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Klaus Eisenack

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Abstract

Cities increasingly address climate change, e.g. by pledging city-level emission reduction targets. This is puzzling for the provision of a global public good: what are city governments' reasons for doing so, and do pledges actually translate into emission reductions? Empirical studies have found a set of common factors which relate to these questions, but also mixed evidence. What is still pending is a theoretical framework to explain those findings and gaps. This paper thus develops an abstract public choice model. The model features economies of scale and distinguishes urban reduction targets from actual emission reductions. It is able to support some stylized facts from the empirical literature and to resolve some mixed evidence as special cases. Two city types result. One type does not achieve its target, but reduces more emissions than a free-riding city. These relations reverse for the other type. The type determines whether cities with lower abatement costs more likely set targets. A third type does not exist. For both types, cities which set targets and have higher private costs of carbon are more ambitious. If marginal net benefits of mitigation rise with city size, then larger cities gain more from setting climate targets. Findings are contrasted with an alternative model where targets reduce abatement costs. Some effects remain qualitatively the same, while others clearly differ. The model can thus guide further empirical and theoretical work.

Keywords: Local provision of public goods; public choice; voters; lobbyists; co-benefits; private costs of carbon.

JEL classification: Q54, Q58, D72.

*klaus.eisenack@hu-berlin.de, Resource Economics Group, Humboldt-Universität zu Berlin, Germany.

1 Introduction

More and more cities worldwide set targets to mitigate greenhouse gas emissions within their jurisdiction, even if these cities are in countries which do not have effective climate targets or policies in place (e.g. Andonova et al., 2017; Rivas et al., 2021). When we consider mitigation as contribution to a global public good, we might expect that such targets are just cheap talk or green washing – and have no effect. Yet, there are some indications that target-setting cities indeed achieve emission reductions (Hsu et al., 2020). It is one common finding in empirical studies on urban climate governance so far, that larger cities are more active in this field (e.g. Andonova et al., 2017; Steffen et al., 2019). In our theoretical paper, we study possible explanations for the existence and effectiveness for city-level climate targets, related to the role of city size, by scrutinizing three kinds of mechanisms: Economies of scale, local public choice mechanisms which might induce local governments to consider more than local opportunity costs, and the possibility that targets might reduce abatement costs. While the paper primarily aims to contribute to the theory of urban climate governance, it also aims at deducing hypotheses which are empirically testable. Since essential data is still notoriously difficult to collect, e.g. whether cities actually reduce emissions, it requires some care that a model also makes predictions about better observable variables.

By the end of 2022, more than 1000 cities from all over the world report their greenhouse gas emissions to the Carbon Disclosure Project (CDP), following a common standard (Protocol, 2015). The greenhouse gas reduction potential of existing measures or targets of non-national government actors is estimated at 1.2 GtCO₂e/year or even larger (Graichen et al., 2017; Roelfsema et al., 2018; Kuramochi et al., 2020). For a representative sample of 885 European cities, Reckien et al. (2018) showed that more than 2/3 had a climate mitigation plan in place as of 2017, and about 1/4 an adaptation plan. So-called transnational municipal networks (TMN) like the Global Covenant of Mayors for Climate and Energy (GCoM), or the International Council of Local Environmental Initiatives (ICLEI) prominently make visible urban climate action (e.g. Castán-Broto and Westman, 2020; Berrueta and Heijden, 2021). At the time of writing, GCoM has more than 12,500 member cities, in total representing more than 1 billion people, and pledging annual emission reductions by 3.8 GtCO₂e until 2050. Although members of TMNs tend to be concentrated in the North, they have global coverage (Bansard et al., 2017). On the other hand, Kona et al. (2018) find that only 17% of GCoM signatories submitted monitoring reports until 2017. Later, among more than 5000 municipalities which submitted a "Sustainable Energy Action Plan" to GCoM, about 1/3 credibly monitor their emissions (Rivas et al., 2021).

Environmental economics has a long tradition in studying local emissions and abatement. While the following summarizes some recent contributions, this research does not aim at explaining cities' contributions to global public goods. While many studies concentrate on the effects and valuation of pollutants and local resources (e.g. Deng and Mendelsohn, 2021; Isphording and Pestel, 2021; Klaiber and Morawetz, 2021; Xia et al., 2022), others address specific policy instruments and measures (e.g. Akbulut-Yuksel and Boulatoff, 2021; Rivera, 2021; Baranzini et al., 2021; Dijkstra, 2022), sometimes with a (positive) public choice angle (e.g. Thomas and Zaporozhets, 2017; Wu and Cao, 2021; Fageda et al., 2022). Other studies focus on adaptation to climate impacts (e.g. Ando et al., 2020). A set of papers expands the monocentric city model of urban economics to study determinants of urban emissions, partially in relation to environmental policy instruments (e.g. Borck and Brueckner, 2018; Regnier and Legras, 2018; Kyriakopoulou and Picard, 2021; Marz and Goetzke, 2022). Quaas and Smulders (2018) develop a city growth model. Local support of renewables is studied by Steffen et al. (2019). Bai et al. (2019) show how tax competition between cities can reduce environmental standards. I'm yet not aware of papers which address the question under which conditions local governments set (or achieve) climate mitigation targets.

The economics models in this paper should be read against the background of existing empirical studies, mostly undertaken in geography and political science (see van der Heijden, 2019; Castán-Broto and Westman, 2020, for excellent overviews). Some of them are case studies, or focus on small sets of cities (e.g. Dale et al., 2020), while others investigate larger samples (e.g. Pablo-Romero et al., 2015; Heikkinen et al., 2020; Krause et al., 2021). They address different research questions, for example to find factors which drive climate adaptation plans or mitigation plans (e.g. Eisenack and Roggero, 2022; Klein et al., 2018), or the interaction of both types of plans in cities (e.g. Lee et al., 2020). Other studies aim to explain participation in TMNs (e.g. Lee, 2019), or emission reductions (e.g. Hsu et al., 2020; Roggero et al., 2023a).

This research has produced some stylized facts and identified areas with mixed evidence. If we want to develop theoretical models of urban climate governance, those should be able to reproduce this evidence. To be clear, I use the term "ambition" in this paragraph to broadly mean different things ranging from policy input to policy outcome: an early adoption of climate plans, higher emission reduction targets, more support of mitigation or adaptation, and so on (the models below will work with a precise definition). With this broad understanding, the literature can support the finding that (1) cities with a larger capacity (proxied by high GDP/capita, city size, or other indicators) are more ambitious, possibly in a hill-shaped pattern (e.g. Lee, 2013; Araos et al., 2016; Andonova et al., 2017; Reckien et al., 2018; Steffen et al., 2019; Krause et al., 2021). (2) Higher vul-

nerability or stronger exposure to impacts may lead to more ambition, but some studies show only a weak relation or the opposite (see Zahran et al., 2008; Wang, 2012; Reckien et al., 2015; Kalafatis, 2018; Boussalis et al., 2018). It is intuitive for mitigation, that the relation is weak at most, but not for adaptation. (3) It might also be that ambition is not so much driven by direct costs and benefits, but more by the preferences of the local constituency. Local voters or the local industry might push their governments for less or more climate action. Yet, while existing studies for the US mostly show a clear effect of local voter preferences, findings on the presence of the fossil fuel industry or on the more general role of voter preferences are inconclusive (e.g. Zahran et al., 2008; Wang, 2012; Pablo-Romero et al., 2015; Kalafatis, 2018; Boussalis et al., 2018; Armstrong, 2019; Hui et al., 2019). (4) Larger co-benefits of mitigation, i.e. if climate action has additional local benefits or selective incentives, e.g. by reducing local air pollution or traffic congestion, might be one reason for city governments to be more ambitious. Empirical studies, however, show that this is not necessarily the case (e.g. Krause, 2011; Lee and van de Meene, 2013; Pablo-Romero et al., 2015; Rashidi and Patt, 2018; Dale et al., 2020; Roggero et al., 2023b). (5) Ambition of cities and national governments can be complements or substitutes (Reckien et al., 2015; Heidrich et al., 2016; Reckien et al., 2018; Woodruff and Stults, 2016; Domorenok, 2019). Some national policies now oblige cities to make plans, but with mixed outcomes (e.g. Reckien et al., 2018).

One suggestion to resolve this mixed evidence is to classify cities into different types. Mechanisms at work are seemingly differently depending on the kind of city (Berrueta and Heijden, 2021; Eisenack and Roggero, 2022). What is also lacking are economic explanations for the discussed and other possible factors, or even of city types. While the factors (1-3) will be center stage in this paper, I will show that some model parameters also address factors (4-5).

I do so by setting up a public choice model: It assumes a local government which is not necessarily maximizing city welfare. In addition to the costs and benefits from mitigation, which scale with city size, the model considers the political preferences of its constituency (e.g. expressed by voters or influential lobbyists). Furthermore, the model distinguishes the climate targets which a government may set (as frequently observed nowadays) from the emission reductions which are actually achieved (and which are more difficult to observe) – thereby admitting a possible mismatch between both. Targets are assumed to be set in response to demands from the constituency. The local government obtains a political value from setting an (un)ambitious target, which is balanced against the costs and benefits from actual mitigation, and future political costs if the target is not met. It is assumed that targets are only set if the political gains are large enough. This setup admits to derive the conditions under which political preferences can explain the

presence of climate targets, and whether they are more likely set by larger cities. The analysis derives different city types which differ by their comparative statics profile – and whether they achieve their targets. It is shown that targets are not achieved by cities where the constituency demands more mitigation than a free-riding city. Cities which contribute more to the global public good are exactly those which set less ambitious targets than their constituency prefers. The comparative statics are then compared against another model, which also distinguishes targets from their achievement, but where the effect of targets is not related to political preferences.

The next section starts with a simple expository model, which is extended in Sect. 3 to include climate targets and political costs (an Appendix considers the alternative model). I then compare the results for the identified city types, and discuss implications for empirical research in Sect. 4. Sect. 5 concludes.

2 Expository model

I start with an expository model to make the puzzle of why cities should contribute to a global public good explicit, and to start introducing notation. The model also leads to a first observation of the role of city size. In the subsequent sections, the model will be extended by considering emission reduction targets in addition to actual emission reductions (mitigation), and to accommodate additional mechanisms.

