

**International  
Corporate Innovation Activities:  
Drivers, Outcomes, Risks**

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# 1 Introduction

Innovations are an important motor for economic growth and competitiveness (Schumpeter, 1934; Griliches, 1979). The economic literature witnessed in numerous studies a positive relationship between research and development (R&D) and innovative output as well as a positive impact on productivity and employment growth (Crépon et al., 1998; Mairesse and Mohnen, 2005; Jefferson et al., 2006; Peters, 2008). Productivity and employment growth are key factors for economic development.

Especially in developed countries such as Germany, the success of firms depends on their ability to regularly produce new or significantly improved products, services or to enhance the production process with process innovations. The need for new ideas and technological know-how is spurred by an increasing technological change. The globalisation process also contributes to firms' search for sources of innovations in order to sustain their competitiveness in international competition and to serve foreign markets. Consequently, firms have to find ways to acquire and develop new knowledge which enables them to be innovative. In this matter, firms pursue strategies which allow them to access global knowledge sources to complement their R&D activities at their headquarters where firms typically gather their innovation capacities. These strategies do not only cover international innovation cooperations with customers, suppliers or competitors but also firm internal strategies to capture worldwide available expertise by setting up firm subsidiaries abroad with R&D tasks.

This research intends to shed more light on the international innovation strategies of corporations. The aim of this thesis is to extend the existing literature concerning the internationalisation of R&D activities with empirical and qualitative analyses. There is limited work that focuses on different activities concerning innovations. To address this shortcoming, this dissertation distinguishes between firm internal R&D activities, the design/conception or construction of new products, the production of innovative goods and the implementation of innovative processes.

In this field of research, a geographical perspective of firms' global innovation activities will do justice to the fast development of emerging countries and the changing landscape of lead markets and business locations. Hence, this research will not only distinguish between firms' international and national innovation activities but also include analyses that consider the different geographical locations of the international innovators.

The distinction between types of innovation activities abroad and the differentiation between host countries are two dimensions which are incorporated in the analyses of the different chapters. The dissertation itself is based on three thematic focuses:

- (1) What motivates or hinders firms to internationalise their innovation activities?
- (2) What are the corporate benefits from international R&D engagements?
- (3) What risks impose international innovation activities on firms' intellectual properties?

## **1.1 Thesis Outline**

The next four chapters will elaborate on these three main topics in the following sequence. Chapter 2 investigates the first thematic focus and examines the driving factors that enable and hinder firms to expand their innovation activities globally. Hereby the influence of firm-specific capabilities, the competitive and innovation environment in the home country are analysed to compose a comprehensive picture of innovation internationalisation drivers. The chapter presents the effects of driving forces on R&D as well as on later-stage innovation activities. A geographic view captures the effects of the internationalisation drivers on different host countries and regions of the world.

Chapter 3 is devoted to the second thematic stream. It evaluates the innovation performance of firms with both national and international R&D activities and compares them with firms which innovate only in their home country. In this assessment not only the potential knowledge gains of international R&D activities are explored but also the factors that are likely to influence the relationship between international R&D and innovation outcome negatively. Chapter 3 observes exclusively the effect of international R&D on the likelihood to generate

innovations and whether international innovating firms are more successful on the market with their innovative products.

A corporate subsidiary abroad which has research and development tasks has not only the potential to enhance the innovativeness of the firm but also to drive operating costs, as well as the risk of knowledge spillovers. Therefore, the question of the return of international research centres to corporate success is straightforward. In Chapter 4 the contributions of international R&D activities to firm performance are examined. Similarly to Chapter 3 national innovating firms are compared with international innovating firms. However, in this chapter the main interest lies in evaluating the relationship between monetary benefits and costs of international R&D activities.

Chapter 5 is dedicated to the third main topic. It aims at analysing the risk of intellectual property infringements by competitors from abroad and in particular whether this risk is higher for international innovating firms. The underlying rationale here is that knowledge does not only spill over from the host country to the foreign subsidiary and potentially increases their knowledge base but also vice versa. To answer the open questions, a case study will be the starting point of the analysis and will be followed by econometric analysis based on a larger data base.

All chapters incorporate empirical studies based on firm level data with at least 800 observations.

The following section will introduce the survey and data set that is used for all empirical analyses. Based on this information basic definitions of innovations and innovative firms are given which are used throughout the following chapters. To point out the importance and extent of international R&D activities, some graphs illustrate the existing and planned foreign R&D and innovation activities of firms in Germany as well as their preferred locations abroad.

## **1.2 Data Description**

### **1.2.1 The Survey**

The data set that has been used throughout the dissertation draws on the innovation survey conducted by the Centre for European Economic Research (ZEW) together with the Fraunhofer Institute for Systems and Innovation Research and the Infas Institute for Applied Social Sciences. The survey is carried out on behalf of the German Federal Ministry of Education and Research (BMBF)

since 1993. The overall aim of the survey is to capture information about corporate innovation activities. The survey targets all firms in Germany with at least 5 employees. The study incorporates all industry sectors as well as mining, energy and water supply, knowledge intensive services and other services. The innovation survey is carried out annually and designed as a panel (Mannheim Innovation Panel, MIP). In this vein, the same sample of firms is surveyed each year. Sample firms that drop out due to liquidations, reduced firm size or a change of industrial sectors are substituted every two years with new firms.

The MIP sample is stratified by firm size, industry classification and location within Germany. As for the firm size, there are eight different size classes (5-9, 10-19, 20-49, 50-199, 200-499, 500-999, >1000) for the manufacturing sectors and seven for service sectors (largest category is here >500). The sample is further stratified on the 2 digit NACE code level and for some service sectors on the 3 digit NACE code (General Industrial Classification of Economic Activities in the European Communities) into 22 industry classifications: 10-14, 15-16, 17-19, 20-22, 23-24, 25, 26, 27-28, 29, 30-32, 33, 34-35, 36-37, 40-41, 51, 60-63/64.1, 65-67, 64.3/72, 73/74.2/74.3, 74.1/74.4, 74.5-74.8/90, 92.1/92.2.

The location of firms within Germany has led to the distinction between firms that have their headquarters in western Germany and the eastern part of Germany. East German firms stem from the federal states of Berlin, Brandenburg, Mecklenburg-Western Pomerania, Saxony, Saxony-Anhalt and Thuringia.

The MIP survey is alternately a longer and a shorter data collection. While short surveys contain mainly core innovation indicators about innovation activities and firm figures, the long surveys additionally include questions about specific innovation related topics. Core innovation indicators comprise firm efforts for R&D in terms of R&D spending, the share of high-skilled employees, continuity of R&D behaviour or non-R&D efforts such as the acquisition of machines to name a few. The outcome of these innovation efforts is captured by surveying successful product and process innovation projects and the termination of unsuccessful projects. The core innovation indicators are complemented with additional questions. Each survey wave has a special thematic focus which is repeated for certain topics in different survey waves. In total, the dissertation employs four survey waves to analyse research questions and test hypotheses:

- The 2005 survey questions were designed to observe the usage of public funds for innovation projects, corporate innovation barriers, innovation cooperation, implications of innovation projects, corporate information

sources for innovation activities and strategies for intellectual property protection

- In 2006, the thematic focus of the survey was on the internationalisation of firms' innovation activities and the fluctuation of employees in R&D departments
- The 2008 survey questions were devoted to firms' innovation cooperations as well as to the usage of knowledge appropriation methods and the occurrence of infringements of intellectual property rights.
- The 2009 survey questioned firms concerning their introduction of organisational, marketing and environmental innovations.

Short surveys consist of 4 pages while long surveys have about 8 pages. The 2005 and 2009 surveys are long surveys, while the 2006 and 2008 surveys were short surveys. The gross sample size for longer surveys is about 10,000 firms larger than for shorter surveys. The questionnaires address the head of research and development departments in larger firms and the general manager in smaller firms. The participation in the survey is voluntary. However, for firms which have more than 500 employees a complete population survey is carried out. Table 1 gives an overview of the employed survey waves regarding their gross and net sample sizes.

*Table 1: Overview of Gross and Net Samples of Employed MIP Survey Waves*

	<b>2005</b>	<b>2006</b>	<b>2008</b>	<b>2009</b>
Gross Sample <sup>1)</sup>	27,926	17,395	19,080	35,195
Net Sample <sup>2)</sup>	5,874	5,187	6,624	7,662
Response Rate (%)	21.0	29.8	34.7	21.8

1) Gross sample corrected for neutral losses

2) Net sample including full population survey of large firms

To avoid distortions in the respondent data regarding the ratio of innovating and non-innovating firms, a second round of data collection among firms that did not return the survey is carried out. In this non-response survey about 4,000 firms are interrogated concerning the core innovation indicators. Every fourth year the information of the MIP survey represents the German contribution to the Europe-wide innovation survey, the Community Innovation Survey (CIS), coordinated by Eurostat. The 2005 and 2009 MIP surveys contributed to this European harmonised data collection. The following table illustrates which chapters of the dissertation employ the different waves of the German innovation data set.

Table 2: Overview of Dissertation Chapters and the Employed Data Sets

Chapter	German Innovation Survey (MIP)				Own case study
	2005	2006	2008	2009	
2	●	●			
3		●		●	
4		●		●	
5		●	●		●

### 1.2.2 Innovation and the Innovative Firm

The MIP survey follows the recommendations for definitions and methodologies provided in the Oslo Manual by the OECD and Eurostat. The Oslo Manual is a guideline for the collection of innovation data at the level of the firm. Hereby the definition of an innovation is given as “the implementation of a new or significantly improved product (good or service)” (OECD and Eurostat, 2005). From its 3<sup>rd</sup> edition on, the Oslo manual comprises not only product and process innovations but also organisational innovations and marketing innovations. Following this differentiation the MIP also asks firms about their marketing and organisational innovations from the 2005 survey onwards in the long survey waves. Since each survey wave enquires companies about their product and process innovations this dissertation uses these two original types of innovation outcomes from the survey. The definitions of product and process innovations are specified as follows:

“A *product innovation* is the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses. This includes significant improvements in technical specifications, components and materials, incorporated software, user friendliness or other functional characteristics.” (OECD and Eurostat, 2005)

“A *process innovation* is the implementation of a new or significantly improved production or delivery method. This includes significant changes in techniques, equipment and/or software.” (OECD and Eurostat, 2005)

Attached to the MIP questionnaire is a booklet which presents examples for product and process innovations to clarify the scientific definition of an innovative product or service for the respondents. Table 3 illustrates some of these examples taken from the 2006 MIP survey.

*Table 3: Examples of Product and Service Innovations from the Mannheim Innovation Panel (MIP), Survey Wave 2006*

<b>Product Innovations</b>	<b>Process Innovations</b>
	<b><i>Industry</i></b>
Waterproof connector plug	New adhesive technology to join components
Use of telematics in motor vehicles	Introduction of automation concepts
Beer-based mixed beverages	IT-networking of production, logistics and accounting
Fibre optics on printed circuit boards	Online monitoring of machinery
	<b><i>Retail and Shipping</i></b>
Integrated logistics concepts	Digital labelling of goods, electronic ordering system
Introduction of e-commerce	Computer-based shipment tracking system
Consultancy on disposal issues	Use of satellite navigation for fleet management
Rapid transit bus routes	Superfast ferries
	<b><i>Financial Services</i></b>
Telephone/direct banking 24/7	Expansion of self-service technology
Issuing of policies at the point of sale	Digital archive, optoelectronic filing of documents
Equity-linked retirement products	New scoring and rating methods to assess credit risks
Hybrid insurance	Online policy preparation
	<b><i>Corporate Services, Software, Media</i></b>
Consultancy on environmental audit regulations	Customer care via the Internet
Real estate forecasting models	Adaptive databases with automatic error recognition
Professional development training by e-learning	Quality assurance systems for consulting
Online presentation of print media	On-line subscription models

For the empirical analyses, the sample of firms that are innovation active was more broadly defined. Innovation active firms are not only firms which have successfully finished their innovation activities with product or process innovations but also firms which have ended their innovation projects without innovative output and firms which have not yet completed their innovation projects. This definition is again based on the Oslo Manual (OECD and Eurostat, 2005) which suggests that innovation activities are indicated by on-going, successful and abandoned innovation projects.

### **1.2.3 The Innovation Activities of Firms Abroad**

Before the analyses about the drivers, outcomes and risks of international innovation activities are presented in the following chapters, some descriptive

analyses will illustrate the extent of the international innovation activities of firms in Germany today and their planned activities in the future. To show the extent of innovation internationalisation among firms in Germany the results of the sample survey are projected for the basic population<sup>1</sup>. Data on the number of firms, employment and revenue figures for the basic population of manufacturing, mining and most service sectors are based on publications of the German Federal Statistical Office.

The descriptive statistics for the basic population in Figure 1 shows the share of R&D and other innovation activities that are carried out abroad by firms which operate the respective activity also in Germany in year 2005. The second column expresses the firms' planned expansion of international innovation activities while the third column illustrates the share of firms that have the respective R&D or innovation activity in Germany and plan to start the localisation of innovation activities abroad.

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<sup>1</sup> The Data used for empirical results is not projected, only information from the net sample is used in chapters 2 to 5.



Figure 1: Share of Firms in Germany with International R&D and Innovation Activities in Year 2005 and Planned Activities in 2006/07<sup>2</sup>

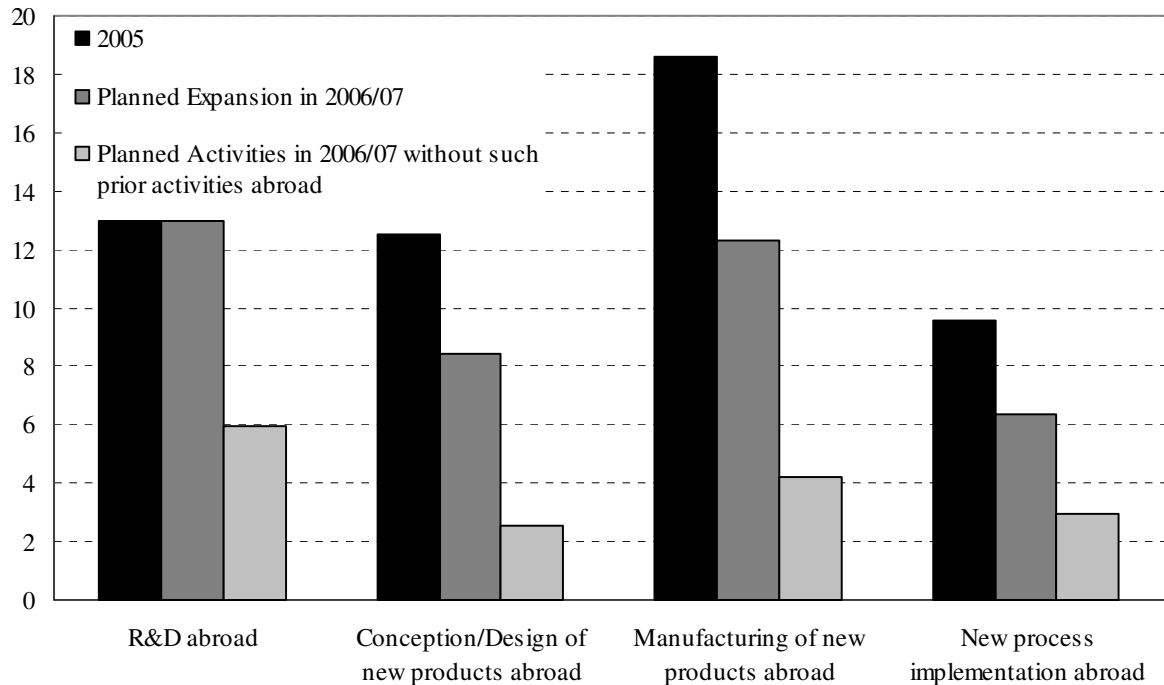


Figure 1 demonstrates that the internationalisation pace of firm innovation activities is persistent. The largest intention of firms is to continue and expand the internationalisation of R&D. 6% of firms with R&D in Germany are planning to start the internationalisation of their R&D activities. The manufacturing of innovations abroad shows the highest share of internationalisation in 2005. Figure 2 adds a geographic perspective and illustrates where firms have located their foreign R&D and innovation activities. Figure 3 compares the location preference of firms' innovation activities abroad in 2005 with the planned innovation locations abroad in years 2006/2007.

<sup>2</sup> Share of firms which carry out the respective activity also in Germany, Source: Rammer and Schmiele (2008).

Figure 2: Share of Firms in Germany that had R&D or Innovation Activities in Various Countries and Regions in Year 2005

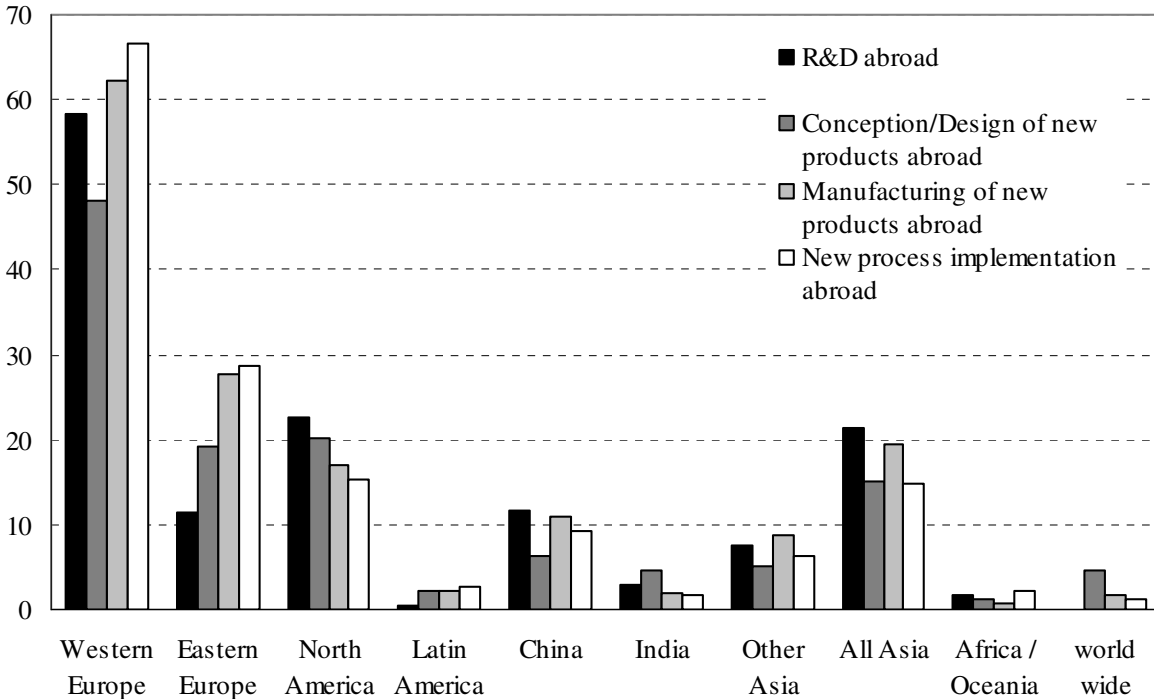
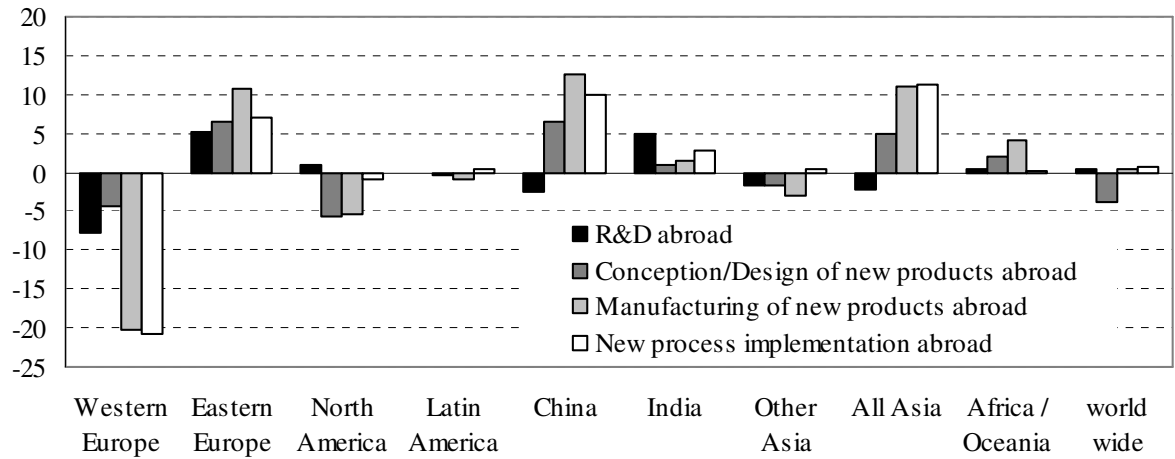


Figure 3 visualises the change of location preference in firms’ international R&D portfolio. In 2005, most of the firms in Germany which have international R&D or innovation activities have located these activities in the Western European region (see Figure 2). As for R&D, North America and Asia have been preferred locations. Later-stage innovation activities, such as the design and production of innovative products, were also located in Eastern Europe. Latin America, Africa or other locations are of low interest to firms in Germany. The planned locations for 2006 and 2007 (see Figure 3) show a higher preference for the Asian region and Eastern Europe than for Western Europe. However, China as an R&D location is of decreasing importance while later-stage innovation activities in China are of increasing importance. Eastern Europe and India show the greatest growth as planned R&D locations.

