0.040	-2.877732 -.068164
gdpcapneighmun	-.0001314	.0005714	-0.23	0.818	-.0012513 .0009886
gdpcapfemadmin	-.004564	.001189	-3.84	0.000	-.0068943 -.0022337
gdpcapethnic	.0038537	.0020524	1.88	0.060	-.000169 .0078764
gdpcap2	-.0024058	.0018281	-1.32	0.188	-.0059888 .0011771
gdpcapregind	9.03e-06	.0001785	0.05	0.960	-.0003409 .0003589
femadminneighmun	-.0001767	.0001427	-1.24	0.216	-.0004565 .0001031
gdpcapfracind	-.0006209	.0021881	-0.28	0.777	-.0049095 .0036676
_cons	-1.93574	1.577081	-1.23	0.220	-5.026761 1.155281

Source: Own calculations, using Stata 13.

**Table A.43: Probit of model 1 with interaction terms**

Probit regression Number of obs = 1996  
LR chi2(44) = 915.70  
Prob > chi2 = 0.0000  
Log likelihood = -811.0111 Pseudo R2 = 0.3608

WWT	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
gdpcap	.1579945	.039795	3.97	0.000	.0799978	.2359912
gini	.0148027	.0106551	1.39	0.165	-.0060808	.0356863
eduind	-.0041253	.0104328	-0.40	0.693	-.0245733	.0163227
urban	.0051801	.0019969	2.59	0.009	.0012663	.0090939
fracind	-.0019736	.0082941	-0.24	0.812	-.0182298	.0142826
ethnic	-.0057493	.0062693	-0.92	0.359	-.018037	.0065384
femadmin	.0283932	.007634	3.72	0.000	.0134307	.0433557
neighmun	.010272	.0039619	2.59	0.010	.0025069	.018037
planind	.0027369	.0013519	2.02	0.043	.0000873	.0053865
regind	.0016597	.0028332	0.59	0.558	-.0038931	.0072126
1.waterutility	.3471963	.1214934	2.86	0.004	.1090735	.5853191
1.Campeche	-2.585712	.6218553	-4.16	0.000	-3.804526	-1.366898
1.Coahuila	-2.126934	.5057761	-4.21	0.000	-3.118237	-1.135631
1.Chiapas	-2.207518	.4848638	-4.55	0.000	-3.157834	-1.257203
1.Chihuahua	-1.229471	.4704513	-2.61	0.009	-2.151539	-.3074035
1.DF	-2.196517	.651977	-3.37	0.001	-3.474368	-.9186652
1.Durango	-.1314664	.624223	-0.21	0.833	-1.354921	1.091988
1.Guanajuato	-1.551911	.4859738	-3.19	0.001	-2.504403	-.5994203
1.Guerrero	-1.77989	.4890748	-3.64	0.000	-2.738459	-.8213211
1.Hidalgo	-2.613671	.4725966	-5.53	0.000	-3.539944	-1.687399
1.Jalisco	-1.691023	.4478756	-3.78	0.000	-2.568843	-.8132026
1.Mexico	-2.009605	.4482285	-4.48	0.000	-2.888117	-1.131094
1.Michoacan	-2.636511	.4657181	-5.66	0.000	-3.549301	-1.72372
1.Morelos	-1.988448	.5478608	-3.63	0.000	-3.062236	-.914661
1.Nayarit	-.2626308	.6698723	-0.39	0.695	-1.575556	1.050295
1.Oaxaca	-2.461483	.456992	-5.39	0.000	-3.357171	-1.565795
1.Puebla	-2.104535	.4507967	-4.67	0.000	-2.98808	-1.220989
1.Queretaro	-1.009892	.5517502	-1.83	0.067	-2.091303	.0715183
1.QuintanaRoo	-1.594813	.8731248	-1.83	0.068	-3.306106	.1164806
1.SanLuisPotosi	-2.161218	.4870446	-4.44	0.000	-3.115808	-1.206628
1.Sonora	-1.19075	.4663944	-2.55	0.011	-2.104867	-.2766343
1.Tabasco	-.4261222	.6668843	-0.64	0.523	-1.733191	.880947
1.Tamaulipas	-1.592639	.5042651	-3.16	0.002	-2.58098	-.6042975
1.Tlaxcala	-1.6675	.4743555	-3.52	0.000	-2.59722	-.7377804
1.Veracruz	-2.42574	.4600638	-5.27	0.000	-3.327448	-1.524031
1.Yucatan	-3.658396	.6032439	-6.06	0.000	-4.840732	-2.47606
1.Zacatecas	-1.201934	.4839674	-2.48	0.013	-2.150493	-.2533757
gdpcapneighmun	-.0002273	.0003528	-0.64	0.519	-.0009188	.0004641
gdpcapfemadmin	-.0024585	.0007368	-3.34	0.001	-.0039027	-.0010143
gdpcapethnic	.0018979	.0012584	1.51	0.132	-.0005686	.0043643
gdpcap2	-.0014818	.0011991	-1.24	0.217	-.003832	.0008684
gdpcapregind	-.0001244	.0002889	-0.43	0.667	-.0006906	.0004419
femadminneighmun	-.0001201	.0000902	-1.33	0.183	-.000297	.0000567
gdpcapfracind	-.0006068	.0013177	-0.46	0.645	-.0031895	.0019759
_cons	-.5458722	.9683072	-0.56	0.573	-2.443719	1.351975

Source: Own calculations, using Stata 13.

**Table A.44: Probit of model 2 with interaction terms**

Probit regression Number of obs = 2290  
LR chi2(41) = 1025.45  
Prob > chi2 = 0.0000  
Log likelihood = -948.1059 Pseudo R2 = 0.3510

WWT	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
gdpcap	.1417962	.036835	3.85	0.000	.0696009	.2139915
gini	.0231082	.0098464	2.35	0.019	.0038095	.0424069
eduind	-.0007073	.0096827	-0.07	0.942	-.019685	.0182704
urban	.0055545	.0018213	3.05	0.002	.0019849	.0091241
fracind	-.0043636	.0076559	-0.57	0.569	-.0193689	.0106418
ethnic	-.0065352	.0056318	-1.16	0.246	-.0175733	.0045029
femadmin	.0278289	.0069184	4.02	0.000	.014269	.0413888
neighmun	.0084453	.0034735	2.43	0.015	.0016374	.0152532
1.waterutility	.3157902	.110364	2.86	0.004	.0994807	.5320997
1.Campeche	-2.098765	.5308985	-3.95	0.000	-3.139307	-1.058223
1.Coahuila	-1.77354	.3688419	-4.81	0.000	-2.496456	-1.050623
1.Chiapas	-1.730798	.3458942	-5.00	0.000	-2.408739	-1.052858
1.Chihuahua	-.7008376	.3413246	-2.05	0.040	-1.369821	-.0318537
1.DF	-1.784654	.5580153	-3.20	0.001	-2.878344	-.6909644
1.Durango	.4665045	.5183567	0.90	0.368	-.549456	1.482465
1.Guanajuato	-1.120773	.3555473	-3.15	0.002	-1.817633	-.423913
1.Guerrero	-1.399783	.3432827	-4.08	0.000	-2.072605	-.7269616
1.Hidalgo	-2.165624	.3442541	-6.29	0.000	-2.84035	-1.490899
1.Jalisco	-1.182818	.3110516	-3.80	0.000	-1.792468	-.5731683
1.Mexico	-1.535129	.3110613	-4.94	0.000	-2.144798	-.9254597
1.Michoacan	-2.163464	.3342437	-6.47	0.000	-2.81857	-1.508358
1.Morelos	-1.387639	.3778718	-3.67	0.000	-2.128254	-.6470238
1.Nayarit	.1748483	.5885119	0.30	0.766	-.9786138	1.32831
1.Oaxaca	-2.020295	.3208594	-6.30	0.000	-2.649168	-1.391423
1.Puebla	-1.625764	.3136753	-5.18	0.000	-2.240556	-1.010972
1.Queretaro	-.5638121	.4467093	-1.26	0.207	-1.439346	.311722
1.QuintanaRoo	-1.005467	.7768823	-1.29	0.196	-2.528129	.5171939
1.SanLuisPotosi	-1.728306	.3565765	-4.85	0.000	-2.427183	-1.029429
1.Sonora	-.7540071	.3387226	-2.23	0.026	-1.417891	-.0901231
1.Tabasco	-.0128152	.5697582	-0.02	0.982	-1.129521	1.10389
1.Tamaulipas	-1.263548	.3794218	-3.33	0.001	-2.007201	-.5198949
1.Tlaxcala	-1.273732	.3444186	-3.70	0.000	-1.94878	-.5986841
1.Veracruz	-1.869508	.3176074	-5.89	0.000	-2.492008	-1.247009
1.Yucatan	-3.114483	.4675764	-6.66	0.000	-4.030916	-2.198051
1.Zacatecas	-.7195343	.3569473	-2.02	0.044	-1.419138	-.0199305
gdpcapneighmun	-.0000848	.0003238	-0.26	0.793	-.0007194	.0005498
gdpcapfemadmin	-.0025903	.00067	-3.87	0.000	-.0039035	-.0012771
gdpcapethnic	.0019865	.0011264	1.76	0.078	-.0002212	.0041943
gdpcap2	-.0014118	.0010827	-1.30	0.192	-.0035338	.0007102
femadminneighmun	-.0000739	.0000796	-0.93	0.353	-.00023	.0000822
gdpcapfracind	-.0003532	.0012011	-0.29	0.769	-.0027074	.002001
_cons	-1.292408	.8497135	-1.52	0.128	-2.957816	.373

Source: Own calculations, using Stata 13.

**Table A.45: Predicted vs actual outcomes in logit model 2**

Classified	True		Total
	D	~D	
+	463	150	613
-	305	1372	1677
Total	768	1522	2290

Classified + if predicted  $\Pr(D) \geq .5$

True D defined as  $WWT \neq 0$

Sensitivity	$\Pr(+ D)$	60.29%
Specificity	$\Pr(- \sim D)$	90.14%
Positive predictive value	$\Pr(D +)$	75.53%
Negative predictive value	$\Pr(\sim D -)$	81.81%
False + rate for true ~D	$\Pr(+ \sim D)$	9.86%
False - rate for true D	$\Pr(- D)$	39.71%
False + rate for classified +	$\Pr(\sim D +)$	24.47%
False - rate for classified -	$\Pr(D -)$	18.19%
Correctly classified		80.13%

Source: Own calculations, using Stata 13.

**Table A.46: Predicted vs actual outcomes in probit model 1**

Classified	True		Total
	D	~D	
+	404	131	535
-	259	1202	1461
Total	663	1333	1996

Classified + if predicted  $\Pr(D) \geq .5$

True D defined as  $WWT \neq 0$

Sensitivity	$\Pr(+ D)$	60.94%
Specificity	$\Pr(- \sim D)$	90.17%
Positive predictive value	$\Pr(D +)$	75.51%
Negative predictive value	$\Pr(\sim D -)$	82.27%
False + rate for true ~D	$\Pr(+ \sim D)$	9.83%
False - rate for true D	$\Pr(- D)$	39.06%
False + rate for classified +	$\Pr(\sim D +)$	24.49%
False - rate for classified -	$\Pr(D -)$	17.73%
Correctly classified		80.46%

Source: Own calculations, using Stata 13.

**Table A.47: Predicted vs actual outcomes in probit model 2**

Classified	True		Total
	D	~D	
+	462	152	614
-	306	1370	1676
Total	768	1522	2290

Classified + if predicted  $\Pr(D) \geq .5$   
 True D defined as  $WWT \neq 0$

Sensitivity	$\Pr(+ D)$	60.16%
Specificity	$\Pr(- \sim D)$	90.01%
Positive predictive value	$\Pr(D +)$	75.24%
Negative predictive value	$\Pr(\sim D -)$	81.74%
False + rate for true ~D	$\Pr(+ \sim D)$	9.99%
False - rate for true D	$\Pr(- D)$	39.84%
False + rate for classified +	$\Pr(\sim D +)$	24.76%
False - rate for classified -	$\Pr(D -)$	18.26%
Correctly classified		80.00%

Source: Own calculations, using Stata 13.

**Table A.48: Predicted vs actual outcomes in logit model 1 with interaction**

. estat classification, cutoff (0.5)

Logistic model for WWT

Classified	True		Total
	D	~D	
+	407	133	540
-	256	1200	1456
Total	663	1333	1996

Classified + if predicted  $\Pr(D) \geq .5$   
 True D defined as  $WWT \neq 0$

Sensitivity	$\Pr(+ D)$	61.39%
Specificity	$\Pr(- \sim D)$	90.02%
Positive predictive value	$\Pr(D +)$	75.37%
Negative predictive value	$\Pr(\sim D -)$	82.42%
False + rate for true ~D	$\Pr(+ \sim D)$	9.98%
False - rate for true D	$\Pr(- D)$	38.61%
False + rate for classified +	$\Pr(\sim D +)$	24.63%
False - rate for classified -	$\Pr(D -)$	17.58%
Correctly classified		80.51%

Source: Own calculations, using Stata 13.





**Table A.50: Logit of model 1 without watavail (1,201 obs.)**

Logistic regression	Number of obs	=	1201
	LR chi2(32)	=	503.28
	Prob > chi2	=	0.0000
Log likelihood = -513.27627	Pseudo R2	=	0.3290

WWT	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
gdpcap	.0638068	.038537	1.66	0.098	-.0117243	.139338
gini	.0669501	.0241716	2.77	0.006	.0195747	.1143256
eduind	.0412521	.0239996	1.72	0.086	-.0057863	.0882905
urban	.0033392	.0041949	0.80	0.426	-.0048827	.0115611
fracind	-.0005779	.007823	-0.07	0.941	-.0159106	.0147548
ethnic	.0021393	.0051481	0.42	0.678	-.0079509	.0122295
femadmin	.0008055	.0071552	0.11	0.910	-.0132184	.0148294
neighmun	.0094604	.0032061	2.95	0.003	.0031765	.0157443
planind	.0046146	.0029412	1.57	0.117	-.00115	.0103793
regind	.0008984	.0024366	0.37	0.712	-.0038771	.005674
1.waterutility	.6853585	.2562003	2.68	0.007	.1832151	1.187502
1.Campeche	-2.305042	1.101824	-2.09	0.036	-4.464577	-.1455065
1.Coahuila	-2.746988	1.098091	-2.50	0.012	-4.899207	-.5947679
1.Chiapas	-3.297203	.711121	-4.64	0.000	-4.690974	-1.903431
1.DF	-3.172585	.9407206	-3.37	0.001	-5.016364	-1.328807
1.Guanajuato	-1.715518	.6879434	-2.49	0.013	-3.063862	-.3671739
1.Guerrero	-1.861923	.7191694	-2.59	0.010	-3.271469	-.4523766
1.Hidalgo	-3.72002	.7093849	-5.24	0.000	-5.110389	-2.329651
1.Jalisco	-2.055554	.5934665	-3.46	0.001	-3.218727	-.8923809
1.Mexico	-2.358777	.5957607	-3.96	0.000	-3.526447	-1.191108
1.Michoacan	-3.083786	.6599328	-4.67	0.000	-4.377231	-1.790341
1.Nayarit	.2709321	1.183868	0.23	0.819	-2.049407	2.591272
1.Oaxaca	-3.305721	.632383	-5.23	0.000	-4.545169	-2.066274
1.Puebla	-2.609685	.6147324	-4.25	0.000	-3.814538	-1.404831
1.Queretaro	-1.541433	.9387299	-1.64	0.101	-3.381309	.2984442
1.SanLuisPotosi	-3.048699	.7173477	-4.25	0.000	-4.454675	-1.642723
1.Sonora	-1.870517	.6738228	-2.78	0.006	-3.191185	-.5498483
1.Tabasco	-.0869349	1.196875	-0.07	0.942	-2.432768	2.258898
1.Tamaulipas	-1.677195	.7258088	-2.31	0.021	-3.099754	-.2546359
1.Tlaxcala	-.8589468	.8268495	-1.04	0.299	-2.479542	.7616484
1.Veracruz	-3.407148	.6646744	-5.13	0.000	-4.709886	-2.10441
1.Zacatecas	-1.372443	.6866685	-2.00	0.046	-2.718288	-.0265971
_cons	-5.649192	2.166833	-2.61	0.009	-9.896107	-1.402276

Source: Own calculations, using Stata 13.

**Table A.51: Logit of model 1 with watavail and without urban (1,201 obs.)**

Logistic regression	Number of obs	=	1201
	LR chi2(32)	=	503.42
	Prob > chi2	=	0.0000
Log likelihood = -513.20311	Pseudo R2	=	0.3291

WWT	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
gdpcap	.0756166	.0353531	2.14	0.032	.0063258	.1449073
gini	.0657102	.0241804	2.72	0.007	.0183174	.1131029
eduind	.0425414	.0241551	1.76	0.078	-.0048017	.0898845
fracind	-.0002229	.0078321	-0.03	0.977	-.0155736	.0151277
ethnic	.0028312	.0051435	0.55	0.582	-.0072499	.0129124
femadmin	.0011725	.0071378	0.16	0.870	-.0128173	.0151623
neighmun	.0093542	.0032073	2.92	0.004	.003068	.0156404
planind	.0046556	.0029392	1.58	0.113	-.001105	.0104162
regind	.0009316	.0024326	0.38	0.702	-.0038362	.0056993
1.watavail	-.195309	.2207285	-0.88	0.376	-.6279288	.2373108
1.waterutility	.7796525	.231487	3.37	0.001	.3259462	1.233359
1.Campeche	-2.199385	1.103685	-1.99	0.046	-4.362567	-.0362031
1.Coahuila	-2.551554	1.087298	-2.35	0.019	-4.68262	-.4204891
1.Chiapas	-3.136382	.7104313	-4.41	0.000	-4.528801	-1.743962
1.DF	-3.032749	.9351467	-3.24	0.001	-4.865603	-1.199895
1.Guanajuato	-1.759044	.6950191	-2.53	0.011	-3.121257	-.396832
1.Guerrero	-1.796626	.7125968	-2.52	0.012	-3.19329	-.3999616
1.Hidalgo	-3.657539	.7153308	-5.11	0.000	-5.059562	-2.255517
1.Jalisco	-2.000484	.593294	-3.37	0.001	-3.163319	-.8376495
1.Mexico	-2.340049	.594194	-3.94	0.000	-3.504648	-1.17545
1.Michoacan	-3.121144	.6651535	-4.69	0.000	-4.424821	-1.817467
1.Nayarit	.3675035	1.186108	0.31	0.757	-1.957226	2.692233
1.Oaxaca	-3.226816	.6327638	-5.10	0.000	-4.467011	-1.986622
1.Puebla	-2.657646	.6226573	-4.27	0.000	-3.878032	-1.43726
1.Queretaro	-1.55637	.9401442	-1.66	0.098	-3.399019	.2862785
1.SanLuisPotosi	-2.917364	.7168427	-4.07	0.000	-4.32235	-1.512378
1.Sonora	-1.896496	.6762549	-2.80	0.005	-3.221931	-.5710608
1.Tabasco	.0172569	1.199057	0.01	0.989	-2.332852	2.367366
1.Tamaulipas	-1.617637	.7235197	-2.24	0.025	-3.03571	-.1995647
1.Tlaxcala	-.9451609	.838324	-1.13	0.260	-2.588246	.6979239
1.Veracruz	-3.292671	.6679962	-4.93	0.000	-4.601919	-1.983422
1.Zacatecas	-1.246308	.6877215	-1.81	0.070	-2.594217	.1016015
_cons	-5.730776	2.173919	-2.64	0.008	-9.991579	-1.469973

Source: Own calculations, using Stata 13.

**Table A.52: Logit of model 1 with neighmun50 (radius=50km)**

Logistic regression	Number of obs	=	1996
	LR chi2(37)	=	877.12
	Prob > chi2	=	0.0000
Log likelihood = -830.29864	Pseudo R2	=	0.3456

WWT	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]
gdpcap	.0895185	.0321336	2.79	0.005	.0265379 .1524992
gini	.033976	.0183168	1.85	0.064	-.0019243 .0698763
eduind	.0084953	.0176732	0.48	0.631	-.0261435 .043134
urban	.0079245	.003433	2.31	0.021	.0011959 .014653
fracind	.0011033	.0056761	0.19	0.846	-.0100216 .0122282
ethnic	.0015839	.0037172	0.43	0.670	-.0057017 .0088695
femadmin	.0029238	.005559	0.53	0.599	-.0079715 .0138192
neighmun50	.0138625	.0035833	3.87	0.000	.0068393 .0208857
planind	.0050314	.0023202	2.17	0.030	.000484 .0095789
regind	.0004175	.001881	0.22	0.824	-.0032693 .0041042
1.waterutility	.6176288	.2070454	2.98	0.003	.2118274 1.02343
1.Campeche	-4.483003	1.285864	-3.49	0.000	-7.00325 -1.962756
1.Coahuila	-3.856661	1.119312	-3.45	0.001	-6.050472 -1.66285
1.Chiapas	-4.164831	1.105306	-3.77	0.000	-6.33119 -1.998471
1.Chihuahua	-2.587116	1.081653	-2.39	0.017	-4.707116 -.467116
1.DF	-4.480925	1.272442	-3.52	0.000	-6.974865 -1.986985
1.Durango	-.2688954	1.448005	-0.19	0.853	-3.106932 2.569142
1.Guanajuato	-2.827489	1.087026	-2.60	0.009	-4.958021 -.6969574
1.Guerrero	-3.213092	1.093409	-2.94	0.003	-5.356134 -1.070049
1.Hidalgo	-4.523048	1.088778	-4.15	0.000	-6.657013 -2.389083
1.Jalisco	-3.124377	1.044085	-2.99	0.003	-5.170745 -1.078009
1.Mexico	-3.595863	1.045073	-3.44	0.001	-5.644168 -1.547559
1.Michoacan	-4.49892	1.072382	-4.20	0.000	-6.600751 -2.397089
1.Morelos	-3.53675	1.159572	-3.05	0.002	-5.80947 -1.26403
1.Nayarit	-.8267031	1.457301	-0.57	0.571	-3.68296 2.029554
1.Oaxaca	-4.396966	1.067672	-4.12	0.000	-6.489564 -2.304368
1.Puebla	-3.584394	1.052149	-3.41	0.001	-5.646569 -1.522219
1.Queretaro	-1.896928	1.188633	-1.60	0.111	-4.226606 .4327494
1.QuintanaRoo	-2.92127	1.61936	-1.80	0.071	-6.095157 .2526172
1.SanLuisPotosi	-3.763252	1.09693	-3.43	0.001	-5.913195 -1.613309
1.Sonora	-2.541751	1.072892	-2.37	0.018	-4.644581 -.438921
1.Tabasco	-.9009867	1.469093	-0.61	0.540	-3.780357 1.978383
1.Tamaulipas	-2.909994	1.113713	-2.61	0.009	-5.092831 -.7271577
1.Tlaxcala	-2.935308	1.074169	-2.73	0.006	-5.040641 -.8299753
1.Veracruz	-4.224868	1.064518	-3.97	0.000	-6.311285 -2.138451
1.Yucatan	-6.048871	1.292676	-4.68	0.000	-8.58247 -3.515272
1.Zacatecas	-2.375188	1.075741	-2.21	0.027	-4.483601 -.2667752
_cons	-1.037126	1.830456	-0.57	0.571	-4.624753 2.550502

Source: Own calculations, using Stata 13.