Consider a single city with size s which decides about mitigation m , its contribution to a global public good. City-level welfare is expressed by $W = B - C$, where B denotes the benefits from mitigation (reduced climate damages and other possible benefits), and C the mitigation costs. Mitigation m is measured as abatement relative to city size (e.g. a share of certain baseline emissions), so that total mitigation from within the city is $q = sm$, which adds to mitigation outside the city q_0 . In the expository model, we assume a linear benefit function, and the following cost function (see Tab. 1 for notation; assumptions are generalized subsequently):

$$B = s\delta \cdot (q + q_0) = s^2\delta m + s\delta q_0, \quad (1)$$

$$C = \frac{\kappa}{2s}q^2 = \frac{1}{2}s\kappa m^2. \quad (2)$$

Cities which are more vulnerable to climate change have higher *private* costs of carbon δ . Cities with higher abatement costs have a higher value of κ . Benefits, expressed as function of total mitigation q , scale linearly with s , because larger cities suffer more climate damages in total (think of δ , applying to each inhabitant).

Marginal mitigation costs $dC/dq = q\kappa/s$, however, decrease with s . This assumption

(which will be generalized below) is important for the remainder of the paper. It is reasonable when assuming that larger cities dispose over a larger set of abatement options, and is also used for abatement cost curves of countries (e.g. Criqui et al., 1999; Eisenack, 2012; Hagen and Schneider, 2021). The intuition becomes stronger when considering the marginal costs as a merit order curve. Each block of the marginal cost curve can be considered as one option. If one option is s times more available, each block becomes s times broader on the q axis, i.e. the marginal cost curve of a larger city is flatter by stretching the q axis by a larger factor s .

In this section I assume that the city selects mitigation $m = m^e$ which maximizes city-level welfare W , i.e. we assume a city which does not care about actors outside the city, but internalises all climate change impacts for actors in the city. The subscript "e" refers to the expository model solution, but can be also understood as the solution that keeps all climate damages outside the city externalized. Thus, it is convenient to call m^e the mitigation level of a free-riding city. The first-order condition is sufficient, so that we obtain

$$m^e = s \frac{\delta}{\kappa}. \quad (3)$$

Intuitively, cities with higher private costs of carbon or with lower abatement costs mitigate more. Interestingly, (relative) mitigation rises with size. For the city mitigation level, there is the quadratic relation $q^e = s^2 \delta / \kappa$. This is driven by larger cities both enjoying more benefits and lower marginal costs.

Table 1: Basic variables.

$s > 0$	city size
$q \geq 0$	city mitigation level (emissions abatement)
$q_0 > 0$	total mitigation of all actors outside the city
$m \geq 0$	city mitigation (emissions abatement relative to size)
$\delta > 0$	private cost of carbon (relative to size)
$\kappa > 0$	cost parameter for abatement costs ("abatement costs" for short)
$t \geq 0$	city mitigation target (relative to size)

At this stage, one might wonder whether findings on national-level climate policies (e.g. on international environmental agreements, Barrett, 1994; Marrouch and Chaudhuri, 2015; Hagen and Eisenack, 2019) can be carried over to the local level. Yet, there are some crucial differences between cities and countries. Cities are embedded in multi-level (national) systems, which leads to binding institutions for local governments, which can both constrain/guarantee their authority or provide/restrict incentives (e.g. Meya and

Neetzow, 2021; Coria et al., 2018). Cities are larger in number but smaller in size than countries, which might shift free-riding incentives (see Foucart and Wan, 2018, for federal systems). Due to size and legal restraints from higher levels, mechanisms of lobbying and rent-seeking presumably work different on the local level (Peterson, 1981). Yet, although there are such constraints, local governments have some authority over climate-relevant policies like transport, spatial planning, building codes or waste management (Holian and Kahn, 2015; Hooghe et al., 2016; Brolinson et al., 2023), and the right or obligation to set climate targets (Reckien et al., 2018), in many countries on the world. The puzzle of the existence of city climate targets might also be understood as private provision of public goods (Olson, 1965; Bergstrom et al., 1986). This huge literature has identified mechanisms which enhance cooperation, but primarily for individuals (in particular in experiments), and not for governments (e.g. Chaudhuri, 2011). The provision of public goods is also studied in fiscal or environmental federalism, for instance to characterize the efficient allocation of decision-making power over different levels of government, or deteriorating environmental standards due to inter-jurisdictional competition (e.g. Oates, 2005; Kuncze and Shogren, 2005). I am yet not aware of economics literature that explains the provision of global public goods by local governments.

It is thus worth studying urban climate action in its own right, by expanding on the expository model. To provide a first idea how the models in the paper might also be used to scrutinize the effects of more variables than abatement costs and private costs of carbon, consider a carbon price set by a national government: This could be captured by a mark-up on the value of δ . Another example are climate policy co-benefits (see, e.g. Regnier and Legras, 2018; Karlsson et al., 2020; Chan and Zhou, 2021). If mitigation leads to other benefits for the city (e.g. better local air quality or energy savings), and if they depend linearly on q , this would be equivalent to increasing δ for the considered city. If co-benefits would depend quadratically on q , it would be equivalent to a lower κ . So, intuitively, more co-benefits or a higher carbon price would raise mitigation.

Yet, without a carbon price, the private cost of carbon δ must assumed to be quite low, even very large cities cannot be expected to contribute much to the global public good voluntarily. If we want to explain why some cities are actually mitigating, we need to add more mechanisms to the model. Furthermore, the model does not represent city mitigation targets t , although this is a policy now frequently observed in cities.

3 Full model with targets as a commitment device

The full model expands the expository one by joining a second decision variable: the possibility of the local government to set a mitigation target t before emissions are actually

reduced. Naturally, efficient quantity instruments, for instance, are only possible if there are targets. There are likely further reasons why a target might matter. I study one in this section, while delegating another to App. (B).

Here, I expand the city welfare function by a public choice perspective to represent the preferences of local governments. That city governments do not necessarily optimize the aggregated welfare of its citizens is reasonable in light of the agency problems and institutional constraints that citizens and their city governments face. Depending on a country’s constitution, local governments are more or less accountable to their constituency. Voters or lobby groups might favour more or less ambitious local climate policies than would be rational for a free-riding city. All we need to assume here is that the local government has some degree of authority over urban climate governance (see Sect. 2).

Once a city mitigation target t is introduced from a public choice perspective, one can naturally compare t against mitigation m . There is no reason to generally assume that $m = t$. This section yet assumes that targets act as a kind of *commitment device* for the local government, which can gain by bringing m closer to t . But intuition and the expository model lend to the expectation that commonly $m < t$, i.e. that cities mitigate less than ”promised”. Yet, it also becomes a logical possibility that cities ”overachieve” mitigation targets with $m > t$. The following shows, inter alia, when this is the case, and under which conditions local governments set targets at all.

3.1 Model structure

Generalize mitigation benefits and costs B, C from the expository model, and assume the local government’s maximand is (see Tab. 2 for assumptions on the functions and parameters):

$$W = V(t; \psi, \nu) - T(t) + B(m; s, \delta) - C(m; s, \kappa) - S(m, t; \sigma). \quad (4)$$

The political value for the city government from target setting is denoted by V . The value might be due to awards or office rents if the city government meets it’s constituency’s political preferences for targets, or if higher institutional levels require some target setting. Citizens might demand for carbon policies (Holian and Kahn, 2015). The political value might also stem from city reputation building, avoiding public unrest, effective civil society involvement, or private sector lobbying (see below for the parameters ψ, ν). The model abstracts from different reasons which might all lead to the general assumptions.

Political costs S link the effect of the target t to achieved mitigation m , thus becoming the commitment device. How strong a deviation from the target is politically ”punished” can depend, again, on various mechanisms. One might be the re-election probability

Table 2: Variables, general monotonicity and convexity assumptions. Subscripts denote derivatives. Throughout this paper, \doteq denotes equivalence in signs.

$B, B_m > 0, B_{mm} = 0$	$B_s, B_\delta > 0, B_{ms}, B_{m\delta} > 0,$	mitigation benefits
$C, C_m, C_{mm} > 0$	$C_s, C_\kappa > 0, C_{ms}, C_{m\kappa} > 0$	mitigation costs
V	$V_t \doteq \psi - t, V_{tt} < 0$	political value
$\psi \geq 0$	$V_{t\psi} > 0$	target bliss-point
$\nu \geq 0$	$V_\nu \doteq V$	target importance
$S, S_{mm}, S_{tt} > 0$	$S_m \doteq m - t, S_t \doteq t - m, S_{mt} < 0$	political costs
$\sigma \geq 0$	$S_\sigma > 0,$	achievement importance
$T(t)$	$T' \geq 0, T'' \geq 0$	transaction costs
$a = (C_{mm} + S_{mm})(S_{tt} - V_{tt} + T'') - S_{mt}^2 > 0$		strict convexity

of politicians which do not keep electoral promises, but aim for sustained office rents (see, e.g. Klingelhöfer, 2021). Not meeting targets can also be associated with a loss of reputation. Furthermore, targets can change private choices for long-lived investments. If targets would not be enforced, assets of those who trusted the targets might strand (see, e.g. Eisenack et al., 2021; Von Dulong et al., 2023), incentivizing their owners to lobby for achieving the targets (see below for parameter σ).

The local government's transaction costs T stem from developing and setting a climate target. Political value V and transaction costs T can be thought to be short-term, while the mitigation cost and benefits B, C and the political costs S occur in the long run (discounted to present value). If the local government sets are target (today), it commits to achieve this to some degree, because it might suffer from higher political costs if the target is not met sufficiently (tomorrow). The strength of this commitment device depends, of course, on the structure of S . If there was no function like S , there would be no reason for governments to achieve any "promised" mitigation targets.

The general monotonicity and convexity assumptions and the interpretation of the parameters ψ, ν, σ is as follows (see Tab. 2). Benefits B are kept linear in m , which is not a strong assumption in this context, since a single city (even a megacity) is marginal compared to the global scale of the problem. A convex cost function C which becomes more steep for rising κ is common. With $C_{ms} > 0$ it is assumed that the cost-reducing effect of more mitigation options being available in larger cities is weaker when marginal costs rise. The political value $V(t; \psi, \nu)$ is a single-peaked concave function in t which rises up to a bliss-point at $t = \psi$, and decreases for higher targets. With this assumption, the political value depends on the relative target t , and not on the total city mitigation level

q which is aimed at. The parameter ψ thus expresses the target that is taken into account by the decision-maker when contemplating the preferences of her constituency. If the assumptions on V would be justified by a probabilistic voting model (e.g. Persson and Tabellini, 2000), ψ might represent the target most preferred by the median voter. The political value is further characterized by ν , which is larger if the single-peaked function has a steeper slope. If the target deviates from ψ , a larger ν means that the local government loses more value. The sign of $V_{t\psi}$ simply expresses that the peak is shifted with ψ . The political value can be positive, but can also take negative values, e.g. to represent sanctions for certain target levels.