*Figure 3: Change in Location Importance of Firms' R&D and Innovation Activities Between 2005 and Planned Activities in Years 2006/07*





## **2 Drivers for International Innovation Activities in Developed and Emerging Countries<sup>3</sup>**

Globalisation has been reshaping the business environment of firms. The corporate response to the increased openness of economies is the ongoing trend to internationalise business processes. Foreign markets allow international firms to achieve scale advantages and to source international assets, including knowledge. As a consequence, firms can enlarge their market size and use internationally dispersed knowledge resources to enhance their competitiveness. Internationalising innovation will allow firms to enlarge their knowledge base by obtaining knowledge, technology and skills from other locations than their home market, potentially contributing to more ambitious and more efficient innovation efforts. By acquiring knowledge from other places firms can overcome knowledge constraints in the home country. Furthermore, approaching new markets often requires innovation designs which are adjusted to the specific environment in these markets. Developing or adapting such innovations at the location of potential customers may be more effective. Moreover, market success of new products depends not only on technological superiority or customer-tailored solutions but also on cost efficiency.

However, firms might not take the risks of shifting business operations away from the centre if their competitive environment and the need to overcome shortcomings in the national innovation environment forced them in some way. Besides these potential pushing forces firms might possess capabilities and resources that enable them to perform innovation activities abroad. This chapter aims to spot both firm-specific factors and characteristics of the home innovation environment in their influence to locate innovation activities abroad. Most of the literature on internationalisation of innovation neglects the competitive forces and R&D attractiveness of the home location and focuses on host country advantages.

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<sup>3</sup> This chapter draws on Schmiele (2011).

Furthermore, existing studies concentrate on R&D and neglect later-stage innovation activities carried out at foreign subsidiaries. This chapter attempts to enrich the empirical literature by employing a large data set on the internationalisation decisions of German firms from various sectors by considering different types of innovation activities: R&D, product design, production of new products and services as well as investments in new processes. Closely related to the decision to carry out innovation activities abroad is the location decision since it also reflects firm intentions. The trend to set up corporate innovative capacities in developing countries, especially in the Asian region, has been witnessed in recent studies (UNCTAD, 2005). However, developing regions are underrepresented in most of the existing studies. This chapter will assist in identifying country effects of the driving forces on the decision to locate research and innovation activities in countries with different levels of knowledge (country clubs as proposed by Castellacci and Achibugi, 2008) as well as a specific analysis for innovation investments in China, Eastern Europe, Western Europe and North America. Summing up, the chapter explores three research questions: To which extent do firm capabilities, the level of home market competition and local innovation disadvantages drive a firm's decision to engage in international innovation activities? Do these determinants differ by type of innovation activity? Do these determinants differ with respect to the stage of economic development of the host country?

The next section introduces the theoretical background to the topic while Section 3 describes the data and the measurement of model variables. Chapter 4 presents the results of empirical analyses of the drivers of internationalisation of innovation whereas the geographic destinations and the impact of the driving forces on the location decision of international R&D is shown in Section 5. Section 6 summarises the main findings and concludes with management recommendations.

## **2.1 Literature Review and Hypotheses**

This chapter is built on the stream of literature about internationalisation of R&D including motives, strategies and barriers that affect internationalisation decisions, determinants of internationalising innovation activities as well as the geographic scope of international R&D activities.

### 2.1.1 Internationalisation of Corporate R&D

The internationalisation of firms is an ongoing trend which is encouraged by the increased openness of economies, the rise of new world players, and the firm's need for new sources of competitiveness. It has been pointed out that the pace of internationalising R&D is accelerating and supported by advances in ICT and transport (UNCTAD, 2005).

In the internationalisation theory about firms, the internationalisation process itself has been emphasised as an innovation of the firm (see Andersen, 1993). In the process of globalisation the internationalisation of firms is not limited to sales activities anymore which have been the base for the early internationalisation theory models (Johanson and Vahlne, 1977;1990).

Today, the globalisation of firms' innovation activities has been a major research topic for a long time (OECD, 2008; OECD, 2007; UNCTAD 2006; UNCTAD, 2005; Veugelers et al., 2005; Brockhoff, 1998; Granstrand et al., 1993; Pearce, 1989). One stream relates to the drivers and motives for engaging in innovation activities abroad, in particular with regard to R&D (Dunning, 1994; Kuemmerle, 1999; Narula and Zanfei, 2005; Dunning and Narula, 1995; Pearce, 1999; Pearce and Papanastassiou, 1999; Patel and Vega, 1999; Le Bas and Sierra, 2002; Hakanson and Nobel, 1993; Chesnais, 1992).

A firm's decision to internationalise its innovation activities may be related to three motives (Granstrand et al., 1993): knowledge seeking, market seeking and efficiency seeking. Knowledge seeking firms aim at exploiting a country's endowment with certain research capacities or technologies in order to augment its existing knowledge assets. Establishing innovation activities on site facilitates the access to foreign knowledge and its integration into firm-internal processes (Cantwell and Piscitello, 2005). Market seekers aim to access foreign markets in order to sell their innovations, i.e. to exploit their existing knowledge assets. This often requires adaptations of technologies to local environments and preferences, including user-producer interactions (Pearce 1992, 1999; Pearce and Papanastassiou, 1999). Innovation activities in the foreign market certainly ease this "localisation" of product innovations. Efficiency seeking firms are primarily interested in reducing costs of innovation activities by performing activities in countries with a lower price/productivity ratio for innovation inputs, particularly human capital. It has been shown that firms often follow more than one motive and recent studies illustrate the trend towards R&D intensive subsidiaries abroad (OECD, 2008; Alcáer and Chung, 2002; Kogut and Chang, 1991).

Depending on the motives to internationalise innovation activities, a firm's R&D and innovation units abroad will serve different purposes. There are a number of studies that aimed to differentiate between different types of R&D activities abroad. Ito and Wakasugi (2007) distinguish between support-oriented R&D and knowledge sourcing R&D, Dunning and Narula (1995) between asset-seeking and asset-exploiting purposes, whereas Kuemmerle (1997) differentiates between two international R&D strategy categories of R&D sites abroad. The home-base exploiting laboratory is in charge of the transfer of the existing knowledge of the home-base to the R&D unit abroad for local manufacturing and marketing (market and efficiency seeking). The home-base augmenting laboratory primarily aims to use the knowledge of the host country and transfer it to the home base (resource seeking). Nobel and Birkinshaw (1998) further distinguish international R&D active firms into local and international adaptors as well as international creators. While the category "international creators" is linked to the home-base augmenting firm characteristics following Kuemmerle (1997), the local and international adaptors are both a counterpart to Kuemmerle's home-base exploiting theory. Local adaptors are basically local support units which have a rather limited role in R&D. Their mandate is mainly to facilitate technology transfer from the home base to the local manufacturing (Nobel and Birkinshaw, 1998). Ito and Wagasaki (2007) follow up on this international R&D strategy research with an analysis of the determinants of firms and host countries which foster one or the other strategy. Related to this research are studies on the management of global R&D activities of multinationals (Gerybadze and Reger, 1999; Von Zedtwitz and Gassmann, 2009; Dodgson, 1993, 2000; Kuemmerle, 1997; Ghoshal and Bartlett, 1988; Gupta and Govindarajan, 2000; Boutellier et al., 2000). Another strand of literature emphasises the role of international co-operation in innovation, including research joint ventures, as a mechanism to exploit global opportunities for a firm's innovation activities (Haagedoorn, 1996, 2002; Veugelers, 1997; Cassiman and Veugelers, 2002). Studies on international technology spillovers are another direction of research which captures internationalisation issues in innovation (Veugelers and Cassiman, 2004; MacGarvie, 2005; Guellec and van Pottelsberghe, 2001; Lichtenberg and van Pottelsberghe, 1998; Coe and Helpman, 1995).

### **2.1.2 Driving Forces for International Innovation Activities**

A number of studies have been dedicated to observe the question why some firms carry out innovation activities abroad and others do not. Viewing firms from their



resource and knowledge base has been one perspective in the literature to explain firms' international R&D activities (Wernerfelt, 1984; Peteraf, 1993; Liebeskind, 1996; Grant, 1996).

Internationalising innovation is a specific type of foreign direct investment (FDI). Thus, the theory of the international firm and the determinants for FDI occurrence are also relevant for the investigation of a firm's decision to internationalise its innovation activities. The determinants of a firm's decision to internationalise business processes and their location choice for R&D facilities are combined in the OLI-model of Dunning (1981). The "eclectic paradigm" combines ownership-specific (O), location-specific (L) and internalising (I) advantages for a firm's decision to enter into economic activities beyond its domestic market.

The ownership advantage refers to competitive advantages, resources and capabilities of a firm which can be capitalised abroad. They can be the result of domestic rivalry which pressures firms to constantly improve their business activities (Porter, 1990). Fierce home market competition may result in a high level of product or service quality which makes entering international markets easier. The location-specific advantages refer to specific factor endowments of potential host countries (such as knowledge or skill resources, raw materials, climate, factor costs) which are difficult or costly to acquire through market transaction and form a location advantage in comparison with home country conditions. Localising their businesses in these host countries allows firms to utilise the country specific potentials. The internalising advantage of a firm refers to the added value which firms can gain when conducting business activities abroad by themselves in comparison with outsourced business processes to local firms abroad. These three OLI-advantages capture the extent of company's and host countries' conditions and provide an instrument to evaluate the prerequisites for a successful internationalisation of business processes including R&D.

The design of the empirical analysis of the chapter will follow the outline of the OLI-model and will therefore test the influence of internal resources, capabilities and experience, business and innovation environment on a firm's likelihood to internationalise its R&D.

### ***Internal Resources***

The internationalisation of corporate R&D is associated with a number of challenges. While many multinational enterprises (MNEs) have acquired experience about foreign markets through exports, sales branches or production

activities, managing international innovation processes is likely to be a different task which requires different capabilities (Le Bas and Sierra, 2002; Patel and Vega, 1999; Ito and Wagasuki, 2007). Every firm has a different base of resources, including knowledge and level of experience, and therefore it develops a varying competence level. When it comes to establishing innovation activities abroad, the role of firm competitive advantages resulting from resources and capabilities becomes particularly important. To be able to engage in international innovation activities innovative firms require certain capabilities to identify, absorb and use the knowledge available in host countries. Cohen and Levinthal (1989, 1990) argue that the absorptive capabilities are developed while performing R&D activities internally. Only then firms possess the competence to recognise and to continue using the relevant knowledge outside their organisation. A high level of skilled employees will facilitate these organisational adaptations. It is thus assumed that:

- *Hypothesis 1: The internationalisation of R&D and innovation activities is driven by a firm's absorptive capacities.*

For the confrontation with foreign cultures and business practices, technological competences might not be sufficient to cope with foreign business environments. The costs resulting from being a “stranger” in “a strange land” are summarised in the literature about liabilities of foreignness (Zaheer, 1995; Zaheer and Mosakowski, 1997; Mezias, 2002). International experience of organisations can reduce the uncertainty arising from the exposure to unfamiliar situations and the distance to the home-base (Zaheer and Mosakowski, 1997; Harvey and Novicevic, 2000). Companies can gain the ability to adapt and cope with local challenges by increasing the organisation's international contacts through engaging in joint innovation projects with international partners or by exporting. Exporters, in addition, require more sophisticated knowledge than domestic suppliers (Ito and Wagasuki, 2007). Therefore, it is anticipated that:

- *Hypothesis 2: Firms with international experience are more likely to internationalise their innovation activities.*

### ***Competitive Environment***

The relationship between the competitive firm environment and corporate innovation activities is a field of contradictory research results. Starting from Schumpeter (1943) who finds a negative impact of competition on innovation more recent studies (Aghion et al., 2005) show an inverted U-shaped relationship

between the level of competition and the innovative activities of firms which might try to escape competition by innovation. These findings confirm the earlier results of Scherer (1967) who also found an inverse U-shaped relationship between the intensity of competition and innovation. In the era of globalised competition the home market environment is supposed to drive the internationalisation of innovation activities of firms twofoldly: On the one hand, the type and quality of competition may force firms to respond by leveraging the location advantages of the home and other countries. This will be particularly relevant in the event that firms experience increased competitive pressure in their home market due to strong price competition or due to the entry of new competitors. Firms that are subject to fierce competitive pressure may be compelled to access additional international knowledge pools in order to sustain or re-develop competitive advantages. On the other hand, domestic firms, on account of the globalisation of competition, increasingly face foreign competitors in their home market. These new rivals might have access to resources that firms lack in their home country. Therefore it is expected that:

- *Hypothesis 3: A high degree of competition in the home market propels the likelihood to undertake innovation activities abroad.*

### ***Attractiveness of Domestic Location for Innovation***

The different motives for international R&D (knowledge, market and efficiency seeking) are very likely to be the result of deficits of the innovation environment at the firm's home base. Entering foreign countries in order to establish innovation activities may also reinforce the importance of typical barriers such as financial constraints, lack of information, lack of management capabilities, liability of foreignness and lack of abilities to deal with unfamiliar market and regulatory environments (Acs et al., 1997). Lack of innovation-specific resources and services lowers the attractiveness of a domestic location to conduct innovation. In regard to factor markets this refers on the one hand to the availability and costs of highly qualified labour with skills which a firm requires for conducting a specific innovation project and to the availability of external financial resources and their costs on the other. Kinkel, Lay and Maloca (2007) found that companies that intend to perform less R&D intensive innovation activities abroad are mostly driven by high costs at home and cost-reducing potentials abroad. A further "factor market" relates to technology. Trading technology is, however, rather limited due to its immaterial and tacit character (Polanyi, 1966). Therefore, having access to technological information and

appropriate partners for collaborating in innovation projects may be an important dimension of a location's attractiveness for innovation. Moreover, the willingness of customers to pay for innovations or, more generally, their responsiveness to innovations may form another important element of location attractiveness.

Obstacles to innovation in the home market can therefore act as a pushing effect for firms which aim to compensate home country disadvantages by internationalising corporate innovation (Almeida, 1996). Location disadvantages, especially for innovative firms, are characterised by a shortage of qualified personnel, technological information, high costs, lack of potential cooperation partners, and lack of demand for innovation. Political issues such as legal innovation barriers can also hamper innovation projects (Lall, 1979). Therefore we assume that:

- *Hypothesis 4: Firms which are suffering from innovation-related location disadvantages in their home country are more likely to internationalise their innovation activities to benefit from location advantages in host countries.*

### **2.1.3 International R&D Location Decision - The Case of Developing Countries**

The geographic decision where to locate innovation activities abroad is closely related to the extent and nature of innovation disadvantages of the home country and firms' internationalisation motives. Empirical studies in this field have dedicated their work to regional R&D location analysis within the USA (Audretsch and Feldman, 1996; Alcáer and Chung, 2007) or concentrated on firm strategies between home and host country (Le Bas and Sierra, 2002). Other studies have analysed the location (domestic or abroad) of innovation by patent citation analysis (Jaffe, Trajtenberg and Henderson, 1993; Frost, 2001). Cross-country studies, instead, would contribute to the literature by demonstrating the influence of location determinants and their different impact on various countries. In this vein, Odagiri and Yasuda (1996) have analysed the impact of firms' capabilities and resources on the probability to innovate in Asia, Europe and the USA.

Knowledge, one of the most valuable resources in today's business, is not equally available everywhere. The different allocation of resources in space creates certain 'pockets of expertise' (Nelson, 1993; Porter, 1990) globally. According to a firm's internationalisation strategy (home base-augmenting and/or home base-exploiting) potential host countries differ in their attractiveness for R&D activities. The

importance of host countries' demand and supply factors such as R&D resources for overseas R&D location decision has been pointed out (Odagiri and Yasuda, 1996). Firms wishing to perform R&D outside their home country generally look for countries that offer attractive market potentials, the availability of highly qualified staff and potential cooperation partners (Thursby and Thursby, 2006). Firms normally locate their R&D in countries which are advanced in the same field (Kumar, 1996). They prefer to set up R&D centres in nations with technological resources, a supply of low-cost staff, and good communication infrastructure (Kumar, 1996). However, it remains unclear whether a host country's supply and demand factors can explain the whole motivation of firms' overseas R&D location decision and to what extent home country innovation barriers contribute to this decision. It has been argued that international R&D aims to offset home country disadvantages (Almeida, 1996; Erken and Gilsing, 2005) Therefore, it seems obvious that both the abundance of host and home country's demand and supply factors impact on the firms' location decision. In this chapter we focus on the home country perspective of firms.

Other moderating effects on the location choice include the cultural and geographic distance between the home and the host country. The more distant the home country is from the host country the higher the propensity for unfamiliar hazards which drive the liabilities of foreignness (Eden and Miller, 2004). Firms are aware of these unexpected costs from own experience or from the experience of other firms and aim to reduce these negative effects. Previous country studies discussed that firms tend to follow a national path in their internationalisation innovation strategy (Granstrand, 1999). Ambos (2005) found that German firms tend to cross borders initially only within Europe or to the USA and only later adopt innovation activities in Asian countries.

In the case of German MNEs, countries with developed economic status and advanced knowledge levels are the premier location choice, later followed by countries with a less developed economy. By that time firms have accumulated international experience by being exposed to unexpected and different business environment characteristics at their first (developed) international R&D locations. The acquired international experience serves as a qualification to minimise uncertainties at the foreign R&D site. Knowing that developing countries often offer an even more challenging business environment it is expected that:

- *Hypothesis 5: The effects of firms' international experience on internationalising innovation are stronger when locating innovation activities in developing regions.*

The rise of the emerging giant economies such as China and India has challenged the attractiveness of developed nations. A study by UNCTAD (2005) asked large MNEs about their preferred prospective international R&D location from 2005 until 2009. 62% of the respondents rank China as premier, the United States (41%) as second and India (29%) as their third most attractive R&D location. The literature has been enriched by studies about the setup and management of foreign R&D labs in China (Von Zedtwitz, 2004, Von Zedtwitz et al., 2007) and the innovation potential of India (World Bank, 2007; EIU 2007; Agarwal, Gupta and Dayal, 2007). Based on the emergence of these not only new big markets but also increasingly large and valuable knowledge pools the motives and drivers for international R&D activities have been extended. Sachwald (2008) finds that talent at lower costs and the increasing supply of scientists and engineers in emerging countries foster the trend of international dispersion of corporate R&D. Other studies have already set their focus on the differences of doing R&D in developed versus less developed countries (Thursby and Thursby, 2006). Gassmann and Han (2004) analysed the motivations behind foreign R&D activities in China based on case studies and found that input-oriented factors (skilled HR, local knowledge) as well as performance factors (low overheads) drive these activities. It has always been argued that lower costs in developing countries are a major pull factor to locate R&D capacities in these countries. However, it has been also suggested to neglect short-term return on investment reasons for the decision to internationalise R&D and innovation activities (Von Zedtwitz and Gassmann, 1998). Based on the rationale that research and innovation activities abroad are carried out to access foreign knowledge pools and to adjust innovations to local market requirements the decision to set up R&D capacities abroad should follow a rather long-term strategy. Therefore, it is anticipated that:

- *Hypothesis 6: Efficiency seeking motives (e.g. high innovation costs and price competition in the home country) are less important drivers for locating innovation activities in regions with less developed knowledge levels.*

## **2.2 Database and Empirical Analysis**

### **2.2.1 Data**

This chapter employs data from the Mannheim Innovation Panel (MIP) which is introduced in chapter 1.2. From the data one set of explanatory variables is

conducted to analyse two types of decisions on internationalising innovation: first, a firm's decision to engage in certain types of innovation activities abroad and, second, on a firm's decision to engage their innovation activities in different regions and countries.

### **2.2.2 Explanatory variables**

The empirical analysis requires information from two survey waves of the Mannheim Innovation Panel: 2005 and 2006. The 2005 survey contributes all variables which will be used to characterise a firm's innovation environment, its competitive conditions as well as its internal resources, capabilities and innovation activities, i.e. the supposed drivers of internationalising innovation activities. The variables of the 2005 survey refer to the situation in the financial year 2004. Table 4 summarises the indicators used.

Among the variables on internal resources for engaging in international innovation activities, experience in international activities is measured by two indicators: one indicator measures whether a firm has had any experience in collaborating with foreign partners in innovation projects in 2002-2004 while the other one measures experience in selling products abroad. A firm is regarded as having accumulated experience in successfully protecting intellectual property (IP) when it has been able to use at least one formal or strategic protection measure (out of patents, trademarks, utility patterns, industrial designs, copyrights, secrecy, complex innovation designs, lead time over competitors) in a way that it has made a high contribution to the IP protection. The availability of internal financial resources is measured by the profit margin. Firms reporting a significant positive profit margin in the years prior to the decision to expand innovation activities abroad are regarded as having sufficient internal funding to engage in a high-risk activity such as establishing innovative activities in foreign locations.

The variables characterising the competitive environment, i.e. the significance of price competition and the degree of competition concentration (number of main competitors) were measured by a firm's own assessment with reference to the firm's main product market. This measure of competition by a firm's own perception has the advantage of capturing the effect of firm-specific competition and explaining why some firms undertake more innovation activities than others in the same product market (Tang, 2006).

The existence of a technological advantage of the firm is measured by patent applications (in the absence of information on granted patents); for firms from the service sectors we also consider applications of trademarks since many service innovations, even if they are entirely new to the market, cannot be protected by a patent while trademarks tend to serve as an effective way to protect radically new service innovations (Schmoch, 2003).