**Table A.53: Logit of model 1 with neighmun100 (radius=100km)**

Logistic regression	Number of obs	=	1996
	LR chi2(37)	=	863.72
	Prob > chi2	=	0.0000
Log likelihood = -836.9985	Pseudo R2	=	0.3404

WWT	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]
gdpcap	.0938982	.0320212	2.93	0.003	.0311378 .1566586
gini	.0341844	.0181718	1.88	0.060	-.0014316 .0698004
eduind	.0113162	.0176312	0.64	0.521	-.0232403 .0458727
urban	.0075216	.0034057	2.21	0.027	.0008465 .0141967
fracind	.0008439	.0056931	0.15	0.882	-.0103143 .0120022
ethnic	.0015013	.0037019	0.41	0.685	-.0057543 .008757
femadmin	.0033868	.0055431	0.61	0.541	-.0074774 .014251
neighmun100	.0069982	.0054537	1.28	0.199	-.0036908 .0176873
planind	.0050651	.0023062	2.20	0.028	.0005451 .0095851
regind	.0003868	.0018682	0.21	0.836	-.0032748 .0040484
1.waterutility	.5971105	.2060018	2.90	0.004	.1933544 1.000867
1.Campeche	-4.825512	1.296268	-3.72	0.000	-7.366151 -2.284874
1.Coahuila	-4.20738	1.120068	-3.76	0.000	-6.402673 -2.012086
1.Chiapas	-4.611258	1.129118	-4.08	0.000	-6.824289 -2.398227
1.Chihuahua	-2.767867	1.078015	-2.57	0.010	-4.880737 -.6549965
1.DF	-4.604052	1.286484	-3.58	0.000	-7.125513 -2.08259
1.Durango	-.2695165	1.447343	-0.19	0.852	-3.106257 2.567224
1.Guanajuato	-2.945093	1.089524	-2.70	0.007	-5.08052 -.8096655
1.Guerrero	-3.508741	1.10639	-3.17	0.002	-5.677225 -1.340256
1.Hidalgo	-5.056474	1.09817	-4.60	0.000	-7.208847 -2.9041
1.Jalisco	-3.333012	1.044708	-3.19	0.001	-5.380602 -1.285422
1.Mexico	-3.837028	1.053938	-3.64	0.000	-5.902709 -1.771348
1.Michoacan	-4.94796	1.084622	-4.56	0.000	-7.07378 -2.82214
1.Morelos	-3.823066	1.164798	-3.28	0.001	-6.106029 -1.540103
1.Nayarit	-.8001717	1.454627	-0.55	0.582	-3.651189 2.050846
1.Oaxaca	-4.883091	1.097281	-4.45	0.000	-7.033721 -2.73246
1.Puebla	-4.011961	1.06575	-3.76	0.000	-6.100792 -1.92313
1.Queretaro	-2.091818	1.197888	-1.75	0.081	-4.439634 .2559989
1.QuintanaRoo	-3.233185	1.592687	-2.03	0.042	-6.354794 -.1115764
1.SanLuisPotosi	-4.173392	1.102176	-3.79	0.000	-6.333617 -2.013167
1.Sonora	-2.645219	1.071495	-2.47	0.014	-4.745309 -.5451276
1.Tabasco	-1.033262	1.475306	-0.70	0.484	-3.924808 1.858283
1.Tamaulipas	-3.137642	1.110843	-2.82	0.005	-5.314854 -.9604303
1.Tlaxcala	-3.302304	1.085582	-3.04	0.002	-5.430006 -1.174603
1.Veracruz	-4.608978	1.08648	-4.24	0.000	-6.738439 -2.479517
1.Yucatan	-6.611441	1.321214	-5.00	0.000	-9.200972 -4.02191
1.Zacatecas	-2.545185	1.073929	-2.37	0.018	-4.650048 -.440323
_cons	-.7140602	1.845825	-0.39	0.699	-4.331811 2.903691

Source: Own calculations, using Stata 13.





**Table A.56: Logit of model 1 with neighmun500 (radius=500km)**

Logistic regression	Number of obs	=	2002
	LR chi2(37)	=	880.11
	Prob > chi2	=	0.0000
Log likelihood = -834.70904	Pseudo R2	=	0.3452

WWT	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
gdpcap	.0961182	.0319158	3.01	0.003	.0335643	.1586721
gini	.0349677	.0181621	1.93	0.054	-.0006294	.0705647
eduind	.0101967	.0176304	0.58	0.563	-.0243582	.0447517
urban	.0074291	.0034035	2.18	0.029	.0007583	.0140998
fracind	-.0000989	.0056902	-0.02	0.986	-.0112515	.0110538
ethnic	.0011773	.0037132	0.32	0.751	-.0061006	.0084551
femadmin	.0033552	.0055383	0.61	0.545	-.0074998	.0142101
neighmun500	-.0562003	.021772	-2.58	0.010	-.0988727	-.013528
planind	.005339	.0023203	2.30	0.021	.0007914	.0098867
regind	-.00003	.001874	-0.02	0.987	-.003703	.0036429
1.waterutility	.6142625	.2064717	2.98	0.003	.2095855	1.01894
1.Campeche	-8.021314	1.756138	-4.57	0.000	-11.46328	-4.579346
1.Coahuila	-4.498445	1.116619	-4.03	0.000	-6.686978	-2.309911
1.Chiapas	-7.847277	1.623759	-4.83	0.000	-11.02979	-4.664767
1.Chihuahua	-2.073781	1.09524	-1.89	0.058	-4.220411	.0728502
1.DF	-7.096511	1.605194	-4.42	0.000	-10.24263	-3.950389
1.Durango	.115796	1.450209	0.08	0.936	-2.726562	2.958154
1.Guanajuato	-4.772838	1.322012	-3.61	0.000	-7.363934	-2.181742
1.Guerrero	-6.128122	1.484326	-4.13	0.000	-9.037348	-3.218897
1.Hidalgo	-7.558692	1.430429	-5.28	0.000	-10.36228	-4.755104
1.Jalisco	-4.457642	1.156339	-3.85	0.000	-6.724025	-2.191259
1.Mexico	-6.266862	1.416951	-4.42	0.000	-9.044034	-3.48969
1.Michoacan	-6.930385	1.302345	-5.32	0.000	-9.482934	-4.377836
1.Morelos	-6.326177	1.522985	-4.15	0.000	-9.311173	-3.341181
1.Nayarit	-1.312529	1.490461	-0.88	0.379	-4.233778	1.60872
1.Oaxaca	-7.84418	1.507575	-5.20	0.000	-10.79897	-4.889386
1.Puebla	-6.716181	1.461749	-4.59	0.000	-9.581157	-3.851206
1.Queretaro	-4.247671	1.456956	-2.92	0.004	-7.103252	-1.39209
1.QuintanaRoo	-6.451564	2.030621	-3.18	0.001	-10.43151	-2.471619
1.SanLuisPotosi	-5.9288	1.291303	-4.59	0.000	-8.459707	-3.397894
1.Sonora	-1.798041	1.096845	-1.64	0.101	-3.947818	.3517353
1.Tabasco	-4.159262	1.906735	-2.18	0.029	-7.896393	-.4221311
1.Tamaulipas	-4.38959	1.233255	-3.56	0.000	-6.806725	-1.972455
1.Tlaxcala	-5.936669	1.47236	-4.03	0.000	-8.822441	-3.050897
1.Veracruz	-7.350076	1.472506	-4.99	0.000	-10.23614	-4.464017
1.Yucatan	-10.06453	1.78949	-5.62	0.000	-13.57187	-6.557192
1.Zacatecas	-3.358474	1.146724	-2.93	0.003	-5.606012	-1.110936
_cons	3.615178	2.437322	1.48	0.138	-1.161885	8.392242

Source: Own calculations, using Stata 13.





**Table A.58: Logit of model 2 with urbanII**

Logistic regression

Log likelihood = -967.03549

Number of obs = 2290  
 LR chi2(35) = 987.59  
 Prob > chi2 = 0.0000  
 Pseudo R2 = 0.3380

WWT	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
gdpcap	.0857891	.0297869	2.88	0.004	.0274079	.1441702
gini	.0509107	.0168828	3.02	0.003	.017821	.0840003
eduind	.0156385	.0165812	0.94	0.346	-.0168601	.0481371
urbanII	.01035	.0034811	2.97	0.003	.0035271	.0171728
fracind	-.00087	.0053048	-0.16	0.870	-.0112673	.0095273
ethnic	.0014388	.0034781	0.41	0.679	-.0053781	.0082558
femadmin	.0025422	.0051199	0.50	0.620	-.0074927	.0125771
neighmun	.0104852	.0022162	4.73	0.000	.0061416	.0148288
1.waterutility	.5831379	.1812023	3.22	0.001	.227988	.9382878
1.Campeche	-3.580293	.9910743	-3.61	0.000	-5.522763	-1.637823
1.Coahuila	-3.181268	.7196919	-4.42	0.000	-4.591838	-1.770698
1.Chiapas	-3.288549	.6930665	-4.74	0.000	-4.646935	-1.930164
1.Chihuahua	-1.490933	.6950518	-2.15	0.032	-2.853209	-.1286561
1.DF	-3.946649	.966923	-4.08	0.000	-5.841783	-2.051515
1.Durango	1.075252	1.187213	0.91	0.365	-1.251642	3.402146
1.Guanajuato	-1.934957	.6944942	-2.79	0.005	-3.296141	-.5737737
1.Guerrero	-2.502103	.6816623	-3.67	0.000	-3.838136	-1.166069
1.Hidalgo	-3.729998	.6976517	-5.35	0.000	-5.09737	-2.362625
1.Jalisco	-2.096903	.6399001	-3.28	0.001	-3.351084	-.842722
1.Mexico	-2.694859	.6390386	-4.22	0.000	-3.947351	-1.442366
1.Michoacan	-3.641463	.6766983	-5.38	0.000	-4.967768	-2.315159
1.Morelos	-2.487405	.7269588	-3.42	0.001	-3.912218	-1.062592
1.Nayarit	.192304	1.203696	0.16	0.873	-2.166897	2.551505
1.Oaxaca	-3.609872	.6529464	-5.53	0.000	-4.889624	-2.330121
1.Puebla	-2.733741	.6425101	-4.25	0.000	-3.993038	-1.474444
1.Queretaro	-1.053	.859102	-1.23	0.220	-2.736809	.630809
1.QuintanaRoo	-2.003138	1.356599	-1.48	0.140	-4.662024	.6557475
1.SanLuisPotosi	-2.977469	.7032022	-4.23	0.000	-4.35572	-1.599218
1.Sonora	-1.519829	.6877328	-2.21	0.027	-2.86776	-.1718972
1.Tabasco	.0582215	1.210381	0.05	0.962	-2.314081	2.430524
1.Tamaulipas	-2.198916	.7360708	-2.99	0.003	-3.641588	-.7562439
1.Tlaxcala	-2.19958	.678076	-3.24	0.001	-3.528585	-.8705756
1.Veracruz	-3.228734	.6470968	-4.99	0.000	-4.49702	-1.960448
1.Yucatan	-4.997336	.8817709	-5.67	0.000	-6.725575	-3.269097
1.Zacatecas	-1.356607	.6918733	-1.96	0.050	-2.712654	-.0005603
_cons	-2.688998	1.526012	-1.76	0.078	-5.679927	.3019313

Source: Own calculations, using Stata 13.

**Table A.59: Logit of model 1 with state categories**

Logistic regression Number of obs = 1996  
 LR chi2(15) = 843.96  
 Prob > chi2 = 0.0000  
 Pseudo R2 = 0.3326

Log likelihood = -846.87754

WWT	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
gdpcap	.0685979	.0283955	2.42	0.016	.0129437	.1242521
gini	.0420011	.0169985	2.47	0.013	.0086847	.0753175
eduind	.0085932	.0156896	0.55	0.584	-.0221578	.0393442
urban	.0069205	.0032483	2.13	0.033	.000554	.013287
fracind	-.0043819	.0054526	-0.80	0.422	-.0150688	.0063049
ethnic	.0010362	.0035795	0.29	0.772	-.0059795	.0080519
femadmin	.0023997	.0047899	0.50	0.616	-.0069882	.0117877
neighmun	.0103463	.0023605	4.38	0.000	.0057198	.0149728
planind	.0044246	.0022249	1.99	0.047	.0000638	.0087854
regind	.0001975	.0017618	0.11	0.911	-.0032557	.0036506
1.waterutility	.5778491	.1976375	2.92	0.003	.1904867	.9652114
1.StateCategory2	-1.948454	.4928249	-3.95	0.000	-2.914373	-.9825347
1.StateCategory3	-2.690642	.4863529	-5.53	0.000	-3.643876	-1.737408
1.StateCategory4	-3.294466	.4931524	-6.68	0.000	-4.261027	-2.327905
1.StateCategory5	-4.022543	.5071049	-7.93	0.000	-5.01645	-3.028636
_cons	-1.444271	1.528559	-0.94	0.345	-4.440193	1.55165

Source: Own calculations, using Stata 13.

**Table A.60: Logit of model 2 with state categories**

Logistic regression Number of obs = 2290  
 LR chi2(13) = 952.03  
 Prob > chi2 = 0.0000  
 Pseudo R2 = 0.3259

Log likelihood = -984.81466

WWT	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
gdpcap	.074587	.0262968	2.84	0.005	.0230462	.1261279
gini	.0581727	.0155205	3.75	0.000	.027753	.0885924
eduind	.0087415	.0146236	0.60	0.550	-.0199202	.0374033
urban	.0072202	.0029851	2.42	0.016	.0013694	.0130709
fracind	-.0045024	.0050785	-0.89	0.375	-.0144562	.0054513
ethnic	.000469	.0033478	0.14	0.889	-.0060926	.0070306
femadmin	.0026117	.0043759	0.60	0.551	-.0059648	.0111883
neighmun	.0110299	.0021296	5.18	0.000	.006856	.0152039
1.waterutility	.481729	.1792985	2.69	0.007	.1303103	.8331476
1.StateCategory2	-1.768057	.4246122	-4.16	0.000	-2.600282	-.9358326
1.StateCategory3	-2.511978	.4166563	-6.03	0.000	-3.328609	-1.695346
1.StateCategory4	-3.110845	.4218228	-7.37	0.000	-3.937602	-2.284087
1.StateCategory5	-3.808211	.4355967	-8.74	0.000	-4.661965	-2.954457
_cons	-2.132198	1.400249	-1.52	0.128	-4.876636	.6122402

Source: Own calculations, using Stata 13.

**Table A.61: Logit of model 1 with gdpicap2005 and eduind2005**

Logistic regression

Number of obs = 1996  
 LR chi2(37) = 871.15  
 Prob > chi2 = 0.0000  
 Pseudo R2 = 0.3433

Log likelihood = -833.28135

WWT	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
gdpicap2005	.0557098	.0377441	1.48	0.140	-.0182672	.1296868
gini	.0423202	.018069	2.34	0.019	.0069057	.0777348
eduind2005	.0241039	.0146367	1.65	0.100	-.0045836	.0527914
urban	.0096149	.0033848	2.84	0.005	.0029809	.0162489
fracind	-.0007923	.0056808	-0.14	0.889	-.0119265	.0103418
ethnic	.0019727	.0037078	0.53	0.595	-.0052944	.0092398
femadmin	.0022773	.0055601	0.41	0.682	-.0086203	.0131749
neighmun	.0097309	.002445	3.98	0.000	.0049387	.0145231
planind	.005081	.0023148	2.20	0.028	.0005441	.0096178
regind	.0002115	.0018823	0.11	0.911	-.0034778	.0039008
1.waterutility	.663349	.2085448	3.18	0.001	.2546088	1.072089
1.Campeche	-4.65467	1.283751	-3.63	0.000	-7.170776	-2.138565
1.Coahuila	-4.032708	1.115632	-3.61	0.000	-6.219306	-1.84611
1.Chiapas	-4.468294	1.094348	-4.08	0.000	-6.613177	-2.323412
1.Chihuahua	-2.429601	1.079443	-2.25	0.024	-4.54527	-.3139318
1.DF	-4.273053	1.24621	-3.43	0.001	-6.71558	-1.830526
1.Durango	-.3189366	1.445866	-0.22	0.825	-3.152781	2.514908
1.Guanajuato	-2.970466	1.084365	-2.74	0.006	-5.095782	-.8451507
1.Guerrero	-3.409013	1.089049	-3.13	0.002	-5.543509	-1.274517
1.Hidalgo	-4.688809	1.079894	-4.34	0.000	-6.805362	-2.572255
1.Jalisco	-3.04026	1.043636	-2.91	0.004	-5.08575	-.9947704
1.Mexico	-3.649216	1.043417	-3.50	0.000	-5.694277	-1.604155
1.Michoacan	-4.549707	1.066269	-4.27	0.000	-6.639556	-2.459857
1.Morelos	-3.63297	1.159501	-3.13	0.002	-5.905551	-1.360389
1.Nayarit	-.9118931	1.456095	-0.63	0.531	-3.765787	1.942001
1.Oaxaca	-4.677438	1.055977	-4.43	0.000	-6.747114	-2.607762
1.Puebla	-3.763904	1.046104	-3.60	0.000	-5.814231	-1.713578
1.Queretaro	-1.895657	1.191002	-1.59	0.111	-4.229978	.4386634
1.QuintanaRoo	-3.072658	1.612898	-1.91	0.057	-6.23388	.0885638
1.SanLuisPotosi	-3.978124	1.088744	-3.65	0.000	-6.112024	-1.844225
1.Sonora	-2.408343	1.075398	-2.24	0.025	-4.516083	-.3006025
1.Tabasco	-.7858011	1.470338	-0.53	0.593	-3.66761	2.096008
1.Tamaulipas	-2.956255	1.113967	-2.65	0.008	-5.139591	-.7729186
1.Tlaxcala	-3.117694	1.069523	-2.92	0.004	-5.213921	-1.021468
1.Veracruz	-4.446392	1.05766	-4.20	0.000	-6.519367	-2.373416
1.Yucatan	-6.299947	1.2785	-4.93	0.000	-8.805761	-3.794133
1.Zacatecas	-2.563023	1.072074	-2.39	0.017	-4.664249	-.4617962
_cons	-1.818659	1.65614	-1.10	0.272	-5.064635	1.427316

Source: Own calculations, using Stata 13.

**Table A.62: Logit of model 2 with gdpicap2005 and eduind2005**

Logistic regression	Number of obs	=	2290
	LR chi2(35)	=	979.65
	Prob > chi2	=	0.0000
Log likelihood = -971.00492	Pseudo R2	=	0.3353

WWT	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
gdpicap2005	.0823279	.0346111	2.38	0.017	.0144913	.1501644
gini	.0552723	.0167295	3.30	0.001	.0224832	.0880615
eduind2005	.0221274	.0135756	1.63	0.103	-.0044803	.0487351
urban	.0094595	.0030802	3.07	0.002	.0034224	.0154967
fracind	-.001342	.0053208	-0.25	0.801	-.0117706	.0090865
ethnic	.0015077	.0034816	0.43	0.665	-.0053162	.0083315
femadmin	.0016901	.0051067	0.33	0.741	-.0083188	.0116991
neighmun	.0103986	.0022146	4.70	0.000	.006058	.0147392
1.waterutility	.5854559	.1882493	3.11	0.002	.216494	.9544178
1.Campeche	-3.691617	.989076	-3.73	0.000	-5.63017	-1.753064
1.Coahuila	-3.302157	.7211943	-4.58	0.000	-4.715672	-1.888642
1.Chiapas	-3.483151	.6916774	-5.04	0.000	-4.838814	-2.127489
1.Chihuahua	-1.413652	.6937668	-2.04	0.042	-2.773409	-.0538935
1.DF	-3.450162	.9339359	-3.69	0.000	-5.280643	-1.619681
1.Durango	.9275401	1.185052	0.78	0.434	-1.39512	3.2502
1.Guanajuato	-2.103614	.6962001	-3.02	0.003	-3.468141	-.7390864
1.Guerrero	-2.616888	.6805444	-3.85	0.000	-3.950731	-1.283046
1.Hidalgo	-3.783788	.6980024	-5.42	0.000	-5.151848	-2.415728
1.Jalisco	-2.067424	.6410212	-3.23	0.001	-3.323803	-.8110454
1.Mexico	-2.673385	.6403279	-4.18	0.000	-3.928404	-1.418365
1.Michoacan	-3.612171	.675683	-5.35	0.000	-4.936485	-2.287857
1.Morelos	-2.51641	.7266685	-3.46	0.001	-3.940654	-1.092166
1.Nayarit	.0270667	1.204298	0.02	0.982	-2.333315	2.387448
1.Oaxaca	-3.69927	.6538759	-5.66	0.000	-4.980844	-2.417697
1.Puebla	-2.768641	.6433408	-4.30	0.000	-4.029566	-1.507716
1.Queretaro	-.9582577	.859788	-1.11	0.265	-2.643411	.7268958
1.QuintanaRoo	-2.070536	1.398618	-1.48	0.139	-4.811776	.6707043
1.SanLuisPotosi	-3.080195	.7001882	-4.40	0.000	-4.452539	-1.707852
1.Sonora	-1.545254	.6904796	-2.24	0.025	-2.89857	-.1919393
1.Tabasco	.2245187	1.212543	0.19	0.853	-2.152022	2.601059
1.Tamaulipas	-2.270141	.7365844	-3.08	0.002	-3.71382	-.8264625
1.Tlaxcala	-2.283091	.6810307	-3.35	0.001	-3.617887	-.9482957
1.Veracruz	-3.378577	.6484768	-5.21	0.000	-4.649568	-2.107586
1.Yucatan	-5.131415	.8822859	-5.82	0.000	-6.860664	-3.402166
1.Zacatecas	-1.617398	.6866632	-2.36	0.019	-2.963233	-.2715624
_cons	-3.013963	1.344186	-2.24	0.025	-5.648519	-.3794075

Source: Own calculations, using Stata 13.

**Table A.63: Logit regression of model 1 with gdpicap2005 and without eduind**

Logistic regression	Number of obs	=	1996
	LR chi2(36)	=	868.41
	Prob > chi2	=	0.0000
Log likelihood = -834.65445	Pseudo R2	=	0.3422

WWT	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]
gdpicap2005	.0823097	.0345464	2.38	0.017	.0146 .1500194
gini	.0425982	.0180611	2.36	0.018	.0071991 .0779972
urban	.0096724	.0033934	2.85	0.004	.0030214 .0163235
fracind	-.0001571	.005665	-0.03	0.978	-.0112602 .0109461
ethnic	-.0008116	.003316	-0.24	0.807	-.0073108 .0056875
femadmin	.0024777	.0055587	0.45	0.656	-.0084173 .0133726
neighmun	.0099158	.0024399	4.06	0.000	.0051336 .014698
planind	.0049866	.0023105	2.16	0.031	.0004581 .009515
regind	.0001838	.0018797	0.10	0.922	-.0035003 .0038679
1.waterutility	.6892626	.2081612	3.31	0.001	.2812742 1.097251
1.Campeche	-4.685289	1.289685	-3.63	0.000	-7.213025 -2.157552
1.Coahuila	-3.974548	1.115929	-3.56	0.000	-6.161729 -1.787367
1.Chiapas	-4.574288	1.091975	-4.19	0.000	-6.71452 -2.434056
1.Chihuahua	-2.487447	1.078074	-2.31	0.021	-4.600434 -.374461
1.DF	-4.293357	1.250669	-3.43	0.001	-6.744623 -1.842091
1.Durango	-.2569797	1.445438	-0.18	0.859	-3.089987 2.576027
1.Guanajuato	-3.065445	1.082997	-2.83	0.005	-5.188081 -.9428087
1.Guerrero	-3.528008	1.086096	-3.25	0.001	-5.656716 -1.3993
1.Hidalgo	-4.688478	1.080232	-4.34	0.000	-6.805693 -2.571262
1.Jalisco	-3.059999	1.043571	-2.93	0.003	-5.10536 -1.014637
1.Mexico	-3.611322	1.043329	-3.46	0.001	-5.65621 -1.566434
1.Michoacan	-4.618249	1.065644	-4.33	0.000	-6.706872 -2.529625
1.Morelos	-3.6203	1.16056	-3.12	0.002	-5.894956 -1.345643
1.Nayarit	-.8998771	1.45556	-0.62	0.536	-3.752723 1.952968
1.Oaxaca	-4.653156	1.055956	-4.41	0.000	-6.722792 -2.583521
1.Puebla	-3.795109	1.045881	-3.63	0.000	-5.844998 -1.745219
1.Queretaro	-1.932763	1.190277	-1.62	0.104	-4.265663 .4001373
1.QuintanaRoo	-3.034923	1.633615	-1.86	0.063	-6.236751 .1669042
1.SanLuisPotosi	-3.974259	1.088956	-3.65	0.000	-6.108573 -1.839944
1.Sonora	-2.349504	1.075288	-2.18	0.029	-4.45703 -.2419783
1.Tabasco	-.710763	1.468949	-0.48	0.628	-3.58985 2.168324
1.Tamaulipas	-2.927292	1.114657	-2.63	0.009	-5.11198 -.7426039
1.Tlaxcala	-3.003429	1.067288	-2.81	0.005	-5.095276 -.9115827
1.Veracruz	-4.479293	1.057358	-4.24	0.000	-6.551676 -2.40691
1.Yucatan	-6.287937	1.279285	-4.92	0.000	-8.795289 -3.780584
1.Zacatecas	-2.52425	1.071631	-2.36	0.018	-4.624607 -.4238924
_cons	-.0852597	1.272967	-0.07	0.947	-2.580228 2.409709

Source: Own calculations, using Stata 13.