The political costs $S(m, t; \sigma)$ are single-dipped: they are convex in m and reach their minimum if the target is achieved at $m = t$. Also political cost are driven by relative mitigation m , and not the mitigation level q . The parameter σ expresses the scale of the political costs: they rise if σ becomes larger. Thus, high values of ν and σ express a situation where the local government cares more about local climate policy, which can be due to their local voters, national-level obligations or incentives imposed on the local government, or vested interest. A high value of ψ means that, by whatever of the latter mechanisms, the local government has reason to set more ambitious targets.

In this way, the model's advantage is that the assumptions are open to different interpretations which can help adjusting for different research objectives and empirical designs. For example, one can focus on different political mechanisms (e.g. driven by voters, lobbyists, bureaucrats or combinations thereof). If one is interested in the effects of national or regional carbon prices, she can check which function would represent this in the best way, e.g. a linear shift of the mitigation benefits B .

Before the city government maximizes W with respect to (t, m) , consider a further decision: whether to set a mitigation target at all. This leads to the following staged decision, which will be solved backwards.

- 1 The local governments decides on setting a target or not.
 - 2a If there is no target, the city decides about mitigation $m = m^o$ under the assumption that $V, S, T \equiv 0$.
 - 2b If there is a target, the government decides on the target level and mitigation (t^*, m^*) .

Stage 1 is relevant if there are not sufficient gains from target setting to justify the transaction costs T (see below). If this is the case, stage 2a assumes a behaviour like a free-riding city from the expository model (with the generalized cost function C). This assumption is not as strong as it appears, since it does not exclude the possibility of political costs due to not setting a target: The value $V(t; \psi, \nu)$ can be understood as the government's forgone

benefits from not setting a target t . Furthermore, the assumption still admits to consider sanctions (e.g. if not following a national government's program) or disadvantages if a city is not mitigating much (which could be represented by modifying B or C). This staged decision structure particularly plays out if there are "fixed" transaction costs which even occur when setting a quite non-ambitious target ($T(t) > 0$ even for t close to zero), while we have a discontinuity with $T = 0$ if the local government does not set a target at all. However, if setting a target in stage 2b leads to higher W for the government than the stage 2a equilibrium, we can assume that the local government decides to set a target in stage 1.

Stage 2a If the local government has decided not to set a target, the maximand becomes $W^\circ(m) = B(m) - C(m)$. Here and in the following, we skip the parameters as arguments of the functions in order to ease notation. The optimum m° is characterized by $B_m = C_m$, equivalent to the free-riding city in the expository model, i.e. $m^\circ = m^e$. The comparative statics are:

$$\frac{dm^\circ}{ds} = \frac{B_{ms} - C_{ms}}{C_{mm}} \doteq B_{ms} - C_{ms}, \quad (5)$$

$$\frac{dm^\circ}{d\delta} = \frac{B_{m\delta}}{C_{mm}} > 0, \quad (6)$$

$$\frac{dm^\circ}{d\kappa} = \frac{-C_{m\kappa}}{C_{mm}} < 0. \quad (7)$$

The effect of δ, κ is qualitatively the same as for the expository model. Larger cities, however, only mitigate more if $B_{ms} - C_{ms} > 0$, i.e. if net benefits of mitigation rise with city size. Since the sign of this expression (which is ambiguous from the assumptions) will be important throughout the analysis, conveniently denote it by the shortcut

$$w := B_{ms} - C_{ms} \lesseqgtr 0. \quad (8)$$

Stage 2b If the local government has decided to set a target, the first-order conditions for (m, t) are

$$B_m(m^*) = C_m(m^*) + S_m(m^*, t^*), \quad (9)$$

$$V_t(t^*) = S_t(m^*, t^*) + T'(t^*). \quad (10)$$

In general, we cannot show that the solution m^*, t^* is non-negative. In the following we assume that this is the case.

When further studying the solutions of stage 2b, it is interesting to compare whether the presence of targets leads to more mitigation than if targets are absent. Thus, we

subsequently call cities with $m^\circ < m^*$ **contributor cities** (ctr), because they contribute more to the public good than a free-riding city ($m^\circ = m^e$) would do. Second, we call cities which mitigate more than "promised" through their targets, $t^* < m^*$, **achiever cities** (ach). The following comparative statics for stage 2b, and further (arguably paradox) results for achiever and contributor cities can be determined:

Proposition 1. *If the local government sets a target (with an inner solution), then (i) the stage 2b comparative statics follow Tab. 3. In particular, size leads to more ambitious targets and to more mitigation if and only if $w > 0$. (ii) If the target t becomes more ambitious by some reason, there is also more mitigation m . (iii) Contributor cities are exactly characterized by $m^\circ < m^* < t^*$, which is equivalent to $C^\circ < C^*$, and to $B_m^* < C_m^*$. (iv) Achiever cities are exactly characterized by $t^* < m^* < m^\circ$, which is equivalent to $C^* < C^\circ$, and to $C_m^* < B_m^*$. (v) Except for cities with $C^* = C^\circ$, every city is either an achiever or a contributor city. (vi) All contributor cities respect $t^* < \psi$. Conversely, $\psi < t^*$ is sufficient to have an achiever city.*

Table 3: Comparative statics of stage 2b for targets as a commitment device.

$\frac{dm^*}{d \cdot}$	$\frac{dt^*}{d \cdot}$
$\frac{d}{ds} \frac{w(S_{tt} - V_{tt} + T'')}{a} \doteq w$	$-\frac{w}{a} S_{mt} \doteq w$
$\frac{d}{d\delta} \frac{B_m \delta (S_{tt} - V_{tt} + T'')}{a} > 0$	$-\frac{B_m \delta S_{mt}}{a} \doteq -S_{mt} > 0$
$\frac{d}{d\kappa} \frac{C_m \kappa (S_{tt} - V_{tt} + T'')}{-a} < 0$	$\frac{C_m \kappa S_{mt}}{a} < 0$
$\frac{d}{d\sigma} \frac{S_{t\sigma} S_{mt} - S_{m\sigma} (S_{tt} - V_{tt} + T'')}{a} \leq 0$	$\frac{S_{m\sigma} S_{mt} - S_{t\sigma} (C_{mm} + S_{mm})}{a} \leq 0$
$\frac{d}{d\psi} -\frac{V_{t\psi} S_{mt}}{a} > 0$	$\frac{V_{t\psi} (C_{mm} + S_{mm})}{a} > 0$
$\frac{d}{d\nu} \frac{S_{mt} V_{t\nu}}{-a} \doteq V_{t\nu}$	$\frac{V_{t\nu} (C_{mm} + S_{mm})}{a} \doteq V_{t\nu}$

The proof in App. (A) uses total differentiation and compares the mitigation, target and cost levels by turning back to the first-order conditions and exploiting the derived monotonicity and convexity properties.

The proposition states that, among those cities which have a target, the larger ones promise and achieve more – if a larger city has higher net benefits from mitigation. The political value and costs can be removed from this condition. Since size does not affect V, S , the "direct net benefits" $B - C$ drive the effect. Higher private costs of carbon raise both targets and achieved mitigation. Since political value and costs are independent from the damage suffered from climate change, the changes in B drive the picture. A similar intuition holds for higher mitigation costs: They unambiguously reduce both targets and mitigation.

Interestingly, if missing the target has higher political costs (high σ), this can both support mitigation or backfire. The local government might anticipate being sanctioned for missing targets, thereby promising less ambitious targets, which would then lead to less mitigation. Also the effect of a stronger target importance (ν) is ambiguous. If ν raises the marginal political value, both target and mitigation will be higher, while the effect reverses otherwise. What is unique, however, is that target and mitigation are higher if the constituency's target bliss-point is larger: Preferences for more ambitious targets indeed convert into both promises and action. In particular, the model predicts that cities which chose targets above ψ , in turn achieve mitigation above their targets. For targets below ψ the same kind of statement cannot be made in general.

Moreover, cities which mitigate more than a free-riding city are exactly those which mitigate less than stated in their targets. In contrast, if a city government sets a higher target than its constituency prefers, it will indeed achieve this target. However, this only happens when both target and mitigation are below the free-riding city level. In light of this paradox effect, Prop. 1 shows that there is no third possibility (except for the boundary case). This can be interpreted as follows. Cities are either of the kind where the constituency demands more mitigation than a free-riding city would supply, or where the constituency demands less mitigation. If the local government sets targets, it would choose them so that they deviate from the free-riding level in the direction which pleases its voters or lobbyists. This "pleasing effect" needs to be balanced with the mitigation costs and the political costs from making too extreme promises, so that mitigation is ultimately between target and the free-riding level. In short, if the local government decides to set a target, this leads achiever cities to contribute *less* to the global public good. In other words: If the model is an appropriate representation of reality, we should not be disappointed if cities fail to meet self-selected targets.

Stage 1 The city government may chose not to have a target if it anticipates in stage 1 that it obtains less with target (W^*) than without (W°). Denote the difference by $\Delta := W^* - W^\circ = B(m^*) - C(m^*) + V(t^*) - S(m^*, t^*) - T(t^*) - B(m^\circ) + C(m^\circ)$. Generally, the assumptions made so far do not imply a specific sign of Δ . However, the comparative statics with respect to the various parameters are more clear. This indicates whether Δ is more likely to be positive if a certain parameter is larger – so whether the likelihood of city to set a target is higher or not. We obtain (see Appendix for the proof which uses the Envelope Theorem):

Proposition 2. *In stage 1, the gains from setting an optimal target depend on the parameters as given in Tab. 4.*

Interestingly, higher private costs of carbon δ do not necessarily make the presence of

Table 4: Comparative statics of stage 1.

$\frac{d\Delta}{ds}$	$B_s(m^*) - C_s(m^*) - B_s(m^\circ) + C_s(m^\circ) \doteq (m^* - m^\circ)w$
$\frac{d\Delta}{d\delta}$	$B_\delta(m^*) - B_\delta(m^\circ) \doteq (m^* - m^\circ)$
$\frac{d\Delta}{d\kappa}$	$-C_\kappa(m^*) + C_\kappa(m^\circ) \doteq -(m^* - m^\circ)$
$\frac{d\Delta}{d\sigma}$	$-S_\sigma(m^*, t^*) < 0$
$\frac{d\Delta}{d\nu}$	$V_\nu(t^*) - V_\nu(0) \leq 0$
$\frac{d\Delta}{d\psi}$	$V_\psi(t^*) - V_\psi(0) > 0$

a climate target more likely – this is only the case for contributor cities. A higher target bliss-point ψ always makes target-setting more likely, while higher costs from failing the target σ makes it less attractive to set one. Contributor cities with higher abatement cost κ have less incentives to set a target, while the opposite holds for achiever cities. This is consistent because the target will be below of what cities without a target will mitigate. In any case, the effect of κ works in the opposite direction of δ . Among those cities with $w > 0$, larger achiever cities are less likely to have a target, while larger contributor cities are more likely to have a target (which reverses for $w < 0$). The effect of the target importance ν depends on further assumptions on the political value V .