Table 4: Explanatory Variables

Model variable	Definition
<b>Internal Resources</b>	
Continuous R&D	1 if a firm conducted in-house R&D continuously in 2002-2004; 0 otherwise
High skilled employees	No. of graduated employees to total number of employees in 2004
Experience in innovation cooperation with foreign partners	1 if a firm co-operated in innovation between 2002 and 2004 with a partner located outside Germany which is at the same time not part of the same enterprise group the firm might belong to; 0 otherwise.
Export experience	1 if a firm had any exports from 2002 to 2004; 0 otherwise
Experience in successfully protecting intellectual property	1 if firm had used at least one formal or strategic protection method for IPR (out of patents, trademarks, utility patterns, industrial designs, copyrights, secrecy, complex innovation designs, lead time over competitors) from 2002 to 2004 which was highly important for protecting its IP; 0 otherwise
Financial resources	Firm reported a profit margin in 2003 and 2004; ordered variable (7 values: 6 categories ranging between 0-15%; 1 for more than 15%)
Technology advantage	1 if a firm has applied for at least one patent and/or (for service sector firms) registered trade mark between 2002 and 2004; 0 otherwise
<b>Home Competitive Environment</b>	
Dominating price competition	1 if price competition is the most important factor of competition in a firm's main product market in 2004; 0 otherwise
Competitive pressure due to market entries	1 if a firm stated that its product market environment (in 2004) is characterised by strong competitive pressure due to market entries; 0 otherwise
Unstable competitive environment	1 if a firm judges the behaviour of competitors as very difficult to foresee in 2004; 0 otherwise
High number of competitors	1 if a firm had more than 6 main competitors in 2004; 0 otherwise
<b>Home Location Attractiveness</b>	
Lack of technological information	1 if a firm stated that the lack of technological information was an important obstacle to innovation between 2002 and 2004 (answers 2 or 3 on a 0 to 3 Likert scale); 0 otherwise
Lack of customer response/demand for innovation	1 if a firm stated that the lack of customer response or demand for innovation was an important obstacle for innovation from 2002 to 2004 (answers 2 or 3 on a 0 to 3 Likert scale); 0 otherwise
Lack of qualified labour	1 if a firm stated that the lack of qualified personnel was an important obstacle to innovation between 2002 and 2004; 0 otherwise
Lack of external sources of finance	1 if a firm stated that the lack of appropriate external financing was an important obstacle to innovation between 2002 and 2004; 0 otherwise
High innovation costs	1 if a firm stated that too high innovation costs was an important obstacle to innovation between 2002 and 2004; 0 otherwise
Lack of appropriate partners	1 if a firm stated that the lack of appropriate partner for innovation was an important obstacle to innovation between 2002 and 2004; 0 otherwise
Regulation as barrier to innovation	1 if a firm stated that regulation and long administrative procedures were an important obstacle to innovation between 2002 and 2004; 0 otherwise
Size	ln(No. employees at FTE in 2004)
Age	ln(time between the year of market entry and 2005)
East German location	1 if a firm is located in East Germany in 2004; 0 otherwise
Manufacturing Industry	1 if a firm belongs to an industry whose NACE classification code is larger than 500

FTE: Full time equivalents; NACE: EU industry classification, rev. 1.2; FSO: Federal Statistical Office of Germany.

The attractiveness of Germany as a location for conducting innovation is measured by a firm's assessment of the relevance of various obstacles to innovation. We consider six such obstacles, each being measured on a 4-point Likert scale: lack of demand for a firm's innovations, lack of qualified personnel, lack of external sources of finance, very high innovation costs, lack of appropriate partners for innovation, and legal innovation barriers. Firms stating that one of these obstacles was medium or very important for impeding their innovation activities from 2002 to 2004 are considered to be facing difficulties with the innovation environment at their domestic location. Control variables for firm size, industry sector, firm age and firm location within Germany are included in both models as well.

### **2.2.3 Dependent Variables**

The first model aims to identify the drivers of a firm's decision to conduct innovation activities outside their home country. Five different types of innovation activities were observed. The variables comprise the *planned* R&D, design/conception of new products, production of new products and the implementation of new processes abroad of firms for the years 2006 and 2007. In order to avoid endogeneity, we do not consider the actual innovation activities abroad (which may refer to firm decisions long time ago) but currently planned internationalisation of innovation activities in the respective year. The sample is restricted to firms with innovation activities at their German home location. Foreign-owned firms were dropped from the sample since the survey information from foreign-owned firms in Germany concerning their international innovation activities can be ambiguous. These firms might have reported innovation activities abroad which are actually located at their foreign headquarters. These cases would not reflect the intention of this study to investigate the internationalisation decision of corporate innovation activities.

The 2006 survey also asked firms in which countries (free text) they currently perform and plan to perform the four different innovation activities predominantly. The second model makes use of this information by analysing how the abilities of firms and the firms' business and innovation environment influence their likelihood to perform innovation activities in a specific country or region. Based on the idea that firms look for developed knowledge pools, lead markets and efficiency advantages, the dependent variables are set up to group countries by their level of knowledge as proposed by Castellacci and Achibugi (2008) as technology clubs. In this vein, three groups of technology clubs are

defined: advanced followers and marginalised countries (for a detailed list of countries and their respective category see Table 5). China and India are in the same technology club (marginalised countries) as African countries, but due to their greater attractiveness for firms in terms of market size, speed of economic growth and absolute numbers of graduates they might have a different priority than other countries in the same technology club. Therefore, country and regional variables for China, North America, Western Europe and Eastern Europe are generated to measure the influence of internationalisation drivers for certain countries and regions of interest.

#### **2.2.4 Empirical Analysis**

In a first step, the sample of model 2 has been restricted to firms that carry out at least one of their R&D and innovation activities abroad in order to be able to compare the effects of the internationalisation drivers for different countries and regions. However, for the reader, the use of a uniform sample for both models seemed easier to follow and the results from both the restricted sample and the sample used in model 1 do not vary significantly. Therefore, the choice of the sample was done in favour of one uniform sample for the R&D abroad and R&D location decision.

Initially, separate probit models for each decision (by type of innovative activity abroad and location abroad) were estimated with marginal effects for both estimation models. However, for the second model, the decision to carry out innovation activities in certain regions can be a simultaneous decision process. Therefore, the location-specific effects of international innovation drivers were estimated with two multivariate probit models with marginal effects. One multivariate probit estimation was done for the advanced, follower and marginalised country classification and a second one for the regions Western Europe, Eastern Europe, North America and China.<sup>4</sup>

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<sup>4</sup> Due to fruitful remarks from Otto Toivanen at the Zvi Griliches Research Summer School in Barcelona, July 2009, a rare event logit model (King and Zeng, 2001) has been estimated to capture the effects of the observable driving forces for rare events such as planned innovation activities of German firms in North America (3 %). However, no varying results have been achieved by this analysis.

Table 5: Definition of Dependent Variables

Model variable	Definition
<b>Planned Research and Innovation Activities Abroad</b>	
Planned internationalisation of innovation activities of type $k$	1 if a firm plans to take up or expand type $k$ innovation activity outside Germany in 2006 or 2007; 0 otherwise ( $k$ : R&D, design/preparation of innovations, production of new products, implementation of new processes)
<b>Planned Research and Innovation Activities in Different Countries and Regions</b>	
Planned internalisation of innovation activities of type $k$ in country $c$	1 if a firm plans to take up or expand type $k$ innovation activity outside Germany in 2006 or 2007 in one of the $c$ countries or technology clubs ( $c$ : advanced, followers, marginalised, China, North America, Western Europe, Eastern Europe); 0 otherwise
Advanced countries	Northern Europe, Scandinavia, Switzerland, Netherlands, Norway, Denmark, UK, Sweden, Finland, Western Europe, Iceland, Japan, USA, Canada, Australia, Israel
Follower countries	Austria, Belgium, Benelux, France, Luxembourg, Poland, Romania, Slovakia, Czech Republic, Hungary, Slovenia, Serbia/Kosovo, Croatia, Bulgaria, Bosnia, Spain, Italy, Turkey, Greece, Cyprus, Portugal, Ireland, Malta, Latvia, South Korea, South East Asia, Singapore, Malaysia, Hong Kong, Thailand, Philippines, South America, Brazil, Chile, Mexico, Argentina, Peru, Columbia, Russia, Ukraine, Georgia, Baltic, Belarus, Lithuania, Saudi Arabia, Lebanon, Libya, UAE, Middle East, Near East, Dubai, South Africa
Marginalised countries	China, India, Pakistan, Vietnam, Taiwan, Sri Lanka, Indonesia, Mongolia, Iran, Macao, Montserrat, Africa (except for South Africa)
China	China
North America (NA)	USA, Canada
Western Europe (WestEU)	Switzerland, Netherlands, Norway, Denmark, UK, Sweden, Finland, Iceland, Austria, Belgium, Benelux, France, Luxembourg, Spain, Italy, Portugal, Ireland, Malta
Eastern Europe (EastEU)	Middle and Eastern European countries (CEE, MEE, MOE)

### 2.3 Drivers of Internationalising Innovation Activities

In the retrieved sample of 1439 innovative firms which are headquartered in Germany about 24% of the companies plan to set up or to expand existing international innovation activities abroad. 16% thereof want to manufacture innovations outside Germany, 11% intend to develop new products and about 10% to implement new processes abroad. In the sample, 8% of the firms plan to set up internal research capacities abroad which makes it the less internationalised of the observed innovation activities (the detailed descriptive statistics is provided in Table 8 in the appendix). Analysing the drivers of internationalising decisions for innovation activities the results in Table 6 clearly show that the most prominent forces to set up R&D capacities abroad are the firm's capabilities and resources. The decision to internationalise any innovation activity shows the strongest influence from previous international experience and the firm's

absorptive capacity. The home innovation environment indicates also a positive stimulus; in particular, the lack of information and high innovation costs spur the internationalisation decision. For each single type of innovative activities previous export experience is found to have a strong influence, especially on the internationalisation of manufacturing innovative products abroad as well as on the design of new products (Hypothesis 2 supported). Export experience seems to provide knowledge about market conditions, demand and location advantages which might increase the likelihood to set up the manufacturing of innovative products and new processes abroad. This is in line with findings from Ito and Wagasuki (2007) stating a positive relationship between export activities and overseas R&D. However, similar to previous studies, the causality between export and international R&D activities remains ambiguous. This study has tried to circumvent this causality problem by relating existing exporting activities in the year 2004 to the intention of firms to internationalise their R&D activities in 2006. Surprisingly, previous international experience gathered by international research cooperation has no significant effects on the decision to locate single innovation activities overseas but it increases the likelihood for the decision to internationalise any innovation activities by 9%. Firms which plan to internationalise their R&D activities show stronger effects on the continuously performed in-house R&D and a high share of skilled labour. These indicators reflecting the importance of absorptive capabilities for international research activities (Hypothesis 1 partly supported) and the design of very innovative firms are supported by the positive effect of technological advantages of these firms on their likelihood to decide for international Research and Design. Surprisingly, the share of highly skilled employees has a negative effect on the decision to implement new processes abroad. Other firm resources which promote the decision of later-stage innovation activities such as the manufacturing of new products and the implementation of new processes abroad are the experience in intellectual property rights use. It seems that the potential loss of knowledge is greatest when it is embodied in products and services. Firms with pronounced financial resources are also more likely to manufacture their products abroad.

Regarding the influence of competition on the likelihood to perform innovation activities abroad, varying results are found. While the quality of competition, namely price competition, in the home market has a negative effect on the manufacturing and export of innovative goods the quantity of competition, here measured as the entry of new competitors, shows positive effects. Firms that face price competition are very likely to operate not at the leading edge of technology, thus explaining the lesser likelihood of carrying out innovation activities abroad.

As for the quantity of competition in the home market, the results show that firms which face competition from new market players are by 3% more likely to implement new processes abroad. Therefore, more intense competition seems to drive the decision to carry out later-stage innovation activities abroad (Hypothesis 3) and to escape competition by innovation. However, competition has no effect on the likelihood of carrying out R&D intensive activities at foreign locations.

The influence of firms' home country innovation environment on their innovation performance abroad shows positive and negative effects. Hereby, it was argued before that firms which are hindered by home country-specific innovation barriers will be more motivated to change their R&D location (Hypothesis 4). For the general decision to internationalise innovation activities the lack of information and high innovation costs demonstrate significant positive incentives. For the decision to expand single innovative activities abroad the lack of labour and high innovation costs in the home country, the often mentioned forces which make firms locate their R&D abroad, actually effect only the decision to set up innovation manufacturing capacities abroad positively. However, the lack of customer response in the home country makes firms less likely to design and manufacture innovative products abroad, which indicates that firms do not try to take advantage of different demands worldwide.

The results for firm size show that larger firms tend to be more likely to decide in favour of the manufacturing and development of new products and processes abroad. Firm age and firm location (in Eastern Germany) are negatively associated with the decision to internationalise innovation activities.

Table 6: Drivers to Internationalise Innovation Activities of German MNEs (by Innovation Activity): Marginal Effects of Probit Models

	Any Innovation Activity Abroad	Planned Research Abroad	Planned Design/ Conception Abroad	Planned Manu- facturing Abroad	Planned New Processes Abroad
<i>Firm Capabilities and Ressources</i>					
Continuous Inhouse R&D	0.068 ***	0.046 ***	0.036 *	0.017	0.010
High skilled employees	0.061	0.059 ***	0.037	-0.011	-0.048 *
Innovation coop. with intl. Partners	0.086 **	0.010	-0.001	0.042	0.015
Export experience	0.131 ***	0.044 ***	0.083 ***	0.116 ***	0.059 ***
Experienced usage of IPR	0.032	0.010	0.013	0.048 **	0.027 *
Financial Ressources	0.007	0.002	0.003	0.011 **	0.001
Technological advantage	0.025	0.028 *	0.036 *	0.004	0.015
<i>Home Competitive Environment</i>					
Price competition	-0.022	-0.001	-0.004	-0.034 *	-0.008
Unstable competitive situation	-0.013	-0.003	-0.002	0.000	-0.006
Competition from new competitors	0.011	0.012	0.026	0.031	0.027 **
High number of competitors	-0.007	-0.014	0.007	-0.006	-0.015
<i>Home Innovation Environment</i>					
Lack of technological information	0.100 **	0.020	0.006	0.033	0.016
Lack of customer response	-0.044	-0.013	-0.055 ***	-0.048 **	-0.014
Lack of qualified labour	0.021	-0.011	0.026	0.057 *	-0.009
Lack of ext. sources of finance	0.002	0.001	-0.001	0.023	0.014
High innovation costs	0.063 **	0.003	0.027	0.089 ***	0.025
Lack of appropriate partners	0.007	0.027	0.042	0.002	-0.002
Regulation as barrier for innovation	-0.020	0.017	0.021	-0.028	0.006
<i>Control Variables</i>					
Firm size	0.017 ***	0.003	0.004	0.019 ***	0.015 ***
Firm age	-0.014	-0.005	-0.023 **	-0.017	-0.013 **
Firm located in East Germany	-0.069 ***	-0.008	-0.044 ***	-0.062 ***	-0.034 ***
Manufacturing Industry	0.025	0.041	0.041	0.171 **	0.100 *
Pseudo R-squared	0.14	0.21	0.12	0.20	0.30
No. of Observations	1439	1202	1198	1200	1193

\*\*\*1% Significance; \*\*5% Significance; \*10% Significance

## **2.4 Drivers for International R&D and Innovation Activities by Host Country, Region and Technology Club**

The regional analysis of international innovation activities aims to observe country-specific effects of driving forces to internationalise innovation. In this regard the host countries of a firm's innovation activities abroad are the central point of interest in this analysis. The descriptive results show that for innovative German firms planning to internationalise their R&D the most popular region (for 13% of the sample firms) are nations with medium developed knowledge levels (follower countries). Nations with both advanced and marginalised knowledge infrastructure account for 6% of the firms in the sample as their preferred prospect innovation location (for detailed descriptive statistics refer to Table 8 in the appendix section, see also Rammer and Schmiele, 2008).

The results of the regional analysis of innovation internationalisation drivers are shown in Table 7 stating that the main factors which lead firms to innovation activities in certain countries and regions are firm capabilities and resources and only to a lesser extent location disadvantages in the home country. Competition rather hinders the location of innovation to one of the observed countries and regions. The results illustrate that the effects of firms' international experience are more pronounced for firms planning to set up or expand innovation capacities in follower countries than in advanced and marginalised countries. International experience via international cooperation partners demonstrates only a stronger impact on the propensity to move innovation activities to China than exports. The direct comparison between the effects of international experience (exports) between advanced and marginalised host countries shows slightly stronger effects for the marginalised group of countries (Hypothesis 5). Furthermore, the effect of firm's technological advantage on firm's decision to innovate in North America is lower than for China.

The last hypothesis was directed towards the motives which make firms set up or expand their innovation activities into countries with developing knowledge levels. The results show that the innovation-related location disadvantages of the home country, namely the lack of appropriate partners and regulation barriers show negative significant coefficients. It demonstrates that firms which are affected by these two innovation barriers are less likely to plan innovation activities in marginalised countries and, particularly in China. High innovation costs as the anticipated drivers for R&D in developing countries show negative



significant results for countries with advanced knowledge levels and slightly positive significance for follower countries.

Similar results are found for the effect of the competitive environment as location choice driver. A high number of competitors as well as unforeseeable competitive behaviour do not have an effect on the likelihood of carrying out innovation activities in a specific region of the world. For China, a negative significant effect is found from the quality of competition. Firms which face price competition in the home country are less likely to move their innovative capacities to China. This result partly supports hypothesis 6.

Other results which describe the nature of firms with plans to build up innovation capacities overseas show that firm size turns out to be a relevant characteristic for firms planning to innovate in China and in the East European countries. The manufacturing industry indicates a slightly positive likelihood to innovate in follower countries while firms from Eastern Germany are less likely to innovate in marginalised and follower countries as well as in North America.

Table 7: Drivers to Internationalise Innovation Activities (by Region): Two Multivariate Probit Models with Marginal Effects

	1	2	3	4	I	II	III	
	China	EastEU	WestEU	NA	Advanced	Followers	Marginalised	
<i>Internal Ressources &amp; Capabilities</i>								
Continuous inhouse R&D	-0.000	0.027 *	0.024 **	0.000	0.009	0.039 **	0.010	
High skilled employees	-0.020	0.018	0.022	0.005	0.015	0.047	-0.007	
Innovation coop. with intl. Partners	0.028 *	-0.003	0.018	0.006	0.027	0.025	0.023	
Export experience	0.014 **	0.042 ***	0.015	0.005	0.024 ***	0.060 ***	0.028 ***	
Experienced usage of IPR	0.001	-0.003	0.021 *	0.005	0.029 ***	0.020	0.002	
Financial ressources	0.003 ***	-0.002	0.003	0.001	0.001	0.001	0.004 **	
Technological advantage	0.018 *	-0.009	-0.009	0.013 *	0.004	-0.004	0.018	
<i>Home Competitive Environment</i>								
Price competition	-0.012 **	-0.005	-0.010	-0.002	-0.007	-0.008	-0.005	
Unstable competitive situation	0.000	-0.004	-0.003	0.001	-0.006	-0.010	0.006	
Competition from new competitors	-0.004	-0.001	0.011	0.003	0.019 **	-0.001	-0.003	
High number of competitors	-0.005	-0.002	0.010	-0.003	0.006	0.010	0.002	
<i>Home Innovation Environment</i>								
Lack of technological information	0.012	0.019	0.005	-0.003	0.007	0.027	0.023	Log likelihood of multivariate probit est. 1-4: -812.919
Lack of customer response	0.015	-0.014	-0.005	-0.003	-0.004	-0.015	0.025	Correlation coeff. betw. Eq. 1-2 0.043
Lack of qualified labour	-0.005	0.011	0.016	0.001	0.011	0.001	0.003	Correlation coeff. betw. Eq. 1-3 0.022
Lack of ext. sources of finance	-0.005	-0.012	0.008	0.005	0.020	-0.012	-0.011	Correlation coeff. betw. Eq. 1-4 0.347 **
High innovation costs	0.010	0.031	-0.016	-0.005	-0.025 ***	0.044 *	0.013	Correlation coeff. betw. Eq. 2-3 0.066
Lack of appropriate partners	-0.006	-0.002	0.014	0.004	0.007	-0.023	-0.022 ***	Correlation coeff. betw. Eq. 2-4 0.302 **
Regulation barrier for innovation	-0.017 ***	-0.005	-0.001	0.009	0.009	-0.015	-0.024 ***	Correlation coeff. betw. Eq. 3-4 0.099
<i>Control Variables</i>								
Firm size	0.004 **	0.007 **	-0.002	0.001	0.003	0.006	0.003	Log likelihood of multivariate probit est. I-III: -868.860
Firm age	-0.002	0.007	-0.002	-0.001	-0.003	0.007	-0.003	Correlation. coeff. betw. Eq. I-II 0.246 **
Firm located in East Germany	-0.005	-0.005	-0.019 **	-0.002	-0.006	-0.040 **	-0.015 *	Correlation. coeff. betw. Eq. I-III 0.200
Manufacturing Industry	0.015	0.008	0.005	-0.000	-0.005	0.091 *	0.018	Correlation. coeff. betw. Eq. II-III 0.616 ***
No. of Observations	1439				1439			

\*\*\*1% Significance; \*\*5% Significance; \*10% Significance

## 2.5 Conclusion

The chapter aimed to shed light on driving forces from firms' local business and innovation environment as well as the influence of firms' capabilities and resources to perform innovation activities abroad. Moreover, this study went beyond the term 'R&D abroad' which is the state of the art in the literature of internationalisation of R&D. The contribution is a detailed analysis of four different innovation activities which firms plan to carry out abroad. Furthermore, the study not only distinguished the effects of the driving forces by the different types of R&D activities abroad but it also analysed the effects of firm capabilities, firm's competitive environment and home country location disadvantages as drivers for the planned innovation activities in developed and developing countries as well as in country groups with different level of technology knowledge.

It could be shown that firm capabilities and resources, in particular absorptive capacities and international experience, are most important for the decision to internationalise innovation activities. High innovation costs and the lack of qualified labour propel only the later-stage innovation activities abroad while firms which are confronted with innovation obstacles are not seeking to overcome these constraints by innovating abroad. Companies performing R&D abroad are not driven by high competition either. The overall retrieved picture from the analysis demonstrated that firms rather use R&D activities abroad to continue strengthening their existing capabilities and business success than to escape intensive competition.