**Table A.64: Probit of model 1 with IV registered cars per 1,000 inhab.**

Probit model with endogenous regressors                      Number of obs =            1905  
 Wald chi2(37) =            554.28  
 Log likelihood = -4559.8851                      Prob > chi2 =            0.0000

	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
gdpicap	.0571673	.0327001	1.75	0.080	-.0069237	.1212583
gini	.0247935	.0113999	2.17	0.030	.0024502	.0471368
eduind	.0078517	.0119935	0.65	0.513	-.0156552	.0313586
urban	.0039567	.002445	1.62	0.106	-.0008353	.0087488
fracind	-.0006257	.0032341	-0.19	0.847	-.0069644	.005713
ethnic	.00119	.0020231	0.59	0.556	-.0027751	.0051551
femadmin	.0000251	.0032733	0.01	0.994	-.0063905	.0064408
neighmun	.0058467	.0014807	3.95	0.000	.0029446	.0087489
planind	.0023441	.0013862	1.69	0.091	-.0003728	.0050609
regind	.0003781	.0011254	0.34	0.737	-.0018277	.0025839
1.waterutility	.3630352	.1221636	2.97	0.003	.123599	.6024714
1.Campeche	-2.411303	.6266055	-3.85	0.000	-3.639427	-1.183179
1.Coahuila	-2.069202	.5053611	-4.09	0.000	-3.059691	-1.078712
1.Chiapas	-2.331268	.4907831	-4.75	0.000	-3.293185	-1.369351
1.Chihuahua	-1.225964	.4714972	-2.60	0.009	-2.150081	-.3018463
1.DF	-2.680876	.6216845	-4.31	0.000	-3.899355	-1.462397
1.Durango	-.1925727	.628136	-0.31	0.759	-1.423697	1.038551
1.Guanajuato	-1.389549	.4863243	-2.86	0.004	-2.342727	-.4363709
1.Guerrero	-1.579673	.5222187	-3.02	0.002	-2.603203	-.5561433
1.Hidalgo	-2.457753	.467962	-5.25	0.000	-3.374942	-1.540565
1.Jalisco	-1.567896	.443942	-3.53	0.000	-2.438007	-.6977861
1.Mexico	-1.89967	.4446317	-4.27	0.000	-2.771132	-1.028207
1.Michoacan	-2.45942	.4597948	-5.35	0.000	-3.360601	-1.558239
1.Morelos	-1.885047	.5443588	-3.46	0.001	-2.951971	-.8181235
1.Nayarit	-.1823902	.6770232	-0.27	0.788	-1.509331	1.144551
1.Oaxaca	-2.418906	.4567081	-5.30	0.000	-3.314037	-1.523774
1.Puebla	-1.899757	.4479155	-4.24	0.000	-2.777655	-1.021859
1.Queretaro	-.912759	.5502264	-1.66	0.097	-1.991183	.1656649
1.QuintanaRoo	-1.444665	.8617368	-1.68	0.094	-3.133638	.2443085
1.SanLuisPotosi	-2.028014	.4850378	-4.18	0.000	-2.978671	-1.077358
1.Sonora	-1.171024	.4653766	-2.52	0.012	-2.083145	-.2589026
1.Tabasco	-.4148376	.6590661	-0.63	0.529	-1.706583	.8769083
1.Tamaulipas	-1.46519	.5006145	-2.93	0.003	-2.446376	-.4840037
1.Tlaxcala	-1.792524	.7025505	-2.55	0.011	-3.169498	-.4155501
1.Veracruz	-2.322285	.4585172	-5.06	0.000	-3.220962	-1.423608
1.Yucatan	-3.320178	.5807176	-5.72	0.000	-4.458364	-2.181992
1.Zacatecas	-1.100419	.4872706	-2.26	0.024	-2.055452	-.1453863
_cons	-1.132715	1.049154	-1.08	0.280	-3.189018	.9235889
/athrho	-.0128005	.0650631	-0.20	0.844	-.1403217	.1147208
/lnsigma	.5679083	.0162008	35.05	0.000	.5361552	.5996613
rho	-.0127998	.0650524			-.139408	.1142201
sigma	1.764572	.0285876			1.709422	1.821502

Instrumented: gdpicap  
 Instruments: gini eduind urban fracind ethnic femadmin neighmun planind  
 regind 1.waterutility 1.Campeche 1.Coahuila 1.Chiapas  
 1.Chihuahua 1.DF 1.Durango 1.Guanajuato 1.Guerrero 1.Hidalgo  
 1.Jalisco 1.Mexico 1.Michoacan 1.Morelos 1.Nayarit 1.Oaxaca  
 1.Puebla 1.Queretaro 1.QuintanaRoo 1.SanLuisPotosi 1.Sonora  
 1.Tabasco 1.Tamaulipas 1.Tlaxcala 1.Veracruz 1.Yucatan  
 1.Zacatecas Regcar

Wald test of exogeneity (/athrho = 0): chi2(1) =            0.04 Prob > chi2 = 0.8440

Source: Own calculations, using Stata 13.

**Table A.65: Linktest of fractional logit**

Generalized linear models		No. of obs	=	425
Optimization	: ML	Residual df	=	422
Deviance	= 40.57952898	Scale parameter	=	.09616
Pearson	= 40.57952898	(1/df) Deviance	=	.09616
		(1/df) Pearson	=	.09616
Variance function:	V(u) = 1	[Gaussian]		
Link function	: g(u) = u	[Identity]		
		<u>AIC</u>	=	.5031693
Log likelihood	= -103.9234702	<u>BIC</u>	=	-2513.402

Share_WWT	OIM		z	P> z	[95% Conf. Interval]	
	Coef.	Std. Err.				
_hat	.2110665	.030816	6.85	0.000	.1506683	.2714648
_hatsq	.017567	.0121449	1.45	0.148	-.0062365	.0413706
_cons	.4815067	.0242616	19.85	0.000	.4339548	.5290585

Source: Own calculations, using Stata 13.

**Table A.66: Test statistic for tobit**

Measures of Fit for tobit of Share\_WWT

Log-Lik Intercept Only:	-351.145	Log-Lik Full Model:	-276.269
D(413):	552.539	LR(10):	149.752
		Prob > LR:	0.000
McFadden's R2:	0.213	McFadden's Adj R2:	0.179
ML (Cox-Snell) R2:	0.297	Cragg-Uhler (Nagelkerke) R2:	0.367
McKelvey & Zavoina's R2:	0.343		
Variance of y*:	0.484	Variance of error:	0.318
AIC:	1.357	AIC*n:	576.539
BIC:	-1946.974	BIC':	-89.231
BIC used by Stata:	625.164	AIC used by Stata:	576.539

Source: Own calculations, using Stata 13.

**Table A.67: Test statistic for fractional logit**

Measures of Fit for tobit of Share\_WWT

Log-Lik Intercept Only:	-351.145	Log-Lik Full Model:	-276.269
D(413):	552.539	LR(10):	149.752
		Prob > LR:	0.000
McFadden's R2:	0.213	McFadden's Adj R2:	0.179
ML (Cox-Snell) R2:	0.297	Cragg-Uhler (Nagelkerke) R2:	0.367
McKelvey & Zavoina's R2:	0.343		
Variance of y*:	0.484	Variance of error:	0.318
AIC:	1.357	AIC*n:	576.539
BIC:	-1946.974	BIC':	-89.231
BIC used by Stata:	625.164	AIC used by Stata:	576.539

Source: Own calculations, using Stata 13.

**Table A.68: Fractional logit without gdpicap outlier**

Generalized linear models		No. of obs	=	424
Optimization	: ML	Residual df	=	413
		Scale parameter	=	1
Deviance	= 251.3873244	(1/df) Deviance	=	.608686
Pearson	= 252.2607567	(1/df) Pearson	=	.6108009
Variance function:	$V(u) = u*(1-u/1)$	[Binomial]		
Link function	: $g(u) = \ln(u/(1-u))$	[Logit]		
		<u>AIC</u>	=	.8840713
Log pseudolikelihood = -176.4231055		<u>BIC</u>	=	-2247.153

Share_WWT	Robust					[95% Conf. Interval]	
	Coef.	Std. Err.	z	P> z			
gdpicap	.0413285	.0370938	1.11	0.265	-.0313739	.1140309	
gini	-.0036122	.0280236	-0.13	0.897	-.0585375	.0513131	
fracind	-.0001667	.0108615	-0.02	0.988	-.0214549	.0211214	
femadmin	-.0077443	.0073598	-1.05	0.293	-.0221693	.0066807	
neighmun	.0075132	.0039087	1.92	0.055	-.0001476	.0151741	
1.waterutility	.7367835	.2135883	3.45	0.001	.318158	1.155409	
1.StateCategory2	-.6477935	.3132275	-2.07	0.039	-1.261708	-.0338789	
1.StateCategory3	-.8199361	.3489201	-2.35	0.019	-1.503807	-.1360653	
1.StateCategory4	-1.528439	.3792641	-4.03	0.000	-2.271783	-.7850945	
1.StateCategory5	-2.069005	.5300046	-3.90	0.000	-3.107795	-1.030215	
_cons	-.7985893	1.257357	-0.64	0.525	-3.262963	1.665784	

Source: Own calculations, using Stata 13.

**Table A.69: Tobit without gdpicap outlier**

Tobit regression		Number of obs	=	424
		F( 10, 414)	=	21.28
		Prob > F	=	0.0000
Log pseudolikelihood = -275.91666		Pseudo R2	=	0.2103

Share_WWT	Robust				[95% Conf. Interval]	
	Coef.	Std. Err.	t	P> t		
gdpicap	.02715	.0114878	2.36	0.019	.0045682	.0497317
gini	.0012226	.0090995	0.13	0.893	-.0166644	.0191096
fracind	-.0012358	.0033426	-0.37	0.712	-.0078064	.0053348
femadmin	-.0026891	.0025607	-1.05	0.294	-.0077228	.0023445
neighmun	.0036832	.0013044	2.82	0.005	.0011191	.0062474
1.waterutility	.2619763	.0749755	3.49	0.001	.1145963	.4093564
1.StateCategory2	-.2195403	.0988759	-2.22	0.027	-.4139017	-.0251788
1.StateCategory3	-.2678493	.108355	-2.47	0.014	-.4808438	-.0548547
1.StateCategory4	-.5098159	.1221003	-4.18	0.000	-.7498298	-.269802
1.StateCategory5	-.6390023	.1595219	-4.01	0.000	-.9525762	-.3254285
_cons	-.164175	.4056065	-0.40	0.686	-.96148	.63313
/sigma	.5656438	.0246855			.5171192	.6141684

Obs. summary: 239 left-censored observations at Share\_WWT<=0  
185 uncensored observations  
0 right-censored observations

Source: Own calculations, using Stata 13.



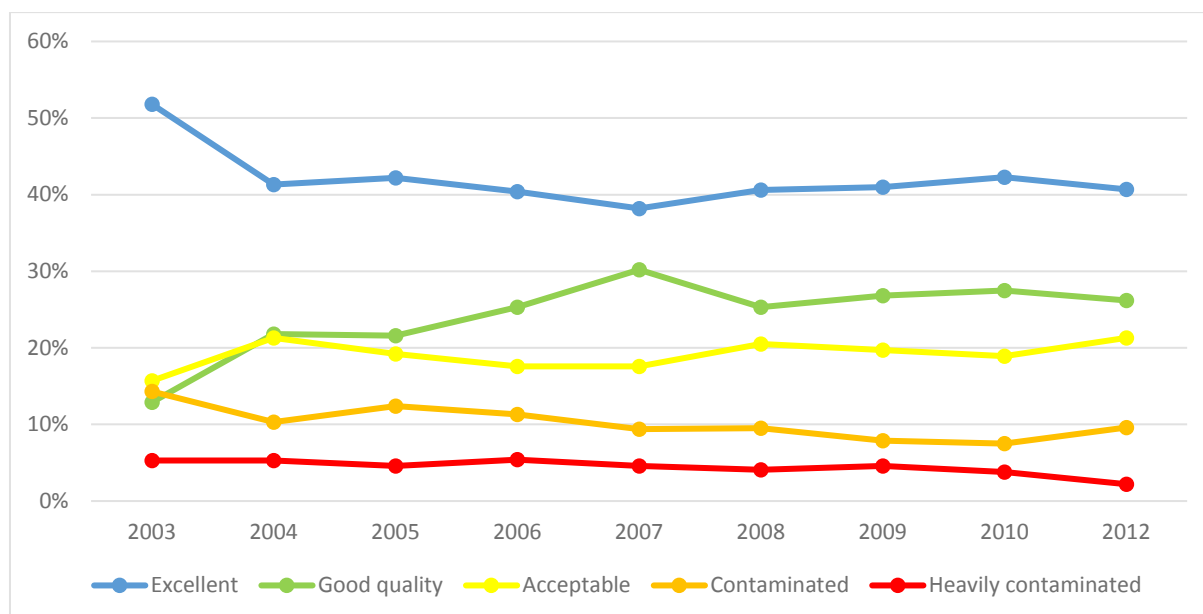
## 9.2. Appendix figures

Water Quality Index	Measure					Measure			Measure		
	1990	1991	1994	2000	2002	Scale BOD <sub>5</sub> (mg/L)	2003 with BOD <sub>5</sub>	2012 with BOD <sub>5</sub>	Scale COD (mg/L)	2003 with COD	2012 with COD
95-100	excellent				good	excellent	excellent	excellent	≤10	excellent	excellent
90-95					10%	6%	51.8%	40.4%		28.8%	32.1%
85-89	acceptable			7%		10% ≤6	good quality	good quality	>10 ≤20	good quality	good quality
80-84							12.9%	26.2%		21.4%	15.2%
70-79	lightly contaminated			medium		>6 ≤30	acceptable	acceptable	>20 ≤40	acceptable	acceptable
60-69	contaminated			65%			15.7%	21.3%		18.4%	21%
50-59	52%	41%	59%	requires major treatment		>30 ≤120	contaminated	contaminated	>40 ≤200	contaminated	contaminated
40-49	heavily contaminated			16%			14.3%	9.6%		20.4%	26.2%
33-39				only for industrial and agricultural use		>120	heavily contaminated	heavily contaminated	>200	heavily contaminated	heavily contaminated
30-32				highly contaminated			5.3%	3.2%		1.1%	1.5%
23-29											
20-22											
16-19											
10-15											
0-9											

**Figure A.1: Surface water quality in Mexico, 1990-2002 and 2003-12**

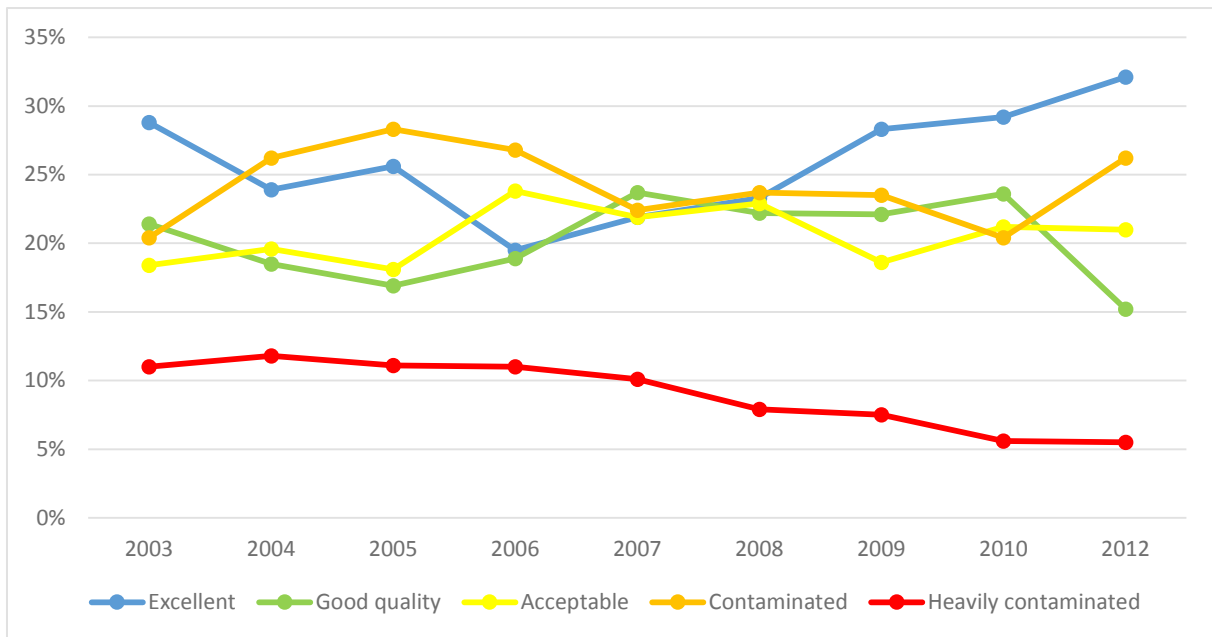
Source: Jiménez (2007), Información y calidad del agua en México: Trayectorias, p. 46, modified and extended by the author with data of CONAGUA (2005 and 2013b).

Note: BOD<sub>5</sub> = Biochemical oxygen demand in 5 days; COD = Chemical oxygen demand.



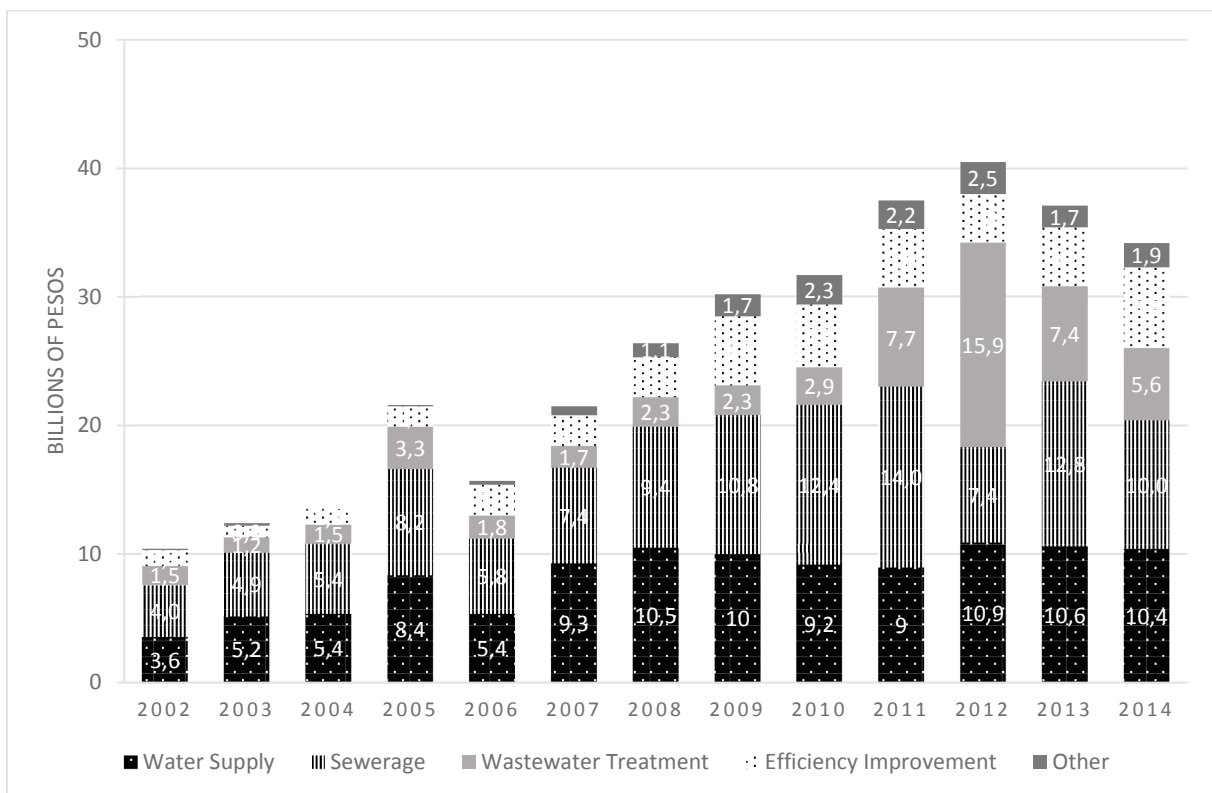
**Figure A.2: BOD<sub>5</sub>-classification of surface water in Mexico (%), 2003-2012**

Source: Own creation, based on data of CONAGUA (2002, 2003, 2005, 2006, 2007, 2008b, 2010a, 2012a, 2014a).



**Figure A.3: COD-classification of surface water in Mexico (%), 2003-2012**

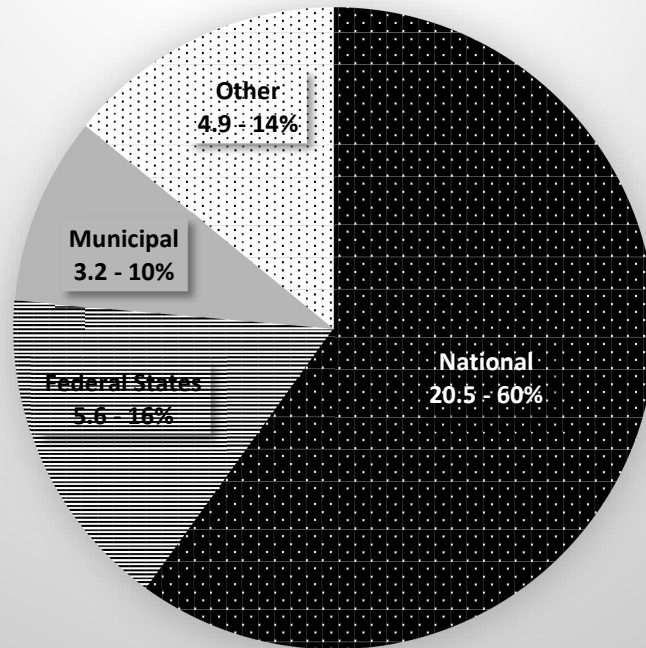
Source: Own creation, based on data of CONAGUA (2002, 2003, 2005, 2006, 2007, 2008b, 2010a, 2012a, 2014a).



**Figure A.4: Investment by field of application (in Mex\$ bn), 2002-14**

Source: CONAGUA (2015). Situación del Subsector Agua Potable, Alcantarillado y Saneamiento, p. 9, modified by the author.

Total investment: 34.2 billion pesos



**Figure A.5: Investment in municipal water by sector of origin (in Mex\$ bn; %), 2014**

Source: CONAGUA (2015). Situación del Subsector Agua Potable, Alcantarillado y Saneamiento, p. 7, modified by the author.