3.2 Refined model

To resolve some ambiguities and to illustrate the findings, this section studies the following more specific version of the previous general model:

(Assumptions commitment) Assume a cost function of the form $C(m) := \frac{\kappa}{s}\tilde{C}(sm)$, based on an arbitrary twice differentiable function $\tilde{C}(\cdot) > 0$ with $\tilde{C}'(\cdot), \tilde{C}''(\cdot) > 0$. For the political value, $V(t) := \nu\tilde{V}(t - \psi)$, based on an arbitrary single-peaked, twice differentiable function $\tilde{V}(\cdot)$ with $\tilde{V}'' < 0$ and $\tilde{V}'(x) \doteq -x$, so that its maximum is at zero. In the same way, take a twice differentiable convex function $\tilde{S}(\cdot) \geq 0, \tilde{S}'' > 0$ with minimum $\tilde{S}(0) = 0$ and $\tilde{S}'(x) \doteq x$, and set $S(m, t) := \sigma\tilde{S}(m - t)$. Thus, there are no political costs if $t = m$, while those costs rise if mitigation deviates from the target in either direction. For the transaction costs we assume the simplest possible form $T(t) = T_0 + \gamma t$ (and $T = 0$ if $t = 0$), where T_0 denotes fixed transaction costs of setting targets. See App. (A.5) for an overview of the partial derivatives resulting from these assumptions. The strict convexity condition can then be simplified to $a = s\kappa\tilde{C}'''(\sigma\tilde{S}'' - \nu\tilde{V}'') - \sigma\nu\tilde{S}''\tilde{V}'' > 0$, which is always satisfied for these assumptions. For B , we stick to the assumptions from the previous section.

The first-order conditions for stage 2a (to obtain m°) and stage 2b (for m^*, t^*) can be explicitly written as

$$s^2\delta = \kappa\tilde{C}'(sm^\circ), \quad (11)$$

$$s^2\delta = \kappa\tilde{C}'(sm^*) + \sigma\tilde{S}'(m^* - t^*), \quad (12)$$

$$\nu\tilde{V}'(t^* - \psi) = \gamma - \sigma\tilde{S}'(m^* - t^*). \quad (13)$$

They admit a further characterization of contributor and achiever cities, and the sign of the decisive term $w(m) = B_{ms}(m) - C_{ms}(m)$. We use the elasticity of marginal costs $\eta = \tilde{C}''\frac{sm}{\tilde{C}'} > 0$, denoted by η° if evaluated at the stage 2a equilibrium, and η^* for stage 2b.

Proposition 3. *If targets function as commitment device, (assumption commitment) holds, and interior optima exist in stage 2a, 2b, then $w^\circ := w(m^\circ) \doteq 2 - \eta^\circ$, and $w^* := w(m^*) \doteq (2 - \eta^*)C_m^* + 2S_m^*$. Moreover,*

1. *Contributor cities (i.e. with $m^\circ < m^* < t^*$) are exactly those which satisfy one of the following equivalent conditions: (i) $\tilde{C}'(sm^\circ) - \tilde{C}'(sm^*) < 0$; (ii) $\tilde{S}' < 0$; (iii) $\gamma < \nu\tilde{V}'(t^* - \psi)$; (iv) $s^2\delta < \kappa\tilde{C}'(sm^*)$.*
2. *Achiever cities are exactly those where all these inequalities are reversed.*
3. *All cities with $\eta^* < 2$ and $w^* < 0$ are contributor cities. All cities with $\eta^* > 2$ and $w^* > 0$ are achiever cities.*
4. *Equivalently, for all contributor cities with $\eta^* > 2$, also $w^* < 0$ holds. For all achiever cities with $\eta^* < 2$, also $w^* > 0$ holds.*
5. *Achiever cities chose $t^* > \psi$ if and only if $\sigma\tilde{S}' > \gamma$. (Contributor cities always chose $t^* < \psi$, and respect $\sigma\tilde{S}' < \gamma$.)*

Obviously, some results are more detailed than in Prop. 1. While it's already known that contributor cities only set targets below ψ (repeated for overview), now achiever cities only set targets above ψ if their (positive) marginal political costs are large enough (part 5). The Prop. has several implications. For instance, a city which has set a target is c.p. more likely a contributor city (part 1) if the (short-term) target importance is high, or if transaction costs are low. Those cities accept marginal mitigation costs above marginal benefits, which is c.p. more likely the case if the city has low private cost of carbon, or is small, or has high mitigation costs.

Parts 3, 4 show that being an achiever or contributor city, and whether w is positive or negative, can occur in multiple combinations which are yet not completely independent

from each other. Tab. 5 lists all possible cases according to Prop. 1 and Prop. 3 (excluding boundary cases). Some of the cases can arguably be excluded from the further discussion by considering the threshold for the marginal cost elasticity from parts 3, 4. If \tilde{C}' is isoelastic, $\eta > 2$ would require the mitigation cost function to be steeper than a quadratic. As this is not quite common in the literature, it is worth concentrating on the shaded cases in Tab. 5.

Table 5: Overview of all possible cases for contributor (ctr) and achiever (ach) cities.

$\eta < 2$	type	$t^* < \psi$	w	further properties
yes	(ctr)	yes	(-)] $\sigma\tilde{S}' < 0 < \gamma < \nu\tilde{V}'$
yes	(ctr)	yes	(+)	
yes	(ach)	yes	(+)	$0 < \nu\tilde{V}', \sigma\tilde{S}' < \gamma$
yes	(ach)	no	(+)	$\nu\tilde{V}' < 0 < \gamma < \sigma\tilde{S}'$
no	(ctr)	yes	(-)	$\sigma\tilde{S}' < 0 < \gamma < \nu\tilde{V}'$
no	(ach)	yes	(-)] $0 < \nu\tilde{V}', \sigma\tilde{S}' < \gamma$
no	(ach)	yes	(+)	
no	(ach)	no	(-)] $\nu\tilde{V}' < 0 < \gamma < \sigma\tilde{S}'$
no	(ach)	no	(+)	

If $\eta < 2$, only contributor cities can have $w < 0$: Among cities with a target, those which are less ambitious if the city is larger can only be contributor cities. Then also $-S_m < (1 - \eta/2)C_m$. The left side of the latter inequality is positive since the city does not achieve its target. Thus, cities where size is associated with lower targets are those with c.p. high abatement costs or where not achieving targets is associated with low political costs (σ).

Whatever the sign of w , all contributor cities with targets (i.e. with $m^\circ < m^* < t^* < \psi$) face transaction costs below the marginal target importance, so that they can afford ambition in this respect. If they would chose an even more ambitious target (in the extreme case above ψ), however, they would suffer too much from failing it in terms of political costs S . Thus, mitigation is below the target because the political costs and value cannot overcompensate the mitigation costs and benefits. One might say that contributor cities with targets are characterized by an ambitious constituency with $\psi > m^\circ$. They chose a compromise between the high bliss-point for targets and the lower mitigation if they were a free-riding city. In this compromise, the target functions as a kind of stepping stone between preferences and action, which raises mitigation, yet in an imperfect way.

If $\nu\tilde{V}' < 0 < \gamma < \sigma\tilde{S}'$ holds, we have an achiever city which sets targets more

ambitious than its constituency wants (i.e. $\psi < t^* < m^* < m^\circ$), a polar case compared to contributor cities. Again, the target can be considered as a stepping stone between preferences and action, yet in the other direction: The city's constituency prefers to have less mitigation than a free-riding city would do. However, Tab. 5 also shows that there can be achiever cities with $t^* < \psi$ (if they have comparatively low marginal political costs, so that they are even less ambitious in light of the transaction costs).

Table 6: Comparative statics of stage 2b (with assumption commitment).

	$\frac{dm^*}{d\cdot}$	$\frac{dt^*}{d\cdot}$
$\frac{d}{ds}$	$\frac{(2s\delta - \kappa m^* \tilde{C}'')(\sigma \tilde{S}'' - \nu \tilde{V}'')}{a} \doteq w$	$\frac{2s\delta - \kappa m^* \tilde{C}''}{a} \sigma \tilde{S}'' \doteq w$
$\frac{d}{d\delta}$	$s^2 \frac{\sigma \tilde{S}'' - \nu \tilde{V}''}{a} > 0$	$s^2 \frac{\sigma \tilde{S}''}{a} > 0$
$\frac{d}{d\kappa}$	$-\frac{\sigma \tilde{S}'' - \nu \tilde{V}''}{a} \tilde{C}' < 0$	$-\sigma \frac{\tilde{S}''}{a} \tilde{C}' < 0$
$\frac{d}{d\sigma}$	$\frac{\nu}{a} \tilde{V}'' \tilde{S}' \doteq -\tilde{S}' \doteq -(m^* - t^*)$	$s \frac{\kappa}{a} \tilde{C}'' \tilde{S}' \doteq \tilde{S}' \doteq m^* - t^*$
$\frac{d}{d\psi}$	$-\frac{\nu \sigma}{a} \tilde{V}'' \tilde{S}'' > 0$	$-\frac{\nu \tilde{V}''}{a} (s \kappa \tilde{C}'' + \sigma \tilde{S}'') > 0$
$\frac{d}{d\nu}$	$\frac{\sigma}{a} \tilde{S}'' \tilde{V}' \doteq \psi - t^*$	$\frac{s \kappa \tilde{C}'' + \sigma \tilde{S}''}{a} \tilde{V}' \doteq \psi - t^*$

Now turn to the comparative statics. Much follows from substituting (assumptions commitment) into into Tab. 3, Tab. 4, where some signs have already been established. Further ambiguities can be resolved by making use of Prop. 3.