Firms which plan to innovate abroad have accumulated experience with foreign markets by exporting. Firms with the decision to innovate in developing countries like China in the near future have shown that more elaborate international contacts via innovation collaborations are necessary. R&D in developing countries is still a very open field in the literature and the results achieved in this chapter help to clarify the conditions leading firms to innovate in countries with 'marginal' knowledge stocks. Again, it becomes obvious that firms which face price competition are not pushed to developing countries to manufacture innovative goods or to carry out other innovation activities in Asian and in marginalised countries.

The results indicate that firms wishing to internationalise their R&D activities should have developed absorptive capacities and international experience. If the choice of location is a country belonging to the group of countries with lower developed knowledge levels or Asian countries additional cultural competence should be gathered by engaging in partnerships with international innovation partners. Policy implications can be directed to foster international innovation projects for firms to make international innovation experience or generally to set incentives to perform R&D on a continuous base and overcome innovation disadvantages at the home location. Furthermore, it could be shown that the trend to move innovative capacities to emerging regions can be blocked by legal innovation regulation.

## **2.6 Limitations**

The research work in this chapter has some limitations that need to be mentioned in order to position the results correctly. The results of this research have to be assumed to be quite time sensitive. When fast emerging countries develop higher levels of knowledge they will supposedly attract more R&D-intensive activities from abroad.

## 2.7 Appendix

Table 8: Descriptive Results for Dependent and Explanatory Variables

No.	Explanatory Variables	Mean	Std.Dev.	Min	Max
	China	0.049	0.215	0	1
	EastEU	0.068	0.252	0	1
	WestEU	0.052	0.222	0	1
	NA	0.027	0.162	0	1
	Advanced	0.058	0.234	0	1
	Followers	0.127	0.333	0	1
	Marginalized	0.060	0.237	0	1
	Planned Research Abroad	0.076	0.266	0	1
	Planned Design/ Conception Abroad	0.111	0.314	0	1
	Planned Manufacturing Abroad	0.159	0.366	0	1
	Planned New processes Abroad	0.096	0.294	0	1
	Planned Any innovation activity Abroad	0.239	0.426	0	1
1	Continuous Inhouse R&D	0.434	0.496	0	1
2	High skilled employees	0.239	0.253	0	1
3	Innovation coop. with intl. Partners	0.127	0.333	0	1
4	Export experience	0.581	0.494	0	1
5	Experienced usage of IPR	0.504	0.500	0	1
6	Financial Resources	2.941	2.110	0	7
7	Technological advantage	0.346	0.476	0	1
8	Price competition	0.448	0.497	0	1
9	Unstable competitive environment	0.502	0.500	0	1
10	Competition from new competitors	0.444	0.497	0	1
11	High number of competitors	0.397	0.489	0	1
12	Lack of technological information	0.082	0.275	0	1
13	Lack of customer response	0.121	0.326	0	1
14	Lack of qualified labour	0.127	0.333	0	1
15	Lack of ext. sources of finance	0.170	0.376	0	1
16	High innovation costs	0.266	0.442	0	1
17	Lack of appropriate partners	0.078	0.269	0	1
18	Regulation as barrier for innovation	0.169	0.375	0	1
19	Firm size	4.187	2.002	0	12.181
20	Firm age	2.679	0.863	-0.693	5.527
21	Firm located in East Germany	0.348	0.477	0	1
22	Manufacturing Industry dummy	0.041	0.199	0	1

Table 9: Correlation matrix of explanatory sample variables (by No., see Table 8)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
1	1																						
2	0.201	1																					
3	0.354	0.193	1																				
4	0.324	-0.018	0.201	1																			
5	0.461	0.137	0.287	0.373	1																		
6	-0.028	-0.029	0.004	-0.037	-0.007	1																	
7	0.472	0.135	0.381	0.314	0.527	-0.036	1																
8	-0.150	-0.172	-0.115	-0.098	-0.145	-0.073	-0.087	1															
9	-0.064	-0.023	-0.080	0.045	-0.017	-0.010	-0.027	0.117	1														
10	-0.089	-0.092	-0.041	-0.057	-0.079	-0.006	-0.053	0.117	0.186	1													
11	-0.058	0.006	-0.005	-0.091	-0.058	0.058	-0.056	0.102	0.039	0.168	1												
12	0.053	0.043	0.042	0.050	0.059	-0.022	0.045	0.001	0.036	0.028	0.007	1											
13	0.086	0.063	0.068	0.002	0.043	0.023	0.050	-0.029	0.009	0.037	0.015	0.404	1										
14	0.069	-0.007	0.022	-0.004	0.025	0.048	0.025	-0.034	0.001	0.020	0.001	0.363	0.222	1									
15	0.101	0.112	0.056	0.026	0.072	-0.094	0.033	0.034	-0.037	0.011	-0.037	0.255	0.224	0.211	1								
16	0.084	0.081	0.034	0.029	0.033	-0.060	0.050	0.009	0.017	0.007	0.038	0.325	0.355	0.302	0.559	1							
17	0.049	0.051	0.049	0.000	0.026	-0.075	0.018	0.021	-0.010	0.005	-0.012	0.323	0.276	0.246	0.369	0.328	1						
18	0.076	0.046	0.078	-0.017	0.066	-0.029	0.073	0.004	0.023	0.031	0.006	0.281	0.335	0.286	0.370	0.460	0.295	1					
19	0.278	-0.221	0.295	0.200	0.246	0.043	0.355	0.033	-0.060	-0.069	0.010	-0.012	0.037	-0.008	-0.132	-0.051	-0.072	-0.006	1				
20	0.011	-0.153	-0.011	0.049	-0.044	-0.011	0.026	0.047	0.037	0.002	0.025	0.010	0.028	0.000	-0.070	-0.031	0.003	-0.049	0.268	1			
21	0.002	0.170	-0.072	-0.098	-0.084	-0.030	-0.105	0.066	0.026	0.019	0.010	-0.013	-0.022	-0.029	0.074	0.100	-0.002	0.062	-0.233	-0.271	1		
22	0.186	-0.005	0.353	0.133	0.189	0.074	0.240	-0.034	-0.022	-0.032	0.014	-0.031	0.014	-0.054	-0.071	-0.038	-0.013	-0.003	0.441	0.113	-0.143	1	

### **3 The Influence of International Dispersed vs. Home-based R&D on Innovation Performance<sup>5</sup>**

A firms' competitiveness depends to a great extent on its innovativeness. Due to the increasing technological complexity of products and processes and the speeding up of technological progress, firms have to source knowledge outside their boundaries in order to complement internal knowledge. This includes the use of globally available resources to foster their innovation outcomes (Kotabe, 1990). In order to do so, firms may pursue different strategies. The two most prominent strategies are to cooperate with international partners or to establish own research and development (R&D) laboratories abroad. Fascinatingly, the recent decade has shown that corporations increasingly globalise their R&D and innovation activities by setting up own foreign R&D departments (UNCTAD, 2005). This phenomenon can be observed for both large multinational firms (MNEs) and international SMEs. In Germany for instance, about 3% of innovative firms without foreign R&D activity in 2005 planned to start it in the subsequent two years 2006/2007 (Rammer and Schmiele, 2008).

The international business literature stresses that firms pursue two main motives by performing their R&D activities abroad (Granstrand et al., 1993, Von Zedtwitz and Gassmann, 2002, Kuemmerle, 1997). On the one hand, firms want to adapt their existing technologies to local demand and manufacturing conditions (exploitation strategy). On the other hand, by setting up foreign R&D subsidiaries firms seek to get access to local science and technology resources which enable them to absorb and integrate knowledge from abroad into their innovation process (home-base augmenting strategy). It has been emphasised that an effective innovation strategy needs to balance the exploitation of existing knowledge with non-local knowledge exploration (Levinthal and March, 1993). It has further been proven that putting existing pieces of knowledge together often leads to

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<sup>5</sup> This research work is based on Peters and Schmiele (2010a).

innovations (Grant, 1996; Arora and Gambardella, 1990; Cohen and Malerba, 2001). In this vein, the internationalisation of innovation activities may lead to the combination of existing knowledge from the firm's knowledge stock with foreign knowledge contributed by foreign local staff and spillovers from the firm's foreign business environment such as cooperating firms, competitors, customers, suppliers and scientific institutions. Given that knowledge spillovers are stronger within countries than across countries (Jaffe et al., 1993; Branstetter, 2001), firms that perform R&D activities only in their home country are less likely to have access to foreign knowledge. Learning-by-exporting has been considered one alternative of how firms could benefit from foreign countries' expertise by engaging in local markets and interacting with customers (Clerides et al., 1998; Bernard and Jensen, 1999). However, it is pointed out that knowledge often cannot overcome national boundaries when it is not codified (implicitly) and embedded in routines and thus hard to transfer (Kogut, 1991; Kogut and Zander, 1992).

The potential knowledge gains from foreign R&D stand facing potential losses. They may arise due to intra-firm knowledge losses, intra-firm coordination costs of research or foregone economies of scale in conducting research. Despite the trend to internationalise R&D, the empirical evidence about the effectiveness of foreign R&D in terms of innovation output is rather scarce and limited to patents. But patent-based indicators have been heavily criticised as being a rather poor yardstick for innovative output (see, e.g., Scherer, 1965; Griliches, 1990). In this chapter we address the question whether international R&D is conducive to a firm's *innovation performance*.

Our research aims at extending the existing literature in three ways. First, we use two alternative well-established market-based innovation performance measures. We provide evidence of how potential gains from foreign R&D activities influence the introduction of new products ("*innovation outcome*") and whether firms with foreign R&D achieve a higher sales growth with innovative products ("*innovation success*"). Product innovations can be either new to the firm only (firm novelty) or to the market as a whole (market novelty), i.e. they greatly vary according to their degree of novelty. We suppose that foreign R&D is more crucial for developing market novelties and thus, secondly, examine whether the effects vary with the degree of product novelty. Since firms are expanding their number of international research locations, we finally investigate the effect of a greater *decentralisation of foreign R&D locations* on firms' innovation performance.



To answer our research question, we estimate knowledge production functions (Pakes and Griliches, 1984) by employing the two-step selection model proposed by Heckman (1979). The empirical analysis draws upon a sample of about 2100 German firms collected within the Community Innovation Surveys (CIS). In contrast to previous studies that mainly compare the contribution of foreign and home-based R&D activities for firms with globalised R&D activities, our data set allows us to liken firms with globalised R&D to firms performing R&D only at their home country or doing no R&D activities at all. The potential added value of foreign R&D to domestic R&D in comparison with only domestic R&D activities in terms of innovation performance is interesting both to scholars and managers.

To summarise our main results: We find that firms with both domestic and foreign R&D activities are more likely to launch new products (both firm and market novelties) than firms with home-based R&D only. Given the introduction of a new product they do likewise achieve a significantly higher sales growth due to this innovation than firms with home-based R&D only. This higher innovation success can be traced back to firm novelties. No differences in innovation success, however, could be found for market novelties. The degree of R&D internationalisation has an inverse u-shaped effect on both innovation performance measures. A moderate number of R&D locations abroad exert the strongest influence on innovation outcome with new products, market and firm novelties. Further, sales growth due to product innovations and firm novelties also peaks with a moderate number of R&D locations abroad.

This chapter continues in the following outline: Section 2 presents related literature and relevant theoretical concepts which lead to the development of hypotheses. Section 3 explores the dataset and the empirical methods which are employed to test the hypotheses. Section 4 sets forth the results of the econometric analysis, and Section 5 concludes with a discussion of the empirical results and management recommendations.

### **3.1 Internationalisation of R&D Activities – What Do We Know so Far?**

#### **3.1.1 Potential Benefits of International R&D**

Multinational Enterprises (MNE) are said to be an important driver of globalization by increasing the interdependency and relatedness of geographically

dispersed actors (Archibugi and Immarino, 2002). The internationalisation of internal R&D activities has followed the internationalisation of production and other market-related business processes. Though R&D still shows the least degree of internationalisation of all business processes, it is an increasing phenomenon (see UNCTAD, 2005). The UNCTAD (2005) report shows that about 40% of the Western European firms have international R&D expenditures in comparison to 24% of the North American MNEs and 15% of the Japanese multinationals. The industries which show the highest degree of international R&D spending are chemicals, pharmaceuticals, electronics and automotive.

The motivations of firms to internationalise their R&D have been distinguished into market seeking, technology seeking and efficiency seeking purposes. However, it is unlikely that firms are driven only by one but rather by all three motivations (DeMeyer, 1993). Furthermore, the objectives of R&D labs abroad have been changing over time towards knowledge sourcing and development tasks (Frost, 2001; Hakanson and Nobel, 1993; Wortmann, 1990). The internationalisation of R&D enables firms to both widen and deepen their technological scope (Pearce and Papanastassiou, 1996) due to improved technical learning which is fostered by international R&D activities (DeMeyer, 1993).

The resourced-based theory of the firm provides a framework to explain the differences in firms' strategic decisions, performance and competitive advantage (Grant, 1996; Liebeskind, 1996). Firms are seen as bundles of resources and capabilities that act as knowledge-integrating institutions and develop and deploy the resource base (Grant, 1996). Firms with superior resources will generate rents (Peteraf, 1993). The knowledge-based view which has evolved from the resource-based theory emphasises knowledge as one of the most valuable resources. The sourcing of global knowledge would allow firms to gather additional and distinct knowledge relative to rivals and inhibits the chance to build an idiosyncratic knowledge base which can become a competitive advantage (Peteraf, 1993). This mindset leads to the assumption that numerous pools of knowledge are more beneficial to a firm's innovativeness than a few sources. For developing new products, however, it is ultimately essential to apply the knowledge which creates a competitive advantage in case of a successful innovation (Liebeskind, 1996; Grant, 1996). The knowledge-based view of the firm thus implies that the foreign knowledge will increase firms' innovativeness and market success with innovations when they possess abilities necessary to utilise their knowledge base. In this regard, the corporate knowledge base also provides the foundation to

decide which and how knowledge is applied in actual and future periods (Ndofor and Levitas, 2004).

### 3.1.2 Moderating Factors of Firms' Benefits of International R&D

The potential benefits of international R&D activities are moderated by a number of factors that can hamper the outcome of international research activities. The improvement of innovation performance can only be as strong as the international R&D performing firms realise and use the chances of these ventures. Thus, it is important for firms to pursue an appropriate strategy to capture the resources abroad which are beneficial to them and to avoid losses.

First, the *roles and tasks* which are assigned to the innovating subsidiaries abroad affect their importance for the firms' innovation output (Iwasa and Odagiri, 2004). The mandates of subsidiaries abroad differ by their level of R&D orientation and their focus on production support. Some R&D labs abroad have the task to absorb new knowledge and to develop new products. They act as 'knowledge augmenting' units (Kuemmerle, 1997) or 'global creators' (Nobel and Birkinshaw, 1998). Other R&D centres abroad are characterised as 'local or global adaptors' (Nobel and Birkinshaw, 1998), 'home base exploiting' (Kuemmerle, 1997) units or 'support laboratories' (Pearce, 1989). Their work description comprises the support of local production, the assimilation of market knowledge and the application to customers' satisfaction (Pearce and Papanastassiou, 1996). According to their different mandates, R&D centres abroad are likely to generate distinct degrees of quality and quantity of knowledge and skills. While some subsidiaries can contribute to the development of new products, the adaptation of existing products is aimed at enhancing the sales of innovative products on foreign markets.

The type of R&D, and as a result the degree of novelty of the innovation output, is also determined by the *international R&D organization* (Chiesa, 1996), in particular by the *degree of decentralisation*. A centralised R&D organization conducts all the necessary work to develop new products in one location (Malecki, 1980) which is mostly in the firm's home country. In decentralised R&D structures, research is carried out within divisions or business units (Argyres and Silverman, 2004). The role of decentralisation for innovation performance is ambiguous. Some scholars have argued that centralization of R&D facilities is the better R&D organization for research purposes since economies of scale and scope can be realised (Malecki, 1980; Von Zedtwitz et al., 2004). The international decentralisation of a firm's R&D organization demands not only the

management of corporate innovation efforts between foreign subsidiaries and the headquarter but also across nation borders. This involves the risk that knowledge is getting lost when it is transferred between R&D units (Szulanski 1996) or that innovation projects are duplicated in different R&D units (Gassman and Von Zedtwitz 1999). The increase in transactions due to the internationalisation is likely to drive the costs as proposed by the transaction cost theory (Coase, 1937; Williamson, 1985). Opponents argue that R&D decentralisation reduces managerial opportunism at a single R&D centre and empowers divisions which are closer to markets and specific demands (Von Hippel, 1988; Williamson, 1985).

Another linchpin is the degree of international R&D decentralisation and the *way of transferring and integrating international subsidiary knowledge* into the corporate innovation process. The management and integration of international R&D centres are an important topic in the international business literature (Gassmann and Von Zedtwitz, 1999; Von Zedtwitz et al., 2004; Edler et al., 2002; Hemmert, 2003/04). It has been argued that the exploitation of the potential global know-how does not depend on the presence of R&D labs in many parts of the world per se but, more importantly, on the internal firm mechanisms to integrate the knowledge across the R&D organization (Singh, 2008). Leveraging the capabilities and resources of subsidiaries across divisions and locations has been put forward to be essential for the global success of firms (Bartlett and Ghoshal, 1989; Birkinshaw et al., 1998; Frost et al., 2002; Nobel and Birkinshaw, 1998). In our research framework, special attention has to be paid to knowledge flows within MNEs. The integration of the foreign R&D labs is on the one hand fostered by personnel contacts and exchanges between home and overseas R&D centres. It is likewise important for the transfer of locally developed knowledge to the domestic headquarter (Hakanson and Nobel, 2001; Björkmann et al., 2004). On the other hand, the integration of the outcomes of R&D performed abroad requires a certain stage of R&D activeness of the recipient firm in the home country. Firms should carry out R&D continuously to keep up with technological developments (Tilton, 1971) and hereby develop their ability to identify and absorb new information from overseas R&D subsidiaries (Cohen and Levinthal, 1989, 1990). These so-called absorptive capabilities of the receiving firm stimulate knowledge flows (Minbaeva et al, 2003) or act as a barrier to MNEs' knowledge flows if they lack these capabilities (Szulanski, 1996).

A firm that sources knowledge from the host country is most likely to benefit from these activities if the *foreign knowledge complements existing knowledge* in

its R&D labs in the home country. The complementarity concept generally means that one activity pays off more if the other activity is also carried out (Milgrom and Roberts, 1995; Schmiedeberg, 2008). Therefore, domestic and foreign R&D act as complements if conducted together. They increase the innovation performance more than one R&D activity alone. A variety of complementarities in R&D activities have been proved to positively influence innovation success. Internal R&D has been found to be complementary to contracted R&D (Schmiedeberg, 2008), external technology acquisition (Cassiman and Veugelers, 2006) and R&D cooperation for different industries and partners (Schmiedeberg, 2008; Cassiman and Veugelers, 2002, 2005; Schmidt, 2005; Arora and Gambardella, 1990). Some of the advantages apply only to truly external firm innovation partners such as risk and cost sharing (Love and Roper, 2004) and do not count for international corporate research centres. Notwithstanding, domestic and foreign R&D may generate complementarities since different locations may imply access to additional sources of knowledge.

### **3.1.3 The Innovation Output of Firms with International R&D**

The existing literature provides only scarce evidence whether international R&D is beneficial to firms' innovation performance. Existing studies either focus on the innovative performance of foreign R&D subsidiaries or on the effect on the headquarter innovations. The to-date studies mostly use patent data to analyse the impact of foreign knowledge sources on firms' innovations. Following this strategy, Iwasa and Odagiri (2004) have examined the contribution of R&D abroad on the firms' invention activity at home and abroad for a sample of 137 Japanese MNEs. They find that innovative (not adaptive) R&D which is carried out abroad in the US and EU exert a positive impact on the number of a firm's inventions in Japan, as measured by the number of granted patents. Their results thus confirm the technology sourcing activities of subsidiaries abroad. Using a panel study of 65 Japanese pharmaceutical firms, Penner-Hahn and Shaver (2005) have examined the role of foreign R&D on the number of patents as performance measure. They confirm that international R&D activities exert a positive effect on patenting. Phene and Almeida (2008) have investigated the determinants of subsidiary innovation. They provide evidence that knowledge from host country firms positively affects scale (number of patents) and quality (number of citation received) of subsidiary innovation. On the contrary, knowledge assimilated from MNE headquarters and other subsidiaries play no significant role for subsidiary innovation. Frost (2001) studied the geographic sources of foreign subsidiaries'

innovation. He distinguishes firms' innovation activities abroad into the exploitation of existing firm knowledge and exploring local knowledge sources abroad. His findings suggest that foreign subsidiaries' patents rather cite knowledge sources from those locations that possess the strongest expertise and technological advantage. Foreign subsidiaries' patents are therefore likely to be based on host country knowledge when it is technologically advanced in that relevant field and if the foreign subsidiary is of larger scale.