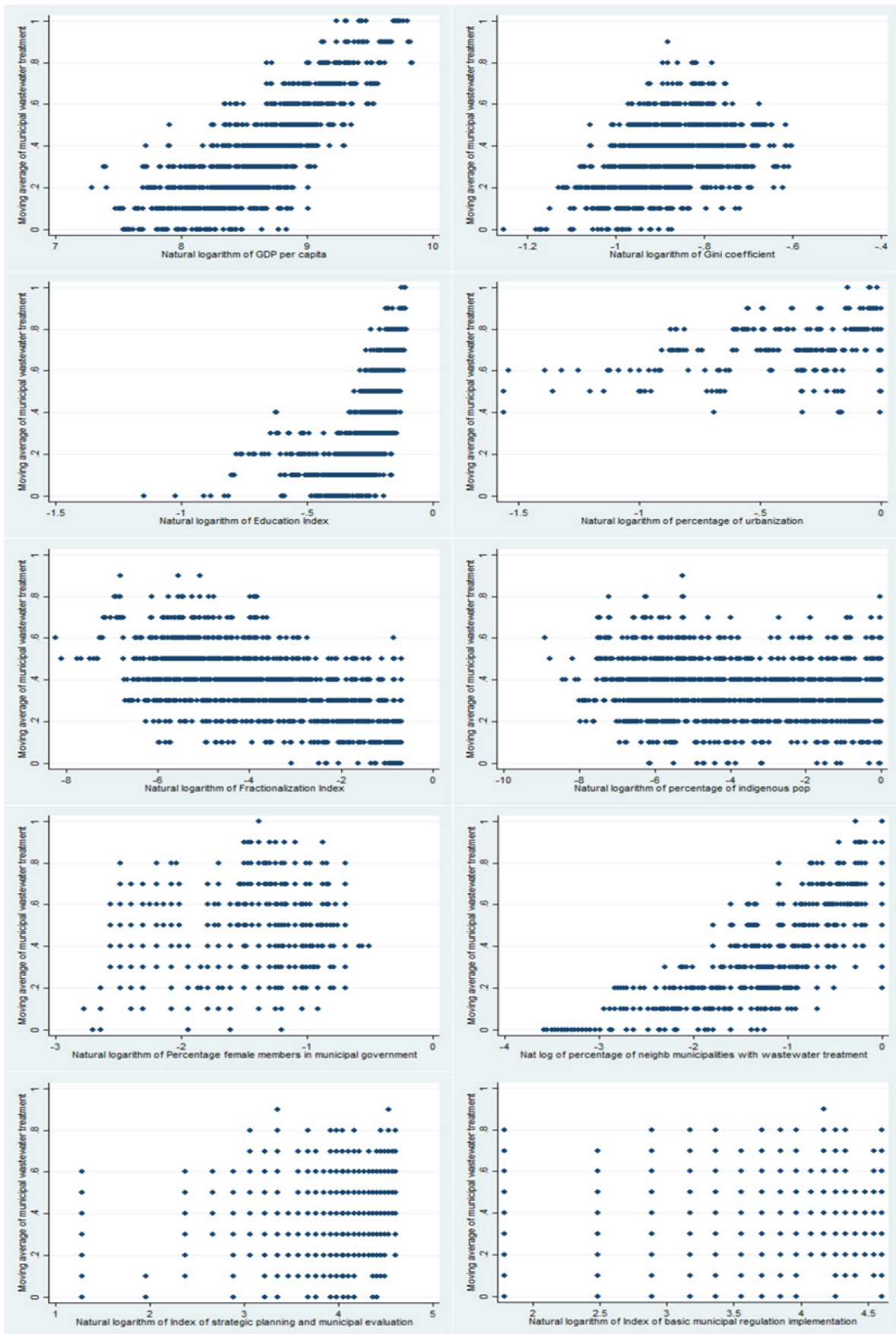
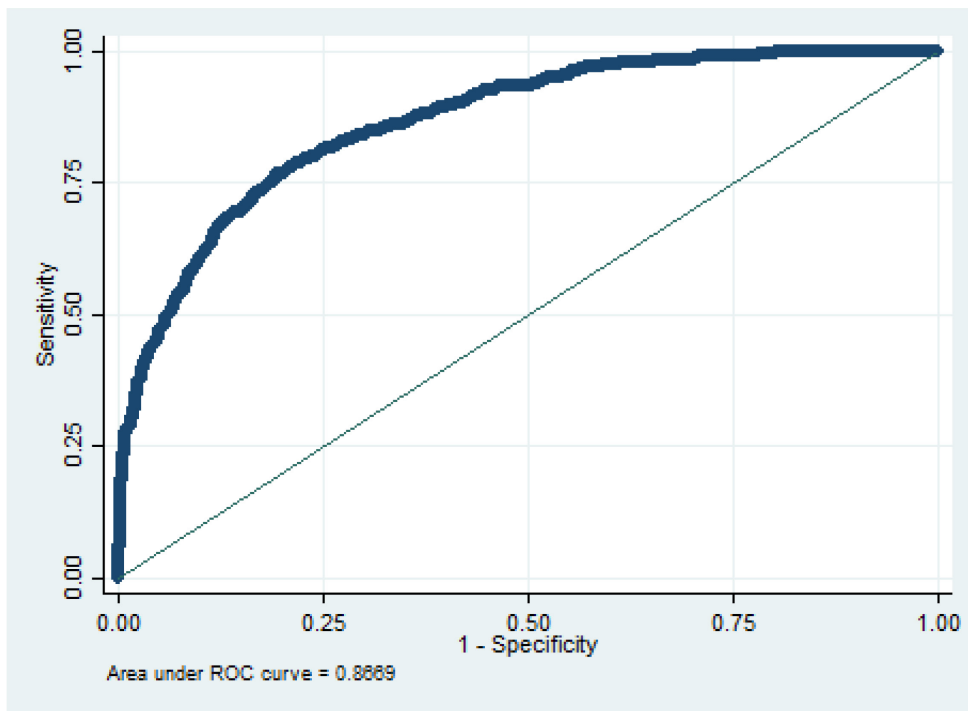
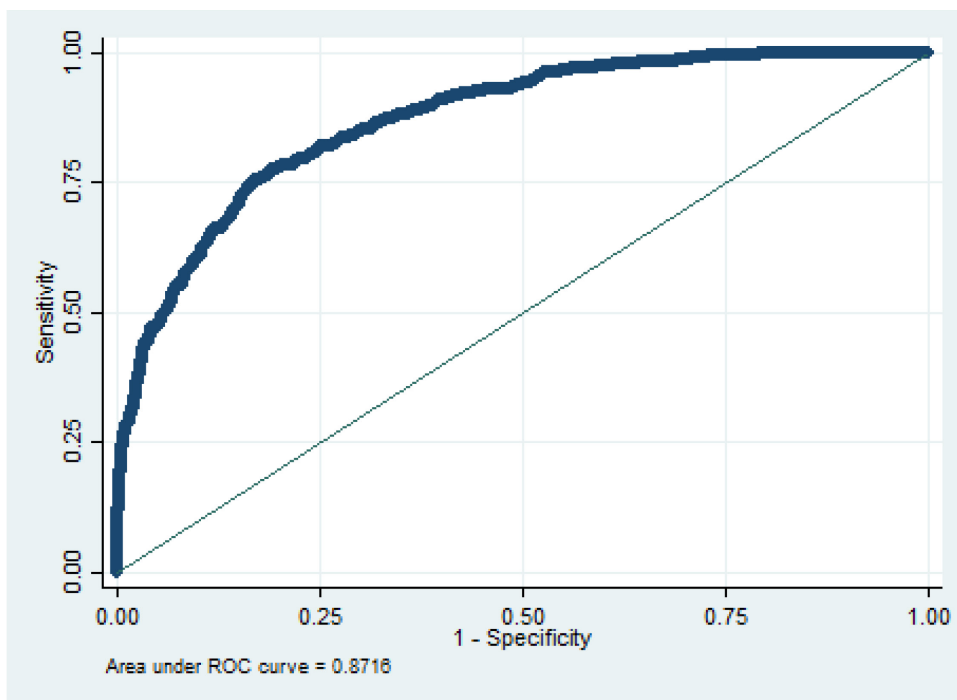


Figure A.6: Moving average of wastewater treatment and  $\log_{10}$  of ind. variables

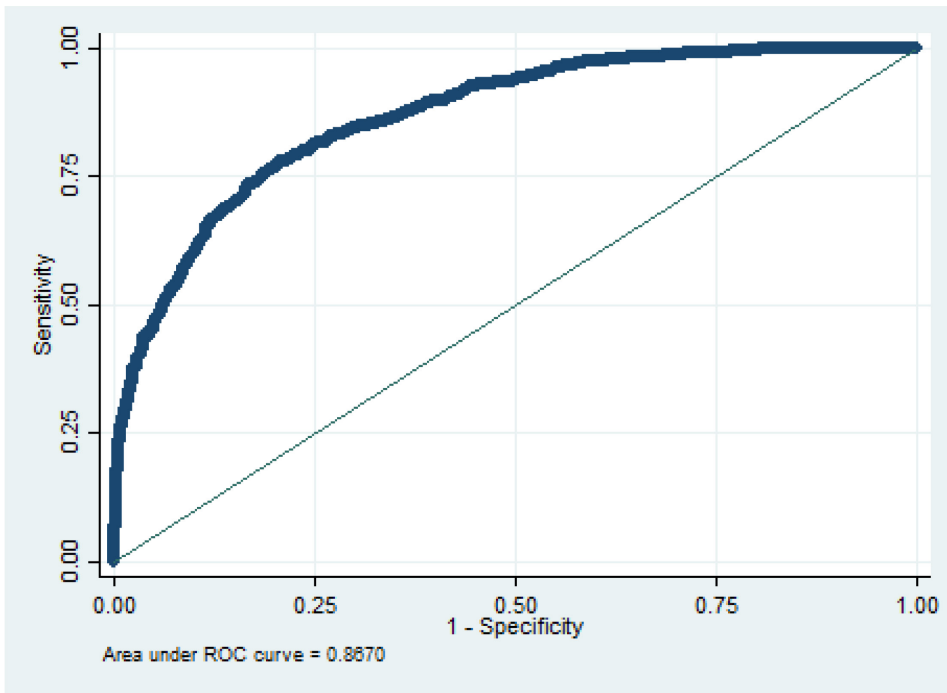
Source: Own creation, using Stata 13.



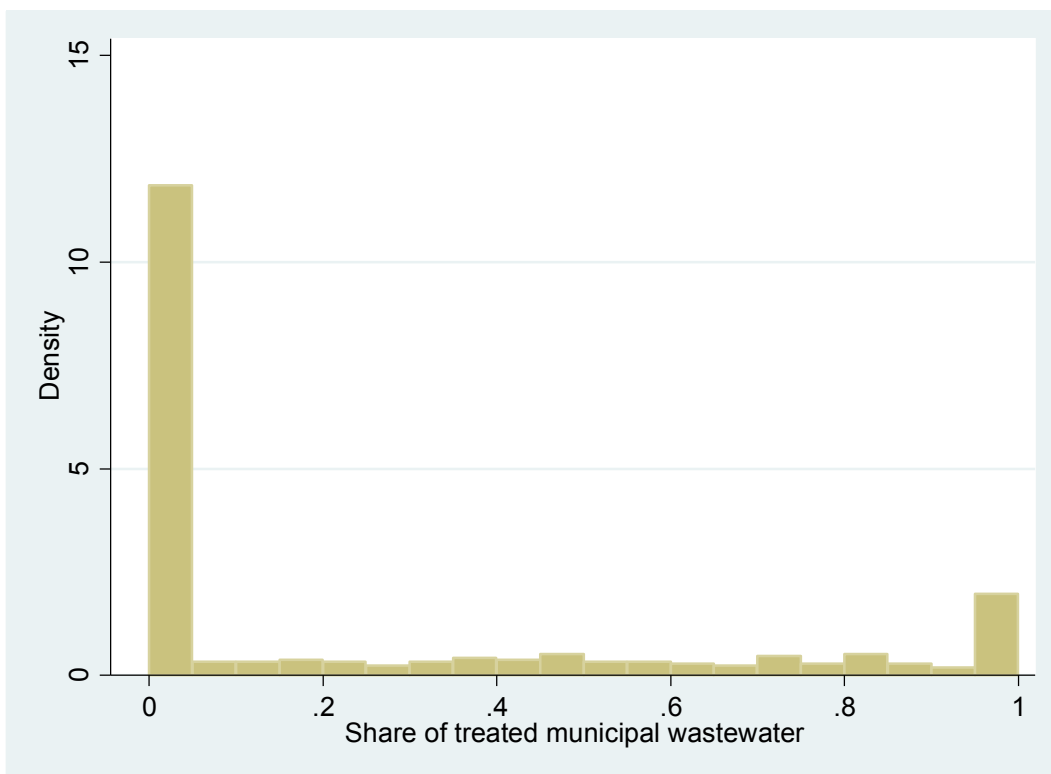
**Figure A.7: ROC-curve of logit model 2**  
 Source: Own calculations, using Stata 13.



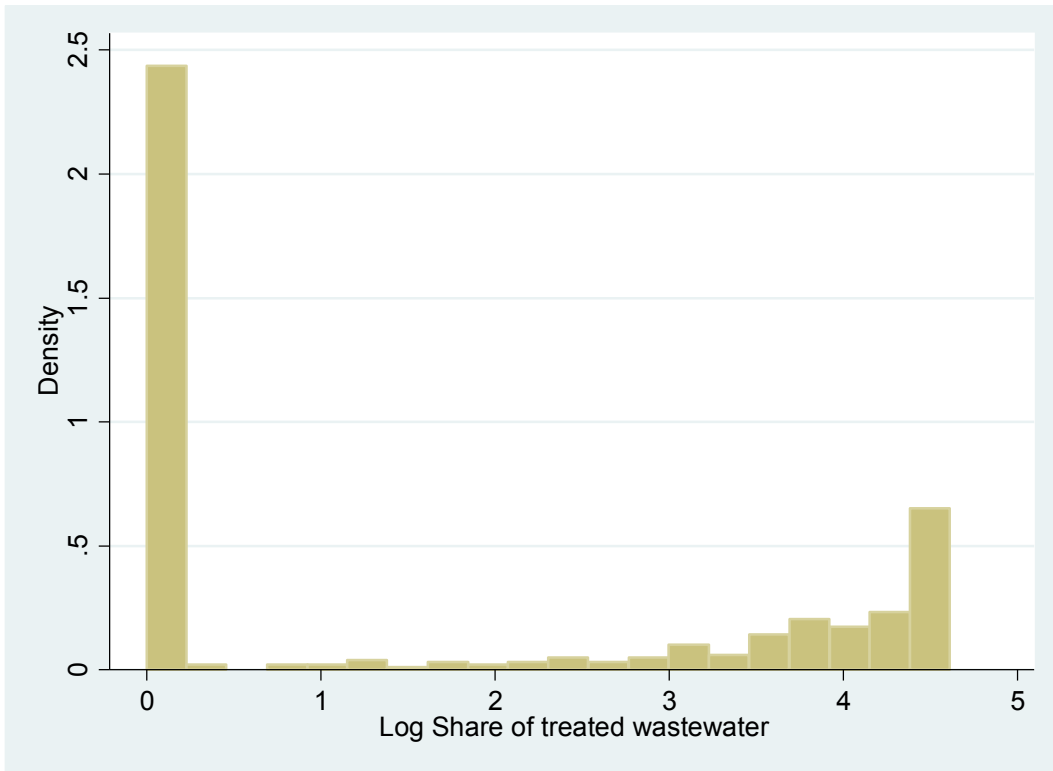
**Figure A.8: ROC-curve of probit model 1**  
 Source: Own calculations, using Stata 13.



**Figure A.9: ROC-curve of probit model 2**  
 Source: Own calculations, using Stata 13.



**Figure A.10: Distribution of share of treated wastewater (425 obs.), 2010**  
 Source: Own calculations, using Stata 13.



**Figure A.11: Distribution of In Share\_WWT (425 obs.), 2010**

Source: Own calculations, using Stata 13.

## 10. Bibliography

- Abedrop López, S. and Reyes Morales, R. (2008). La regulación de los servicios de agua potable en México - condiciones para su viabilidad, in Olivares, R. and Sandoval, R. (eds.): El agua potable en México – historia reciente, actores, procesos y propuestas, DF, México, pp. 317-326.
- Aboites A.L. (1998). El agua de la nación: una historia política de México (1888-1946), Ciesas, México.
- Aboites A.L., Cifuentes, E., Jiménez, B. and Torregrosa, M.L. (2008). Agenda del agua, Red del Agua, Academia Mexicana de Ciencias, D.F., México.
- Aguilar Amilpa, E. (2010). Normatividad de los servicios de agua y saneamiento en México: Los casos de Chiapas, Tabasco y Veracruz, CEPAL, D.F., México.
- Aguilar Ibarra, A. and Pérez Espejo, R. H. (2007). La contaminación agrícola del agua en México: retos y perspectivas - problemas del desarrollo, revista latinoamericana de economía, Universidad Nacional Autónoma de México, Vol. 39, número 153, pp. 205-215.
- Alcamo, J., Döll, P., Kaspar, F. and Siebert, S. (1997). Global change and global scenarios of water use and availability: An application of water, GAP 1.0, University of Kassel.
- Alcamo, J., Henrichs, T. and Rösch, T. (2000). World water in 2025 – global modeling and scenario analysis for the world commission on water for the 21<sup>st</sup> century, University of Kassel.
- Alcántara Palma, V. (1996). Marco legal actual de los servicios de agua potable, alcantarillado y saneamiento a nivel local – una visión de conjunto, Federalismo y Desarrollo, Vol. 9, No. 54, pp. 55-66.
- Alesina, A. and La Ferrara, E. (2000). Participation in heterogeneous communities, Quarterly Journal of Economics, Vol. 115, No. 3, pp. 847–904.
- Alesina, A. and La Ferrara, E. (2005). Ethnic diversity and economic performance, Journal of Economic Literature, Vol. 43, No.3, pp. 762–800.
- Alesina, A., Baqir R. and Easterly, W. (1999). Public goods and ethnic divisions, Quarterly Journal of Economics, Vol. 114, No. 4, pp. 1243–1284.
- Alesina, A., Devleeschauwer, A., Easterly, W., Kurlat, S. and Wacziarg, R. (2003). Fractionalization, Journal of Economic Growth, Vol. 8, No.2, pp. 155–194.
- Alm, J. and Banzhaf, H.S. (2012). Designing economic instruments for the environment in a decentralized fiscal system, Journal of Economic Surveys, Vol. 26, No. 2, pp. 177–202.
- Amemiya, T. (1981). Qualitative response models: A Survey, Journal of Economic Literature, Vol. 19, No. 4, pp. 1483-1536.
- Anda Sánchez, J. de and Maniak, U. (2007). Modificaciones en el régimen hidrológico y sus efectos en la acumulación de fósforo y fosfatos en el lago de Chapala, México, Interciencia, Vol. 32, No. 2.



- Andersona, L.R., Mellora, J.M. and Milyo, J. (2008). Inequality and public good provision: An experimental analysis, *The Journal of Socio-Economics*, Vol. 37, Issue 3, pp. 1010–1028.
- Angelakis, A. N. and Gikas, P. (2014). Water reuse: Overview of current practices and trends in the world with emphasis on EU states, *Water Utility Journal*, Vol. 8, pp. 67-78.
- Ansuategi, A. and Perrings, C. (2000). Transboundary externalities in the environmental transition hypothesis, *Environmental Resource Economics*, Vol. 17, No. 4, pp. 353–373.
- Arrow, K., Bolin, B., Costanza, R., Folke, C., Holling, C.S., Janson, B., Levin, S., Maler, K., Perrings, C. and Pimental, D. (1995). Economic growth, carrying capacity, and the environment, *Science*, Vol. 15, pp. 91– 95.
- Ayalon, O., Brody, S. and Shechter, M. (2013). Household waste generation, recycling and prevention, in Brown, Z., Johnstone, N., Serret-Itzicsohn, Y. (ed.), *Greening household behaviour: Overview from the 2011 survey*, OECD Publishing, Paris, France.
- Azizullah, A., Khattak, M.N.K., Richter, P. and Häder, D.-P. (2011). Water pollution in Pakistan and its impact on public health — A review, *Environmental International*, Vol. 37, Issue 2, pp. 479–497.
- Azomahou, T., Laisney, F. and Nguyen, P. (2006). Economic development and CO2 emissions: a nonparametric panel approach, *Journal of Public Economics*, Vol. 90, pp. 1347–1363.
- Baek, J. and Gweisah, G. (2013). Does income inequality harm the environment? Empirical evidence from the United States, *Energy Policy*, Vol. 62, pp. 1434–1437.
- Baiocchi, G., Minx, J. and Hubacek, K. (2010). The impact of social factors and consumer behavior on carbon dioxide emissions in the United Kingdom, *Journal of Industrial Ecology*, Vol. 14, pp. 50–72.
- Bakir, H.A. (2001). Sustainable wastewater management for small communities in the Middle East and North Africa, *Journal of Environmental Management*, Vol. 61, pp. 319–328.
- Baksi S. and Bose P. (2010). Environmental regulation in the presence of an informal sector, WP 2010-03, The University of Winnipeg, Canada.
- Balakrishnan, N. (1992). *Handbook of the Logistic Distribution*, Marcel Dekker, New York.
- Baldwin, K. and Huber, J.D. (2010). Economic versus cultural differences: Forms of ethnic diversity and public goods provision, *American Political Science Review*, Vol. 104, pp. 644–662.
- Banerjee, A.V. (1992). A simple model of herd behavior, *Quarterly Journal of Economics*, Vol. 107, No. 3, pp. 797–817.
- Barkin, D. (2006). *La gestión del agua urbana en México – retos, debates y bienestar*, Universidad de Guadalajara, Jalisco, México.
- Barkin, D. (2011). The governance crisis in urban water management in Mexico, in Oswald Spring, Ú. (ed.): *Water resources in Mexico – scarcity, degradation, stress, conflicts, management, and policy*, Springer Verlag, Berlin Heidelberg, Germany, pp. 379-393.

Barkin, D. and Klooster, D. (2006). Estrategias de la gestión del agua urbana, in Barkin, D. (Coord.), La gestión del agua urbana en México – retos, debates y bienestar, Universidad de Guadalajara, Jalisco, México, pp. 1-46.

Barro, R.J. (1997). The determinants of economic growth, MIT Press, Cambridge (MA), USA.

Barro, R.J. and Lee, J.-W. (2010). A new data set of educational attainment in the world, 1950–2010, NBER Working paper series, Working paper 15902, retrieved on 2016/25/06 from <http://www.nber.org/papers/w15902>.

Batchelor, C. (2007). Water governance literature assessment, International Institute for Environment and Development, retrieved on 2016/15/07 from <http://www.iied.org/pubs/pdfs/G02523.pdf>.

Baum, C.F. (2008). Stata tip 63: Modeling proportions, The Stata Journal 8, No. 2, pp. 299–303.

Baum, C.F. (2013). Generalized linear models, EC 823: Applied econometrics, Boston College, MA, USA, retrieved on 2016/08/07 from <http://fmwww.bc.edu/ec-c/S2014/823/EC823.S2014.php>.

Baum, R., Luh, J. and Bartram, J. (2013). Sanitation: A Global Estimate of Sewerage Connections without Treatment and the Resulting Impact on MDG Progress, Environmental Science & Technology, Vol. 47, Issue 4, pp 1994–2000.

Beckerman, W. (1992). Economic growth and the environment: Whose growth? Whose environment, World Development, Vol. 20, pp. 481-496.

Bellows, A.C., Onyango, B., Diamond, A.W. and Hallman, K. (2008). Understanding consumer interest in organics: production values vs. purchasing behavior, Journal of Agricultural and Food Industrial Organization, Vol. 6, No. 1, pp. 1169-1169.

Berge, E. (1994). Democracy and human rights: Conditions for sustainable resource utilization, in B. R. Johnson (ed.): Who pays the price? The sociocultural context of environmental crisis, Island Press, Covelo, Canada.

Bernauer, T. and Koubi, V. (2009). Effects of political institutions on air quality, Ecological Economics, Vol. 68, pp. 1355–1365.

Berthe, A. and Elie, L. (2015). Mechanisms explaining the impact of economic inequality on environmental deterioration, Ecological Economics, Vol. 116, pp. 191–200.

Bhattarai, M. and Hammig, M. (2004). Governance, economic policy, and the environmental Kuznets curve for natural tropical forests, Environment and Development Economics, Vol. 9, pp. 367–382.

Bimonte, S. (2002). Information access, income distribution, and the Environmental Kuznets curve, Ecological Economics, Vol. 41, Issue 1, pp. 145–156.

Bird, R. and Smart, M. (2002). Intergovernmental fiscal transfers: International lessons for developing countries, World Development, Vol. 30, No. 6, pp. 899–912.

Biswas, A. (2003). *Water resources of North America*, Springer, Heidelberg-New York, Germany.