Proposition 4. *When (assumptions commitment) holds, the comparative statics follow Tab. 6 for stage 2b, and Tab. 7 for stage 1. If $t^* < \psi$ (e.g. for contributor cities), then $\frac{d\Delta}{d\nu} > 0$. Stage 2a reads as follows:*

$$\begin{aligned} \frac{dm^\circ}{ds} &= \frac{2s\delta - \kappa m^\circ \tilde{C}''}{s \kappa \tilde{C}''} = \frac{2\delta}{\kappa \tilde{C}''} - \frac{m^\circ}{s} \doteq 2s\delta - \kappa m^\circ \tilde{C}'' = w, \\ \frac{dm^\circ}{d\delta} &= \frac{s}{\kappa \tilde{C}''} > 0, \\ \frac{dm^\circ}{d\kappa} &= -\frac{\tilde{C}'}{s \kappa \tilde{C}''} < 0. \end{aligned}$$

By comparing with the tables from the general model, the ambiguity of target importance ν and achievement importance σ is mostly resolved: For contributor cities, a higher target importance leads to both more ambitious targets and more mitigation. These cities also mitigate more if the achievement importance is stronger. Yet, in anticipation of these political costs they set less ambitious targets. For achiever cities, the effect of stronger achievement importance reverses: they admit higher targets more so that they can accept less mitigation. The effect of target importance depends on whether the achiever city is of the kind which is polar to the contributor cities (then the effects reverse).

Table 7: Comparative statics of stage 1 with (assumptions commitment).

$\frac{d\Delta}{ds}$	$2s\delta(m^* - m^\circ) + \frac{1}{s}(C^* - C^\circ) + \frac{1}{s}(m^\circ C_m^\circ - m^* C_m^*) \doteq (m^* - m^\circ)w$
$\frac{d\Delta}{d\delta}$	$s^2(m^* - m^\circ) \doteq (m^* - m^\circ) \doteq (t^* - m^*)$
$\frac{d\Delta}{d\kappa}$	$\frac{1}{s}(\tilde{C}^\circ - \tilde{C}^*) \doteq -(m^* - m^\circ) \doteq -(t^* - m^*)$
$\frac{d\Delta}{d\sigma}$	$-\tilde{S}^* < 0$
$\frac{d\Delta}{d\nu}$	$\tilde{V}(t^* - \psi) - \tilde{V}(-\psi) \leq 0$
$\frac{d\Delta}{d\psi}$	$\nu(\tilde{V}'(-\psi) - \tilde{V}'(t^* - \psi)) > 0$

In order to prepare the next section, see Tab. 8 for a summary of some main results. The names of the cases (COM.1-COM.4) will be used subsequently. The table emphasizes the effects on the presence Δ and level of targets t , as these comparative statics are arguably more easily observed empirically than the effect on mitigation m . It becomes apparent that the cases have quite different comparative statics profiles (except for $dt^*/d\delta, dt^*/d\kappa$).

Table 8: Comparative statics summary for targets as commitment device (COM). Case (COM.2) is splitted in two subcases depending on $t^* \leq \psi$. Also (COM.4) can be splitted to resolve the last ambiguity. Yet (COM.4) is only possible if $\eta > 2$, a situation which may be unlikely (thus not shaded). For (COM.3), the relation between target bliss-point and target does not matter. Note that (COM.1) is only possible if $\eta < 2$.

case	w	type	$t^* < \psi$	$\frac{d\Delta}{ds}$	$\frac{d\Delta}{d\delta}$	$\frac{d\Delta}{d\kappa}$	$\frac{dt^*}{ds}$	$\frac{dt^*}{d\delta}$	$\frac{dt^*}{d\kappa}$	$\frac{dt^*}{d\sigma}$	$\frac{dt^*}{d\nu}$
(COM.1)	(+)	(ctr)	yes	(+)	(+)	(-)	(+)	(+)	(-)	(-)	(+)
(COM.2a)	(+)	(ach)	yes	(-)	(-)	(+)	(+)	(+)	(-)	(+)	(+)
(COM.2b)	(+)	(ach)	no	(-)	(-)	(+)	(+)	(+)	(-)	(+)	(-)
(COM.3)	(-)	(ctr)	both	(-)	(+)	(-)	(-)	(+)	(-)	(-)	(+)
(COM.4)	(-)	(ach)		(+)	(-)	(+)	(-)	(+)	(-)	(+)	(?)

4 Comparison and Discussion

Now compare the deduced implications of the different cases (see Tab. 8). Cells where the models or cases make different predictions might be one reason why previous empirical studies show mixed results. Further empirical studies might be able to discriminate between the derived cases, and to test the model assumptions leading to these cases. I concentrate the discussion on the likelihood of having a target (Δ) and the mitigation

target (t^*). For both the presence and ambition of plans, large data sets are increasingly becoming available (e.g. Reckien et al., 2018; Hsu et al., 2020; Rivas et al., 2021; Moran et al., 2022). As possible drivers, consider city size s , mitigation costs κ , and δ . The latter might be proxied by vulnerability indicators (e.g. Tapia et al., 2017). For cities in low-lying coastal areas, or which are badly adapted to climate change impacts, the private costs of carbon can be expected to be higher. The city-level mitigation costs parameter κ might be estimated by downscaling country-level or sectoral abatement costs curves to the specific economic structure of cities, or in the bottom-up way by collecting and computing abatement options. Different proxies for city size, e.g. measured by population, area or GDP, are well available (e.g. Eurostat, 2020; OECD, 2020).

For all cases, higher social costs of carbon imply more ambitious targets. There are yet cases where δ makes the presence of targets less likely, but this applies only to achiever cities with $w > 0$. Abatement costs κ can be either conducive or detrimental for the presence of targets, but always decrease their level. Consistently across all cases, the sign of $w = B_{ms} - C_{ms}$ is important for the effect of city size on setting climate targets. However, among the $\eta < 2$ cases, the common observations that larger cities more likely set targets can only be supported for contributor cities with if $w > 0$ (see App. (B) for further possibilities if model assumptions are changed). Further testable implications can be derived. As an example, consider it empirically robust that large cities more frequently have climate targets (see Sect. 1). Then the cases COM.2a, COM.2b and COM.3 are ruled out. Within the model, only case COM.1 or COM.4 apply. Among those cities, it might be that the higher- δ ones have no target (COM.4). If this is the case, those cities need to be of the $w < 0$ kind (or can be characterized as achiever cities, e.g. by using at least one of the equivalent criteria from Prop. 3). This entails a mitigation cost elasticity η larger than two. This can be tested empirically with city-level data on abatement costs. In addition, whatever the effect of vulnerability, $d\Delta/ds > 0$ implies the prediction that $w < 0$ only appears in conjunction with $\eta < 2$. Several other empirical strategies can be developed from Tab. 8, and further models could explain findings which are not captured here.

So far, I concentrated on variables which might be observed more easily. The model yet also captures further variables, some of which might be proxied with empirical data, in order to test the model implications summarized in Tab. 6, Tab. 7. Political target importance ν might be measured by variables which correlate with the general politisation of a city's citizens (e.g. education, voter turnout), or by variables about the importance of environmental issues (e.g. from opinion polls, environmental awareness studies, vote shares of green parties). If climate referenda have occurred, we obtain information about the bliss point ψ , and sentiments in journalistic sources might indicate the sign of $(t - \psi)$. Information about achievement importance might be obtained from public surveys, and ar-

guably do not differ much between climate and other policy fields. Explicitly determining the sign of w will not be straightforward, since (in the refined model) $w^* = 2\delta s - \kappa m^* \tilde{C}''$ depends on (future) mitigation m^* , which is still difficult to observe. Yet, particularly small or not much vulnerable (small $s\delta$) cities should be of the $w < 0$ kind. Furthermore, recall from Sect. 2, that the formal properties of the parameters δ, κ allow for further interpretations, some of which are addressed in the empirical literature (e.g. co-benefits or national policies). Co-benefits from improving on air pollution in cities are assessed in several studies. The different models/cases might thus explain the mixed empirical findings on co-benefits, for instance (Sect. 1). Although measuring the ambition of national climate policies is not straightforward, data or indicators on those are available (e.g. Germanwatch, 2020; Wendling et al., 2020). In addition, all model cases predict that the level of city climate targets (where present) is a complement to a national carbon price (which raises δ) – data on which is well documented. The partially mixed evidence on vulnerability, co-benefits and national-level incentives for the presence of plans yet breaks down to different cases.

Empirical research will likely qualify some of the model implications. If such finding do not align, we might consider other core assumptions than climate targets functioning as a commitment device. App. (B) thus studies an alternative model where targets function as a cost-saving device. This alternative model leads partially to the same comparative statics results, but also to some other cases. Interestingly, the parameter whether marginal net benefits of mitigation rise with city size plays a role in the alternative model as well.

5 Conclusions

The analysis started from the theoretical puzzle of why city governments might set local climate targets (and engage in mitigation), although they face a global public goods problem. This was contrasted with the state of the empirical literature that many cities indeed set climate targets and possibly reduce greenhouse gas emissions. However, some theoretically reasonable factors which might explain target setting are not empirically confirmed so far. In contrast, some arguably non-obvious factors like city size seem to play an important role. This paper has thus developed a set of theoretical models in order to explain the state of the empirical literature and to make predictions which can be validated against forthcoming data. I explored the possibility that setting local climate targets might reduce mitigation costs (targets as "cost-saving device"), and the possibility that targets are set for political gains of local governments (the public choice model with targets as "commitment device").

The public choice model particularly shows that we need to distinguish, among those

cities that set mitigation targets, between achiever and contributor cities – *tertium non datur*. Both types can be characterized in several equivalent ways. Achiever cities mitigate even more than they “promise” to their constituency when setting targets, but mitigate less than a city without climate targets. Contributor cities, in contrast, mitigate more than cities without a target. Interestingly, the latter cities’ targets are below the bliss-point of their political constituency, and they do not even reach the target. Furthermore, the likelihood of setting a climate target can increase or decrease with vulnerability (depending on the derived conditions).

Across all models, more vulnerable cities set more ambitious targets, if they chose to have targets at all. The same holds if cities are subject to a national carbon price. The effect of city size on the presence and ambition of targets is ambiguous. Yet, if size raises the marginal net benefits of mitigation, ambition rises with contributor cities’ size. The effect of higher mitigation costs for the target level and for achieved mitigation is negative in the commitment device model. This intuitive results does not hold for the cost-savings model. The effect of vulnerability or a carbon price for the presence of targets is ambiguous in both models (again, the different cases can be characterized).

Since the proposed models abstract from the concrete political processes, the analysis comes with some limits. In particular, one might conceive further mechanisms than those studied here. One advantage is that several formal parameters can be reasonably interpreted in different ways, so that the models also make predictions about the role of climate policy co-benefits or national-level policies for urban climate governance. The paper can also provide a starting point for micro-foundations (Sect. 3 discusses some directions focusing on electoral accountability or on lobbying in the presence of specific investments), possibly in combination with further empirical research. In principle, the characterizations and predictions of the models can be tested quantitatively (see Sect. 4). Since parameters like political preferences or private costs of carbon presumably differ between cities, not all cities on the world can be expected to follow the same case. More generally, all models indicate that cities need to be distinguished by type in order to identify clear-cut drivers of urban climate governance, a finding in line with other studies (Berrueta and Heijden, 2021; Eisenack and Roggero, 2022).