Despite the controversial discussion about the effect of an increasing degree of international R&D decentralisation, the international business literature still lacks empirical evidence. So far, the impact of R&D organization on innovative outcome has been analysed for the number of *national* R&D locations within Finland (Leiponen and Helfat, 2010) and the US (Argyres and Silverman, 2004). Leiponen and Helfat (2010) find that R&D decentralisation fosters the extent and positive impact (e.g. reduction of costs, opening of new markets, fulfilling standard or regulations) of innovation outcomes. Argyres and Silverman (2004) explore the link between firms' R&D organization and the importance of innovations produced for a small sample of 71 US firms. To measure the importance of innovations, they employed distinct indicators based on patent citations. In contrast to Leiponen and Helfat (2010), their findings suggest that firms with centralised R&D organizations generate innovations with greater technological impact (number of citations) and they impact upon a broader range of technological areas. However, the effect was found to be non-linear. That is, firms with strongly decentralised R&D exhibit a greater innovation impact than firms with slightly decentralised R&D. In a related study, Singh (2008) has evaluated the effect of geographically dispersed but not necessarily international R&D activities on the quality of innovation performance.<sup>6</sup> Employing the number of patent citations as performance indicator he finds on average a significantly negative influence of the geographic spread of R&D activities on the innovation value. This result indicates that potential gains from access to diverse knowledge from different locations are offset by difficulties in managing and integrating knowledge across dispersed R&D units. Firms pursuing cross-regional knowledge integration strategies<sup>7</sup> benefit more from dispersed R&D though the overall effect remains negative. Notwithstanding, there is no evidence so far whether these

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<sup>6</sup> The spread is measured as the average geographic distance between the address of the first inventors in any two patent pairs of the firm.

<sup>7</sup> Cross-regional knowledge integration is measured along three dimensions: inventors with regional ties, regional mobility of inventors and knowledge sourcing from other locations within the firm.

results also hold for international R&D decentralisation and our research aims to fill this gap.

Furthermore, all above-mentioned studies are based on patent data. As it has been argued before, patents might not always be the appropriate way to capture the innovation success of R&D activities. Patents prove the result of inventive activities and display the location of inventors. However, not all patented inventions result in innovations and not all inventions and innovations are patented (Griliches, 1990; Jaffe and Trajtenberg, 2002). Therefore, patents cover only a threshold of the results from innovation activities abroad (Levin et al., 1987; Arundel and Kabla, 1998). Some underlying reasons are time and costs which are involved in the patent application process, as well as the aspect of knowledge disclosure by patents and the fact that only new inventions can be patented, innovations new to the firm are not patentable. In a recent study on a related topic, Criscuolo et al. (2010) have employed both patent data and firm level innovation data to investigate the effect of global engagement on innovation performance. They find that globally engaged firms (per definition multinational parent firms and multinational affiliates) applied for more patents, have a higher likelihood of introducing innovations and achieve a higher share of sales with innovations. These results add a more international perspective to the existing innovation performance literature. However, this study merely analyses how firm status, measured by indicator variables for a multinational parent, a multinational affiliate, a local exporting firm and a local non-exporting firm, affects innovation performance. The effect of both domestic and foreign research and development activities on innovation performance remains unobserved. Therefore this chapter aims to contribute firm-level evidence about international R&D activities and their effect on innovation outcome and innovation success.

### **3.1.4 Hypotheses**

In order to investigate the relationship between international R&D activities and innovation performance, we test six hypotheses. Following the rationale of the knowledge-based view, a larger number of R&D locations gives firms the opportunity to interact with a greater number of international actors and a wider range of knowledge sources. Accordingly, firms' international R&D activities represent an advantage by having multiple contacts with foreign knowledge sources. The access to a larger knowledge pool should result in a better innovation outcome (H1) and innovation success (H2):

- *Hypothesis 1: Firms with international R&D activities are more innovative than firms that undertake R&D solely in their home country.*
- *Hypothesis 2: Firms with international R&D activities achieve higher innovation success than firms that only have domestic R&D capacities.*

Section 2.2 has elaborated on some moderating factors that affect benefits. The second set of hypotheses is devoted to the degree of R&D internationalisation and its impact on innovation. The literature provides two competing hypotheses how the degree of internationalisation of R&D dispersion may affect innovation outcome and innovation success. Therefore, we define hypotheses 3a and 4a based on the arguments stemming from the knowledge-based view and the expected positive effects of a decentralised R&D organisation raised by Von Hippel (1988):

- *Hypothesis 3a: The degree of R&D internationalisation has a positive influence on the likelihood of introducing innovations (innovation outcome).*
- *Hypothesis 4a: The degree of R&D internationalisation has a positive influence on firms' innovation success.*

Following the line of reasoning that increased international R&D decentralisation implies the loss of economies of scale and scope, the higher likelihood of redundant innovation projects and higher transaction costs, we formulate hypothesis 3b and 4b which state that these costs outweigh the gain due to the better access to foreign knowledge:

- *Hypothesis 3b: The degree of R&D internationalisation has a negative influence on the likelihood of introducing innovations (innovation outcome).*
- *Hypothesis 4b: The degree of R&D internationalisation has a negative influence on firms' innovation success.*

A rejection of hypothesis 3a would lead to the conclusion that the costs outweigh the benefits of the international R&D activities and thus confirms hypothesis 3b. Due to lack of data and similar to Singh (2008), we cannot test hypotheses about the other moderating factors, i.e. about the effect of subsidiaries' mandates and internal organisational mechanisms to transfer knowledge across different R&D units within the firm efficiently. Instead we will draw indirect inference on these matters based on our results.



## 3.2 Empirical Analysis

### 3.2.1 Data Set

To test our hypotheses, we employ data from the Mannheim Innovation Panel (MIP). Detailed information about this data source is provided in chapter 1.2. The MIP provides rich information on firms' innovation behavior such as the introduction of product and process innovation, innovation expenditure, R&D engagement, share of sales with new products, information sources, hampering factors and general firm information such as sales, employment, exports, type of ownership and so on. The data has increasingly been exploited in empirical research to study a variety of innovation-related questions (see e.g. Cassiman and Veugelers, 2006; Criscuolo et al., 2010 and the survey by Mairesse and Mohnen, 2010). Usually, the MIP goes beyond the extent of the core CIS surveys and poses additional questions on innovation-related topics. The 2006 survey additionally collects data about foreign innovation activities. Firms were asked whether they conduct foreign innovation activities in 2005 and if so what kind of activity they perform abroad (R&D, implementation of new processes, conception/design/construction of new products, manufacturing of new products or merely sales of new products). For each type of activity firms were furthermore requested to state in a free text field in which countries they predominantly perform them.

Its design as a panel data set presents a main virtue of the MIP. Unfortunately, information on international R&D activities is only available in one wave. However, by merging different waves, the panel structure allows us to analyse the effect of R&D activities abroad on future innovation performance. More precisely, we merge the 2006 survey with the latest available 2009 survey. This creates a time lag of 3 years between existing corporate R&D activities abroad in 2005 (2006 survey) and the measurement of innovation performance in the period 2006-2008 (2009 survey). Since empirical evidence has pointed towards the fact that firms tend to carry out rather applied R&D at foreign locations, the observed time lag of up to three years between innovation efforts and observed performance seems to be adequate. Moreover, this approach reduces potential endogeneity problems between the location of R&D activities and innovation output which usually arise in cross-sectional analyses. Endogeneity might occur because the most innovative firms may have the prerequisites to perform R&D abroad, i.e. self-select into the sample of international R&D performing firms.

The samples in 2006 and 2009 consist of 5187 and 7662 firms, respectively. Though the surveys are designed as a panel, merging the two cross-sections leads to a reduction of about 50% in the amount of observations since participation is voluntary. For estimation purposes we further exclude firms with incomplete data for any of the relevant variables. 2118 firms remain for the empirical analysis.

### **3.2.2 Dependent Variables**

We define two sets of dependent variables, following the approach taken by many other studies to analyse the effect of firms' national R&D activities on innovation success (see e.g. Griffith et al., 2006; Parisi et al., 2006). That is, we first investigate whether a firm has introduced *new products* in the period 2006 to 2008. According to the Oslo Manual, these new products could be either new to the market (*market novelties*) or new to the firm only (*firm novelties*), i.e. they greatly differ in their degree of novelty. We suppose that foreign R&D is more crucial for developing market novelties. Thus, we additionally differentiate between two binary variables, namely market novelties and firm novelties.

Given that the firm has introduced a product innovation, market and firm novelty, respectively, we investigate the market success with these innovation outcomes in a similar manner as it has been done by a variety of studies before (Criscuolo and Haskel, 2003; Mairesse and Mohnen, 2005; Jefferson et al., 2006). In contrast to these studies that define innovation success by the share of sales in a given year due to innovations in the prior three years, we employ a dynamic success measure that accounts for sales changes as proposed by Harrison et al. (2008). Innovation success is measured by the *sales growth rate between the years 2006 and 2008 due to new products, market novelties and firm novelties* introduced in this period of time, respectively. It is computed as the share of sales due to new products in 2008 times sales in 2008 divided by sales in 2006. Table 10 summarises the definition of the six dependent variables.

Table 10: Definition of Dependent Variables

Dependent Variables	Definition
Firms with product innovations	1 if firm had new products (market or firm novelties) in 2006-2008
Firms with market novelties	1 if firm had market novelties in 2006-2008
Firms with firm novelties	1 if firm had firm novelties in 2006-2008
Sales growth due to new products	Growth rate of turnover betw. 2006-2008 due to new products in that period; Computed as: Share of sales with new products * (Sales in 2008 / Sales in 2006)
Sales growth due to market novelties	Growth rate of turnover betw. 2006-2008 due to market novelties in that period; Computed as: Share of sales with market novelties * (Sales in 2008 / Sales in 2006)
Sales growth due to firm novelties	Growth rate of turnover betw. 2006-2008 due to firm novelties in that period; Computed as: Share of sales with firm novelties * (Sales in 2008 / Sales in 2006)

### 3.2.3 Explanatory Variables

The literature on innovation performance has identified the following main factors that influence innovation output: (i) firms' actual innovation effort, (ii) technological capabilities describing the degree of technological accumulation and efficiency in the innovative search process, (iii) absorptive capacities, and (iv) the use of external knowledge.<sup>8</sup> In this regard, the importance of continuous internal R&D activities as an indicator for innovative capabilities and absorptive capacities has been emphasised by many scholars. Becker and Peters (2000) for instance have shown that firms with pronounced absorptive capacities are more likely to have higher sales with new products.

#### *Domestic and Foreign R&D Activities*

Our study is aimed at comparing the effect of domestic and foreign R&D on firms' future innovation outcome and market success with innovations. We first construct two binary variables indicating German firms that solely perform R&D activities in Germany in 2005 (*firms with domestic R&D only*) and that have both R&D laboratories in Germany and abroad (*firms with foreign R&D*).<sup>9</sup> Note that differences between the effect of domestic and foreign R&D on innovation performance might capture differences in the access to external knowledge as well as differences in innovative capabilities and absorptive capacities that are built in the course of R&D activities. Furthermore, note that not all firms have performed R&D activities in 2005. Among the non-R&D performing firms we further

<sup>8</sup> For an overview see for instance Peters (2008) and Hall and Mairesse (2006) and the references cited therein.

<sup>9</sup> Only one firm in the sample reported to perform R&D activities solely abroad. We therefore decided to exclude this firm from the estimation.

separate between firms with no innovations activities (*firms without innovation activities*) and firms with innovation activities but without conducting any R&D activities (*innovative firms without R&D*). The latter group reflects the well-known fact that R&D is not the only way for an enterprise to introduce new products.<sup>10</sup> The reference category in our analysis comprises *innovative firms without R&D* activities in 2005.

In a second step, we further subdivide international R&D performers according to their degree of R&D internationalisation. We create three binary variables indicating the intensity of firms' foreign R&D engagement by using the number of countries in which the firms carry out R&D activities. A firm is defined to have *centralised*, *medium decentralised* and *decentralised foreign R&D activities* if it performs R&D in one, two to three and more than three foreign countries, respectively. A detailed list of variable definitions is provided in Table 11 .

### 3.2.4 Control Variables

In addition to dummies indicating the location of R&D activities, we include *R&D intensity* (R&D expenditure per sales in 2005) and *non-R&D innovation intensity* (innovation expenditure (except R&D expenditure) per sales in 2005) to capture innovation efforts. We expect the impact on innovation performance to be positive. We model a second order polynomial to account for any non-linearities. In addition to R&D, technological capabilities are measured by the share of *high skilled employees* in 2005 (Löf and Heshmati, 2002).

Besides proxies for innovation effort, technological capabilities, absorptive capacity and use of external knowledge, we control for the effect of a variety of additional variables. We include *firm size* (number of employees in 2005, in log.), firm location (dummy variable that is 1 if the firm is located in *East Germany*) as well as the ownership structure of the firms. That is, we distinguish whether the firm is a *single entity* (reference category), *part of a national group*, *part of an international group with a German headquarter* or *an international group with headquarter abroad*.

Nelson (1959) stressed that more diversified firms possess more opportunities for exploiting new knowledge and complementarities among their diversified activities (economies of scope in innovation) and therefore tend to be more innovative. The degree of product diversification might also indicate the level of

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<sup>10</sup> Other innovation activities include for instance the acquisition of machines and external knowledge such as patents and licenses.

firm knowledge and skills (Vermeulen and Barkema, 2002). It has been found to have an impact on firm performance (Chatterjee and Wernerfelt, 1991) and innovation success (Crepon et al. 1998). We include the *degree of product diversity* in our estimations that is measured by 1 divided by the share of sales with the most important product in 2005. We furthermore include three variables that characterise the competitive environment of firms: two variables that measure whether the competition is rather *price* or *technology* driven (average importance of price and technology advantage as competitive factor, measured at the industry level, i.e. NACE 3 digit level) and a dummy variable that equals one if the firm serves international markets in 2005 (*exporter*). Finally, we define five industry dummies: firms belonging to *high R&D-intensive manufacturing*, *medium R&D-intensive manufacturing*, *low R&D-intensive manufacturing*, *knowledge-intensive services* and *other services* (reference category). The categorisation of industries has been done following the method of Legler and Frietsch (2007) for the Federal Ministry of Education and Research to distinguish industries by their level of R&D intensity and knowledge intensity.

Table 11: Definition of Explanatory Variables

<b>Innovation activities in year 2005</b>	<b>Definition</b>
Firms without innovation activities	1 if the firm has no innovation activities (in year 2005)
Firms with domestic R&D only	1 if the firm has R&D labs in Germany only
Firms with domestic R&D and abroad	1 if the firm has R&D labs in Germany and at least one R&D lab abroad
Firms with centralised foreign R&D	1 if the firm has an R&D lab in only 1 country abroad
Firms with medium decentralised foreign R&D	1 if the firm has R&D labs in 2 or 3 countries abroad
Firms with decentralised foreign R&D	1 if the firm has R&D labs in 4 or more countries abroad
Firms without R&D (reference group)	1 if the firm has innovations but no R&D activities
<b>Control Variables related to year 2005</b>	<b>Definition</b>
R&D intensity	R&D expenditure per sales
Non-R&D-intensity	Innovation expenditure (except R&D) per sales
High-Skilled Employees	No. of graduated employees per total number of employees
Degree of product diversification	1 divided by the share of sales with the most important product
National group	1 if firm is a national group
Intern. Group with German HQ	1 if firm is an international group headquartered in Germany
Intern. Group with HQ abroad	1 if firm is an international group headquartered abroad
Exporter	1 if Firm is having exports
Firm size	No. of employees (in log)
Firm in East Germany	1 if firm is located in Eastern Germany
<b>Competitive Environment</b>	
Competition: Price	Average importance of price as indicator of competition (at NACE 3 industry level)
Competition: Technology	Average importance of technological advantage as indicator of competition (at NACE 3 industry level)
<b>Industry</b>	
High R&D-intensive manufacturing	1 if firm belongs to the industry classification of knowledge-intensive manufacturing sectors following Legler and Frietsch (2007)
Medium R&D-intensive manufacturing	1 if firm belongs to the industry classification of Other (than the previous category) knowledge-intensive manufacturing sectors following Legler and Frietsch (2007)
Low R&D-intensive manufacturing	1 if firm belongs to the industry classification of not knowledge intensive manufacturing sectors following Legler and Frietsch (2007)
Knowledge-intensive services	1 if firm belongs to the industry classification of knowledge-intensive Services sectors following Legler and Frietsch (2007)

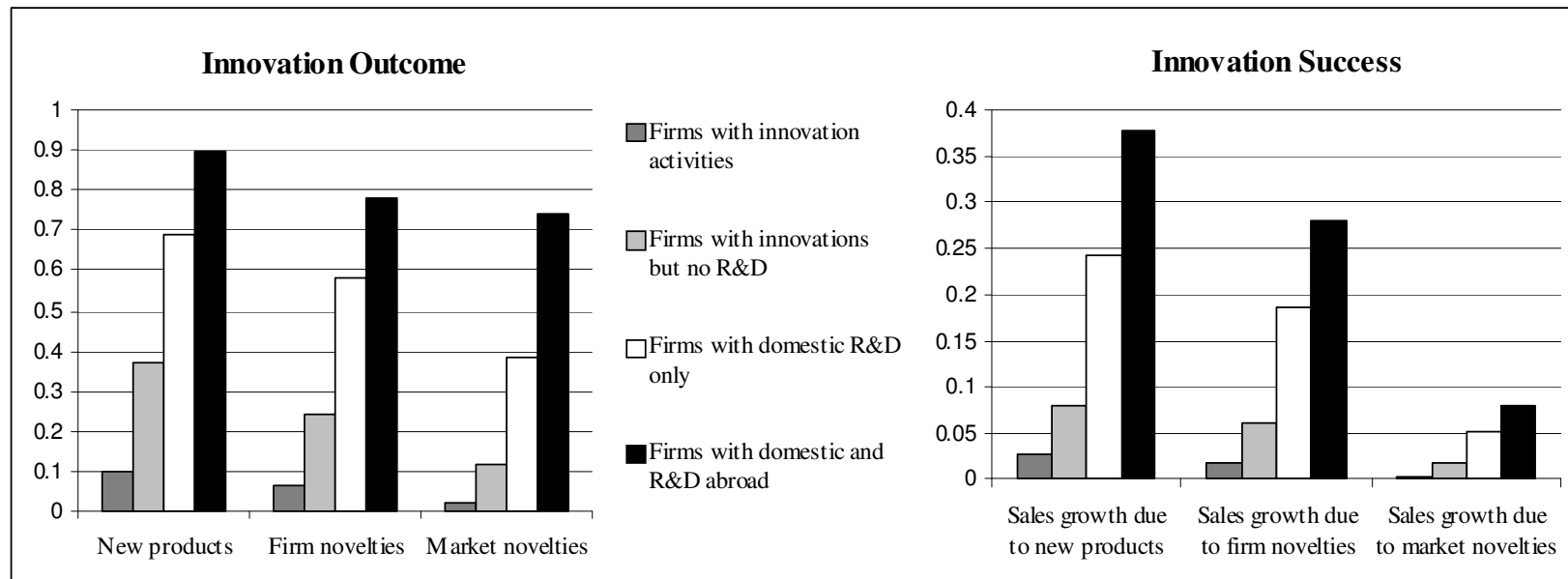
### 3.2.5 Descriptive Statistics

After merging the 2006 and 2009 survey via the identification number of firms we retrieve a sample of 2118 innovation active firms in Germany. The descriptive statistics in Table 14 in the appendix section demonstrates that R&D activities are still predominately concentrated in the national innovation environment. 28% of the sample firms conducted R&D activities solely in their home country in 2005. 11% of the firms performed R&D activities in both Germany and foreign countries. About half of them (5%) preferred to focus their R&D work in one foreign country. Two or three foreign countries as sources in their innovation

network are used by 3% of our sample firms and 2% of the firms are characterised by decentralised R&D activities, i.e. they had R&D labs in more than three countries. 19% of firms undertook innovation activities without doing R&D in 2005 while 42% of firms had no innovation activities.

Regarding innovation outcome, about 39% of the sample firms have introduced new products in the period between 2006 and 2008, of which 21% launched market novelties and 34% reported firm novelties. The average sales growth between 2006 and 2008 that is due to new products is about 13%. 3% sales growth can be attributed to market novelties whereas firm novelties account for on average 10% sales growth in our sample. The average firm size in our sample is 4.278, that corresponds to 2488 employees. 18% of the firms are domestic groups. Multinational firms with headquarters in Germany comprise about 13% of the sample firms while 7% are headquartered abroad. The following graphs illustrate the innovation outcome and innovation success by firms' R&D efforts and the geographic location of R&D activities. Consistently across all three types of product innovations, firms with international R&D activities show a higher innovation outcome and given the introduction of a new product they are also more successful on the market with these products compared to firms with domestic R&D, firms with innovations but no own R&D and firms without any innovation efforts in 2005. This is particularly evident for firm novelties, less so for market novelties. Since these differences might also capture the effect of other firm-level variables or industry effects, we carry out an econometric analysis.

Figure 4: Innovation Outcome and Innovation Success by R&D Location



Notes: Innovation outcome is measured as the share of firm that have introduced an innovation. Innovation success is measured as the average sales growth rate due to each type of product innovation.



### 3.2.6 Estimation Method

To test our hypotheses we estimate three knowledge production functions (Griliches, 1986), one for each type of innovation (product innovation, market novelties, firm novelties). Since market success with innovations can only be observed if the firm has introduced an innovation, we carry out the two-step estimation procedure proposed by Heckman (1976, 1979). The selection equation estimates the effects of the explanatory variables on the likelihood to launch innovations (innovation outcome). Given the introduction of an innovation, the second step of the Heckman estimation is designed to estimate the impact of the explanatory variables on the growth of sales due to this innovation outcome (structural equation).

Firm size and the degree of product diversification serve as exclusion restriction. That is, we include them in the selection equation but exclude them from the structural equation. This partial overlap of the explanatory variables in the selection and structural equation ensures that the identification of parameters does not solely rely on functional form assumptions. The validity of these exclusion restrictions cannot be formally tested (see Wooldridge, 2005). However, they seemed to be justified since when including the full set of variables in both equations the two variables are significant in the selection equation but have no significant effects in the structural equation (see Table 17 and Table 16 for results of marginal effects).<sup>11</sup>

## 3.3 Empirical Results

Table 12 and Table 13 present the main estimation results that are the effect of international and national R&D locations as well as of different degrees of R&D internationalization on firms' innovation outcome and innovation success. Columns 2, 4 and 6 of Table 12 and Table 13 report marginal effects for a firm's likelihood to generate product innovations, firm novelties and market novelties. Corresponding innovation success is explained in columns 3, 5 and 7. Figures show the marginal effect defined as conditional expectation.