Blackman A. and Bannister, G.J. (1998). Pollution control in the informal sector: The Ciudad Juarez brickmakers' project, *Resources for the Future Discussion Paper*, DP 98-15, retrieved on 2017/03/30 from <http://www.rff.org/research/publications/pollution-control-informal-sector-ciudad-ju-rez-brickmakers-project>.

Blocker, T. J. and Eckberg, D.L. (1997). Gender and environmentalism: Results from the 1993 general social survey, *Social Science Quarterly*, Vol. 78, pp. 841–58.

Blocker, T.J. and Eckberg, D.L. (1989). Environmental issues as women's issues: General concerns and local hazards, *Social Science Quarterly*, Vol. 70, pp. 586–93.

Bo, S. (2011). A literature survey on Environmental Kuznets Curve, *Energy Procedia*, Vol. 5, pp. 1322–1325.

Boadway, R. and Shah, A. (2007). *Intergovernmental fiscal transfers: Principles and practices*, The World Bank, Washington, D.C., USA.

Bord, R.J. and O'Connor, R.E. (1997). The gender gap in environmental attitudes: the case of perceived vulnerability to risk, *Social Science Quarterly*, Vol. 78, No. 4, pp. 830-840.

Boyce, J.K. (1994). Inequality as a cause of environmental degradation, *Ecological Economics*, Vol. 11, pp. 169–178.

Boyce, J.K. (2003). Inequality and environmental protection, Working Paper 52, Political Economy Research Institute, University of Massachusetts, MA, USA.

Boyce, J.K. (2007). Inequality and environmental protection, in Baland, J.-M., Bardhan, P.K. and Bowles, S. (eds.), *Inequality, collective action, and environmental sustainability*, Princeton University Press, Russell Sage Foundation, Princeton, NY, USA, pp. 314–348.

Bravo Inclán, L., Sánchez Chávez, J., Tomasini Ortiz, C. and Córdova Rodríguez, M. (2008). Trophic state assessment of a high altitude, waterbody, Lake Pátzcuaro, México, 12<sup>th</sup> International Conference on Integrated Diffuse Pollution Management – 25-29 August 2008, Khon Kaen University, Thailand.

Briceño, E.R. (2008). Agua y saneamiento en México: avances, errores y alternativas, in Olivares R. and Sandoval. R. (eds.): *El agua potable en México – historia reciente, actores, procesos y propuestas*, DF, México, pp. 29-48.

Bruyn de, S. and Heintz, R. (1999). 'The Environmental Kuznets Curve hypothesis', in Bergh, J. van den (ed.), *Handbook of environmental and resource economics*, Edward Elgar, Cheltenham, UK, pp. 656–677.

Caia, H., Chena, Y. and Gong, Q. (2016). Polluting thy neighbor: Unintended consequences of China's pollution reduction mandates, *Journal of Environmental Economics and Management*, Vol. 76, pp. 86–104.

Callan, S.J. and Thomas, J.M. (2006). Analyzing demand for disposal and recycling services: A systems approach, *Eastern Economic Journal*, Vol. 32, No. 2, pp. 221–240.

Cámara de Diputados (1992a). Diario de los debates, LV legislatura, segundo periodo de sesiones ordinarias, primer año de ejercicio, 2 de julio, núm. 23, retrieved on 2016/02/23 from <http://cronica.diputados.gob.mx/>.

Cámara de Diputados (1992b). Diario de los debates, LV legislatura, primer periodo de sesiones ordinarias, segundo año de ejercicio, 10 de noviembre, núm. 6, retrieved on 2016/02/23 from <http://cronica.diputados.gob.mx/>.

Cameron, A.C. and Trivedi, P.K. (2005). *Microeconometrics: Methods and applications*, Cambridge University Press, New York, USA.

Cameron, A.C. and Trivedi, P.K. (2009). *Microeconometrics using Stata*, Stata Press, Texas, USA.

Carroll, S.J., Dodson, D.L. and Mandel, R.B. (1991). *The impact of women in public office: an overview*, Center for the American Woman and Politics, New Brunswick, NJ, USA.

Carson R., Jeon, Y. and McCubbin, D.R. (1997). The relationship between air pollution emissions and income: US data, *Environment and Development Economics*, Vol. 2, pp. 433-450.

Carson, R.T. (2010). The Environmental Kuznets curve: seeking empirical regularity and theoretical structure, *Review of Environmental Economics and Policy*, Vol. 4, No. 1, pp. 3–23.

CDI – Comisión Nacional para el Desarrollo de los Pueblos Indígenas (2017). Data on speakers of indigenous languages in Mexico, retrieved on 2017/03/05 from <http://www.gob.mx/cdi>.

CEPAL – Comisión Económica para América Latina y el Caribe (2012). *Población, territorio y desarrollo sostenible*, Santiago de Chile, Chile.

Chaudhuri, S. (2005). Pollution and welfare in the presence of informal sector: Is there any tradeoff?, Department of Economics, University of Calcutta India, retrieved on 2017/03/30 from <http://econwpa.repec.org/eps/othr/papers/0510/0510012.pdf>.

Choumert, J., Motel, P.C. and Dakpo, H.K. (2013). Is the Environmental Kuznets Curve for deforestation a threatened theory? A meta-analysis of the literature, *Ecological Economics*, Vol. 90, pp. 19–28.

CIA – Central Intelligence Agency (2015a). *The World Factbook – country ranking on population size and composition*, retrieved on 2015/12/23 from [www.cia.gov/library/publications/the-worldfactbook/rankorder/2119rank.html](http://www.cia.gov/library/publications/the-worldfactbook/rankorder/2119rank.html).

CIA – Central Intelligence Agency (2015b). *The World Factbook – country ranking on life expectancy*, retrieved on 2015/12/25 from [www.cia.gov/library/publications/the-worldfactbook/rankorder/2102rank.html#download](http://www.cia.gov/library/publications/the-worldfactbook/rankorder/2102rank.html#download).

Clément, M. and Meunié, A. (2010). Inégalités, développement et qualité de l'environnement: Mécanismes et application empirique, *Mondes Développement*, No. 151, pp. 67–82.

Cleves, M.A. (2002). From the help desk: Comparing areas under receiver operating characteristic curves from two or more probit or logit models, *The Stata Journal*, Vol. 2, No. 3, pp 301-313.

Coase, R.H. (1960). The Problem of social cost, *Journal of Law and Economics*, Vol. 3, pp. 1–44.

Código Municipal para el Estado de Coahuila de Zaragoza (2001). Secretaría de gobernación, Unidad General de Asunto Jurídicos, retrieved on 2016/05/03 from <http://www.ordenjuridico.gob.mx/Publicaciones/CDLeyes/pdf/Coahuila.pdf>.

Cole, M.A. (2003). Development, trade, and the environment: How robust is the Environmental Kuznets curve?, *Environment and Development Economics*, Vol. 8, pp. 557–580.

Cole, M.A. (2007). Corruption, income and the environment: An empirical analysis, *Ecological Economics*, Vol. 62, pp. 637–647.

Cole, M.A. and Neumayer, E. (2004). Examining the impact of demographic factors on air pollution, *Population Environment*, Vol. 26 No. 1, pp. 5–21.

Cole, M.A., Elliott, R.J.R. and Fredriksson, P.G. (2006). Endogenous pollution havens: Does FDI influence environmental regulations?, *Scandinavian Journal of Economics*, Vol. 108, No. 1, pp. 157–178.

Cole, M.A., Rayner, A.J. and Bates, J.M. (1997). The environment Kuznet curve: an empirical analysis, *Environ. Dev. Econ.*, 2, pp. 401–416.

Collado, J. (2008). Entorno de la provisión de los servicios públicos de agua potable en México, in Olivares, R. and Sandoval, R. (eds.): *El agua potable en México – historia reciente, actores, procesos y propuestas*, DF, México, pp. 3-28.

CONAGUA – Comisión Nacional del Agua (1989). *Lineamientos para el Programa Nacional de Agua Potable y Alcantarillado*, DF, Mexico.

CONAGUA – Comisión Nacional del Agua (2002). *Estadísticas del Agua en México 2002*, Comisión Nacional del Agua, México.

CONAGUA – Comisión Nacional del Agua (2003). *Estadísticas del Agua en México 2003*, Comisión Nacional del Agua, DF, México.

CONAGUA – Comisión Nacional del Agua (2005). *Estadísticas del Agua en México 2005*, Comisión Nacional del Agua, DF, México.

CONAGUA – Comisión Nacional del Agua (2006). *Estadísticas del Agua en México 2005*, Comisión Nacional del Agua, DF, México.

CONAGUA – Comisión Nacional del Agua (2007). *Manual de agua potable, alcantarillado y saneamiento, Datos Básicos*, DF, México, retrieved on 2015/09/14 from <ftp://ftp.conagua.gob.mx/Mapas/libros%20pdf%202007/Datos%20B%E1sicos.pdf>.

CONAGUA – Comisión Nacional del Agua (2008a). *Cuencas hidrológicas con su disponibilidad media anual de aguas superficiales publicada (Actualización al 31 de diciembre de 2007)*, Subdirección General Técnica, DF, México, retrieved on 2014/04/08 from [http://www.conagua.gob.mx/CONAGUA07/Contenido/Documentos/SINA/TM\(Cuencas\\_hidrologicas\\_agrupadas\).xls](http://www.conagua.gob.mx/CONAGUA07/Contenido/Documentos/SINA/TM(Cuencas_hidrologicas_agrupadas).xls).

CONAGUA – Comisión Nacional del Agua (2008b). Estadísticas del agua en México 2008, Mexico, Comisión Nacional del Agua, DF, México.

CONAGUA – Comisión Nacional del Agua (2010a). Estadísticas del agua en México 2010, Comisión Nacional del Agua, DF, México.

CONAGUA – Comisión Nacional del Agua (2010b). Inventario nacional de plantas municipales de potabilización y de tratamiento de aguas residuales, DF, Mexico.

CONAGUA – Comisión Nacional del Agua (2011a). Estadísticas del agua en México 2011, Comisión Nacional del Agua, DF, México.

CONAGUA – Comisión Nacional del Agua (2011b). Programa de mejoramiento de eficiencias de organismos operadores - PROME, Subdirección General de Agua Potable, Drenaje y Saneamiento, DF, México, retrieved on 2016/06/17 from [http://www.gob.mx/cms/uploads/attachment/file/110757/Manual de Operaci n y Procedimientos del Programa de Mejoramiento de Eficiencias de Organismos Operadores Junio 2011.PDF](http://www.gob.mx/cms/uploads/attachment/file/110757/Manual_de_Operaci_n_y_Procedimientos_del_Programa_de_Mejoramiento_de_Eficiencias_de_Organismos_Operadores_Junio_2011.PDF).

CONAGUA – Comisión Nacional del Agua (2012a). Situación del Subsector Agua Potable, Alcantarillado y Saneamiento Edición 2012, DF, México

CONAGUA – Comisión Nacional del Agua (2012b). Programa para la Modernización de Organismos Operadores de Agua (PROMAGUA), Coyoacán, DF, México.

CONAGUA – Comisión Nacional del Agua (2012c). Recuento de la Cooperación Internacional de la Conagua 2009-2012, DF, México, retrieved on 2017/02/05 from [http://www.conagua.gob.mx/CONAGUA07/Contenido/Documentos/RecuentoCooperacionInternacional\\_Conagua\\_2009-2012.pdf](http://www.conagua.gob.mx/CONAGUA07/Contenido/Documentos/RecuentoCooperacionInternacional_Conagua_2009-2012.pdf)

CONAGUA – Comisión Nacional del Agua (2012d). Estadísticas del Agua en México, edición 2012, Comisión Nacional del Agua, DF, retrieved on 2016/07/25 from México, <https://agua.org.mx/wp-content/uploads/2013/10/EstadisticasAguaenMexico2012.pdf>.

CONAGUA – Comisión Nacional del Agua (2013a). Situación del Subsector Agua Potable, Alcantarillado y Saneamiento Edición 2012, DF, México, <http://www.conagua.gob.mx/CONAGUA07/Publicaciones/Publicaciones/DSAPAS2013.pdf>.

CONAGUA – Comisión Nacional del Agua (2013b). Estadísticas del Agua en México, edición 2013, Comisión Nacional del Agua, DF, México.

CONAGUA – Comisión Nacional del Agua (2013c). Subdirección General de Agua Potable, Drenaje y Saneamiento, Gerencia de Programas Federales de Agua Potable and Saneamiento, Coyoacán, DF, México.

CONAGUA – Comisión Nacional del Agua (2013e). Manual de sistemas de tratamiento de aguas residuales utilizados en Japón, Edición 2013, DF, México.

CONAGUA – Comisión Nacional del Agua (2014a). Estadísticas del Agua en México 2013, Comisión Nacional del Agua, DF, México.

CONAGUA – Comisión Nacional del Agua (2014b). Directorio de organismos operadores y comisiones estatales – 16/06/2014, Respuesta a la Solicitud de Acceso a la Información folio SSI: 1610100114614 de Paloma Caloca del organismo operador del municipio Magdalena, Jalisco, México, Gerencia de Descentralización y de Transparencia y Acceso a la Información Pública, DF, México.

Conagua – Comisión Nacional del Agua (2014c). Situación del Subsector Agua Potable, Drenaje y Saneamiento, Edición 2014, DF, México, <http://www.conagua.gob.mx/CONAGUA07/Publicaciones/Publicaciones/SGAPDS-6-14.pdf>.

CONAGUA – Comisión Nacional del Agua (2014d). Atlas del Agua en México 2014, DF, México, retrieved on 2016/04/11 from <http://www.conagua.gob.mx/archivohistoricodelagua13/NotaP/Atlas del Agua Mexico 2014.pdf>.

CONAGUA – Comisión Nacional del Agua (2014e). Manual de Operación y Procedimientos del Programa de Mejoramiento de Eficiencias de Organismos Operadores, Coyoacán, DF, México.

CONAGUA – Comisión Nacional del Agua (2014f). Reporte del Clima en México Reporte – Anual 2014, Coordinación General del Servicio Meteorológico Nacional, Gerencia de Meteorología y Climatología, Subgerencia de Pronóstico a Mediano y Largo Plazo, DF, México.

Conagua – Comisión Nacional del Agua (2015a). Situación del Subsector Agua Potable, Drenaje y Saneamiento, Edición 2015, DF, México.

CONAGUA – Comisión Nacional del Agua (2016). Manual de Operación y Procedimientos del Programa de Desarrollo Integral para Organismos Operadores de Agua Potable y Saneamiento (PRODI), DF, México, retrieved on 2017/02/05 from <http://www.conagua.gob.mx/CONAGUA07/Contenido/Documentos/ccintegrados%20marzo.pdf>.

CONAGUA – Comisión Nacional del Agua (Noviembre 2015b). Manual de Operación y Procedimientos del Programa de Mejoramiento de Eficiencias de Organismos Operadores(PROME), Coyoacán, DF, México.

CONAPO – El Consejo Nacional de Población (2015). Proyecciones de la población en México, 2010-2030, retrieved on 2015/12/23 from <http://www.gob.mx/conapo>.

CONEVAL – Consejo Nacional de Evaluación de la Política de Desarrollo Social (2015). Anexo estadístico de pobreza 2008- 2010 – medición por ingresos, 2012, retrieved on 2015/12/25 from [www.coneval.gob.mx](http://www.coneval.gob.mx).

Congleton, R.D. (1992). Political institutions and pollution control, Review of Economics and Statistics, Vol. 74, pp. 412–421.

Congreso del Estado de Aguascalientes (2007). Ley de agua para el Estado de Aguascalientes, Gobierno del Estado de Aguascalientes, retrieved on 2016/03/22 from [http://www.aguascalientes.gob.mx/gobierno/leyes/leyes\\_PDF/01112007\\_125855.pdf](http://www.aguascalientes.gob.mx/gobierno/leyes/leyes_PDF/01112007_125855.pdf).

Congreso del Estado de Michoacán (2007). Ley del agua y gestión de cuencas para el estado de Michoacán, Congreso del Estado de Michoacán, retrieved on 2016/03/22 from <http://trans>

[parencia.congresomich.gob.mx/media/documentos/trabajo legislativo/LEY DEL AGUA Y GESTI%C3%93N DE CUENCAS PARA EL ESTADO DE MICHOAC%C3%81N.pdf](http://parencia.congresomich.gob.mx/media/documentos/trabajo_legislativo/LEY_DEL_AGUA_Y_GESTI%C3%93N_DE_CUENCAS_PARA_EL_ESTADO_DE_MICHOAC%C3%81N.pdf).

Congreso del Estado de Sonora (2011). Ley de Agua del Estado de Sonora, Congreso del Estado de Sonora, retrieved on 2016/03/22 from <http://congresoson.gob.mx/Transparencia/Leyes>.

Constitución Política de los Estados Unidos Mexicanos (1917). Texto vigente, Diario Oficial de la Federación(DOF), retrieved on 2015/07/10 from <http://www.dof.gob.mx/>.

Constitución Política del Estado de Veracruz de Ignacio de la Llave (2012). Texto vigente, Secretaría de Gobernación del Estado de Veracruz, Unidad General de Asunto Jurídicos, retrieved on 2015/07/13 <http://web.segobver.gob.mx/juridico/libros/1.pdf>.

Contreras Zepeda, H. (2006). Tiene los organismos de agua en México los incentivos para lograr una gestión eficiente de los servicios de agua potable, alcantarillado y saneamiento?, in Barkin, D. (ed.), La gestión del agua urbana en México – retos, debates y bienestar, Universidad de Guadalajara, Jalisco, México, pp. 75-102.

Contreras, H. (2008). La última generación de proyectos de participación pública privada en sistemas de agua en México: quince años de experiencia, in Olivares, R. and Sandoval, R. (eds.): El Agua Potable en México – Historia reciente, actores, procesos y propuestas, DF, México, pp. 105-122.

Corcoran, E., Nellemann, C., Baker, E., Bos, R., Osborn, D. and Savelli, H. (2010). Sick Water? The central role of wastewater management in sustainable development: A rapid response assessment, GRID-Arendal, United Nations Environment Program, UN-HABITAT, retrieved on 2017/03/12 from <http://www.grida.no/publications/rr/sickwater/>.

Cortés, F. I. A., Pérez, M. L. and Mogollón, H. M. (2011). Mexico's Water Challenges for the 21<sup>st</sup> century, in Oswald Spring, Ú (ed.): Water resources in Mexico – scarcity, degradation, stress, conflicts, management, and policy, Springer, Berlin Heidelberg, Germany, pp.367-377.

Costantini, V., Mazzanti, M. and Montini, A. (2013). Environmental performance, innovation and spillovers. Evidence from a regional NAMEA, Ecological Economics, Vol. 89, pp. 101–114.

Cox, A., Collins, A., Woods, L. and Ferguson, N. (2012). A household level Environmental Kuznets curve? Some recent evidence on transport emissions and income, Economics Letters, Vol. 115, pp. 187–189.

Culas, R.J. (2007). Deforestation and the Environmental Kuznets curve: An institutional perspective, Ecological Economics, Vol. 61, pp. 429–437.

Cutler, D.M. and Miller, G. (2005). The role of public health improvements in health advances: the twentieth-century United States, Demography, Vol. 42, pp. 1–22.

Cutter, W.B. and DeShazo, J. R. (2007). The environmental consequences of decentralizing the decision to decentralize, Journal of Environmental Economics and Management, Vol. 53, pp. 32–53.



- Damania, R., Fredriksson, P.G. and List, J.A. (2003). Trade liberalization, corruption, and environmental policy formation: Theory and evidence, *Journal of Environmental Economics and Management*, Vol. 46, No. 3, pp. 490–512.
- Danielson, L., Hoban, T.J., Van Houtven, G. and Whitehead, J.C. (1995). Measuring the benefits of local public goods: Environmental quality in Gaston County, North Carolina, *Applied Economics*, Vol. 27, pp. 1253–1260.
- Das, J. and DiRienzo, C.E. (2010). Is ethnic diversity good for the environment? A cross-country analysis. *The Journal of Environment & Development*, Vol. 19, No. 1, pp. 91–113.
- Dau Flores, E. (2008). Retroperspectiva, análisis y propuestas para impulsar una etapa definitoria del sector afua potable y saneamiento mexicano, in Olivares, R. and Sandoval, R. (eds.): *El agua potable en México – historia reciente, actores, procesos y propuestas*, DF, México, pp. 97-104.
- Deacon, R.T. (1999). The political economy of environment-development relationships: a preliminary framework, mimeo, Department of Economics, University of California, Santa Barbara, California, USA.
- Deacon, R.T. and Norman, C.S. (2006). Does the Environmental Kuznets curve describe how individual countries behave?, *Land Economics*, Vol. 82, pp. 291–315.
- Deci, E.L. and Ryan, R.M. (2000). The “what” and “why” of goal pursuits: Human needs and the self-determination of behavior, *Psychological Inquiry*, Vol. 11, pp. 227–268.
- Devia, M.G., Davidsona, B. and Boland, A.M. (2007). Economics of wastewater treatment and recycling: An investigation of conceptual issues, presented at the 51<sup>st</sup> Annual Conference of Australian Agricultural and Resource Economics Society – 13-16 February, 2007, Queenstown, New Zealand.
- Diaz, R. and Rosenberg, R. (2008). Spreading dead zones and consequences for marine ecosystems, *Science* 321, pp. 926-929.
- Dietz, T., Dan, A. and Shwom, R. (2007). Support for climate change policy: Social psychological and social structural influences, *Rural Sociology*, Vol. 72, No. 2, pp. 185-214.
- Dietz, T., Kalof, L. and Stern, P.C. (2002). Gender, values, and environmentalism, *Social Science Quarterly*, Vol. 83, pp.353–64.
- Dijkstra, B.R. and Fredriksson, P.G. (2010). Environmental regulatory federalism, *Annual Review of Resource Economics*, Vol 2, pp. 319–339.
- Dinda, S. (2004). Environmental Kuznets curve hypothesis: A survey, *Ecological Economics*, Vol. 49, pp. 431– 455.
- Dinda, S., Coondoo, D. and Pal, M. (2000). Air quality and economic growth: an empirical study, *Ecological Economics*, Vol. 34, pp. 409–423.
- Dinius, S.H. (1987). Design of an index of water quality, in *Water Resources Bulletin*, Vol. 23, No. 5, pp. 833–843.

DOF – Diario Oficial de la Federación (1949). Reglamento de Juntas Federales de Agua Potable, Secretaría de Gobernación (SEGOB), retrieved on 2016/02/20 from <http://www.dof.gob.mx/>.

DOF – Diario Oficial de la Federación (2001). Diario Oficial de la Federación del 5 de diciembre de 2001, Secretaría de Gobernación (SEGOB), retrieved on 2016/02/20 from <http://www.dof.gob.mx/>.

DOF – Diario Oficial de la Federación (2003). Ley General de Derechos Lingüísticos de los Pueblos Indígenas, Nueva Ley publicada en el Diario Oficial de la Federación el 13 de marzo de 2003, retrieved on 2017/03/05 from [http://www.diputados.gob.mx/LeyesBiblio/pdf/257\\_171215.pdf](http://www.diputados.gob.mx/LeyesBiblio/pdf/257_171215.pdf).

DOF – Diario Oficial de la Federación (2016). Constitución Política de los Estados Unidos Mexicanos - Texto Vigente de 27/01/2016, retrieved on 2016/02/17 from <http://www.diputados.gob.mx/LeyesBiblio/htm/1.htm>.

DOF – Diario Oficial de la Federación (2017). Diario Oficial de la Federación del Martes 8 de marzo de 2016 – ACUERDO por el que se actualiza la disponibilidad media anual de las aguas superficiales nacionales de las 731 cuencas hidrológicas que comprenden las 37 regiones hidrológicas en que se encuentra dividido los Estados Unidos Mexicanos, retrieved on 2017/01/10 from <http://www.dof.gob.mx/> and <http://www.conagua.gob.mx/CONAGUA07/Noticias/Disponibilidad%20731.pdf>.

Doxiadis, C.A. (1968). *Ekistics: An Introduction to the science of human settlements*, Oxford University Press, Oxford, UK.

Drezner, D.W. (2001). Globalization and policy convergence, *International Studies Review*, Vol. 31, No. 1, pp. 53–78.