The paper also contributes to the more general literature on environmental policy targets. To my knowledge, nearly all environmental economics papers on policy instruments start from the premise that targets are met (see Chiappinelli and May, 2022, for one exception). This makes sense if one aims to determine optimal policies, or if policy instruments like an emissions trading system are explicitly designed to meet an emission target. In political practice, however, environmental policy targets are frequently agreed upon before the policy instruments to achieve them are chosen and adopted. The continued policy

process might then lead to instruments which ultimately do not achieve the targets. While a possible mismatch between targets and their achievement has been noted in some papers on urban climate governance (e.g. Kona et al., 2018; Hsu et al., 2020; Roggero et al., 2023a), I think the present paper is one of the first to provide a more general theoretical entry-point to study under which conditions environmental policy targets are reached to which degree.

Although puzzling, the existence of urban climate governance is a real trend which should not be ignored by environmental economics. The empirical literature so far indicates that not all urban climate plans are cheap talk or greenwashing, enforcing the call to study polycentric climate governance (Ostrom, 2012; Cole, 2015). What is needed are templates for economic research on the conditions under which local governments contribute to global public goods. I hope that the suggested approach, which does not picture local governments as welfare maximizers, helps a bit towards this end. Expanding this theoretical research and using it to guide novel empirical studies can lead to the identification of drivers for successful city-level climate action, thereby characterizing how local governments can take their share in solving global problems. More generally, such research would explore the pitfalls and promises of the "think globally – act locally" mantra in a precise way.

A Appendix: Proofs

A.1 Proof of proposition 1

Proof. For statement (i), the comparative statics can be directly computed by total differentiation of both first-order conditions, and subsequent simplification.

Statement (ii) follows from differentiating by t the identity $0 \equiv B_m(\bar{m}(t)) = C_m(\bar{m}(t)) + S_m(\bar{m}(t), t^*)$, with $\bar{m}(t)$ obtained from Eq. (9), with $\bar{m}'(t) = -\frac{S_{mt}}{C_{mm} + S_{mm}} > 0$.

For statement (iii), the cost relation $C^\circ < C^*$ directly follows from the definition of contributor cities ($m^\circ < m^*$) and $C_{mm} > 0$. For the rest of this statement, first recall that the first-order conditions state that $C_m(m^\circ) - B_m(m^\circ) = 0$, and $C_m(m^*) - B_m(m^*) = -S_m(m^*, t^*)$. Also note that $\frac{d}{dm}(C_m(m) - B_m(m)) = C_{mm} > 0$. With this inequality and the general assumptions (Tab. 2), a city is a contributor city ($m^\circ < m^*$) if and only if $0 = C_m(m^\circ) - B_m(m^\circ) < C_m(m^*) - B_m(m^*) = -S_m(m^*, t^*) \doteq t^* - m^*$, so that $m^\circ < m^* < t^*$. Statements (iv) and (v) then follow by contraposition.

The implications in statement (vi) are obtained by considering Eq. (10), the first-order condition for t^* . For a contributor city, $t^* - m^* > 0$ by (iii), so that $S_t > 0$. Since also $T' \geq 0$, the first-order condition implies $V_t > 0$. By the properties of V , this implies

$t^* < \psi$. The second implication again follows by contraposition. \square

A.2 Proof of proposition 2

Proof. Employ the envelope theorem for the derivatives of Δ . With s , for instance, $\frac{d\Delta}{ds} = W_s^* - W_s^\circ = B_s(m^*) - C_s(m^*) + V_s(t^*) - S_s(m^*, t^*) - T_s(t^*) - B_s(m^\circ) + C_s(m^\circ)$. Evaluating and simplifying for all parameters yields the Table. The sign $d\Delta/ds$ (and for δ, κ) can be alternatively expressed because $\frac{d}{dm}(B_s(m) - C_s(m)) = w$. For ψ , the derivative follows from $t^* > 0$ (by assumption) and $V_{t\psi} > 0$. \square

A.3 Proof of proposition 3

Proof. To establish the sign of w , use (assumptions commitment) to express

$$w = B_{ms} - C_{ms} = 2\frac{B_m}{s} - \kappa m \eta \frac{\tilde{C}'}{sm} \doteq 2B_m - \kappa \eta \tilde{C}'(sm) = 2B_m - \eta C_m. \quad (14)$$

When evaluated at m° , then $B_m = C_m > 0$, so that $B_{ms} - C_{ms} \doteq 2 - \eta^\circ$. At m^* , the first-order condition yields

$$w = B_{ms} - C_{ms} \doteq 2B_m(m^*) - \eta^* C_m(m^*) \quad (15)$$

$$= 2(C_m(m^*) + S_m(m^*, t^*)) - \eta^* C_m(m^*) = (2 - \eta^*)C_m^* + 2S_m^*. \quad (16)$$

Now turn to part 1 and 2. Obtain (ii) by using Prop. 1 and noting that $S_m \doteq m^* - t^*$. Since $\tilde{C}'' > 0$, (i) is also implied by Prop. 1. Combining the first-order conditions yields

$$\kappa(\tilde{C}'(sm^\circ) - \tilde{C}'(sm^*)) = \sigma \tilde{S}'(m^* - t^*) = \gamma - \nu \tilde{V}'(t^* - \psi), \quad (17)$$

which is positive for achiever cities, and negative for contributor cities. Both cities types can be further characterized by inferring from Prop. 1 that the contributor cities are exactly those with $V_t > T'$, and exactly those with $B_m^* < C_m^*$ (which is equivalent to $m^* < m^\circ$).

Part 2 directly follows by Prop. 1 because there is no third kind of cities except the boundary case.

Part 3 further exploits Eq. (14) to obtain the following sufficient conditions for being a contributor or achiever city. If $\eta^* < 2$ and $w^* < 0$, then $0 > w^* \doteq B_m^* - \frac{\eta^*}{2} C_m^* > B_m^* - C_m^*$, implying a contributor city. If $\eta^* > 2$ and $w^* > 0$, then $0 < w^* \doteq B_m^* - \frac{\eta^*}{2} C_m^* < B_m^* - C_m^*$, so an achiever city. Part 4 is equivalent to part 3.

The last part is already shown in Prop. 1 for contributor cities. For achiever cities, $\psi - t^* \doteq \nu \tilde{V}' = \gamma - \sigma \tilde{S}'$, so that $t^* < \psi$ iff $\tilde{S}' < \gamma/\sigma$. \square

A.4 Proof of proposition 4

Proof. Most are straightforward substitutions, simplifications, using previous results. The implication for $t^* < \psi$ can be derived geometrically. \square

A.5 Derivatives for targets as commitment device (refined model) (option for being removed in final version)

$$B(m) = s\delta(sm + q_0),$$

$$B_m = s^2\delta, B_s = \delta(2sm + q_0),$$

$$B_\delta = s(sm + q_0),$$

$$B_{ms} = 2s\delta, B_{m\delta} = s^2,$$

$$C_m = \kappa\tilde{C}' > 0,$$

$$C_{mm} = s\kappa\tilde{C}'' > 0,$$

$$C_s = \frac{\kappa}{s^2}(sm\tilde{C}' - \tilde{C}) = \frac{mC_m - C}{s},$$

$$C_{ms} = \kappa m\tilde{C}'' = \frac{m}{s}C_{mm} > 0,$$

$$C_\kappa = \frac{1}{s}\tilde{C} = C/\kappa > 0,$$

$$C_{m\kappa} = \tilde{C}' = C_m/\kappa > 0,$$

$$V_t = \nu\tilde{V}' \doteq \psi - t,$$

$$V_{tt} = \nu\tilde{V}'' < 0,$$

$$V_\nu = \tilde{V} = V/\nu,$$

$$V_{t\nu} = \tilde{V}' = V_t/\nu,$$

$$V_\psi = -\nu\tilde{V}' = -V_t,$$

$$V_{t\psi} = -\nu\tilde{V}'' = -V_{tt} > 0,$$

$$S_m = \sigma\tilde{S}' \doteq m - t,$$

$$S_{mm} = \sigma\tilde{S}'' > 0,$$

$$S_{mt} = -\sigma\tilde{S}'' = -S_{mm} < 0,$$

$$S_t = -\sigma\tilde{S}' = -S_m,$$

$$S_{tt} = \sigma\tilde{S}'' = S_{mm} > 0,$$

$$S_\sigma = \tilde{S} = S/\sigma > 0,$$

$$S_{m\sigma} = \tilde{S}' = S_m/\sigma,$$

$$S_{t\sigma} = -\tilde{S}' = -S_m/\sigma,$$

$$a = (s\kappa\tilde{C}'' + \sigma\tilde{S}'')(\sigma\tilde{S}'' - \nu\tilde{V}'') - \sigma^2\tilde{S}''^2 = s\kappa\tilde{C}''\sigma\tilde{S}'' - s\kappa\tilde{C}''\nu\tilde{V}'' - \sigma\tilde{S}''\nu\tilde{V}'' > 0.$$

B Appendix: Alternative model with targets as cost-saving device

The paper's main model assumes that the main role of targets is political. Yet, other mechanisms might be drivers of target setting and their achievement. If other mechanisms can be justified theoretically, it would be interesting to check whether they would imply qualitatively different results. One possibility could be targets which act as a *cost-saving device*, i.e. they might serve to reduce abatement costs. One reason for saving costs can

be credible targets (with associated policy instruments) which incentivize long-term investments in assets (e.g. renewables, insulated buildings) which ease emission reductions, while without such targets, investors might not be willing to take such risk, thereby missing mitigation opportunities. Furthermore, ambitious policy targets might spur innovation (Ambec et al., 2013). In addition, public targets might also help to solve coordination dilemmas in the city, thereby reducing mitigation costs: some abatement options involve local network externalities (e.g. in the transport sector), so that multiple actors taking them into account can reduce costs. Different public administration departments might need to detail out mitigation plans (before implementing them), ideally in a way that fits to the plans of other related departments (e.g. the introduction of low emission zones in relation to re-allocating parking space and public transport).