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<sup>11</sup> In this specification the parameters of the structural equation are identified because the inverse Mills ratio is a non-linear function of the variables included in the selection equation. However, the non-linearity of the inverse Mills ratio arises from the assumption of normality in the selection equation.

Table 19 and Table 20 in the appendix section of the chapter present a robustness check of the previous estimations by eliminating firms from the sample that belong to a group with headquarter abroad.

### **3.3.1 Innovation Outcome of International R&D Activities**

The estimates show that the influence of international R&D locations is significantly positive on all innovation outcome measures. Domestic R&D activities turned out to be conducive to innovation outcome as well. However, firms without any innovation activities in the year 2005 are significantly less (negative) likely to develop and to introduce new products in the following period 2006-2008. Having said this, our prime intention was to compare firms with domestic versus international R&D activities. We thus statistically test on equality between both effects. As can be gauged from the F-test, the effects of domestic R&D and R&D abroad are significantly different from each other. Firms with international R&D activities exhibit a significantly higher propensity to introduce product novelties, market novelties and firm novelties. The relative difference between the marginal effect of national and international R&D is greatest for market novelties, which is also reflected in the test statistics (significant at the 1% level (0.009)). The influence of international R&D activities on new product development and firm novelties is about one third larger than the effect of domestic R&D activities. Overall, the results strongly confirm our first hypothesis and thus the assumptions of the knowledge-based view that multiple locations offer firms attractive sources of knowledge. In addition, the results suggest that foreign subsidiaries are actually carrying out knowledge sourcing tasks and that foreign knowledge is successfully integrated into the innovation process of the whole firm.

The empirical analysis further reveals intriguing results regarding the impact of the degree of R&D internationalisation on innovation outcomes (Table 13). On the one hand, it turns out that innovation outcome is positively related to the degree of R&D internationalisation. That is, the propensity to introduce products new to the market and new to the firm increases with the degree of decentralisation. Firms with medium decentralised foreign R&D activities have a significantly higher likelihood to develop both market and firm novelties compared to firms with only one foreign subsidiary (centralised foreign R&D). Comparing firms that have medium decentralised and decentralised foreign R&D activities, the results are not clear-cut. A more decentralised foreign R&D organization does not exert an additional stimulating effect on the propensity to

develop market novelties. On the other hand, it further increases the likelihood to develop firm novelties. Actually, we could not retrieve marginal effects for the effect of firms with decentralised foreign R&D on the likelihood to generate new products and firm novelties. The underlying reason is that all firms in our sample which have a high degree of R&D internationalisation (R&D departments in more than three countries) have product innovations and firm novelties. The explanatory variable therefore predicts innovation outcome perfectly well, so that these observations are dropped. The findings mainly support our hypothesis 3a in which we expected innovation outcome to increase with the degree of R&D internationalisation. Comparing our results with studies examining the effect of nationally dispersed R&D activities, we have to ascertain that our results contradict the findings of Argyres and Silverman (2004) who report a U-shaped relationship. They are in line with Leiponen and Helfat (2010) who find that two R&D locations are most beneficial to product and process innovations as well as to any kind of innovation.

Another interesting result emerges when we compare firms with domestic R&D and internationally dispersed R&D activities. It turns out that firms with domestic R&D and centralised foreign R&D do not significantly differ in their propensity to develop new products, neither market novelties nor firm novelties. The prior finding that firms with foreign R&D activities benefit much more in terms of innovation outcome than domestic R&D performers is thus mainly driven by firms with medium or decentralised international R&D activities.

The robustness check (in Table 19 and Table 20 in the appendix section) of these results in which we run the same estimations but on a sample which does only include national firms approve all results for innovation outcomes of domestic and international innovating firms.

Table 12: Effect of Domestic and International R&D on Innovation Outcome and Innovation Success

	Product Innovation		Market Novelties		Firm Novelties	
	Yes/No	Sales growth	Yes/No	Sales growth	Yes/No	Sales growth
<i>Prior innovation activities in 2005 (ref.: firms with innovation activities except R&amp;D)</i>						
Firms without innovation activities	-0.200 *** (0.021)	-0.070 * (0.037)	-0.131 *** (0.024)	-0.027 (0.020)	-0.188 *** (0.023)	-0.077 ** (0.031)
Firms with domestic R&D only	0.115 *** (0.022)	0.046 ** (0.023)	0.079 *** (0.019)	0.008 (0.013)	0.126 *** (0.022)	0.046 ** (0.022)
Firms with domestic R&D and abroad	0.168 *** (0.035)	0.069 ** (0.028)	0.136 *** (0.026)	0.005 (0.017)	0.186 *** (0.034)	0.069 *** (0.026)
Firm size	0.033 *** (0.005)	-	0.031 *** (0.004)	-	0.031 *** (0.005)	-
Degree of diversification	0.024 *** (0.008)	-	0.008 (0.006)	-	0.003 (0.005)	-
R&D intensity	0.525 *** (0.190)	0.486 *** (0.129)	0.388 *** (0.128)	0.384 *** (0.091)	0.310 * (0.177)	0.185 * (0.112)
Non-R&D innov. intensity	-0.018 (0.097)	0.038 (0.089)	0.091 (0.076)	0.141 *** (0.050)	0.024 (0.095)	-0.115 (0.080)
Share of high skilled employees	0.098 ** (0.044)	0.064 * (0.038)	0.132 *** (0.038)	0.022 (0.019)	0.078 * (0.045)	0.053 (0.034)
Exporter	0.057 *** (0.019)	-0.001 (0.020)	0.062 *** (0.017)	-0.009 (0.012)	0.044 ** (0.019)	0.012 (0.017)
Firm in East Germany	0.003 (0.018)	0.012 (0.017)	-0.033 ** (0.017)	-0.019 ** (0.009)	0.002 (0.018)	0.026 * (0.017)
<i>Ownership (ref: unaffiliated firm)</i>						
National group	-0.004 (0.023)	0.027 (0.019)	-0.019 (0.020)	0.011 (0.010)	-0.006 (0.023)	0.023 (0.017)
Internat. group, German HQ	0.054 * (0.032)	0.032 (0.023)	0.026 (0.025)	0.011 (0.011)	0.052 * (0.031)	0.031 (0.021)
Internat. group, HQ abroad	-0.047 (0.034)	0.030 (0.026)	-0.049 * (0.027)	0.030 ** (0.013)	-0.085 ** (0.034)	0.019 (0.025)
<i>Competition</i>						
Price	-0.050 * (0.026)	-0.026 (0.020)	-0.021 (0.021)	0.008 (0.010)	-0.070 *** (0.026)	-0.030 * (0.018)
Technology	-0.007 (0.015)	0.022 (0.014)	-0.007 (0.013)	0.004 (0.007)	0.005 (0.015)	0.018 (0.013)
<i>Industries</i>						
High R&D-intensive manufacturing	0.127 *** (0.045)	-0.064 (0.043)	0.072 * (0.037)	-0.002 (0.019)	0.100 ** (0.044)	-0.064 (0.041)
Medium R&D-intensive manufacturing	0.129 *** (0.040)	-0.017 (0.038)	0.083 ** (0.033)	0.014 (0.018)	0.093 ** (0.040)	-0.028 (0.036)
Low R&D-intensive manufacturing	0.058 ** (0.024)	0.004 (0.027)	0.042 * (0.024)	0.019 (0.015)	0.064 ** (0.025)	-0.013 (0.026)
Knowledge-intensive services	0.044 (0.032)	-0.051 (0.035)	-0.004 (0.031)	-0.018 (0.018)	0.039 (0.033)	-0.036 (0.032)
rho		0.336		0.505		0.464
sigma		0.470		0.241		0.447
lambda		0.158 (0.120)		0.122 ** (0.062)		0.207 (0.137)
W_all	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.009 ***
H0: dom. R&D >= for. R&D	0.054 *	0.112	0.004 ***	0.594	0.022 **	0.084 *
N° of observations	2118		2118		2118	
censored obs.	1303		1666		1400	
uncensored obs.	815		452		718	

Notes: Marginal effects are reported. W\_all is the test statistic of a Wald test on joint significance of all explanatory variables. Dom R&D >= for. R&D tests the null hypothesis that domestic and foreign R&D activities have a larger or the same effect. The p-value of the F-test is reported.

### 3.3.2 Innovation Success of International R&D activities

Next we investigate the effect of international R&D activities on the innovation success measured by the sales growth due to new products, market novelties and firm novelties. Columns 3, 5 and 7 of Table 13 present average marginal effects for the expected value of the corresponding sales growth rates conditional on being selected. The estimates reveal that firms with international R&D activities exhibit higher product innovation success than firms without R&D. Compared to firms that solely perform domestic R&D, they also tend to achieve higher sales growth due to new products although the difference is not statistically significant (p-value of a one-sided test: 0.112). These overall results for product innovations are mainly driven by firm novelties. On the contrary, we cannot ascertain significant results regarding the innovation success with market novelties. Given the introduction of a market novelty, firms with international R&D activities do not outperform other firms. That is, once a firm has introduced a market novelty, the location of R&D activities does not matter for innovation success. In sum, these findings do not confirm our second hypothesis in which we anticipated that firms with international R&D activities will achieve higher innovation success than firms with only domestic R&D activities.

Investigating the impact of different degrees of international R&D decentralisation on innovation success with new products, we find a strong non-linear effect. Firms with medium decentralised R&D abroad achieve a higher sales growth with new products than firms which conduct R&D at home only. The difference is statistically significant. Interestingly, they also outperform firms with highly decentralised R&D activities. Overall, medium decentralised international R&D turns out to be most beneficial. As before, this finding is mainly driven by firm novelties, not by market novelties. That is, given the introduction of a market novelty, the degree of decentralisation of international R&D activities does not play a role for innovation success. In this vein, we neither can confirm our hypothesis 4a nor 4b. However, our results are in line with Leiponen and Helfat (2010). They find a positive significant impact for firms with two R&D locations on the share of sales with product innovations. The results for prior non-innovative firms show a negative significant effect for the sales growth with firm novelties.

In comparison with the innovation outcome estimations we obtain fewer significant results in our innovation success analysis. One possible explanation can be that much more departments than R&D alone are involved until

innovations are ready for the market. However, as was put forward by Singh (2008), it might also well be that foreign R&D activities do not lead to a higher quality of innovations and therefore limit their market success.

Foreign R&D of German subsidiary firms that belong to an international group with a headquarter abroad might be quite different compared to foreign R&D of German firms with headquarter in Germany. However, the robustness check corroborates that the positive effects of (domestic and) international R&D activities is not driven by the former group of firms. Overall, the robustness estimates show a few less significant effects: the weak significance of domestic R&D on sales growth due to new products as well as the weak significant effect of centralised international R&D on sales growth due to firm novelties vanishes.

Table 13: Effect of Degree of Decentralisation of International R&D on Innovation Outcome and Innovation Success

	Product Innovation		Market Novelties		Firm Novelties	
	Yes/No	Sales growth	Yes/No	Sales growth	Yes/No	Sales growth
<i>Prior innovation activities in 2005 (ref.: firms with innovation activities except R&amp;D)</i>						
Firms without innovation activities	-0.210 *** (0.021)	-0.065 (0.040)	-0.129 *** (0.024)	-0.027 (0.021)	-0.203 *** (0.022)	-0.078 ** (0.033)
Firms with domestic R&D only	0.100 *** (0.022)	0.042 * (0.023)	0.079 *** (0.019)	0.007 (0.013)	0.102 *** (0.022)	0.041 ** (0.021)
Firms with centralised foreign R&D	0.093 ** (0.041)	0.051 (0.032)	0.092 *** (0.030)	0.004 (0.018)	0.097 ** (0.039)	0.049 * (0.029)
Firms with medium decent. foreign R&D	0.352 *** (0.107)	0.125 *** (0.036)	0.196 *** (0.043)	0.013 (0.020)	0.277 *** (0.072)	0.112 *** (0.032)
Firms with decentralised foreign R&D	- (0.043)	0.036 (0.043)	0.189 *** (0.059)	-0.010 (0.025)	- (0.036)	0.038 (0.036)
Firm size	0.034 *** (0.005)	-	0.030 *** (0.004)	-	0.033 *** (0.005)	-
Degree of diversification	0.024 *** (0.008)	-	0.008 (0.006)	-	0.003 (0.005)	-
R&D intensity	0.664 *** (0.193)	0.496 *** (0.133)	0.387 *** (0.129)	0.397 *** (0.099)	0.472 *** (0.178)	0.192 * (0.116)
Non-R&D innov. intensity	-0.010 (0.097)	0.036 (0.092)	0.092 (0.075)	0.141 *** (0.052)	0.033 (0.095)	-0.120 (0.082)
Share of high skilled emp	0.105 ** (0.045)	0.060 (0.040)	0.137 *** (0.038)	0.024 (0.020)	0.086 * (0.045)	0.050 (0.035)
Exporter	0.060 *** (0.019)	-0.001 (0.021)	0.062 *** (0.017)	-0.009 (0.013)	0.048 ** (0.020)	0.014 (0.018)
Firm in East Germany	-0.001 (0.018)	0.015 (0.018)	-0.035 ** (0.016)	-0.019 ** (0.010)	-0.001 (0.019)	0.028 (0.017)
<i>Ownership (ref: unaffiliated firm)</i>						
National group	-0.003 (0.023)	0.028 (0.020)	-0.018 (0.020)	0.012 (0.010)	-0.006 (0.023)	0.025 (0.017)
Internat. group, German HQ	0.053 (0.032)	0.025 (0.025)	0.019 (0.025)	0.012 (0.012)	0.053 * (0.032)	0.027 (0.022)
Internat. group, HQ abroad	-0.046 (0.034)	0.028 (0.027)	-0.050 * (0.027)	0.029 ** (0.014)	-0.080 ** (0.035)	0.018 (0.025)
<i>Competition</i>						
Price	-0.046 * (0.026)	-0.019 (0.021)	-0.018 (0.021)	0.010 (0.011)	-0.063 ** (0.026)	-0.024 (0.018)
Technology	-0.008 (0.016)	0.022 (0.015)	-0.005 (0.013)	0.004 (0.007)	0.004 (0.016)	0.019 (0.013)
<i>Industries</i>						
High R&D-intensive manufacturing	0.130 *** (0.045)	-0.061 (0.045)	0.063 * (0.037)	-0.000 (0.020)	0.108 ** (0.045)	-0.060 (0.042)
Medium R&D-intensive manufacturing	0.130 *** (0.040)	-0.020 (0.040)	0.069 ** (0.034)	0.014 (0.018)	0.106 *** (0.040)	-0.028 (0.038)
Low R&D-intensive manufacturing	0.061 ** (0.024)	0.003 (0.028)	0.041 * (0.024)	0.021 (0.015)	0.070 *** (0.025)	-0.013 (0.027)
Knowledge-intensive services	0.047 (0.033)	-0.045 (0.037)	-0.003 (0.031)	-0.017 (0.019)	0.043 (0.034)	-0.028 (0.033)
rho		0.279		0.495		0.434
sigma		0.471		0.246		0.448
lambda		0.131 (0.119)		0.122 * (0.065)		0.195 (0.131)
W_all	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.016 **
H0: dom. R&D>=cent. for. R&D	0.578	0.373	0.298	0.577	0.548	0.372
H0: dom. R&D>=med.decent. for. R&D	0.009 ***	0.004 ***	0.002 ***	0.321	0.007 ***	0.004 ***
H0: dom. R&D>=decent. for. R&D	-	0.566	0.027 **	0.807	-	0.542
H0: cent.for.R&D>=med.decent.for.R&D	0.010 ***	0.017 **	0.010 ***	0.276	0.009 ***	0.017 **
H0: decent. for.R&D>=med.decent.for.R&D	-	0.021 **	0.460	0.102	-	0.021 **
H0: cent.for.R&D>=decent.for.R&D	-	0.636	0.055 *	0.776	-	0.618
N° of observations	2086		2086		2086	
censored obs.	1298		1659		1393	
uncensored obs.	788		427		693	

Notes: See Table 12

### 3.3.3 Estimation Results of Control Variables

Overall, the results highlight the stimulating role of innovative capabilities for innovation outcome. Both firms' *R&D intensity* and *share of high skilled employees* increase the likelihood of developing firm and market novelties. With respect to R&D intensity, we find a non-linear effect for all kinds of innovations.<sup>12</sup> Interestingly, we do not find a significant impact of *non-R&D innovation intensity* on innovation outcome. Firms that have a higher *degree of product diversification* are furthermore more likely to introduce new products. Past *export* activities turn out to be conducive to future innovation activities as we find significant effects for all kinds of product innovation. The ownership of firms shows inconclusive results. We do not find any significant differences between *unaffiliated firms*, *national groups* and *firms belong to a multinational group with headquarters in Germany*. On the contrary, *international firms which are headquartered abroad* are less likely to introduce firm and market novelties. Regarding the competitive environment, we find a negative effect of *price competition* on the introduction of firm novelties and product innovations, but no impact of *technology competition* on innovation.

Innovation success is driven by the firms' *R&D* and *non-R&D innovation intensity* (in case of market novelties). The results further indicate that firms belonging to a *multinational group with headquarters abroad* achieve higher innovation success with market novelties than other firms. Firm location, in our estimations defined as whether the firm is located in the eastern part of Germany, has an ambiguous effect. On the one hand, firms located in *East Germany* are less likely to introduce market novelties and they benefit less in terms of innovation success. On the other hand, they outperform West German firms regarding the sales growth due to firm novelties. Firms that operate their businesses in a competitive environment that is characterised by *price competition* develop not only less firm novelties they also achieve a lower sales growth rate with these new products.

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<sup>12</sup> Table 12 and Table 13 only report the marginal effect of *R&D intensity* that is calculated based on the estimates of the linear and squared term of *R&D intensity*. The original coefficient estimates are provided in Table 18 in the appendix.



### 3.4 Conclusions

Central objective of this chapter was to examine whether international R&D activities are conducive to innovation performance. We investigated whether firms with R&D activities outside their home country benefit from these ventures in terms of a better innovation outcome and higher innovation success. We furthermore analysed how the degree of R&D internationalisation, in terms of the decentralisation into various countries, moderates firms' innovativeness and innovation success. To show the benefits of a strategy to disperse R&D across foreign countries, we compared the estimation outcomes with the results of firms that solely perform R&D within the borders of their home country and non-R&D performing firms. Against the background of the trend to expand R&D facilities globally, our results are useful for firms to decide whether to internationalise their R&D activities at all as well as to extend their existing overseas R&D locations. The literature review of this study has revealed that, relying only on patent data, the few existing studies may have answered the question of international R&D benefits insufficiently. This chapter contributes to the literature by adding insights about innovation outcomes that would not be captured by patent data, such as firm novelties and overall product innovations, as well as probably a certain share of market novelties. Moreover, we have also related the added value of international R&D activities to the market success with innovations.

Our results show that firms which follow the trend and internationalise R&D activities have a great potential to strengthen their innovation performance. Firms with international R&D have a higher probability to develop product, market and firm novelties in comparison to firms that perform only domestic R&D or non-R&D performers. However, regarding the innovation success, the results are not as clear-cut. Given the introduction of a firm novelty, firms with international R&D centres are also more successful than non-R&D performers and tend to be more successful than firms conducting domestic R&D. On the contrary, the findings highlight that the location of R&D does not matter for the success of market novelties once the market novelty has been launched to the market.

In our analysis, we also investigate how the number of locations affects innovation outcome and innovation success. The econometric results disclose an inverse u-shaped relationship. That is, a moderate number of R&D locations abroad is most beneficial for generating innovation outcomes (product innovations, market and firm novelties). The same conclusion can be drawn for the sales growth due to new products and firm novelties. Another interesting

finding originates from this analysis: Firms which have expanded their R&D only to one foreign country do not outperform firms with domestic R&D. Admittedly, we cannot say whether this is a general picture or whether this is due the fact that many of these firms might have just recently started to internationalise their R&D and are therefore still in a learning phase. This question is put on the agenda for future research.

To sum up, international R&D seems to ease the access to new knowledge which evidently results in a higher probability of developing innovations and therefore contributes to firms' competitiveness. Due to a lack of data, we cannot observe how knowledge is transferred and integrated within a multinational firm across countries. But based on our findings, we can conclude that on average firms with international R&D activities have successfully installed knowledge transfer methods to channel foreign knowledge from global subsidiaries back to the home country. Our results also emphasise the perspective that international R&D activities seem to complement existing research efforts. However, for the decision to set up R&D facilities at foreign subsidiaries, managers should carefully choose the specific locations and limit the number to a moderate extent.