Dryzek, J.S. (1987). *Rational ecology: Environment and political economy*, Blackwell, Oxford, UK.

Duke N.C., Bell, A.M., Pederson, D.K., Roelfsema, C.M. and Nash, S.B. (2005). Herbicides implicated as the cause of severe mangrove dieback in the Mackay region, North East Australia: Consequences for marine plant habitats of the GBR World Heritage Area, *Marine Pollution Bulletin*, Vol. 51, No. 1-4, pp. 308-324.

Easterly, W. and Levine, R. (1997). Africa's growth tragedy: Policies and ethnic divisions, *Quarterly Journal of Economics*, Vol. 112, No. 4, pp. 1203–1250.

Ebenstein, A. (2012). The consequences of industrialization: Evidence from water pollution and digestive cancers in China, *Review of Economics and Statistics*, Vol. 94, pp. 186–201.

Ek, K. and Soderholm, P. (2008). Norms and economic motivation in the Swedish green electricity market, *Ecological Economics*, Vol. 68, No. 1–2, pp. 169–182.

El Khouli, R.H., Macura, K.J., Barker, P.B., Habba, M.R., Jacobs, M.A. and Bluemke, D.A. (2009). The Relationship of temporal resolution to diagnostic performance for dynamic contrast enhanced (DCE) MRI of the breast, *Journal of Magnetic Resonance Imaging*, Vol. 30, No. 5, pp. 999–1004.

Elgin C. and Oztunali, O. (2012). Environmental pollution and informality, mimeo, Bogazici University, Istanbul, Turkey.

Encyclopædia Britannica (2017). Mexico – ethnic groups, retrieved on 2017/03/05 from <https://www.britannica.com/place/Mexico/Ethnic-groups>.

Epstein, G. (2017). Local rulemaking, enforcement and compliance in state-owned forest commons, *Ecological Economics*, Vol. 131, pp. 312–321.

Ergas, C. and York, R. (2012). Women’s status and carbon dioxide emissions: a quantitative cross-national analysis, *Social Science Research*, Vol. 41, No. 4, pp. 965-976.

Esty, D.C. (1996). Revitalizing environmental federalism, *Michigan Law Review*, Vol. 95, pp. 570–653.

Evans, G.W. and Kantrowitz, E. (2002). Socioeconomic status and health: The potential role of environmental risk exposure, *Annual Review Public Health*, Vol. 23, pp. 303–331.

Falkenmark, M. and Widstrand, C. (1992). Population and water resources: A delicate balance, *Population Bulletin*, Population Reference Bureau, Washington D.C., USA.

FAO – Food and Agriculture Organization of the United Nations (2003). Review of world water resources by country, *Water Reports*, Vol. 23, Rome, Italy.

FAO – Food and Agriculture Organization of the United Nations (2012). Coping with water scarcity – an action framework for agriculture and food security, *Water Reports*, Vol. 38, Rome, Italy.

FAO – Food and Agriculture Organization of the United Nations (2015). AQUASTAT database, retrieved on 2015/10/09 from [www.fao.org/nr/water/aquastat/data/query/index.html?lang=en](http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en)

Farzanegan, M.R. and Markwardt, G. (2012). Pollution, economic development and democracy: Evidence from the MENA countries, *Joint Discussion Paper Series in Economics*, No. 27-2012.

Farzin, Y.H. and Bond, C.A. (2006). Democracy and environmental quality, *Journal of Development Economics*, Vol. 81, pp. 213–235.

FCM - Federation of Canadian Municipalities (2008). Innovative mechanisms for fiscal transfers to municipalities – the Canadian experience in municipal financing, Canadian International Development Agency (CIDA), Gatineau, Quebec, Canada, retrieved on 2017/02/06 from [https://www.fcm.ca/Documents/case-studies/International/Innovative\\_Mechanisms\\_for\\_Fiscal\\_Transfers\\_to\\_Municipalities%E2%80%93The\\_Canadian\\_Experience\\_in\\_Municipal\\_Financing\\_EN.pdf](https://www.fcm.ca/Documents/case-studies/International/Innovative_Mechanisms_for_Fiscal_Transfers_to_Municipalities%E2%80%93The_Canadian_Experience_in_Municipal_Financing_EN.pdf).

Ferrara, I. and Missios, P. (2005). Recycling and waste diversion effectiveness: Evidence from Canada, *Environmental Resource Economics*, Vol. 30, No. 2, pp. 221–238.

- Fielding, K.S., Head, B.W., Laffan, W., Western, M. and Hoegh-Guldberg, O. (2012). Australian politicians' beliefs about climate change: Political partisanship and political ideology, *Environmental Politics*, Vol. 21, No. 5, pp. 712-733.
- Fleurbaey, M., Kartha, S., Bolwig, S., Chee, Y.L., Chen, Y., Corbera, E., Lecocq, F., Lutz, W., Muy-laert, M.S., Norgaard, R.B., Okereke, C. and Sagar, A.D. (2014). Sustainable development and equity, in Edenhofer, O., Pichs-Madruga, R., Sokona, Y., Farahani, E., Kadner, S., Seyboth, K., Adler, A., Baum, I., Brunner, S., Eickemeier, P., Kriemann, B., Savolainen, J., Schlömer, S., von Stechow, C., Zwickel, T. and Minx, J.C. (eds.), *Climate change 2014: Mitigation of climate change*, Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, New York, USA.
- Flynn, J., Slovic, P. and Mertz, C.K. (1994). Gender, race and perception of environmental health risks, *Risk Analysis*, Vol. 14, pp. 1101-1108.
- Fredriksson, P.G. and Svensson, J. (2003). Political instability, corruption and policy formation: The case of environmental policy, *Journal of Public Economics*, Vol. 87, pp. 1383–1405.
- Fredriksson, P.G. and Wang, L. (2011). Gender and environmental policy in the U.S. House of Representatives, *Economics Letters*, Vol. 113, No. 3, pp. 228-230.
- Fredriksson, P.G. and Wollscheid, J.R. (2014). Environmental decentralization and political centralization, *Ecological Economics*, Vol. 107, pp. 402–410.
- Fredriksson, P.G., Matschke, X. and Minier, J. (2010). Environmental policy in majoritarian systems, *Journal of Environmental Economics and Management*, Vol. 59, pp. 177–91.
- Freitas, L.C. de, Kaneko, S., AlmeidaPaccac, S. and Hosseini, H.M. (2013). Determinants of sugarcane productivity in Brazil: evidences from spatial analysis, in Hosseini, H.M. and Kaneko, S. (2013). *Can environmental quality spread through institutions?* *Energy Policy*, Vol. 56, pp. 312–321.
- Garrone, P., Piscitello, L. and Wang, Y. (2014). Innovation performance and international knowledge spillovers: Evidence from the renewable energy sector in OECD countries, *Industry and Innovation*, Vol. 21, No. 7-8, pp. 574-598.
- Garza, E.J.V. de la (2008). Política pública en materia de agua potable, drenaje, alcantarillado, tratamiento, y disposición de las aguas residuales, in Olivares, R. and Sandoval, R. (eds.): *El agua potable en México – historia reciente, actores, procesos y propuestas*, DF, México, pp. 123-140.
- Germani, A.R., Morone, P. and Testa, G. (2014). Environmental justice and air pollution: A case study on Italian provinces, *Ecological Economics*, Vol. 16, pp. 69–82.
- Gerring, J., Thacker, S.C., Lu, Y. and Huang, W. (2015). Does diversity impair human development? A multi-level test of the diversity debit hypothesis, *World Development*, Vol. 66, pp. 166–188.

Gisselquist, R.M., Leiderer, S, and Niño-Zarazúa, M. (2016). Ethnic heterogeneity and public goods provision in Zambia: Evidence of a subnational “Diversity dividend”, *World Development*, Vol. 78, pp. 308–323.

GIZ - Deutsche Gesellschaft für Internationale Zusammenarbeit (2017). Cooperación Triangular México-Alemania, Eschborn, Germany, derived on 2017/02/05 from <https://www.giz.de/en/worldwide/36487.html>.

Glaeser, E.L. and Saks, R.E. (2006). Corruption in America, *Journal of Public Economy*, Vol. 90, No. 6–7, pp. 1053–1072.

Glibert, P.M., Mayorga, E. and Seitzinger, S. (2008). Procentrum minimum tracks anthropogenic nitrogen and phosphorus inputs on a global basis: Application of spatially explicit nutrient export models, *Harmful Algae*, Vol 8, No. 1, pp. 33-38.

Gourieroux, C. (2000). *Econometrics of qualitative dependent variables*, Klassen, P.B. (Translator), Cambridge University Press, Cambridge, UK.

Grafton, R.Q. (2013). Household behaviour and water use, in Brown, Z., Johnstone, N. and Serret-Itzicsohn, Y. (eds.), *Greening household behaviour: Overview from the 2011 survey*, OECD Publishing, Paris, France, pp. 149-181.

Grafton, R.Q., Knowles, S. and Owen, P.D. (2004). Total Factor Productivity, Per Capita Income and Social Divergence, *The Economic Record*, Vol. 80, No. 250, pp. 302 – 313.

Granados, C. and Sánchez, F. (2014). Water reforms, decentralization and child mortality in Colombia, 1990–2005, *World Development*, Vol. 53, pp. 68–79.

Grael, C. E., Morris, L.B. and Carrillo Rivera, J.J. (1999). Effects of urbanization on groundwater resources of Merida, Yucatan, Mexico, *Environmental Geology*, Vol. 37, No. 4, pp. 303-312.

Gray, W.B. and Shadbegian, R.J. (2004). ‘Optimal’ pollution abatement: whose benefits matter, and how much?, *Journal Environment and Economic Management*, Vol. 47, pp. 510–534.

Greenbaum, A. (1995). Taking stock of two decades of research on the social bases of environmental concern, in Mehta, M.D. and Ouellet, E. (eds.), *Environmental sociology*, Captus Press, North York, Ontario, Canada, pp. 125-152.

Greene, W.H. (2012). *Econometric Analysis*, 7<sup>th</sup> Edition, Prentice-Hall, Upper Saddle River, New York, USA.

Grimes, P. and Kentor, J. (2003). Exporting the greenhouse: Foreign capital penetration and CO2 emissions 1980–1996, *Journal of World-Systems Research*, Vol. 9, No. 2, pp. 260–275.

Groot, H.L.F. de, Withagen, C.A. and Minliang, Z. (2004). Dynamics of China's regional development and pollution: An investigation into the environmental Kuznets curve, *Environment and Development Economics*, Vol. 9, No. 04, pp. 507–537.

Grossman, G.M. and Krueger, A.B. (1991). Environmental impacts of a North American Free Trade Agreement, NBER Working Paper No. 3914.

Grossman, G.M. and Krueger, A.B. (1993). Environmental impacts of the North American Free Trade Agreement, in Garber, P. (ed.), *The U.S. –Mexico free trade agreement*, pp. 13–56, MIT Press, Cambridge, UK.

Grossman, G.M. and Krueger, A.B. (1995). Economic growth and the environment, *Quarterly Journal of Economics*, Vol 110, No. 2, pp. 353– 377.

Guerrero Reynoso, V. (2008). Análisis de experiencia, perspectivas y propuesta de la gestión de las entidades estatales de agua, in Olivares, R. and Sandoval, R. (eds.), *El agua potable en México – historia reciente, actores, procesos y propuestas*, DF, México, pp. 217-228.

Gujarati, D.N. (1995). *Basic econometrics*, 3rd (international) edition, McGraw-Hill Book Co., Singapore.

Gupta, I. and Manish, R. (2012). Public expenditure choices and gender quotas, *Indian Growth and Development Review*, Vol. 5, Issue 2, pp. 108-130.

Gylfason, T. (2001). Natural resources, education, and economic development, *European Economic Review*, Vol. 45, pp. 847-859.

Haas, E.B. (1980). Why collaborate? Issue-linkage and international regimes, *World Politics*, Vol. 32, pp. 357–405.

Habyarimana, J., Humphreys, M., Posner, D.N. and Weinstein, J.M. (2007). Why does ethnic diversity undermine public goods provision?, *American Political Science Review*, Vol. 101, pp. 709–725.

Halkos, G.E. (2003). Environmental Kuznets curve for sulfur: Evidence using GMM estimation and random coefficient panel data model, *Environment and Development Economics*, Vol. 8, pp. 581–601.

Hall, G. and Patrinos, H.A. (2006). *Indigenous peoples, poverty and human development in Latin America: 1994-2004*, Palgrave Macmillan, New York, USA.

Hamilton, T.L. and Phaneuf, D.J. (2015). An integrated model of regional and local residential sorting with application to air quality, *Journal of Environmental Economics and Management*, Vol. 74, pp. 71–93.

Hanemann, W.M. (2006). The economic conception of water, in Rogers, P.P., Llamas, M.R. and Martinez-Cortina, L. (eds.), *Water Crisis: Myth or Reality?*, Taylor & Francis, London, New York, pp. 61-91.

Hanley, N., Shogren, J. and White, B. (2013). *Introduction to environmental economics*, Second Edition, Oxford University Press, Oxford, UK.

Hansen, A.M. and Juárez, C.C. (2011). Evaluation of the pollution of hydrological river basins: Priorities and needs, in Oswald Spring, Ú. (ed.): *Water resources in Mexico – scarcity, degradation, stress, conflicts, management, and policy*, Springer, Berlin Heidelberg, Germany, pp. 201-215.

- Harbaugh, W.T., Levinson, A. and Wilson, D.M. (2002). Reexamining the empirical evidence for an Environmental Kuznets curve, *Review of Economics and Statistics*, Vol. 84, pp. 541–551.
- Hardin, G. (1968). The tragedy of the commons, *Science* 162, pp. 1243–1248.
- Hardin, J.W. and Hilbe, J.M. (2012). *Generalized linear models and extensions*, 3<sup>rd</sup> edition, Stata Press Publication, Texas, USA.
- Heerink, N., Mulatu, A. and Bulte, E. (2001). Income inequality and the environment: Aggregation bias in Environmental Kuznets curves, *Ecological Economics*, Vol. 38, pp. 359–367.
- Heil, M.T. and Selden, T.M. (2001). International trade intensity and carbon emissions: A cross-country econometric analysis, *The Journal of Environment Development*, Vol. 10, No. 1, pp. 35–49.
- Heilbrunner, R.L. (1974). *An inquiry into the human prospect*, Norton, New York, USA.
- Helland, E. and Whitford, A.B. (2003). Pollution incidence and political jurisdiction: Evidence from the TRI, *Journal Environmental and Economic Management*, Vol. 46, pp. 403–424.
- Henze, M., Loosdrecht, M.C.M. van, Ekama, G.A. and Brdjanovic, D. (2008). *Biological wastewater treatment: Principles, modelling and design*, IWA-Publishing, London, UK.
- Hepworth, N., Hooper, V. and Lankford, B. (2013). What factors determine the performance of institutional mechanisms for water resources management in developing countries in delivering pro-poor outcomes and supporting sustainable economic growth?, CEE review 11-006, Collaboration for Environmental Evidence, retrieved on 2016/03/17 from [www.environmentalevidence.org/SR11006.html](http://www.environmentalevidence.org/SR11006.html).
- Hernández-Sancho, F., Molinos-Senante, M. and Sala-Garrido, R. (2010). Economic valuation of environmental benefits from wastewater treatment processes: An empirical approach for Spain, *Science of the Total Environment*, Vol. 408, No. 4, pp. 953–957.
- Hernandez-Trillo, F. (2016). Poverty alleviation in federal systems: The case of México, *World Development*, Vol. 87, pp. 204–214.
- Herrera, V. and Post, A.E. (2014). Can developing countries both decentralize and depoliticize urban water services? Evaluating the legacy of the 1990s reform wave, *World Development*, Vol. 64, pp. 621–641.
- Hettige, H., Mani, M. and Wheeler, D. (1999). Industrial pollution in economic development: Kuznets revisited, in Fredricksson, Per G. (ed.), *Strutt, Anna, Trade, global policy, and the environment*, World Bank discussion papers, No. WDP 402, World Bank, Washington, D.C., USA.
- Hidano, N., Kato, T. and Aritomi, M. (2005). Benefits of participating in contingent valuation mail surveys and their effects on respondent behaviour: A panel analysis, *Ecological Economics*, Vol. 52, pp. 63–80.
- Holland, T.G., Peterson, G.D. and Gonzalez, A. (2009). A cross-national analysis of how economic inequality predicts biodiversity loss, *Conservation Biology*, Vol. 23, pp. 1304–1313.

- Hosmer, D.W. Jr., and Lemeshow, S. (1980). Goodness-of-fit tests for the multiple logistic regression model, *Communications in Statistics: Theory and Methods*, Vol. 9, pp. 1043-1069.
- Hosmer, D.W. Jr., Lemeshow, S.A. and Sturdivant, R.X. (2013). *Applied logistic regression*, 3rd edition, Hoboken, NJ, Wiley, USA.
- Hosseini, H.M. and Kaneko, S. (2013). Can environmental quality spread through institutions?, *Energy Policy*, Vol. 56, pp. 312–321.
- Hoxby, C. (2000). Does competition among public schools benefit students and taxpayers?, *American Economic Review*, Vol. 90, No. 5, pp. 1209–1238.
- Huguenin, A. and Jeannerat, H. (2017). Creating change through pilot and demonstration projects: Towards a valuation policy approach, *Research Policy*, Vol. 46, Issue 3, pp. 624–635.
- Hunter, L.M. and Hatch, A. (2004). Cross-national gender variation in environmental behaviors, *Social Science Quarterly*, Vol. 85, pp. 677–694
- Hunter, L.M., Hatch, A. and Johnson, A. (2004). Cross-national gender variation in environmental behaviors, *Social Sciences Quarterly*, Vol. 85, pp. 677-694.
- Huntington, S. (1968). *Political order in changing societies*, Yale University Press, New York, USA.
- IIENATEC (2016). Encuentro nacional de áreas técnicas – del 10 al 12 de agosto, León, Guanajuato, Mexico.
- IMTA – Instituto Mexicano de Tecnología del Agua (2014a). TAV 1.0 Tránsito de avenidas en vasos – manual de usuario y referencia técnica, Cuernavaca, Morelos, México.
- IMTA – Instituto Mexicano de Tecnología del Agua (2014b). PIGOO - Programa de indicadores de gestión de organismos operadores, retrieved on 2014/06/20 from <http://www.pigoo.gob.mx/>.
- INAFED – Instituto Nacional para el Federalismo y el Desarrollo Municipal (2000). Sistema nacional de información municipal (SNIM) – número de hombres y mujeres dentro del gobierno municipal, base de datos en archivo magnético, DF, México, retrieved on 2014/06/21 from <http://www.gob.mx/inafed>.
- INAFED – Instituto Nacional para el Federalismo y el Desarrollo Municipal (2015). Índice de Desarrollo Municipal - 2010, DF, México, retrieved on 2015/12/29 from [www.inafed.gob.mx/work/models/inafed/Resource/228/1/.../siha\\_4\\_2\\_2\\_2\\_xls\(1\).xlsx](http://www.inafed.gob.mx/work/models/inafed/Resource/228/1/.../siha_4_2_2_2_xls(1).xlsx) and <http://www.inafed.gob.mx/>.
- INAFED – Instituto Nacional para el Federalismo y el Desarrollo Municipal(2016). Desempeño Institucional Municipal - Índice de planeación estratégica y evaluación municipal, 2012, retrieved on 2016/01/02 from [http://www.inafed.gob.mx/es/inafed/Desempeno Institucional Municipal](http://www.inafed.gob.mx/es/inafed/Desempeno_Institucional_Municipal).
- INALI – Instituto Nacional de Lenguas Indígenas (2017). Data on speakers of indigenous languages in Mexico, DF, Mexico, retrieved on 2017/03/05 from <http://www.inali.gob.mx/>.



INEGI – Instituto Nacional de Estadística y Geografía (1950, 1970, 1990, 2000, 2010). Censos de población y vivienda 1950, 1970, 1990, 2000 y 2010, DF, Mexico, retrieved on 2015/09/22 from <http://www.inegi.org.mx/est/contenidos/Proyectos/ccpv/default.aspx>.

INEGI – Instituto Nacional de Estadística y Geografía (2005). Perfil sociodemográfica de la población hablante de náhuatl – XII Censo general de población y vivienda 2000, Aguascalientes, DF, Mexico.

INEGI – Instituto Nacional de Estadística y Geografía (2010). Estados Unidos Mexicanos – Censo de población y vivienda 2010, Resultados definitivos, Tabulados básicos, DF, Mexico, retrieved on 2015/09/28 from [www.inegi.org.mx](http://www.inegi.org.mx) and <http://www3.inegi.org.mx/sistemas/sisept/Default.aspx?t=mdemo148&s=est&c=29192>.

INEGI – Instituto Nacional de Estadística y Geografía (2011). Principales resultados del censo de población y vivienda 2010, DF, Mexico, retrieved on 2015/09/28 from <http://www3.inegi.org.mx/sistemas/temas/default.aspx?s=est&c=17484>.

INEGI – Instituto Nacional de Estadística y Geografía (2015a). Anuario estadístico y geográfico de los Estados Unidos Mexicanos, DF, México.

INEGI – Instituto Nacional de Estadística y Geografía (2015b). Población de México - Cuentame, DF, Mexico, retrieved on 2015/12/25 from <http://www3.inegi.org.mx/sistemas/biinegi/>.

INEGI – Instituto Nacional de Estadística y Geografía (2017). Marco Geoestadístico Municipal 2010, versión 5.0, DF, Mexico, retrieved on 2017/02/14 from [http://cuentame.inegi.org.mx/mapas/pdf/nacional/div\\_territorial/nacionalsd.pdf](http://cuentame.inegi.org.mx/mapas/pdf/nacional/div_territorial/nacionalsd.pdf).

Israel, D. and Levinson, A. (2004). Willingness to pay for environmental quality: testable empirical implications of the growth and environmental literature, *Contributions to Economic Analysis and Policy*, Vol. 3, No. 1, Article 2.

Iwanaga, K. (2008). Women's political representation in Japan, in Iwanaga, K. (ed.), *Women's political participation and representation in Asia: Obstacles and challenges*, NIAS Press, Copenhagen, Denmark, pp. 1-22.

Jackson, K. (2013). Diversity and the distribution of public goods in sub-saharan Africa, *Journal of African Economies*, Vol. 22, pp. 437–462.

Jaeger, William K. (2005). *Environmental economics for tree huggers and other skeptics*, Island Press, Washington, USA.

Jalan, J. and Ravallion, M. (2003). Does piped water reduce diarrhea for children in rural India?, *Journal of Econometrics*, Vol. 112, pp. 153–173.

Jenkins K., Kingsford, R. and Ryder, D. (2009). Developing indicators for floodplain wetlands: Managing water in agricultural landscapes, *Chiang Mai Journal of Science*, Vol. 36, pp. 224-235.

Jephcote, C., Chen, H. and Ropkins, K. (2016). Implementation of the polluter-pays principle (PPP) in local transport policy, *Journal of Transport Geography*, Vol. 55, pp. 58–71.

Jiménez Cisneros, B.E. (2007). Información y calidad del agua en México, Universidad Autónoma de Nuevo León, Nuevo León, México, Trayectorias, Vol. IX, No. 24, pp. 45-56.

Jiménez Cisneros, B.E. (2008). Calidad del agua en México: principales retos, in Olivares, R. and Sandoval, R. (eds.): El agua potable en México – historia reciente, actores, procesos y propuestas, DF, México, pp. 159-172.

Jiménez Cisneros, B.E., Torregrosa, M.L. and Aboites Aguilar, A.L. (2010). El agua en México: cauces y encauces, primera edición 2010, Academia Mexicana de Ciencias, DF, México.

Jones, M.P. (1997). Legislator gender and legislator policy priorities in the Argentine Chamber of Deputies and the United States House of Representatives, *Policy Studies Journal*, Vol. 25, No. 4, pp. 613-629.

Jorgenson, A.K. (2007). The effects of primary sector foreign investment on carbon dioxide emissions from agriculture production in less-developed countries, 1980–99, *International Journal of Comparative Sociology*, Vol. 48, No. 1, pp. 29–42.

Kahn, K.F. (1993). Gender differences in campaign messages: The political advertisements of men and women candidates for U.S. Senate, *Political Research Quarterly*, Vol. 46, pp. 481-502.