B.1 General model

With targets as a cost-saving device (and ignoring political incentives like in the other model), one can assume that the city government maximizes (with respect to t, m):

$$W = B(m; s, \delta) - C(m, t; s, \kappa) - T(t). \quad (18)$$

The benefit function B is of the same kind as before, while the cost function C also depends on the target t (i.e. the target saves costs). As before, T denotes the transaction cost of developing and setting public climate targets. The general monotonicity and convexity assumptions are given in Tab.9. The last assumption $a > 0$ guarantees existence and uniqueness of the optimum of Eq.(18). Below, App.(B.2) introduces a refined model version. The decision structure is as before. In Stage 1, the local government decides to set a target if and only if this leads to a larger maximand W than if $t, T \equiv 0$. In Stage 2a (without a target), the city decides on mitigation m° , while in Stage 2b (with a target), the government decides on the target level and mitigation t^*, m^* .

Stage 2a: If the government has decided not to set a target, the optimal m° is obtained from maximizing $B(m) - C(m, 0)$ with respect to m . This is simply the expository model, now with the more general assumptions, so that $m^\circ = m^e$. The first-order condition $B_m(m^\circ) = C_m(m^\circ, 0)$ yields the same comparative statics as for targets as commitment device.

Stage 2b: If the government has decided to set a target, the first order conditions for (m^*, t^*) are $B_m(m^*) = C_m(m^*, t^*)$, $T'(t^*) = -C_t(m^*, t^*)$, which are sufficient due to the general convexity assumptions. From now on assume that both variables are positive

Table 9: General assumptions for targets as cost-saving device.

$B(m) \geq 0$	mitigation benefits
$B_m > 0, B_{mm} = 0$	linear
$B_s, B_\delta > 0$	large and vulnerable cities benefit more...
$B_{ms}, B_{m\delta} > 0$...also in terms of marginal benefits
$C(m, t) \geq 0$	mitigation costs
$C_m, C_{mm} > 0$	costs convex in m
$C_t < 0, C_{tt} > 0$	targets reduce costs diminishingly
$C_{mt} < 0$	targets reduce marginal costs
$C_\kappa, C_{m\kappa} > 0$	κ rises costs and marginal costs
$C_s, C_{ms} > 0$	larger cities have higher (marginal) costs
$C_{t\kappa} < 0$	more effective targets in costly cities
$C_{ts} < 0$	more effective targets in large cities
$T(t) > 0$	transaction costs
$T' \geq 0, T'' \geq 0$	more ambitious target is costly
$a := C_{mm}(C_{tt} + T'') - C_{mt}^2 > 0$	strict convexity

in the optimum. The comparative statics of the solution are:

$$\frac{dm^*}{ds} = \frac{C_{ts}C_{mt} + w(C_{tt} + T'')}{a} \leq 0, \quad (19)$$

$$\frac{dt^*}{ds} = -\frac{wC_{mt} + C_{mm}C_{ts}}{a} \leq 0, \quad (20)$$

$$\frac{dm^*}{d\delta} = \frac{B_{m\delta}(C_{tt} + T'')}{a} > 0, \quad (21)$$

$$\frac{dt^*}{d\delta} = -\frac{C_{mt}B_{m\delta}}{a} > 0, \quad (22)$$

$$\frac{dm^*}{d\kappa} = \frac{C_{t\kappa}C_{mt} - C_{m\kappa}(C_{tt} + T'')}{a} \leq 0, \quad (23)$$

$$\frac{dt^*}{d\kappa} = \frac{C_{m\kappa}C_{mt} - C_{mm}C_{t\kappa}}{a} \leq 0. \quad (24)$$

At least one sufficient condition for a unique sign of Eq. (19) and Eq. (20) can be identified. It is also possible to compare mitigation between Stage 2a and 2b:

Proposition 5. *If targets are a cost-saving device and the local government decides to have a target, the comparative statics of the target t^* and mitigation m^* follows Eq. (19)-Eq. (24). If $w > 0$, then both Eq. (19) and Eq. (20) are positive, and $dm^*/ds > 0$. For*

mitigation, $m^* \geq m^\circ$ always holds.

Proof. Comparative statics are obtained by total differentiation and the assumptions in Tab. 9. The implication of $w > 0$ is easily verified. For $m^* \geq m^\circ$, define the function $\bar{m}(t)$ by $B_m(\bar{m}(t)) - C_m(\bar{m}(t), t) \equiv 0$. The optimum in the absence of a target is expressed as $m^\circ = \bar{m}(0)$, and $m^* = \bar{m}(t^*)$. By differentiating, $B_{mm}\bar{m}'(t) - C_{mm}\bar{m}'(t) - C_{mt} = 0$, so that $\bar{m}' = -\frac{C_{mt}}{C_{mm}} > 0$. Since t^* cannot be negative by definition, $m^* = \bar{m}(t^*) \geq \bar{m}(0) = m^\circ$. \square

Note that the assumptions for targets as a cost-saving device do not require a specific metric for the target (e.g. targets for relative or absolute emission reductions, or abatement technologies) since they just represent a (political) activity which reduces costs. Thus, it does not make sense to determine whether targets are achieved or not for this model version.

Stage 1: When comparing a situation with target $W^* = B(m^*) - C(m^*, t^*) - T(t^*)$ and without target $W^\circ = B(m^\circ) - C(m^\circ, 0)$, the properties of the difference in government's benefits $\Delta = W^* - W^\circ$ are as follows:

Proposition 6. *When targets are a cost-saving device, the gain from setting them depend on the parameters as follows. If $w > 0$, then $d\Delta/ds > 0$.*

$$\frac{d\Delta}{ds} = (B_s(m^*) - C_s(m^*, t^*)) - (B_s(m^\circ) - C_s(m^\circ, 0)) \leq 0, \quad (25)$$

$$\frac{d\Delta}{d\delta} = B_\delta(m^*) - B_\delta(m^\circ) \geq 0, \quad (26)$$

$$\frac{d\Delta}{d\kappa} = C_\kappa(m^\circ, 0) - C_\kappa(m^*, t^*) \leq 0. \quad (27)$$

Proof. For any kind of parameter, e.g. s , the envelope theorem guarantees

$$\begin{aligned} \frac{d\Delta}{ds} &= W_s(m^*, t^*) - W_s^\circ(m^\circ) \\ &= B_s(m^*) - C_s(m^*, t^*) - T_s(t^*) - B_s(m^\circ) + C_s(m^\circ, 0) + T_s(0), \end{aligned} \quad (28)$$

which is simplified here for s, δ, κ . The second inequality holds due to Prop. 5 and $B_{\delta m} > 0$.

For the first inequality, employ \bar{m} from Prop. 5 again, and note that $B_s(m^*) - C_s(m^*, t^*) = NB(t^*) := B_s(\bar{m}(t^*)) - C_s(\bar{m}(t^*), t^*)$, and $B_s(m^\circ) - C_s(m^\circ, 0) = NB(0)$. Then, $\frac{NB}{dt} = B_{sm}\bar{m}' - C_{sm}\bar{m}' - C_{st} = (B_{ms} - C_{ms})\bar{m}' - C_{st}$. The convexity assumptions and $t^* > 0$ then show that $w > 0$ is a sufficient (but not necessary) condition for $NB(t^*) > NB(0)$. Thus, Eq. (25) is positive. \square

B.2 Refined model

(Assumptions cost-saving) Assume a cost function of the form $C = \frac{\kappa}{s} f(t) \tilde{C}(sm)$, where the functions f, \tilde{C} satisfy: $f > 0, f(0) = 1, f' < 0, f'' > 0$, and $\tilde{C}, \tilde{C}', \tilde{C}'' > 0$. This form captures a multiplicative cost-saving effect from targets through the function f . Transaction costs T and benefits B are the same as for the commitment device model. Thus, $a = C_{mm}C_{tt} - C_{mt}^2 = \kappa^2 \left(f\tilde{C}f''\tilde{C}'' - (f'\tilde{C}')^2 \right)$. Since $a > 0$ is needed, the choice of f, \tilde{C} is more restricted. Define $u := \tilde{C}\tilde{C}'' - \tilde{C}'^2$ and $v := ff'' - f'^2$. Then, $u, v > 0 \Rightarrow a > 0$, and $u, v < 0 \Rightarrow a < 0$, and $u \cdot v < 0 \Rightarrow a \leq 0$. The decision problem is not well-posed if both u, v are negative. By using the cost elasticity $\epsilon := \tilde{C}'(sm) \frac{sm}{\tilde{C}} > 0$, it can be noted that $sm\tilde{C}' - \tilde{C} = \epsilon\tilde{C} - \tilde{C} = (\epsilon - 1)\tilde{C}$. Thus, iff the cost elasticity of \tilde{C} is always above unity, both C_s, C_{ts} are uniquely positive.

Stage 2a If there is no target, the first-order condition is $s^2\delta = \kappa\tilde{C}''(sm^\circ)$, with the comparative statics

$$\frac{dm^\circ}{ds} = \frac{2s\delta - \kappa m^\circ \tilde{C}''}{s\kappa\tilde{C}''}, \quad (29)$$

$$\frac{dm^\circ}{d\delta} = \frac{s}{\kappa\tilde{C}''} > 0, \quad (30)$$

$$\frac{dm^\circ}{d\kappa} = -\frac{\tilde{C}'}{s\kappa\tilde{C}''} < 0. \quad (31)$$

From App. (B.1), $w = B_{ms} - C_{ms} > 0$ is sufficient for $\frac{dm^\circ}{ds} > 0$. For the comparative statics in the optimum, $C_m = B_m$, so Eq. (14) can be written as follows. If the marginal costs have an elasticity of 2 or less (in the optimum), then – in the absence of a target – increasing size makes optimal mitigation larger:

$$w \doteq 2B_m - \eta C_m = (2 - \eta)B_m. \quad (32)$$

Stage 2b The first-order conditions for (m, t) are $s^2\delta = \kappa f(t^*)\tilde{C}'(sm^*)$, $\gamma = \frac{\kappa}{s}f'(t^*)\tilde{C}(sm^*)$, and the comparative statics for s, δ, κ evaluate to

$$\frac{dm^*}{ds} = -\frac{m^*}{s} + \frac{\kappa}{s^2a}\tilde{C}\left(2s^2\delta f'' - \kappa f'^2\tilde{C}'\right), \quad (33)$$

$$\frac{dt^*}{ds} = \frac{\kappa}{sa}f'\left(\kappa f\tilde{C}\tilde{C}''' - 2s^2\delta\tilde{C}'\right), \quad (34)$$

$$\frac{dm^*}{d\delta} = \frac{s\kappa}{a}f''\tilde{C} > 0, \quad (35)$$

$$\frac{dt^*}{d\delta} = -\frac{s^2\kappa}{a}f'\tilde{C}' > 0, \quad (36)$$

$$\frac{dm^*}{d\kappa} = \frac{\kappa}{sa}\tilde{C}\tilde{C}'(f'^2 - ff'') \doteq -v, \quad (37)$$

$$\frac{dt^*}{d\kappa} = \frac{\kappa}{a}ff'(\tilde{C}'^2 - \tilde{C}\tilde{C}''') \doteq u. \quad (38)$$