### 3.5 Appendix

Table 14: Descriptive Statistics

No.	Dependent and Explanatory Variables	Mean	Std.Dev.	Min	Max
	Firms with Product innovations	0.385	0.487	0	1
	Firms with Market novelties	0.213	0.410	0	1
	Firms with Firm novelties	0.339	0.473	0	1
	Sales growth due to new products	0.127	0.338	0	7.292
	Sales growth due to market novelties	0.026	0.125	0	4.228
	Sales growth due to firm novelties	0.101	0.288	0	6.946
	Innovator without R&D (reference group)	0.188	0.391	0	1
1	Firms with innovation activities	0.427	0.495	0	1
2	Firms with domestic R&D only	0.276	0.447	0	1
3	Firms with domestic R&D and abroad	0.111	0.314	0	1
4	Firms with centralised foreign R&D	0.051	0.221	0	1
5	Firms with medium decentralised foreign R&D	0.030	0.171	0	1
6	Firms with decentralised foreign R&D	0.016	0.125	0	1
7	Firm size	4.278	2.220	0	12.121
8	Degree of product diversification	1.668	1.496	1	50
9	High-Skilled employees	0.195	0.232	0	1
10	Exporter	0.492	0.500	0	1
	National firm, unaffiliated (reference group)	0.621	0.485	0	1
11	National group	0.179	0.384	0	1
12	International Group with German HQ	0.132	0.338	0	1
13	International Group with HQ abroad	0.068	0.251	0	1
14	R&D intensity	0.027	0.116	0	2.667
15	Non-R&D intensity	0.026	0.086	0	1.534
16	Firm in East Germany	0.349	0.477	0	1
17	Competition: Price	5.122	0.400	3.286	6
18	Competition: Technology	3.283	0.710	1	5
19	Industry: High R&D-intensive Manufacturing	0.068	0.253	0	1
20	Industry: Medium R&D-intensive Manufacturing	0.108	0.310	0	1
21	Industry: Low R&D-intensive Manufacturing	0.405	0.491	0	1
22	Industry: R&D-intensive Services	0.197	0.398	0	1
	Industry: Low R&D-intensive services (ref. group)	0.222	0.416	0	1

Table 15: Correlation matrix of explanatory variables (by No., see previous table)

No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
1	1.000																						
2	-0.427	1.000																					
3	-0.120	0.260	1.000																				
4	-0.088	0.192	0.178	1.000																			
5	-0.288	0.642	0.070	0.086	1.000																		
6	-0.225	0.487	0.181	0.189	0.272	1.000																	
7	-0.165	0.357	0.052	0.080	0.049	0.064	1.000																
8	-0.128	0.277	0.161	0.224	0.210	0.262	0.079	1.000															
9	-0.365	0.806	0.055	0.062	0.777	0.581	0.320	0.187	1.000														
10	-0.154	0.464	0.449	0.294	0.020	0.028	0.202	0.262	-0.018	1.000													
11	0.009	0.044	0.014	-0.017	0.037	-0.016	0.027	-0.047	0.024	0.049	1.000												
12	-0.003	0.101	0.029	-0.004	0.092	0.031	-0.013	0.008	0.115	0.011	-0.198	1.000											
13	0.062	0.072	0.033	0.013	0.048	0.052	0.020	0.019	0.070	0.026	-0.069	-0.038	1.000										
14	0.079	0.278	0.094	0.069	0.201	0.223	0.086	0.104	0.267	0.123	0.076	0.172	-0.026	1.000									
15	-0.015	0.284	0.089	0.107	0.233	0.295	0.083	0.100	0.292	0.045	0.233	0.204	-0.236	0.301	1.000								
16	-0.057	0.042	0.032	0.013	0.031	0.063	0.019	0.021	0.035	0.020	0.028	-0.013	-0.172	0.064	0.216	1.000							
17	0.652	0.176	0.061	0.056	0.131	0.143	0.068	0.090	0.168	0.053	-0.067	0.120	0.207	0.329	-0.011	-0.112	1.000						
18	0.065	-0.102	-0.020	-0.025	-0.093	-0.078	0.001	-0.028	-0.098	-0.001	-0.035	-0.090	0.187	-0.152	-0.244	-0.238	0.038	1.000					
19	0.059	0.079	0.025	0.077	0.073	0.091	0.028	0.062	0.084	0.021	-0.039	0.068	0.076	0.147	0.034	-0.054	0.315	0.001	1.000				
20	0.051	0.160	0.037	0.041	0.111	0.126	0.039	0.080	0.141	0.058	0.012	0.100	-0.068	0.318	0.135	0.036	0.422	-0.033	-0.147	1.000			
21	0.067	-0.095	-0.027	-0.050	-0.074	-0.086	-0.002	-0.046	-0.083	-0.024	0.036	-0.003	-0.340	-0.004	-0.003	0.010	-0.220	-0.005	-0.285	-0.339	1.000		
22	-0.039	-0.017	-0.021	-0.010	-0.019	-0.028	-0.026	-0.027	-0.019	-0.027	-0.062	-0.078	0.513	-0.223	-0.148	-0.022	-0.069	0.003	-0.186	-0.221	-0.430	1.000	

Table 16: Results of Heckman estimation (No exclusion restrictions) – domestic and R&D abroad: Marginal effects

	Product Innovation		Market Novelties		Firm Novelties	
	Yes/No	Sales growth	Yes/No	Sales growth	Yes/No	Sales growth
<i>Prior innovation activities in 2005 (ref.: firms with innovation activities except R&amp;D)</i>						
<b>Firms without innovation activities</b>	-0.200 *** (0.021)	-0.083 ** (0.040)	-0.131 *** (0.024)	0.020 (0.082)	-0.188 *** (0.023)	-0.106 *** (0.024)
<b>Firms with domestic R&amp;D only</b>	0.115 *** (0.022)	0.051 ** (0.022)	0.079 *** (0.019)	-0.025 (0.051)	0.126 *** (0.022)	0.061 *** (0.017)
<b>Firms with domestic R&amp;D and abroad</b>	0.168 *** (0.035)	0.071 *** (0.026)	0.136 *** (0.026)	-0.043 (0.071)	0.186 *** (0.034)	0.081 *** (0.020)
<b>Firm size</b>	0.033 *** (0.005)	0.003 (0.006)	0.031 *** (0.004)	-0.014 (0.017)	0.031 *** (0.005)	0.007 * (0.004)
<b>Degree of diversification</b>	0.024 *** (0.008)	0.001 (0.003)	0.008 (0.006)	-0.003 (0.004)	0.003 (0.005)	0.002 (0.004)
<b>R&amp;D intensity</b>	0.525 *** (0.190)	0.464 *** (0.124)	0.388 *** (0.128)	0.683 *** (0.263)	0.310 * (0.177)	0.178 ** (0.091)
<b>Non-R&amp;D innov. intensity</b>	-0.018 (0.097)	0.033 (0.081)	0.091 (0.076)	0.258 ** (0.131)	0.024 (0.095)	-0.075 (0.065)
<b>Share of high skilled employees</b>	0.098 ** (0.044)	0.066 * (0.035)	0.132 *** (0.038)	-0.013 (0.064)	0.078 * (0.045)	0.056 ** (0.027)
<b>Exporter</b>	0.057 *** (0.019)	0.004 (0.020)	0.062 *** (0.017)	-0.050 (0.054)	0.044 ** (0.019)	0.018 (0.013)
<b>Firm in East Germany</b>	0.003 (0.018)	0.012 (0.016)	-0.033 ** (0.017)	-0.026 (0.019)	0.002 (0.018)	0.021 (0.013)
<i>Ownership (ref: unaffiliated firm)</i>						
<b>National group</b>	-0.004 (0.023)	0.023 (0.019)	-0.019 (0.020)	0.030 (0.027)	-0.006 (0.023)	0.014 (0.015)
<b>Internat. group, German HQ</b>	0.054 * (0.032)	0.027 (0.023)	0.026 (0.025)	0.019 (0.025)	0.052 * (0.031)	0.023 (0.018)
<b>Internat. group, HQ abroad</b>	-0.047 (0.034)	0.022 (0.028)	-0.049 * (0.027)	0.083 (0.060)	-0.085 ** (0.034)	-0.005 (0.024)
<i>Competition</i>						
<b>Price</b>	-0.050 * (0.026)	-0.026 (0.018)	-0.021 (0.021)	0.023 (0.026)	-0.070 *** (0.026)	-0.033 ** (0.014)
<b>Technology</b>	-0.007 (0.015)	0.020 (0.013)	-0.007 (0.013)	0.010 (0.015)	0.005 (0.015)	0.013 (0.010)
<i>Industries</i>						
<b>High R&amp;D-intensive manufacturing</b>	0.127 *** (0.045)	-0.049 (0.047)	0.072 * (0.037)	-0.035 (0.057)	0.100 ** (0.044)	-0.022 (0.037)
<b>Medium R&amp;D-intensive manufacturing</b>	0.129 *** (0.040)	-0.007 (0.039)	0.083 ** (0.033)	-0.005 (0.047)	0.093 ** (0.040)	0.000 (0.030)
<b>Low R&amp;D-intensive manufacturing</b>	0.058 ** (0.024)	0.009 (0.026)	0.042 * (0.024)	0.018 (0.031)	0.064 ** (0.025)	0.007 (0.021)
<b>Knowledge-intensive services</b>	0.044 (0.032)	-0.041 (0.036)	-0.004 (0.031)	-0.040 (0.042)	0.039 (0.033)	-0.013 (0.026)
<b>rho</b>		0.494		-0.279		0.930
<b>sigma</b>		0.487		0.227		0.576
<b>lambda</b>		0.241 (0.201)		-0.063 (0.144)		0.536 * (0.289)
<b>W_all</b>	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.080 *
<b>H0: dom. R&amp;D &gt;= for. R&amp;D</b>	0.054 *	0.135	0.004 ***	0.747	0.022 **	0.078 *
<b>N° of observations</b>	2118	2118	2118	2118	2118	2118
<b>censored obs.</b>	1303		1666		1400	
<b>uncensored obs.</b>	815		452		718	

Notes: W\_all is the test statistic of a Wald test on joint significance of all explanatory variables. Dom R&D >= for. R&D tests the null hypothesis that domestic and foreign R&D activities have a larger or the same effect. The p-value of the F-test is reported.

Table 17: Results of Heckman estimation (No exclusion restrictions) – domestic R&D and degree of international R&D decentralisation: Marginal effects

	Product Innovation		Market Novelties		Firm Novelties	
	Yes/No	Sales growth	Yes/No	Sales growth	Yes/No	Sales growth
<i>Prior innovation activities in 2005 (ref.: firms with innovation activities except R&amp;D)</i>						
Firms without innovation activities	-0.210 *** (0.021)	-0.057 (0.057)	-0.129 *** (0.024)	0.012 (0.078)	-0.203 *** (0.022)	-0.095 *** (0.032)
Firms with domestic R&D only	0.100 *** (0.022)	0.040 (0.027)	0.079 *** (0.019)	-0.021 (0.050)	0.102 *** (0.022)	0.047 *** (0.018)
Firms with centralised foreign R&D	0.093 ** (0.041)	0.050 (0.034)	0.092 *** (0.030)	-0.026 (0.058)	0.097 ** (0.039)	0.050 ** (0.024)
Firms with medium decent. foreign R&D	0.352 *** (0.107)	0.126 *** (0.038)	0.196 *** (0.043)	-0.032 (0.079)	0.277 *** (0.072)	0.111 *** (0.028)
Firms with decentralised foreign R&D	0.000 (0.059)	0.039 (0.047)	0.189 *** (0.059)	-0.067 (0.092)	0.000 (0.033)	0.031 (0.031)
Firm size	0.034 *** (0.005)	-0.002 (0.008)	0.030 *** (0.004)	-0.012 (0.016)	0.033 *** (0.005)	0.004 (0.006)
Degree of diversification	0.024 *** (0.008)	-0.000 (0.004)	0.008 (0.006)	-0.003 (0.004)	0.003 (0.005)	0.003 (0.004)
R&D intensity	0.664 *** (0.193)	0.502 *** (0.141)	0.387 *** (0.129)	0.670 ** (0.299)	0.472 *** (0.178)	0.201 ** (0.100)
Non-R&D innov. intensity	-0.010 (0.097)	0.038 (0.097)	0.092 (0.075)	0.246 * (0.140)	0.033 (0.095)	-0.093 (0.077)
Share of high skilled emp	0.105 ** (0.045)	0.058 (0.043)	0.137 *** (0.038)	-0.007 (0.064)	0.086 * (0.045)	0.053 * (0.030)
Exporter	0.060 *** (0.019)	-0.004 (0.026)	0.062 *** (0.017)	-0.045 (0.054)	0.048 ** (0.020)	0.017 (0.015)
Firm in East Germany	-0.001 (0.018)	0.015 (0.019)	-0.035 ** (0.016)	-0.025 (0.019)	-0.001 (0.019)	0.024 (0.016)
<i>Ownership (ref: unaffiliated firm)</i>						
National group	-0.003 (0.023)	0.031 (0.023)	-0.018 (0.020)	0.028 (0.027)	-0.006 (0.023)	0.019 (0.017)
Internat. group, German HQ	0.053 (0.032)	0.027 (0.027)	0.019 (0.025)	0.022 (0.025)	0.053 * (0.032)	0.023 (0.020)
Internat. group, HQ abroad	-0.046 (0.034)	0.033 (0.034)	-0.050 * (0.027)	0.075 (0.061)	-0.080 ** (0.035)	0.005 (0.028)
<i>Competition</i>						
Price	-0.046 * (0.026)	-0.019 (0.022)	-0.018 (0.021)	0.025 (0.027)	-0.063 ** (0.026)	-0.025 (0.016)
Technology	-0.008 (0.016)	0.023 (0.016)	-0.005 (0.013)	0.009 (0.015)	0.004 (0.016)	0.015 (0.012)
<i>Industries</i>						
High R&D-intensive manufacturing	0.130 *** (0.045)	-0.070 (0.060)	0.063 * (0.037)	-0.023 (0.051)	0.108 ** (0.045)	-0.035 (0.047)
Medium R&D-intensive manufacturing	0.130 *** (0.040)	-0.026 (0.050)	0.069 ** (0.034)	0.003 (0.042)	0.106 *** (0.040)	-0.010 (0.038)
Low R&D-intensive manufacturing	0.061 ** (0.024)	-0.000 (0.033)	0.041 * (0.024)	0.023 (0.029)	0.070 *** (0.025)	-0.000 (0.027)
Knowledge-intensive services	0.047 (0.033)	-0.051 (0.045)	-0.003 (0.031)	-0.034 (0.041)	0.043 (0.034)	-0.016 (0.031)
rho		0.203		-0.193		0.712
sigma		0.466		0.230		0.500
lambda		0.095 (0.201)		-0.044 (0.153)		0.356 (0.284)
W_all	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.064 *
H0: dom. R&D>=cent. for. R&D	0.578	0.358	0.298	0.595	0.548	0.437
H0: dom. R&D>=med.decent. for. R&D	0.009 ***	0.007 ***	0.002 ***	0.614	0.007 ***	0.006 ***
H0: dom. R&D>=decent. for. R&D	-	0.515	0.027 **	0.818	-	0.694
H0: cent.for.R&D>=med.decent.for.R&D	0.010 *	0.020 **	0.010 *	0.561	0.009 ***	0.013
H0: decent. for.R&D>=med.decent.for.R&D	-	0.972	0.540	0.848	-	0.994
H0: cent.for.R&D>=decent.for.R&D	-	0.602	0.055 *	0.803	-	0.725
N° of observations	2086	2086	2086	2086	2086	2086
censored obs.	1298		1659		1393	
uncensored obs.	788		427		693	

Notes: See Table 16.

*Table 18: Coefficients of non-linear variables from Heckman estimation with exclusion restriction*

	Product Innovation		Market Novelties		Firm Novelties	
	Yes/No	Sales growth	Yes/No	Sales growth	Yes/No	Sales growth
R&D intensity	2.867 *** (0.832)	1.228 *** (0.349)	2.387 *** (0.805)	1.409 *** (0.217)	2.062 *** (0.770)	0.532 (0.351)
R&D intensity squared	-2.241 *** (0.750)	-0.703 ** (0.328)	-1.835 ** (0.735)	-0.940 *** (0.198)	-1.853 *** (0.714)	-0.220 (0.326)

Table 19: Robustness Check I: Marginal effects of Heckman estimations – domestic and foreign R&D, firms belonging to an international group headquartered abroad excluded from the sample

	Product Innovation		Market Novelties		Firm Novelties	
	Yes/No	Sales growth	Yes/No	Sales growth	Yes/No	Sales growth
<i>Prior innovation activities in 2005 (ref.: firms with innovation activities except R&amp;D)</i>						
Firms without innovation activities	-0.192 *** (0.022)	-0.070 * (0.039)	-0.115 *** (0.024)	-0.021 (0.022)	-0.186 *** (0.023)	-0.077 ** (0.033)
Firms with domestic R&D only	0.121 *** (0.023)	0.045 * (0.025)	0.087 *** (0.020)	0.009 (0.014)	0.127 *** (0.023)	0.046 ** (0.023)
Firms with domestic R&D and abroad	0.195 *** (0.039)	0.067 ** (0.031)	0.155 *** (0.027)	0.008 (0.019)	0.209 *** (0.037)	0.070 ** (0.029)
Firm size	0.029 *** (0.006)	-	0.028 *** (0.004)	-	0.029 *** (0.005)	-
Degree of diversification	0.023 *** (0.009)	-	0.006 (0.005)	-	0.002 (0.005)	-
R&D intensity	0.542 *** (0.200)	0.509 *** (0.136)	0.362 *** (0.128)	0.403 *** (0.108)	0.320 * (0.184)	0.188 (0.115)
Non-R&D innov. intensity	-0.053 (0.099)	0.023 (0.092)	0.082 (0.074)	0.146 *** (0.056)	-0.024 (0.097)	-0.118 (0.081)
Share of high skilled employees	0.091 ** (0.045)	0.060 (0.040)	0.110 *** (0.038)	0.023 (0.020)	0.075 * (0.045)	0.053 (0.036)
Exporter	0.044 ** (0.020)	-0.007 (0.021)	0.058 *** (0.017)	-0.011 (0.014)	0.032 (0.020)	0.005 (0.018)
Firm in East Germany	0.004 (0.018)	0.006 (0.018)	-0.030 * (0.017)	-0.023 ** (0.010)	0.010 (0.019)	0.020 (0.016)
<i>Ownership (ref: unaffiliated firm)</i>						
National group	0.002 (0.023)	0.026 (0.019)	-0.016 (0.019)	0.010 (0.010)	-0.003 (0.023)	0.022 (0.017)
Internat. group, German HQ	0.063 ** (0.032)	0.029 (0.024)	0.027 (0.024)	0.008 (0.012)	0.057 * (0.032)	0.027 (0.022)
<i>Competition</i>						
Price	-0.054 ** (0.026)	-0.026 (0.021)	-0.030 (0.021)	0.011 (0.011)	-0.077 *** (0.026)	-0.033 * (0.018)
Technology	-0.009 (0.016)	0.021 (0.015)	-0.004 (0.014)	0.001 (0.007)	0.007 (0.016)	0.019 (0.013)
<i>Industries</i>						
High R&D-intensive manufacturing	0.101 ** (0.047)	-0.065 (0.045)	0.051 (0.038)	0.003 (0.020)	0.075 (0.046)	-0.066 (0.042)
Medium R&D-intensive manufacturing	0.146 *** (0.041)	-0.016 (0.041)	0.087 *** (0.034)	0.022 (0.018)	0.094 ** (0.041)	-0.031 (0.038)
Low R&D-intensive manufacturing	0.055 ** (0.024)	0.001 (0.028)	0.038 (0.024)	0.023 (0.016)	0.057 ** (0.025)	-0.018 (0.027)
Knowledge-intensive services	0.047 (0.033)	-0.054 (0.038)	-0.005 (0.031)	-0.014 (0.019)	0.032 (0.034)	-0.043 (0.034)
rho	0,229		0,496		0,434	
sigma	0,470		0,243		0,441	
lambda	0,108 (0.132)		0,121 (0.070)		0,191 (0.150)	
W_all	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.032 **
H0: dom. R&D >= for. R&D	0.020	0.140	0.001	0.541	0.007	0.099
N° of observations	1975		1975		1975	
censored obs.	1230		1567		1317	
uncensored obs.	715		408		658	



Table 20: Robustness Check II: Marginal effects from Heckman estimations - domestic R&D and degree of international R&D decentralisation, firms belonging to an international group headquartered abroad excluded from the sample