Kahn, M.E. (2004). Domestic pollution havens: Evidence from cancer deaths in border counties, *Journal Urban Economics*, Vol. 56, pp. 51–69.

Kahneman, D., Slovic, P. and Tversky, A. (1982). *Judgment under uncertainty: Heuristics and biases*, Cambridge University Press, New York, USA.

Karia, G.L. and Christian, R.A. (2013). *Wastewater treatment: Concepts and design approach*, second edition, PHI Learning Pvt. Ltd, Delhi, India.

Kaufman, D. and Wei, S. (1999). Does ‘Grease money’ speed up the wheels of commerce?, mimeo, NBER Working Paper No. 7093.

Kerr, N.L., Garst, J., Lewandowski, D.A. and Harris, S.E. (1997). That still, small voice: commitment to cooperate as an internalized versus a social norm, *Personality and Social Psychology Bulletin*, Vol. 23, pp. 1300–1311.

Klineberg, S.L., McKeever, M. and Rothenbach, B. (1998). Demographic predictors of environmental concern, *Social Science Quarterly*, Vol. 79, pp. 734-753.

Klitkou, A., Coenen, L. and Andersen, P.D. (2013). Role of demonstration projects in innovation: transition to sustainable energy and transport, 4th International Conference on Sustainability Transitions, retrieved on 2017/02/08 from [http://orbit.dtu.dk/en/publications/role-of-demonstration-projects-in-innovation-transition-to-sustainable-energy-and-transport\(49b3e375-fbbf-4560-9f69-84b77088948e\).html](http://orbit.dtu.dk/en/publications/role-of-demonstration-projects-in-innovation-transition-to-sustainable-energy-and-transport(49b3e375-fbbf-4560-9f69-84b77088948e).html).

Kohler, U. and Kreuter, F. (2012). *Data analysis using Stata*, 3<sup>rd</sup> edition, Stata Press, College Station, Texas, USA.

Kotov, V. and Nikitina, E. (1995). Russia and international environmental cooperation, in Bergesen, H. O. and Parmann, G. (eds.), *Green Globe Yearbook of International Cooperation on Environment and Development*, Oxford University Press, Oxford, UK.

Kunce, M. and Shogren, J.F. (2005a). On efficiency of decentralized environmental regulation, *Journal of Regulatory Economics*, Vol. 28, pp. 129–140.

Kunce, M. and Shogren, J.F. (2005b). On interjurisdictional competition and environmental federalism, *Journal of Environmental Economics and Management*, Vol. 50, pp. 212–224.

Kuznets, S. (1955). Economic growth and income inequality, *American Economic Review*, Vol. 65, pp. 1-28.

LAEAC - Ley de Agua para el Estado de Aguascalientes (2007). H. Congreso del Estado de Aguascalientes, Instituto de Investigaciones Legislativas, Aguascalientes, México, retrieved on 2016/02/28 from [http://www.aguascalientes.gob.mx/gobierno/leyes/leyes\\_PDF/01112007\\_125855.pdf](http://www.aguascalientes.gob.mx/gobierno/leyes/leyes_PDF/01112007_125855.pdf)

LAN – Ley de las Aguas Nacionales (1992). Diario Oficial de la Federación de 1 de Marzo de 1992, DF, Mexico, retrieved on 26/02/2016 from <http://www.diputados.gob.mx/LeyesBiblio/ref/lan.htm>.

LAN - Ley de las Aguas Nacionales (2014). Version de 11 de agosto 2014, Diario Oficial de la Federación, DF, Mexico retrieved on 26/02/2016 from <http://www.diputados.gob.mx/LeyesBiblio/htm/1.htm>.

Lange, G.M. and Jiddawi, N. (2009). Economic value of marine ecosystem services in Zanzibar: Implications for marine conservation and sustainable development, *Ocean & Coastal Management*, Vol. 52, Issue 10, pp. 521-532.

Latif, U. and Dickertin, F.L. (2015). Chemical oxygen demand, in Moretto, L.M., and Kalcher, K. (eds.): *Environmental analysis by electrochemical sensors and biosensors applications*, Vol. 2, pp. 729-734.

LCEA - Ley que crea la Comisión Estatal del Agua como Organismo Público Decentralizado del Poder Ejecutivo del Estado de Morelos (2012). Consejería jurídica, Cuernavaca, Morelos, México, retrieved on 2016/02/28 from <http://marcojuridico.morelos.gob.mx/archivos/leyes/pdf/LCREACEAEM.pdf>.

Leitão, A. (2010). Corruption and the Environmental Kuznets curve: Empirical evidence for sulfur, *Ecological Economics*, Vol. 69, Issue 11, pp. 2191–2201.

León, L.F. (1991). Índice de Calidad del Agua, ICA. Inf. # SH-9101/01, Instituto Mexicano de Tecnología del Agua, Cuernavaca, Morelos, México.

León, L.F. and González, J.A. (1992). La Red Nacional de Monitoreo en RAISON, Informe Técnico CH-9202/01: Transferencia del Sistema RAISON a la Gerencia de Calidad del Agua, México: Instituto México de Tecnología del Agua.

LeSage, J. and Pace, R.K. (2009). *Introduction to spatial econometrics*, Chapman and Hall/CRC, Boca Raton, Florida, USA.

- Levinson, A. (2003). Environmental regulatory competition: A status report and some new evidence, *National Tax Journal*, Vol. 56, pp. 91–106.
- Li, Q. and Reuveny, R. (2006). Democracy and environmental degradation, *International Studies Quarterly*, Vol. 50, pp. 935–956.
- Libralato, G., Volpi, G.A. and Avezzù, F. (2012). To centralise or to decentralise: An overview of the most recent trends in wastewater treatment management, *Journal of Environmental Management*, Vol. 94, pp. 61–68.
- Lieberman, E.S. and McClendon, G.H. (2013). The ethnicity-policy preference link in Sub-Saharan Africa, *Comparative Political Studies*, Vol. 46, pp. 574–602.
- Lin, N.F., Tang, J. and Ismael, H.S.M. (2000). Study on environmental etiology of high incidence areas of liver cancer in China, *World Journal Gastroenterol.*, Vol. 6, pp. 572–576.
- Lindsay, D.S. and Dubey, J.P. (2009). Long term survival of *Toxoplasma gondii* sporulated oocysts in seawater, *Journal of Parasitology*, Vol. 95, No. 4, pp. 1019–1020.
- Lipscomb, M. and Mobarak, A.M. (2013). Decentralization and pollution spillovers: Evidence from the re-drawing of county borders in Brazil, unpublished manuscript, University of Virginia and Yale University, New Haven, Connecticut, USA.
- List, J. and Gallet, C. (1999). The Environmental Kuznets curve: Does one size fit all, *Ecological Economics*, Vol. 31, pp. 409–423.
- List, J.A. and Gerking, S. (2000). Regulatory federalism and environmental protection in the United States, *Journal of Regional Science*, Vol. 40, pp. 453–71.
- Liu, X.Z., Heilig, G.K., Chen, J.M. and Heino, M. (2007). Interactions between economic growth and environmental quality in Shenzhen, China's first special economic zone. *Ecological Economics*, Vol. 62, pp. 559–570.
- Livingston, M.L. (1995). Designing water institutions: Market failures and institutional response, *Water Resources Management*, Vol. 9, pp. 203–220.
- López-Menéndez, A.J., Pérez, R. and Moreno, B. (2014). Environmental costs and renewable energy: Re-visiting the Environmental Kuznets curve, *Journal of Environmental Management*, Vol. 145, pp. 368–373.
- Lu, Y.L., Song, S., Wang, R.S., Liu, Z.Y., Meng, J., Sweetman, A.J., Jenkins, A., Ferrier, R.C., Li, H., Luo, W. and Wang, T.Y. (2015). Impacts of soil and water pollution on food safety and health risks in China, *Environmental International*, Vol. 77, pp. 5–15.
- Maddala, G.S. (1983). *Limited-dependent and qualitative variables in econometrics*, Cambridge University Press, Cambridge, UK.
- Maddison, D. (2006). Environmental Kuznets curves: A spatial econometric approach, *Journal of Environmental Economics and Management*, Vol. 51, pp. 218–230.
- Maddison, D. (2007). Modelling sulphur emissions in Europe: A spatial econometric approach, *Oxford Economic Papers*, Vol. 59, pp. 726–743.

- Magill, K.P. and Rogers, E.M. (1981). Federally sponsored demonstrations of technological innovations, *Knowledge-Creation Diffusion Utilization*, Vol. 3, No. 1, pp. 23-42.
- Magnani, E. (2000). The Environmental Kuznets curve, environmental protection policy and income distribution, *Ecological Economics* 32, pp. 431 – 443.
- Majerová, I. (2012). Comparison of old and new methodology in human development and poverty indexes: A case of the least developed countries, *Journal of Economics Studies and Research*, Vol. 2012, Article ID 290025.
- Malik, O.A., Hsu, A., Johnson, L.A. and Sherbinin, A. de (2015). A global indicator of wastewater treatment to inform the Sustainable Development Goals (SDGs), *Environmental Science & Policy*, Vol. 48, pp. 172 – 185.
- Mankiw, N.G. and Taylor, M.P. (2014). *Economics*, 3rd edition, Cengage Learning EMEA, Hampshire, UK.
- Mara, D. (2003). *Domestic wastewater treatment in developing countries*, Earthscan, London, UK.
- March, J. and Simon, H. (1993). *Organizations*, Second edition, David Blackwell, Cambridge, Mass., USA.
- Martinez Omaña, M.C. (2006). Gestión del agua urbana en la segunda mitad del siglo XX, in Barkin D. (ed.), *La gestión del agua urbana en México – retos, debates y bienestar*, Universidad de Guadalajara, Jalisco, México, pp. 57-74.
- Martínez, M.L., Intralawan, A., Vázquez, G., Pérez-Maqueo, O., Sutton, P. and Landgrage, R. (2007). The cost of our world: Ecological, economic and social importance, *Ecological Economics*, Vol. 63, pp. 254-272.
- Massoud, M.A., Tarhini, A. and Nasr, J.A. (2009). Decentralized approaches to wastewater treatment and management: Applicability in developing countries, *Journal of Environmental Management*, Vol. 90, pp. 652–659.
- Maurer, M. Rothenberger, D. and Larsen, T.A. (2006). Decentralised wastewater treatment technologies from a national perspective: At what cost are they competitive? *Water Science and Technology*, Vol. 5, pp. 145-154.
- Mazhar, U. and Elgin, C. (2013). Environmental regulation, pollution and the informal economy, *SBP Research Bulletin*, Vol. 9, No. 1, pp. 62-81.
- McConnell, K. (1997). Income and the demand for environmental quality, *Environment and Development Economics*, Vol. 2, pp. 383-399.
- McCright, A.M. (2010). The effects of gender on climate change knowledge and concern in the American public, *Population and Environment*, Vol. 32, pp. 66-87.
- McFadden, D. (1974). The measurement of urban travel demand, *Journal of Public Economics*, Vol. 3, pp. 303-328.

- McFadden, D. (1984). Econometric analysis of qualitative response models, in Griliches, Z. and Intriligator, M. (eds.), *Handbook of econometrics*, Vol. 2, pp 1395-1457.
- McGuire, M. and Olson, M. (1996). The economics of autocracy and majority rule: The invisible hand and the use of force, *Journal of Economic Literature*, Vol. 34, No. 2, pp. 72–96.
- McStay, J. and Dunlap, R.E. (1983). Male-female differences in concern for environmental quality, *International Journal of Women’s Studies*, Vol. 6, pp. 291–301.
- Mehiriz, K. (2016). The impacts of intergovernmental grants on municipal infrastructure: Evidence from the Canada-Quebec infrastructure works 2000 program, *Evaluation and Program Planning*, Vol. 58, pp. 184–193.
- Meltzer, A.H. and Richard, S.F. (1981). A rational theory of the size of government, *Journal of Political Economy*, Vol. 89, No. 5, pp. 914–927.
- Metz, C.E. (1978). Basic principles of ROC analysis, *Seminars in Nuclear Medicine*, Vol. 8, pp.283–298.
- Mexican Federal Reserve Board (2016). Foreign exchange rates – G.5A Annual, January 4<sup>th</sup> 2016, DF, Mexico, retrieved on 2016/08/23 from [www.federalreserve.gov/releases/g5a/current/](http://www.federalreserve.gov/releases/g5a/current/).
- Meyer, A. (2015). Does education increase pro-environmental behavior? Evidence from Europe, *Ecological Economics*, Vol. 116, pp. 108–121.
- Midlarsky, M. (1998). Democracy and the environment: An empirical assessment, *Journal of Peace Research*, Vol. 35, pp. 341–361.
- Mielnik, O. and Goldemberg, J. (2002). Viewpoint: Foreign direct investment and decoupling between energy and gross domestic product in developing countries, *Energy Policy*, Vol. 30, No. 2, pp. 87–89.
- Mikkelson, G.M., Gonzalez, A. and Peterson, G.D. (2007). Economic inequality predicts biodiversity loss, *PLOS ONE*, Vol. 2, No. 5, e444.
- Millimet, D.L. (2003). Assessing the empirical impact of environmental federalism, *Journal of Regional Science*, Vol. 43, pp. 711–33.
- Millimet, D.L. (2013). Environmental federalism: A survey of the empirical literature, IZA Discussion Paper No. 7831.
- Millock, K. and Nauges, C. (2013). Household behaviour and food consumption, in Brown, Z., Johnstone, N. and Serret-Itzicsohn, Y. (eds.), *Greening household behaviour: Overview from the 2011 survey*, OECD Publishing, Paris, France, pp. 183-217.
- Minh, V.H. and Nguyen-Viet, H. (2011). Economic aspects of sanitation in developing countries, *Environmental Health Insights*, Vol. 5, pp. 63–70.
- Mirza, S. (2007). Attention danger. L’effondrement imminent de l’infrastructure municipale du Canada, *Fédération Canadienne des Municipalités*, Ottawa, Canada.

- Mohai, P. (1992). Men, women, and the environment. *Society and Natural Resources*, Vol. 5, pp. 1-19.
- Molinos-Senante, M. and Sala-Garrido, R. (2015). The impact of privatization approaches on the productivity growth of the water industry: A case study of Chile, *Environmental science & policy*, Vol. 50, pp. 166–179.
- Molinos-Senante, M., Hernández-Sancho, F. and Sala-Garrido, R. (2010). Economic feasibility study for wastewater treatment: A cost–benefit analysis, *Science of the Total Environment*, Vol. 408, pp. 4396–4402.
- Molle, F., Mollinga, P.P. and Wester, P. (2009). Hydraulic bureaucracies: Flows of water, flows of power, *Water Alternatives*, Vol. 2, No. 3, pp. 328-349.
- Monier, S., Hassan, D., Nichele, V. and Simioni, M. (2009). Organic food consumption patterns, *Journal of Agricultural and Food Industrial Organization*, Vol. 7, No. 2, ISSN (Online) 1542-0485.
- Morales-Suarez-Varela, M.M., Llopis-Gonzalez, A. and Tejerizo-Perez, M.L. (1995). Impact of nitrates in drinking water on cancer mortality in Valencia, Spain, *European Journal of Epidemiology*, Vol. 11, pp. 15–21.
- Munasinghe, M. (1999). Is environmental degradation an inevitable consequence of economic growth: tunneling through the Environmental Kuznets curve, *Ecological Economics*, Vol. 29, pp. 89–109.
- Münch, A. (2011). In search for Tiebout's mechanism 'vote with their feet' in Bavaria, *Economic Research Papers: # 2011 – 023*, Friedrich Schiller University of Jena, Jena, Germany.
- Mundaca, L., Neij, L., Worrell, E. and McNeil, M. (2010). Evaluating energy efficiency policies with energy-economy models, *Annual Review of Environment and Resources*, Vol 35, No 1, pp. 305–344.
- Muñoz, H., Armienta, M.A., Vera, A. and Cenicerros, N. (2004). Nitratos en el valle de Huamantla, Tlaxcala, México, *Revista Internacional de Contaminación Ambiental*, Vol. 20, No. 3, pp. 91-97.
- Murphy, K., Shleifer, A. and Vishney, R. (1991). The allocation of talent: Implication for growth, *Quarterly Journal of Economics*, Vol. 105, pp. 503–530.
- Myers, S. (1978). The demonstration project as a procedure for accelerating the application of new technology, *Institute of Public Administration*, Washington D.C., USA.
- Nellemann, C., Corcoran, E., Duarte, C.M., Valdés, L., De Young, C., Fonseca, L. and Grimsditch, G. (2009). Blue carbon, a rapid response assessment, GRID-Arendal, United Nations Environment Programme, Arendal, Norway.
- North, D.C. (1990). *Institutions, institutional change, and economic performance*, Cambridge University Press, New York, USA.
- North, D.C. (1991). Institutions, *Journal of Economic Perspectives*, Vol. 5, No. 1, pp. 97-112.

Nyenje, P.M., Foppena, J.W., Uhlenbrooka, S. Kulabakob C.R. and Muwanga, A. (2010). Eutrophication and nutrient release in urban areas of sub-Saharan Africa — a review, *Science of the Total Environment*, Vol. 408, Issue 3, pp. 447-455.

Oates, W.E. (1972). *Fiscal federalism*, Harcourt Brace Jovanovich, New York, USA.

Oates, W.E. (1999). An essay on fiscal federalism, *Journal of Economic Literature*, Vol. 37, No. 3, pp. 1120–1149.

Oates, W.E. (2002). A reconsideration of environmental federalism, in List, J.A. and Zeeuw, A. de (eds.), *Recent advances in environmental economics*, Edward Elgar, Cheltenham, UK, pp. 1–32.

Oates, W.E. and Portney, P.R. (2003). The political economy of environmental policy, in Mäler, K.-G. and Vincent, J.R. (eds.), *Handbook of environmental economics*, Vol. 1, pp. 326-350.

OECD – Organisation for Economic Co-Operation and Development (1992). *The polluter-pays principle: OECD analysis and recommendations*, OECD Publishing GD (92)81, Paris, France.

OECD – Organisation for Economic Co-Operation and Development (2013). *Hacer posible la reforma de la gestión del agua en México*, OECD Publishing, Paris, France.

Olivares, R. (2008). Las reformas al 115 – una reflexión retrospectiva, in Olivares, R. and Sandoval, R. (eds.): *El agua potable en México – historia reciente, actores, procesos y propuestas*, DF, México, pp. 49-56.

Olivares, R. and Sandoval, R. (2008). *El agua potable en México – historia reciente, actores, procesos y propuestas*, DF, México.

Olson, M. (1993). Dictatorship, democracy and development, *American Political Science Review*, Vol. 87, No. 3, pp. 567–576.

OpenStreetMap-Contributors (2017). [Online]. Available: <http://www.openstreetmap.org/copyright> (Accessed 27 November 2017 at <http://www.openstreetmap.org/#map=5/24.187/-101.646>).

Pacheco-Vega, R. (2013). The politics of wastewater governance, Blog ‘Understanding and solving intractable resource governance problems’, retrieved on 2017/03/17 from <http://www.raulpacheco.org/2013/12/the-politics-of-wastewater-governance/>

Paehlke, R. (1996). Environmental challenges to democratic practice, in Lafferty, W. and Meadowcroft, J. (eds.), *Democracy and the environment: Problems and prospects*, Edward Elgar, Cheltenham, U.K.

Panayotou T. (1997). Demystifying the Environmental Kuznets curve: Turning a black box into a policy tool, *Environment and Development Economics*, Vol. 2, pp. 465–484.

Panayotou, T. (1993). Empirical tests and policy analysis of environmental degradation at different stages of economic development, Working Paper WP238, Technology and Employment Programme, International Labour Office, Geneva, Switzerland.



- Papavero, L. (2010). Female representation and legislative behavior in the Italian Parliament: 1987-2008, Conference paper presented at the International Conference on democracy as Idea and Practice, Oslo 14<sup>th</sup>-15<sup>th</sup> January 2010, Norway.
- Papke, L.E. and Wooldridge, J.M. (1996). Econometric methods for fractional response variables with an application to 401(k) plan participation rates, *Journal of Applied Econometrics*, Vol. 11, Issue 6, pp. 619–632.
- Papyrakis, E. (2013). Environmental performance in socially fragmented countries, *Environment and Resource Economics*, Vol. 55, pp. 119–140.
- Parkinson, J. and Tayler, K. (2003). Decentralized wastewater management in peri-urban areas in low-income countries, *Environment and Urbanization*, Vol. 15, No. 1, pp. 75–90.
- Paudel, K.P. and Schafer, M.J. (2009). The Environmental Kuznets curve under a new framework: The role of social capital in water pollution, *Environmental and Resource Economics*, Vol. 42, No. 2, pp. 265-278.
- PEH de Morelos – Programa Estatal Hídrico 2014-2018 (2014). Comisión estatal del agua del Estado de Morelos, Gobierno de Morelos, Cuernavaca, Morelos, retrieved on 2016/03/30 from [https://hacienda.morelos.gob.mx/images/docu\\_planeacion/planea\\_estrategica/programas\\_sectoriales/15.-PROGRAMA\\_ESTATAL\\_HIDRICO.pdf](https://hacienda.morelos.gob.mx/images/docu_planeacion/planea_estrategica/programas_sectoriales/15.-PROGRAMA_ESTATAL_HIDRICO.pdf).
- Peña, M.E. de la, Ducci, J. and Zamora, V. (2013). Tratamiento de aguas residuales en México, Nota Técnica # IDB-TN-521, Banco Interamericano de Desarrollo, Sector de Infraestructura y Medio Ambiente, Washington D.C., USA.
- Peri, G. (2005). Determinants of knowledge flows and their effects on innovation, *The Review of Economics and Statistics*, Vol. 87, No. 2, pp. 308–322.
- Perkins, R. and Neumayer, E. (2008). Fostering environment-efficiency through transnational linkages? Trajectories of CO<sub>2</sub> and SO<sub>2</sub>, 1980–2000, *Environment and Planning*, Vol. 40, No. 12, pp. 2970–2989.
- Perkins, R. and Neumayer, E. (2009). Transnational linkages and the spillover of environment-efficiency into developing countries, *Global Environmental Change*, Vol. 19, Issue 3, pp. 375–383.
- Perkins, R. and Neumayer, E. (2012). Do recipient country characteristics affect international spillovers of CO<sub>2</sub>-efficiency via trade and foreign direct investment? *Climatic Change*, Vol. 112, Issue 2, pp. 469–491.
- Pescod, M.B. (1992). Wastewater treatment and use in agriculture, FAO irrigation and drainage paper 47, Food and Agriculture Organization of the United Nations, Rome, Italy, retrieved on 2016/04/12 from <http://www.fao.org/docrep/t0551e/t0551e00.htm#Contents>.
- Pierce, J. and Lovrich, N.P. Jr. (1980). Belief systems concerning the environment: the general public, attentive public and state legislators, *Political Behavior*, Vol. 2, No. 3, pp. 259-286.

Pierce, J. and Lovrich, N.P. Jr. (2005). Trust in the technical information provided by interest groups: The views of legislators, activists, experts, and the general public, *Policy Studies Journal*, Vol. 11, No. 4, pp. 626-639.

Pierce, J., Lovrich, N.P. Jr., Tsuratsani, T. and Abe, T. (1987). Environmental belief systems among Japanese and American elites and publics, *Political Behavior*, Vol. 9, No. 2, pp. 139-159.

Pineda Pablos, N. and Salazar Adams, A. (2008). De las juntas federales a las empresas de agua: la evolución institucional de los servicios urbanos de agua en México 1948-2008, in Olivares, R. and Sandoval, R. (eds.): *El agua potable en México – historia reciente, actores, procesos y propuestas*, DF, México.

Plassmann, F. and Khanna, N. (2006). Household income and pollution: Implications for the debate about the Environmental Kuznets curve hypothesis, *The Journal of Environment and Development*, Vol. 15, pp. 22–41.

PND (2013). Plan nacional de desarrollo 2013-2018, Gobierno de la República de los Estados Unidos Mexicanos, DF, México, retrieved on 2016/03/30 from <http://pnd.gob.mx/>.