Proposition 7. *Suppose (assumptions cost-saving) hold. Then $\frac{dm^\circ}{d\delta}, \frac{dm^*}{d\delta}, \frac{dt^*}{d\delta} > 0$, and $\frac{dm^\circ}{d\kappa} < 0$. If $\eta < 2$, then $w, \frac{dm^\circ}{ds}, \frac{dm^*}{ds}, \frac{dt^*}{ds} > 0$. It holds that $\frac{dm^*}{d\kappa} < 0$ iff $v > 0$ (which is always the case if $u < 0$). Furthermore, $\frac{dt^*}{d\kappa} < 0$ iff $u < 0$. Finally, $u < 0$ iff $C^\circ < C^*$.*

Proof. The comparative statics have already been shown. With applying Eq.(32) for stage 2, $\eta < 2$ guarantees $w > 0$. This is, due to Prop.5, a sufficient condition for $\frac{dm^*}{ds}, \frac{dt^*}{ds} > 0$. For a well-posed problem, $u < 0$ requires $v > 0$, so that $\frac{dm^*}{d\kappa} < 0$. For the cost comparison, use $\bar{m}(t)$ from Prop. 5, and observe

$$\frac{d}{dt}C(\bar{m}(t), t) = C_m\bar{m}' + C_t = -C_m\frac{C_{mt}}{C_{mm}} + C_t \quad (39)$$

$$= -\kappa f\tilde{C}'\frac{\kappa f'\tilde{C}'}{s\kappa f\tilde{C}''} + \frac{\kappa}{s}f'\tilde{C} \quad (40)$$

$$= \frac{\kappa}{s}f'\left(-\tilde{C}'\frac{\tilde{C}'}{\tilde{C}''} + \tilde{C}\right) \doteq \left(\frac{\tilde{C}'^2 - \tilde{C}\tilde{C}'''}{\tilde{C}''}\right). \quad (41)$$

Thus (since $t^* > 0$) if $-u = \tilde{C}'^2 - \tilde{C}\tilde{C}''' > 0$, then $C^* = C(\bar{m}(t^*), t^*) > C(\bar{m}(0), 0) = C^\circ$. \square

Stage 1 For the decision whether to set a target, the derivatives of Δ from Prop. 6 evaluate to

$$\frac{d\Delta}{ds} = 2s\delta(m^* - m^\circ) + \frac{1}{s}(m^\circ C_m^\circ - m^* C_m^* - C^\circ + C^*) \leq 0, \quad (42)$$

$$\frac{d\Delta}{d\delta} = B_\delta(m^*) - B_\delta(m^\circ) = s^2(m^* - m^\circ) \geq 0, \quad (43)$$

$$\frac{d\Delta}{d\kappa} = \frac{1}{s}(\tilde{C}^\circ - f^* \tilde{C}^*) = \frac{1}{\kappa}(C^\circ - C^*). \quad (44)$$

Proposition 8. *Suppose (assumptions cost-saving) hold. Then, the likelihood of having a target changes according to Eq. (42)-Eq. (44). If $\eta < 2$, then Eq. (42) becomes positive. Eq. (44) is negative iff $u < 0$.*

Proof. The comparative statics are straightforward by substituting the derivatives into the results from Prop. 6. If $\eta < 2$, Prop. 7 shows that $w > 0$, which implies Eq. (42) to be positive by Prop. 6. Due to Prop. 7, the last expression is positive iff $u > 0$. \square

Table 10: Comparative statics summary for targets as a cost-saving device (refined model). The specifications of u, v depend on the mitigation costs C , and is given in App. (B.2) (both can be negative or positive in principle). If $\eta < 2$, only the shaded cases are possible.

case	w	u	$\frac{d\Delta}{ds}$	$\frac{d\Delta}{d\delta}$	$\frac{d\Delta}{d\kappa}$	$\frac{dt^*}{ds}$	$\frac{dt^*}{d\delta}$	$\frac{dt^*}{d\kappa}$	$\frac{dm^*}{ds}$	$\frac{dm^*}{d\delta}$	$\frac{dm^*}{d\kappa}$
(CST.1)	(+)	(-)	(+)	(+)	(-)	(+)	(+)	(-)	(+)	(+)	(-)
(CST.2)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	$-\text{sgn}(v)$
(CST.3)	(-)	(-)	(?)	(+)	(-)	(?)	(+)	(-)	(?)	(+)	(-)
(CST.4)	(-)	(+)	(?)	(+)	(+)	(?)	(+)	(+)	(?)	(+)	$-\text{sgn}(v)$

Tab. 10 summarizes the main results. For Stage 1, $w > 0$ is again sufficient for larger cities being more likely to set a target (Prop. 6), and for the refined model $\eta < 2$ is also sufficient (Prop. 8). See main text why $\eta < 2$ might be more appropriate. Mitigation costs κ have an ambiguous effect for setting a target (depending on the sign of u). The effect of δ is unique (non-negative), as in the commitment-device model. It can thus be said that (by also using Prop. 5) – if the hypothesis holds that climate targets are primarily a cost-saving device – cities with higher δ are more likely to set such a target, and if they indeed set it, it is more ambitious and they mitigate more.

Also for Stage 2b, $w > 0$ is a sufficient condition for larger cities mitigating more, but not a necessary one. It is also possible that with $B_{ms} < C_{ms}$, some target setting cities still have a positive effect of size, while this would not be the case if they do not set a target. In the refined model a cost elasticity $\eta < 2$ is also a sufficient condition for larger cities

abating more (Prop. 7). Cost-saving targets generally increase mitigation (Prop. 5). This is intuitive, since targets always reduce mitigation costs and (besides transaction costs) have no other disadvantages in this section's model.

If the cases CST.1, CST.2 are more relevant, then, the cost-saving model is consistent with the empirical finding that larger cities tend to have climate plans more frequently. For the common class of isoelastic cost functions $\tilde{C}(q) = \kappa q^u$, for instance, $u < 0$ (and the boundary case $u = 0$ follows from an exponential cost function). Then, as shown above, only $v > 0$ is possible. In those cases, cities with higher mitigation costs κ chose lower targets and reduce emissions less. In such a setting, cities with targets have higher mitigation expenditures. In a nutshell, the model with targets as cost-saving device then follows the basic intuition.

B.3 Comparison

We can now compare the deduced implications for the cost-savings model with those of the commitment-device model (Tab. 11 displays some differences). For all model versions and cases, higher social costs of carbon imply more ambitious targets (I was not able to find model assumptions with a qualitatively different $dt^*/d\delta$). Yet, other implications admit to discriminate between the models. For higher private costs of carbon δ , there are some cases where the presence of targets becomes less likely (COM.2, COM.3), but this is not possible if targets are a cost-saving device.

The commitment-device model leads to the prediction that the conventional finding that larger cities are more likely to have climate targets implies: If we would also observe that more vulnerable cities less likely have climate targets, this is only consistent with $\eta > 2$ (COM.4). The cost-savings model, however, would never be consistent with this observation. Even with also considering that targets reduce costs, the only explanation for higher- δ cities having no target remains COM.2 (and COM.4 if we admit $\eta > 2$).

With respect to higher abatement costs κ , in the commitment-device model cities always set less ambitious targets. Now, when targets are cost-reducing, abatement costs κ can also be supportive for the level of targets (CST.2, CST.4). If a set of cities is identified where higher mitigation costs are associated with more ambitious targets, the model with targets as commitment device is ruled out as an explanation for them. Targets as cost-saving device would yet be consistent, if u can be estimated to be positive. For most models/cases (except for COM.2 and $\eta > 2$), mitigation costs shift both the likelihood and the target ambition in the same direction.

Finally, compare the effect of size s . The effect on the level of targets does not differ among the $w > 0$ cases, but might differ otherwise depending on how the further ambiguities are resolved (CST.3, CST.4). Among the $\eta < 2$ cases, the commitment-device

model can only explain that larger cities more likely set targets for contributor cities with if $w > 0$ (COM.1). Yet, two cases of the cost-savings model are also consistent (CST.1, CST.2). Interestingly, these cases also require $w > 0$.

Table 11: Comparing models and cases (shaded rows consistent with $\eta < 2$).

case	w	type	u	$\frac{d\Delta}{ds}$	$\frac{d\Delta}{d\delta}$	$\frac{d\Delta}{d\kappa}$	$\frac{dt^*}{ds}$	$\frac{dt^*}{d\kappa}$
(CST.1)	(+)		(-)	(+)	(+)	(-)	(+)	(-)
(CST.2)	(+)		(+)	(+)	(+)	(+)	(+)	(+)
(COM.1)	(+)	(ctr)		(+)	(+)	(-)	(+)	(-)
(COM.2)	(+)	(ach)		(-)	(-)	(+)	(+)	(-)
(CST.3)	(-)		(-)	(?)	(+)	(-)	(?)	(-)
(CST.4)	(-)		(+)	(?)	(+)	(+)	(?)	(+)
(COM.3)	(-)	(ctr)		(-)	(+)	(-)	(-)	(-)
(COM.4)	(-)	(ach)		(+)	(-)	(+)	(-)	(-)

B.4 Overview of derivatives (refined cost-savings model) (option for being removed in final version)

$$C_m = \kappa f \tilde{C}' > 0,$$

$$C_t = \frac{\kappa}{s} f' \tilde{C} = \frac{f'}{f} \tilde{C} < 0,$$

$$C_s = \frac{\kappa}{s^2} f (sm \tilde{C}' - \tilde{C}) = \frac{mC_m - C}{s},$$

$$C_\kappa = \frac{1}{s} f \tilde{C} = C/\kappa > 0,$$

$$C_{mm} = s\kappa f \tilde{C}'' > 0,$$

$$C_{tt} = \frac{\kappa}{s} f'' \tilde{C} > 0,$$

$$C_{mt} = \kappa f' \tilde{C}' < 0,$$

$$C_{ms} = \kappa m f \tilde{C}'' = \frac{m}{s} C_{mm} > 0,$$

$$C_{ts} = \frac{\kappa}{s^2} f' (sm \tilde{C}' - \tilde{C}) = \frac{mC_{mt} - C_t}{s},$$

$$C_{m\kappa} = f \tilde{C}' = C_m/\kappa > 0,$$

$$C_{t\kappa} = \frac{1}{s} f' \tilde{C} = C_t/\kappa < 0,$$

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