PNH (2008). Plan nacional hídrico – edición 2008, Comisión Nacional del Agua, DF, México, retrieved on 2015/10/14 from [http://www.conagua.gob.mx/CONAGUA07/Contenido/Documentos/PNH\\_05-08.pdf](http://www.conagua.gob.mx/CONAGUA07/Contenido/Documentos/PNH_05-08.pdf).

PNH (2014). Plan nacional hídrico – edición de Abril de 2014, Comisión Nacional del Agua, DF, México, retrieved on 2016/04/30 from <http://www.conagua.gob.mx/CONAGUA07/Contenido/Documentos/Capitulo1.pdf>

PNUD – Programa de las Naciones Unidas para el Desarrollo México (2005). *Desarrollo humano y género – indicadores municipales de desarrollo humano en México*, DF, México, retrieved on 2013/08/29 from <http://www.undp.org.mx/desarrollohumano/disco/index.html> and on 2015/11/30 from <http://archive.is/i61wk>.

PNUD – Programa de las Naciones Unidas para el Desarrollo México (2014). Appendix of "Índice de desarrollo humano municipal en México – nueva metodología", DF, Mexico, retrieved on 2016/01/09 from <http://www.mx.undp.org/content/dam/mexico/docs/Publicaciones/PublicacionesReduccionPobreza/InformesDesarrolloHumano/UNDP-MX-PovRed-IDHmunicipalMexico-032014.pdf>.

PROFEPA – Procuraduría Federal de Protección al Ambiente (2016). *Denuncias ambientales – ¿Qué puedes denunciar?*, DF, México, retrieved on 2016/04/15 from [http://www.profepa.gob.mx/innovaportal/v/34/1/mx/denuncias\\_ambientales.html](http://www.profepa.gob.mx/innovaportal/v/34/1/mx/denuncias_ambientales.html).

Putnam, R. (2000). *Bowling alone*, Simon and Schuster, New York, USA.

Quadri de la Torre, G. (2008). Políticas públicas, sustentabilidad y eficiencia en los sistemas de agua, in Olivares, R. and Sandoval, R. (eds.): *El agua potable en México – historia reciente, actores, procesos y propuestas*, DF, México, pp. 241-246.

Ramsey, F. and Schafer, D. (2013): *The statistical sleuth: A course in methods of data analysis*, 3rd edition, Brooks/Cole, Boston, MA, USA.

RAS (2000). Reglamento técnico del sector de agua potable y saneamiento básico – RAS 2000 título E, Dirección de Agua Potable y Saneamiento Básico, Ministerio de Desarrollo Económico de la República de Colombia, Bogotá, Colombia, retrieved on 2015/11/15 from [http://www.cra.gov.co/apc-aa-files/37383832666265633962316339623934/3\\_presentaciondocumento\\_tecnico.pdf](http://www.cra.gov.co/apc-aa-files/37383832666265633962316339623934/3_presentaciondocumento_tecnico.pdf).

Raschid-Sally, L. and Jayakody, P. (2008). Drivers and characteristics of wastewater agriculture in developing countries: Results from a global assessment, International Water Management Institute, Research report 127, retrieved from on 2016/03/17 from [http://www.iwmi.cgiar.org/Publications/IWMI\\_Research\\_Reports/PDF/PUB127/RR127.pdf](http://www.iwmi.cgiar.org/Publications/IWMI_Research_Reports/PDF/PUB127/RR127.pdf).

Reingold, B. (2000). Representing women: Gender, gender, and legislative behavior in Arizona and California, University of North Carolina Press, Chapel Hill, NC, USA.

Rendón, G.O. (1997). La política del agua en México en el marco del desarrollo sustentable, Ingeniería Hidráulica en México, Vol. XII, No. 3, pp. 59-70.

Revesz, R.L. (2001). Federalism and environmental regulation: A public choice analysis, Harvard Law Review, Vol. 115, No. 2, pp. 553–641.

Ring, I. (2002). Ecological public functions and fiscal equalisation at the local level in Germany, Ecological Economics, Vol. 42, pp. 415-427.

Ringquist, E. (1997). Equity and the distribution of environmental risk: The case of TRI facilities, Social Science Quarterly, Vol. 78, No. 4, pp. 811–829.

Roca, J. (2003). Do individual preferences explain the Environmental Kuznets curve?, Ecological Economics, Vol. 45, Issue 1, pp. 3–10.

Rockström, J.W., Steffen, K., Noone, Å., Persson, F.S., Chapin, E.F., Lambin, T.M., Lenton, M., Scheffer, C., Folke, H.J., Schellnhuber, B., Nykvist, C.A., de Wit, T., Hughes, S., van der Leeuw, H., Rodhe, S., Sörlin, P.K., Snyder, R., Costanza, U., Svedin, M., Falkenmark, L., Karlberg, R.W., Corell, V.J., Fabry, J., Hansen, B., Walker, D., Liverman, K., Richardson, P., Crutzen and Foley, J.A. (2009). A safe operating space for humanity, Nature, Vol. 461, pp. 472-475.

Roemer, J.E. (1993). Would economic democracy decrease the amount of public bads?, The Scandinavian Journal of Economics, Vol. 95, pp. 227–238.

Rogers, P. and Hall, A.W. (2003). Effective water governance, TEC Background, Papers No. 7, Global Water Partnership, Technical Committee, Stockholm, Sweden.

Rolland, L. and Vega Cárdenas, Y. (2010). La gestión del agua en México, Universidad Autónoma Metropolitana Unidad Iztapalapa, Polis: Investigación y Análisis Sociopolítico y Psicosocial, Vol. 6, No. 2, pp. 155-188.

Roushdy, R., Sieverding, M. and Radwan, H. (2012). The impact of water supply and sanitation on child health: Evidence from Egypt, New York Population Council, New York, USA.

Ryan, M.C. (1989). An investigation of inorganic nitrogen compounds in the groundwater in the valley of Mexico, Universidad Nacional Autónoma de México UNAM, Geofísica Internacional, Vol. 28, No. 2, pp. 417-433.

Salazar Adams, A. and Lutz Ley, A.N. (2012). An empirical study of factors affecting water loss in Mexican cities, *Journal of Water Sustainability*, Vol. 2, Issue 3, pp. 167–178.

Salazar Adams, A. and Lutz Ley, A.N. (2015). Factores asociados al desempeño en organismos operadores de agua potable en México, *Región y Sociedad*, Vol. XXVII, No. 62, pp. 5-26.

Saltiel, G. (2008). Problemática del sector de agua potable, alcantarillado y saneamiento mexicano – análisis, ejemplos y propuestas, in Olivares, R. and Sandoval, R. (eds.): *El agua potable en México – historia reciente, actores, procesos y propuestas*, DF, México, pp. 229-238.

Samuelson, P.A. (1954). The pure theory of public expenditure, *Review of Economics and Statistics*, Vol. 36, No. 4, pp. 387-389.

Samuelson, P.A., Koopmans, T.C. and Stone, J.R.N. (1954). Report of the evaluative committee for *Econometrica*, *Econometrica*, Vol. 22, No. 2, pp. 141-146.

Sánchez Cohen, I., Oswald Spring, Ú., Díaz Padilla, G. and González Barrios, J.L. (2011). Integrated water management in hydrological basins: Multidisciplinary and multi-institutionality as an action paradigm, in Oswald Spring, Ú. (ed.): *Water resources in Mexico – scarcity, degradation, stress, conflicts, management, and policy*, Springer, Heidelberg, Germany, pp. 39-49.

Sandoval, R. (2008). Regulación, participación social y gobernabilidad del agua potable en México – elementos para un análisis de su evolución institucional, in Olivares, R. and Sandoval, R. (eds.): *El agua potable en México – historia reciente, actores, procesos y propuestas*, DF, México, pp. 247-258.

Santibañez, L. (2016). The indigenous achievement gap in Mexico: The role of teacher policy under intercultural bilingual education, *International Journal of Educational Development*, Vol. 47, pp. 63–75.

Santos, R., Ring, I., Antunes, P. and Clemente, P. (2012). Fiscal transfers for biodiversity conservation: The Portuguese Local Finances Law, *Land Use Policy*, Vol. 29, Issue 2, pp. 261–273.

Scruggs, L.A. (1998). Political and economic inequality and the environment, *Ecological Economics*, Vol. 26, pp. 259–275.

Seabright, P. (1996). Accountability and decentralisation in government: An incomplete contracts model, *European Economic Review*, Vol. 40, pp. 61–89.

SEDESOL, CONAPO and INEGI (2012). Delimitación de las zonas metropolitanas de México 2010, DF, México, retrieved on 2016/05/13 from <http://www.inegi.org.mx/Sistemas/multiarchivos/doc/702825003884/DZM20101.pdf>.

Selden, T.M. and Song, D. (1994). Environmental quality and development: Is there a Kuznets curve for air pollution emissions?, *Journal of Environmental Economics and Management*, Vol. 27, pp. 147–162.

SEMARNAT – Secretaría de Medio Ambiente y Recursos Naturales (2002). Informe de la situación del medio ambiente en México – Compendio de estadísticas ambientales, DF,

México, retrieved on 2016/03/16 from [http://dgeiawf.semarnat.gob.mx:8080/ibi\\_apps/WFServlet?IBIF\\_ex=D3\\_R\\_AGUA05\\_01&IBIC\\_user=dgeia\\_mce&IBIC\\_pass=dgeia\\_m](http://dgeiawf.semarnat.gob.mx:8080/ibi_apps/WFServlet?IBIF_ex=D3_R_AGUA05_01&IBIC_user=dgeia_mce&IBIC_pass=dgeia_m).

SEMARNAT – Secretaría de Medio Ambiente y Recursos Naturales (2008). Programa sectorial del medio ambiente y recursos naturales, Tlalpan, DF, México, retrieved on 2016/04/23 from [http://www.semarnat.gob.mx/archivosanteriores/programas/psmarn/Documents/PSMAyR\\_N%2021%20ene%2008.pdf](http://www.semarnat.gob.mx/archivosanteriores/programas/psmarn/Documents/PSMAyR_N%2021%20ene%2008.pdf).

SEMARNAT – Secretaría de Medio Ambiente y Recursos Naturales (2009). Informe de la situación del medio ambiente en México, Compendio de estadísticas ambientales, indicadores clave y de desempeño ambiental, edición 2008, DF, México.

SEMARNAT – Secretaría de Medio Ambiente y Recursos Naturales (2012). Reglamento interior de la secretaría de medio ambiente y recursos naturales, DF, México, retrieved on 2016/02/25 from <http://biblioteca.semarnat.gob.mx/janium/Documents/Ciga/agenda/PPD1/2969.pdf>.

SEMARNAT – Secretaría de Medio Ambiente y Recursos Naturales (2013). Informe de la situación del medio ambiente en México, Compendio de estadísticas ambientales, Indicadores clave y de desempeño ambiental, edición 2012, DF, México.

SEMARNAT – Secretaría de Medio Ambiente y Recursos Naturales (2014a). Reglas de operación para los programas de Infraestructura hidroagrícola y de agua potable, alcantarillado y saneamiento a cargo de la comisión nacional del agua, DF, México, retrieved on 2016/02/28 from <http://www.conagua.gob.mx/CONAGUA07/Noticias/ROP2015.pdf>.

SEMARNAT – Secretaría de Medio Ambiente y Recursos Naturales (2014b). Normas oficiales mexicanas NOM-001-SEMARNAT-1996, NOM-002-SEMARNAT-1996, NOM-003-SEMARNAT-1997, D.F., México, retrieved on 2016/02/25 from <http://www.conagua.gob.mx/CONAGUA07/Noticias/NormasOficialesMexicanas.pdf>.

Shafik, N. (1994). Economic development and environmental quality: An econometric analysis, Oxford Economic Papers, Vol. 46, pp. 757–773.

Shafik, N. and Bandyopadhyay, S. (1992). Economic growth and environmental quality: Time series and cross-country evidence, Policy, research working papers No. WPS 904, World development report, World Bank, Washington D.C., USA.

Shua, L., Fantanga, Z., Huaiyanga, F. and Zhencheng, X. (2012). An empirical test of the Environmental Kuznets curve in Guangdong Province, China, International Conference on Environmental Science and Development (ICESD 2012), 5-7 January 2012, Hong Kong, China.

Sigman, H. (2003). Letting states do the dirty work: State responsibility for federal environmental legislation, National Tax Journal, Vol. 56, pp. 107–122.

Sigman, H. (2014). Decentralization and environmental quality: An international analysis of water pollution levels and variation, Land Economics, Vol. 90, No. 1, pp. 114–130.

Silva, E.C.D. and Caplan, A.J. (1997). Transboundary pollution control in federal systems, Journal of Environmental Economics and Management, Vol. 34, pp. 82–101.

Simmons, B.A., Dobbin, F. and Garrett, G. (2006). Introduction: The international diffusion of liberalism, *International Organizations*, Vol. 60, pp. 781–810.

SNIM – Sistema Nacional de Información Municipal (2010). Descripción de base de datos 2010, Instituto Nacional para el Federalismo y el Desarrollo Municipal, DF, México, retrieved on 2015/04/29 from <http://www.snim.rami.gob.mx/>.

SNIM – Sistema Nacional de Información Municipal (2014). Indicadores sociales de municipios mexicanos, Instituto Nacional para el Federalismo y el Desarrollo Municipal, DF, México, retrieved on 2014/04/15 from <http://www.snim.rami.gob.mx/>.

SNIM – Sistema Nacional de Información Municipal (2015). Municipios en cifras – población, Instituto Nacional para el Federalismo y el Desarrollo Municipal, DF, México, retrieved on 2015/12/28 from <http://www.snim.rami.gob.mx/>.

Song, Z.T. and Tong, L. (2008). An empirical test of the environmental Kuznets curve in China: A panel cointegration approach, *China Economic Review*, Vol. 19, pp. 381–392.

Stern, D.I. (2004). The rise and fall of the Environmental Kuznets curve, *World Development*, Vol. 32, No. 8, pp. 1419–1439.

Stern, D.I. (2005). Beyond the Environmental Kuznets curve: Diffusion of sulfur-emissions-abating technology, *Journal of Environment & Development*, Vol. 14, No. 1, pp. 101-124.

Stern, P.C. and Dietz, T. (1994). The value basis of environmental concern, *Journal of Social Issues*, Vol. 50, No. 3, pp. 65-84.

Stern, P.C., Dietz, T. and Kalof, L. (1993). Value orientations, gender and environmental concern, *Environment and Behavior*, Vol. 25, No. 3, pp. 322-348.

Sundström, A. and McCright, A.M. (2013). Examining gender differences in environmental concern across four levels of the Swedish polity, QoG Working Paper Series 2013:10, QoG - The Quality of Government Institute, Gothenburg, Sweden.

Svaleryd, H. (2009). Women's representation and public spending, *European Journal of Political Economy*, Vol. 25, pp. 186–198.

Tiebout, C.M. (1956). A pure theory of local expenditures, *The Journal of Political Economy*, Vol. 64, No. 5, pp. 416-424.

Tobin, J. (1958). Estimation of relationships for limited dependent variables, *Econometrica*, Vol. 26, No. 1, pp. 24–36.

Torgler, B. and García-Valiñas, M.A. (2007). The determinants of individuals' attitudes towards preventing environmental damage, *Ecological Economics*, Vol. 63, No. 2–3, pp. 536–552.

Torras, M. and Boyce, J.K. (1998). Income, inequality, and pollution: A reassessment of the environmental Kuznets curve, *Ecological Economics*, Vol. 25, pp. 147–160.

Tortajada, C. (2002). Abastecimiento de agua y manejo de descargas residuales en México: Un análisis de las políticas ambientales, in Ávila García, P. (ed.): *Agua, Cultura y Sociedad en*

México, Instituto Mexicano de Tecnología del Agua, Cuernavaca, Morelos, México, pp. 233-246.

Treisman, D. (2002). Decentralization and the quality of government, mimeo, University of California, Los Angeles, USA.

Tremblay, M. (1998). Do female MPs substantively represent women? A study of legislative behaviour in Canada's 35th Parliament, *Canadian Journal of Political Science*, Vol. 31, pp. 435-465.

UN Water (2008). Tackling a global crisis: International year of sanitation 2008, NY, USA, retrieved on 2015/02/15 from [http://www.wsscc.org/fileadmin/files/pdf/publication/IYS\\_2008\\_-\\_tackling\\_a\\_global\\_crisis.pdf](http://www.wsscc.org/fileadmin/files/pdf/publication/IYS_2008_-_tackling_a_global_crisis.pdf).

UNDP – United Nations Development Programme (2010). Human development report 2010, NY, USA, retrieved on 2015/11/15 from [http://hdr.undp.org/sites/default/files/reports/270/hdr\\_2010\\_en\\_complete\\_reprint.pdf](http://hdr.undp.org/sites/default/files/reports/270/hdr_2010_en_complete_reprint.pdf).

UNDP – United Nations Development Programme (2013). Human development report 2013 – technical notes, NY, USA, retrieved on 2015/11/15 from [http://hdr.undp.org/sites/default/files/hdr\\_2013\\_en\\_technotes.pdf](http://hdr.undp.org/sites/default/files/hdr_2013_en_technotes.pdf).

UNDP – United Nations Development Programme (2014). Human development report 2014, NY, USA.

UNDP – United Nations Development Programme (2015). Human development report 2015 – work for human development, NY, USA, retrieved on 2015/12/01 from <http://report.hdr.undp.org/> and <http://hdr.undp.org/en/composite/HDI>.

UNO – United Nations (2002). General Assembly – Message from H. E. Dr. Han Seung-soo, President of the General Assembly, on the occasion of World Day for Water, 22 March 2002, retrieved on 2017/03/12 from <http://www.un.org/ga/president/56/speech/020322.htm>.

UNSD – United Nations Statistics Division (2012). System of environmental-economic accounting for water United Nations, NY, USA, retrieved on 2015/11/23 from <http://unstats.un.org/unsd/envaccounting/seeaw/seeawaterwebversion.pdf>

UNSTATS – United Nations Statistics Division (2016). Population density and urbanization – Standards and methods, NY, USA, retrieved on 2016/01/09 from <http://unstats.un.org/unsd/demographic/sconcerns/densurb/densurbmethods.htm>.

Veblen, T. (1899). The theory of the leisure class: An economic study in the evolution of institutions, The Macmillan Company, New York, USA.

Veisten, K., Hoen, H.F., Navrud, S. and Strand, J. (2004). Scope insensitivity in contingent valuation of complex environmental amenities, *Journal of Environmental Management*, Vol. 73, pp. 317–331.

Verdolinia, E. and Galeotti, M. (2011). At home and abroad: An empirical analysis of innovation and diffusion in energy technologies, *Journal of Environmental Economics and Management*, Vol. 61, Issue 2, pp. 119–134.

- Videras J. and Bordoni, C.J. (2006). Ethnic heterogeneity and the enforcement of environmental regulation, *Review of Social Economy*, Vol. 64, No. 4, pp. 539–562.
- Vona, F. and Patriarca, F. (2011). Income inequality and the development of environmental technologies, *Ecological Economics*, Vol. 70, pp. 2201–2213.
- Wagner, M. (2008). The carbon Kuznets curve: A cloudy picture emitted by bad econometrics?, *Resource and Energy Economics*, Vol. 30, pp. 388–408.
- Wallis, J.J. (2015). Structure and change in economic history: The ideas of Douglass North – 27 November 2015, retrieved on 2017/02/20 from <http://voxeu.org/article/ideas-douglass-north>.
- Wang, Q. and Yang, Z. (2016). Industrial water pollution, water environment treatment, and health risks in China, *Environmental Pollution*, Vol. 218, pp. 358–365.
- WB-SCEA (2006). Pakistan strategic country environmental assessment – main report, Report No. 36946-PK, World Bank, pp. 1–66.
- Weiss, E.B. and Jacobsen, H.K. (1999). Getting countries to comply with international agreements, *Environment*, Vol. 41, pp. 16–23.
- Wester, P., Rap, E. and Vargas-Velázquez, S. (2009). The hydraulic mission and the Mexican hydrocracy: Regulating and reforming the flows of water and power, *Water Alternatives*, Vol. 2, No. 3, pp. 395-415.
- WHO – World Health Organization (2011). *World health statistics 2011*, Luxembourg.
- WHO – World Health Organization (2015). *World health statistics 2015*, Luxembourg.
- Wilder, M. (2010). Water governance in Mexico: Political and economic apertures and a shifting state-citizen relationship, *Ecology and Society*, Vol 15, No. 2, Art. 22.
- Wilkinson, R. and Pickett, K. (2010). *The spirit level: Why equality is better for everyone*, Penguin books, London, UK.
- Williams, R. (2016). Analyzing proportions: Fractional response and zero one inflated beta models, University of Notre Dame, Paris, France, retrieved on 2016/07/11 from <http://www3.nd.edu/~rwilliam/>.
- Wisman, J.D. (2011). Inequality, social respectability, political power, and environmental devastation, *Journal of Economic Issues*, Vol. 45, Issue 4, pp. 877-900.
- Witte, K. de and Geys, B. (2011). Evaluating efficient public good provision: Theory and evidence from a generalised conditional efficiency model for public libraries, *Journal of Urban Economics*, Vol. 69, Issue 3, pp. 319–327.
- Wong, Y.L. (Andrew) and Lewis, L. (2013). The disappearing Environmental Kuznets curve: A study of water quality in the Lower Mekong Basin (LMB), *Journal of Environmental Management*, Vol. 131, pp. 415-425.



Woodhouse, P. and Muller, M. (2017). Water governance — an historical perspective on current debates, *World Development*, Vol. 92, pp. 225–241.

Woods, N.D. (2013). Environmental federalism: Empirics, in Shogren, Jason (ed.), *Encyclopedia of energy, natural resource, and environmental economics*, Elsevier Academic Press, Vol. 3, pp. 271-277.

World Bank (2015a). World development indicators, Washington D.C., USA, retrieved on 2015/12/25 from <http://data.worldbank.org/country/mexico>.

World Bank (2015b). PovcalNet – an online analysis tool for global poverty monitoring, Washington D.C., USA, retrieved on 2015/12/25 from <http://iresearch.worldbank.org/PovcalNet/>.

World Bank (2015c). Indicators, Washington D.C., USA, retrieved on 2015/12/25 from <http://data.worldbank.org/indicator>.

Wunder, S., Engel, S. and Pagiola, S. (2008). Payments for environmental services in developing and developed countries, *Ecological Economics*, Special Issue, Vol. 65, pp. 663–852.

WWAP – United Nations World Water Assessment Programme (2015). The United Nations world water development report 2015: Water for a sustainable world, UNESCO, Paris, France.

Xiao, C. and McCright, A.M. (2012). A test of the biographical availability argument for gender differences in environmental behaviors, *Environment and Behavior*, Vol. 46, Issue 2, pp. 241-263.

XIIENCA (2015). Encuentro nacional de cultura del agua – del 5 al 7 de agosto, Monterrey, Nuevo León, Mexico.

XVIIIENAC (2016). Encuentro nacional de áreas comerciales – del 10 al 12 de agosto, León, Guanajuato, Mexico.

You, W.H., Zhu, H.M., Yu, K. and Peng, C. (2015). Democracy, financial openness, and global carbon dioxide emissions: Heterogeneity across existing emission levels, *World Development*, Vol. 66, pp. 189–207.

Young, R.A. and Haveman, R.H. (1985). Economics of water resources: A survey, in Kneese, A. V. and Sweeney, J. L. (eds.), *Handbook of natural resource and energy economics*, Vol. 2, pp. 465-529.

Zanden, J.L. van Baten, J., Mira d'Ercole, M., Rijpma, A., Smith, C. and Timmer, M. (2014). *How was Life?: Global well-being since 1820*, OECD Publishing, Paris, France.

Zelezny, L.C., Chua, P.P. and Aldrich, C. (2000). Elaborating on gender differences in environmentalism, *Journal of Social Issues*, Vol. 56, pp. 443-457.

Zepeda, L. and Li, J. (2007). Characteristics of organic food shoppers, *Journal of Agricultural and Applied Economics*, Vol. 39, No. 1, pp. 17-28.

Zetland, D. (2011). *The end of abundance: Economic solutions to water scarcity*, Aguanomics Press, California, USA.