	Product Innovation		Market Novelties		Firm Novelties	
	Yes/No	Sales growth	Yes/No	Sales growth	Yes/No	Sales growth
<i>Prior innovation activities in 2005 (ref.: firms with innovation activities except R&amp;D)</i>						
Firms without innovation activities	-0.202 *** (0.022)	-0.062 (0.043)	-0.114 *** (0.024)	-0.021 (0.023)	-0.199 *** (0.023)	-0.075 ** (0.035)
Firms with domestic R&D only	0.106 *** (0.022)	0.040 (0.026)	0.085 *** (0.019)	0.008 (0.015)	0.103 *** (0.022)	0.041 * (0.022)
Firms with centralised foreign R&D	0.134 *** (0.047)	0.044 (0.037)	0.114 *** (0.032)	0.008 (0.020)	0.123 *** (0.044)	0.047 (0.032)
Firms with medium decent. foreign R&D	0.332 *** (0.111)	0.125 *** (0.040)	0.218 *** (0.047)	0.016 (0.022)	0.294 *** (0.084)	0.115 *** (0.035)
Firms with decentralised foreign R&D	- (0.047)	0.038 (0.047)	0.210 *** (0.063)	-0.008 (0.028)	- (0.039)	0.044 (0.039)
Firm size	0.030 *** (0.006)	-	0.027 *** (0.004)	-	0.031 *** (0.005)	-
Degree of diversification	0.023 *** (0.009)	-	0.006 (0.005)	-	0.001 (0.005)	-
R&D intensity	0.705 *** (0.203)	0.523 *** (0.142)	0.359 *** (0.129)	0.417 *** (0.117)	0.501 *** (0.184)	0.193 (0.122)
Non-R&D innov. intensity	-0.049 (0.100)	0.023 (0.097)	0.080 (0.074)	0.146 ** (0.058)	-0.017 (0.097)	-0.124 (0.085)
Share of high skilled emp	0.096 ** (0.046)	0.057 (0.042)	0.115 *** (0.038)	0.024 (0.021)	0.083 * (0.046)	0.050 (0.037)
Exporter	0.047 ** (0.020)	-0.007 (0.023)	0.059 *** (0.017)	-0.011 (0.015)	0.035 * (0.020)	0.007 (0.019)
Firm in East Germany	0.001 (0.019)	0.008 (0.019)	-0.031 * (0.016)	-0.023 ** (0.011)	0.006 (0.019)	0.022 (0.017)
<i>Ownership (ref: unaffiliated firm)</i>						
National group	0.003 (0.023)	0.027 (0.020)	-0.015 (0.019)	0.011 (0.010)	-0.002 (0.023)	0.023 (0.018)
Internat. group, German HQ	0.065 ** (0.032)	0.019 (0.028)	0.019 (0.024)	0.009 (0.012)	0.061 * (0.032)	0.020 (0.025)
<i>Competition</i>						
Price	-0.051 * (0.027)	-0.021 (0.022)	-0.028 (0.021)	0.014 (0.012)	-0.072 *** (0.027)	-0.027 (0.019)
Technology	-0.009 (0.016)	0.023 (0.016)	-0.001 (0.014)	0.001 (0.007)	0.008 (0.016)	0.020 (0.014)
<i>Industries</i>						
High R&D-intensive manufacturing	0.103 ** (0.047)	-0.065 (0.048)	0.039 (0.038)	0.006 (0.021)	0.079 * (0.047)	-0.064 (0.044)
Medium R&D-intensive manufacturing	0.150 *** (0.042)	-0.024 (0.044)	0.075 ** (0.034)	0.023 (0.019)	0.103 ** (0.041)	-0.034 (0.040)
Low R&D-intensive manufacturing	0.057 ** (0.025)	-0.001 (0.029)	0.037 (0.024)	0.025 (0.016)	0.061 ** (0.025)	-0.020 (0.028)
Knowledge-intensive services	0.049 (0.033)	-0.051 (0.040)	-0.004 (0.031)	-0.013 (0.020)	0.034 (0.034)	-0.036 (0.035)
rho	0.229		0.488		0.378	
sigma	0.470		0.249		0.440	
lambda	0.108 (0.132)		0.122 (0.074)		0.166 (0.142)	
W_all	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.058 *
H0: dom. R&D>=cent. for. R&D	0.261	0.436	0.148	0.492	0.311	0.405
H0: dom. R&D>=med.decent. for. R&D	0.020 **	0.007 ***	0.001 ***	0.299	0.010 *	0.006 ***
H0: dom. R&D>=decent. for. R&D		0.516	0.020 **	0.784		0.471
H0: cent.for.R&D>=med.decent.for.R&D	0.045 **	0.021 **	0.018 **	0.314	0.028 **	0.022 **
H0: decent. for.R&D>=med.decent.for.R&D		0.033 **	0.454	0.106		0.036 **
H0: cent.for.R&D>=decent.for.R&D		0.553	0.068 *	0.795		0.532
N° of observations	1945		1945		1945	
censored obs.	1230		1560		1311	
uncensored obs.	715		385		634	



## **4 The Contribution of International R&D to Firm Profitability<sup>13</sup>**

The profitability of a firm is an essential criterion to measure the effectiveness and success of firm operations. It reflects their ability to operate successfully in the competitive environment and therefore combines the results of firm strategy and execution as well as market response to firm output. In developed countries, the competitive advantage and performance of firms depends to a large extent on their ability to create new and innovative products (Hall et al. 2009).

In the search for new sources of technology and ideas firms increasingly expand their innovative capacities across borders. This has led to the growing internationalisation of corporate research and development (R&D) activities in the last decade (UNCTAD, 2005). Firms equip their subsidiaries abroad with R&D departments and set up centres of excellence in leading industry-specific locations. The internationalisation of R&D reflects the global strategies of multinational enterprises (MNE) and the intention to look for new sources of competitiveness beyond domestic borders. Like any other business process, the internationalisation towards decentralised R&D activities is aimed at strengthening the economic performance of the firm. Due to the proximity to foreign knowledge resources that might not be available in the home country, firms hope to increase the chances to benefit from local knowledge spillovers. Absorbing and integrating additional knowledge allows firms to build an idiosyncratic knowledge base, improve their innovativeness and as a result to generate competitive advantages and higher profitability.

Viewing the process to internationalise R&D from the cost perspective, these ventures may be associated with many barriers to profitability gains, ranging from set up costs, foregone economies of scale and scope, coordination costs, costs for intra-firm knowledge transfer, liabilities of foreignness or outgoing knowledge spillovers. Hence, from a theoretical point of view, the relationship between

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<sup>13</sup> This chapter is based on Peters and Schmiele (2010b).

international R&D and firm profitability is ambiguous and has to be determined empirically. However, the literature provides no empirical evidence on the profitability of foreign R&D activities so far.

The objective of this chapter is to assess benefits and costs of international corporate R&D activities. More specifically, we address the question of whether international R&D activities enhance future profitability. The answer to this question is naturally important from a managerial point of view since it allows the manager to assess the success of different corporate R&D strategies. Evidence on the relation between gains and pains of international R&D activities is especially important against the background of growing international competition and a persisting trend to carry out R&D globally. The empirical analysis is based on information collected within the Community Innovation Surveys (CIS) on a large sample of 1364 German companies for the period 2005-2008. In order to answer our research question, we compare the profit development of international innovators with that of firms conducting R&D at home or performing no R&D at all. Comparing profits of firms with or without foreign innovation activities comprises the overall assessment of both arising costs and benefits due to international R&D activities. This approach thus demonstrates a complete view on firms' strategies to internationalise R&D by considering both efforts and results of this business venture.

Our analysis contributes to the scant literature on international R&D and firm performance in the following aspects. First, compared to previous studies we do not measure firm performance by means of productivity but use profitability instead. The fact that we do not compare the profit contribution of different R&D strategies within multinational enterprises but compare different R&D strategies across firms is another main novelty of the chapter. In line with the literature that examines the relationship between the degree of multinationality and firm performance, we thirdly investigate how the *degree of R&D internationalisation* affects profitability.

For this purpose the chapter continues in the following sequence: Section 2 reviews existing studies in this field of research, and it explores the theoretical frameworks which we use to derive our hypotheses. Section 3 introduces the dataset and focuses on the empirical approach to estimate the profitability of firms with international R&D activities. The results from our estimations are presented in Section 4 and Section 5 discusses the findings and concludes with management recommendations.

## 4.1 Literature Review

### 4.1.1 Internationalisation, R&D and Firm Performance

In a broader sense, our research ties on to two different strands of the literature. The first is the one that deals with the relationship between R&D activities and firm performance. Inspired by the seminal work by Griliches (1986), many studies have investigated the impact of R&D on productivity at the firm level. Most studies ascertain a significant positive private return to R&D, ranging mostly between 20 to 30% and therefore feeding the widespread believe that R&D is a key long-term driving force for competitiveness and growth of enterprises (see the survey by Hall et al. 2009 and the references cited therein). Using different measures of firm performance, Lööf and Heshmati (2006) find that R&D and innovation activities are also conducive to both the level of firms' profits (after depreciation) and the growth rates of profits. The authors confirm such a positive R&D effect for both manufacturing and service firms. Similarly, Czarnitzki and Kraft (2010) find a positive impact of the patent stock on profitability. Innovations thus allow firms to distinguish their products from competitors and as a result of this firms make higher profits (Kotabe et al., 2002). These studies, however, do not differentiate whether the *location* of R&D activities matters.

Second, our research is related to the extensive literature that has investigated the effects of firms' geographical diversification on their performance (Vernon, 1971; Qian et al., 2008; Hitt et al., 1997; Wan and Hoskisson, 2003; Rugman and Verbeke, 2004; Kafouros et al., 2008; Gande et al., 2009). While some researchers have distinguished the degree of internationalisation by the number of firms' overseas subsidiaries (Qian et al., 2008; Hitt et al., 1994; Morck and Yeung, 1991), most studies defined it by using the share of international sales to total sales or foreign assets to total assets (see Qian et al., 2008 and Sullivan, 1994 for an overview). Concerning the measurement of firm performance, most scholars used the ratio of return on assets and return on sales (Sullivan, 1994; Kumar, 1984; Geringer et al., 1989). All in all, these studies come up with quite contradicting results ranging from negative or positive linear effects to horizontal s-curved or u-shaped relationships between firms' degree of internationalisation and firm performance (see Qian et al., 2008 and Sullivan, 1994). More importantly with respect to our research question, these studies do not take into account the *kind of activities* foreign subsidiaries perform. In particular, they neglect whether firms carry out innovation activities at their foreign subsidiaries. In a recent study, Kotabe et al. (2002) showed that MNEs with higher R&D

capabilities (R&D intensity) benefit more from internationalisation. But this study likewise does not distinguish between the location of R&D activities of MNEs.

#### **4.1.2 Potential Benefits from International R&D**

The trend of firms to internationalise has developed from exporting to more knowledge intensive business processes. Foreign subsidiaries of MNEs do not act as prolonged sales entities of their mother company anymore but as units that often have implemented whole value chain processes including own R&D activities. These R&D activities are often a requirement of attractive markets to serve them with the appropriate technology and designs. Basically, the literature invokes two streams of motives to explain why firms expand their R&D activities to foreign countries around the world:

Demand-oriented motives result from the necessity to customise certain products to different foreign preferences, requirements or legal regulations. By tailoring products to local requirements, firms aim to enlarge their market size and generate higher profits by leveraging R&D outcomes across borders.

Supply-oriented motives are related to the firms' wish to make use of resources at foreign locations that are not available in the same quality or quantity as in the home country. In particular, resources such as knowledge and skilled employees drive firms' decision to perform R&D abroad. Having R&D departments in multiple countries enables firms to benefit from the pool of global knowledge resources. Foreign subsidiaries are usually embedded in local networks with customers, suppliers and competitors and are therefore linked to local knowledge, ideas and know-how (McEvily and Zaheer, 1999). Proximity to foreign knowledge sources enables foreign subsidiaries that carry out R&D activities to integrate the knowledge from the foreign business environment into their own innovation process either through co-operations or through incoming knowledge spillovers (Frost, 2001). Absorptive capabilities (Cohen and Levinthal, 1989) and knowledge sharing infrastructure allow firms to assimilate the foreign knowledge and enhance the learning process of the whole organization (Zahra and Hayton, 2008). Following the perspective and assumptions of the knowledge based view, firms are bundles of knowledge and work as knowledge integrating institutions (Grant, 1996). Based on their corporate knowledge base, they can develop competitive advantages. The competitive advantage depends on the uniqueness of the knowledge base. In this vein, multiple sources of knowledge open up better possibilities to firms to build an idiosyncratic knowledge base which incorporates additional knowledge, capabilities and know-how. Firms may increase their

innovativeness by drawing upon this larger and improved knowledge base and can as a result develop and exploit competitive advantages. Increasing competitiveness and as a consequence also profitability are of course the final goals of the strategy to internationalise corporate R&D.

Recent empirical evidence confirms that domestic firms benefit on average from foreign R&D activities by improving their innovation performance. Using a sample of MNEs performing R&D abroad, Iwasa and Odagiri (2004) ascertain a positive contribution of international innovative R&D on patent output. Comparing firms with and without international R&D, it has been shown that firms with foreign R&D produce more patents (Penner-Hahn and Shaver, 2005), are more successful in generating product innovations and achieve a higher sales growth due to new products than firms having only domestic R&D activities (Peters and Schmiele, 2010a). A related stream of literature examines the innovation performance of R&D laboratories abroad and its drivers. Ambos and Ambos (2009) found that R&D facilities in Non-Triad countries are less innovative and to a lesser degree (horizontally) integrated than foreign labs in Triad-nations. This relates to the finding of Phene and Almeida (2008) who identified knowledge from host country firms to increase the scale (number of patents) and quality (number of citations received) of subsidiary innovation. Furthermore, the relationship between the size of an R&D site abroad and the performance of the lab turns out to be concave (Kuemmerle, 1998). Grevesen and Damanpour (2007) corroborate that knowledge sharing infrastructure in firms has a strong positive impact on innovation performance of foreign R&D subsidiaries.

#### **4.1.3 Costs of International R&D Activities**

Depending on the organization of R&D activities, different costs may arise. In general, the management of international R&D activities is characterised by a significantly higher degree of complexity than local R&D management (Gassmann and Von Zedtwitz, 1999). A centralised organization, on the one hand, is assumed to cause higher transaction costs (Coase, 1937; Williamson, 1985), costs to run information systems, opportunity costs for not responding to foreign market preferences and ignoring foreign resources. Running R&D facilities abroad, on the other hand, involves various risks and costs since the internationalisation of R&D naturally represents a decentralisation of corporate innovation activities.

Besides direct set-up and infrastructure costs, the lower chance to realize *economies of scale* and *scope* is the primary concerns when R&D activities are

decentralised (Malecki, 1980). Economies of scale may arise if the research equipment is indivisible or if a critical mass of researchers is needed for a relatively efficient R&D (Mansfield et al. 1979). Wallmaak et al. (1973) demonstrated that research efficiency increases exponentially with the research team size. If other typical headquarters activities such as marketing, trial production, testing, management of intellectual property rights or controlling are complementary to R&D activities, a firm may not fully exploit these synergy effects if it shifts R&D activities abroad (Sanna-Radaccio and Veugelers, 2007).

Instead of exploiting these economies of scale and scope, firms have to bear the extra *costs of coordinating* research between different R&D laboratories and coordinating work between foreign R&D labs and headquarter activities. In general, minimal coordination costs would arise if the firm delegated autonomy and decision making to foreign R&D divisions (Argryes and Silverman, 2004). But since knowledge produced in different R&D locations is aimed to be shared across the whole organization, a certain degree of coordination is necessary (Leiponen and Helfat, 2010). Because monitoring R&D activities abroad is much more difficult in distant locations, coordination is particularly important to avoid additional *inefficiencies due to duplicative and redundant R&D projects* that are more likely in rather decentralised international R&D structures (Gassmann and Von Zedtwitz, 1999). All in all, the international decentralisation of corporate R&D activities urges innovative firms to tighten their control over foreign activities especially because R&D activities represent their core competences. Firms have to balance the likely benefits of coordinating research against the loss of independence and presumable innovativeness of foreign R&D laboratories.

Closely related is the argument that firms may be confronted with *intra-firm knowledge losses*. Researchers are most likely to share their knowledge when they work close to each other. More generally, knowledge spillovers are taking place rather within greater proximity than across long distances (Jaffe et.al., 1993; Branstetter, 2001). This finding can partly be explained by the characteristics of knowledge itself, i.e. the fact that new knowledge produced by research is often complex and is in part tacit and not codifiable (Zander and Kogut, 1995; Szulanski, 1996). Another reason might be that division R&D managers may have little incentive to transfer knowledge across divisions, for instance if their compensation is tied to the performance of their divisions (Kay, 1988; Leiponen and Helfat 2010). As a result, firms may be confronted with a situation in which the knowledge existing in the R&D centres is stuck within national borders. To overcome this problem, decentralised R&D structures require a high level of



*organisational costs* related to managerial attention, efforts to establish knowledge sharing infrastructure, a strong facilitation of knowledge flows, for instance through knowledge exchanges and the establishment of incentives mechanisms to integrate subsidiary knowledge into the organizational knowledge base. Firms that have a small number of R&D centres abroad might be less affected from these organisational problems than firms which have a global network of subsidiaries with R&D mandates (Gassmann and Von Zedtwitz, 1999).<sup>14</sup>

In addition to these organisational expenses, firms may incur costs due to increasing *outgoing knowledge spillovers*. Foreign R&D subsidiaries do not only source local knowledge but are also prone to knowledge leakage to local competitors. The extent of such spillover costs depends on the absorptive capacities of local competitors and the strength of the product market competition (Sanna-Radaccio and Veugelers, 2007). Thus, to appropriate the results from R&D ventures abroad firms might also have to invest in stronger appropriability mechanisms.

Foreign business environments confront firms with additional complexity. The costs which arise from unfamiliar business environments (Hymer, 1976) are summarised in the concept of *liabilities of foreignness* (Zaheer, 1995).

These costs result from cultural, political and economic differences which confront firms with unexpected situations and extraordinary risks. Furthermore, larger communication and organization costs due to the greater distance as well as a lack of networks and contacts constitute disadvantages in comparison to local firms abroad (Zaheer and Mosakowski, 1997). Therefore, liabilities of foreignness, as for example too much trust in formal contracts or local R&D partners, are supposedly affecting the performance of firms with international R&D activities. In certain countries contracts are rather based on personal relationships and the respect of intellectual properties and their legal enforcement is not that embedded (Yang, 2005). The more the host country's culture differs from the culture of the firm's home country the higher these costs might be. Cultural distance is also emphasised by Hutzschenreuter and Voll (2008) as a driver of additional complexity in international expansion which evidently reduces firm performance.

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<sup>14</sup> In this regard, Gassmann and Von Zedtwitz (1999) have observed the trend to recentralise international R&D activities and rather establish an integrated R&D network with a smaller number of leading R&D labs. This cost reducing strategy enables firms to utilise economies of scale and reduces redundant R&D projects.

All in all, the international phenomenon of decentralising R&D to foreign locations and specifically the tendency to an increasing number of R&D locations abroad seems to worsen the corporate firm performance by raising various additional costs.

#### **4.1.4 Benefits versus Costs of International R&D – Hypotheses**

In a theoretical approach Sanna-Radaccio and Veugelers (2007) combined both perspectives on international R&D: benefits and costs. They highlight that shifting R&D expenses abroad implies a cut in the R&D budget at home (in the short run with fixed budgets) and therefore lowers the profitability of the parent company. This negative effect is at least partly offset by knowledge gains. Firms' profits from international R&D thus strongly depend on the knowledge transfer efficiency between the subsidiaries and the parent company and that incoming knowledge spillovers from the foreign business environment exceed outgoing spillovers. Therefore, the influence of the symmetry between costs and benefits resides to a major extent in the hand of firms in terms of optimising knowledge flows and limiting knowledge spillovers to foreign competitors. *If* the firm can master the risks of local competition and knowledge leakage and encourage international incoming knowledge spillovers, then a positive impact on profits can be expected.

Since the relation between the gain and the pain of international R&D remains theoretically ambiguous, it has to be determined empirically. We formulate two sets of hypotheses. Following the knowledge-based view, we hypothesise that firms that set up R&D facilities abroad benefit from a better access to foreign knowledge pools that increase their innovativeness and subsequently their competitive advantage and profitability. In this vein, a stronger decentralisation of R&D should increase profitability as it allows firms to tap and combine knowledge from multiple sources. We implicitly assume that these firms possess an appropriate amount of resources and intercultural experience to set up both sufficiently efficient intra-firm coordination and knowledge transfer mechanisms and sufficiently efficient knowledge protection methods to prevent outgoing knowledge spillovers.

- *Hypothesis 1a: The benefits outweigh the costs of international R&D and leave the international knowledge sourcing firm with a greater profitability compared to firms which perform R&D only at the home base.*

- *Hypothesis 2a: Firms which have dispersed their R&D activities in a wider range of foreign locations benefit from the access to a greater knowledge pool and as a result they make higher profits.*

The alternative hypotheses follow the arguments of foregone economies of scale and scope, outgoing spillovers, liabilities of foreignness, added cultural distance and increasing organisational costs:

- *Hypothesis 1b: International R&D activities drive corporate costs extraordinarily high, so that costs exceed benefits and therefore affect the firm profitability negatively.*
- *Hypothesis 2b: Firms that have dispersed their R&D activities in a wider range of foreign locations incur proportionately high costs and thus larger losses in profitability than firms which concentrated R&D activities in a small number of locations abroad.*

Sanna-Radaccio and Veugelers (2007) stated that the profitability of foreign R&D activities decreases with strong host product market competition. With strong product market competition local rivals exhibit a stronger absorptive capacity which increases the risk of knowledge leakage. This raises the cost of outgoing knowledge spillovers and reduces profitability if spillovers are asymmetric (sufficiently in disfavour of the MNE).

- *Hypothesis 3: The profitability of foreign R&D activities declines with strong competition on the host product market.*

#### **4.1.5 Empirical Evidence**

Studies which have examined the effects of international R&D activities on firm performance – to the best of our knowledge to-date – have investigated the impact on productivity growth. In this vein, Mansfield (1984) ascertained for a sample of 15 US MNEs that foreign R&D has a positive impact on productivity of home-country US plants. Fors (1997), however, could not confirm this result for Swedish MNEs. He found that both R&D at home and R&D at foreign subsidiaries show the same rate of return on productivity growth for the respective firm entity. Furthermore, he provided evidence that R&D performed at home increases productivity in foreign plants. However, there is no indication of a knowledge transfer in the sense that home plants benefit from R&D abroad. Fors argued that this finding can be expected if foreign R&D is mainly adaptive, i.e. geared towards the exploitation of existing knowledge. However, due to data constraints he was not able to cope with different types of R&D activity in foreign

subsidiaries. Todo and Shimizutani (2008) approached this research gap by analyzing the effects of adaptive and innovative (augmenting-knowledge) R&D activities abroad on productivity growth in the home country. Using data for Japanese MNEs, they found a positive impact of innovative R&D on home productivity growth. In contrast, adaptive foreign R&D does not raise the parent firm's productivity growth. Interestingly, they did not detect any positive interaction between home and foreign R&D activities on parent firm's productivity growth.

Our aim is to contribute to the scant literature on international R&D and firm performance in the following aspects: First, instead of focussing on productivity performance, the present chapter is aimed at investigating how firms' profitability is influenced by international R&D activities. Furthermore, we investigate how the *degree of R&D internationalisation* affects profitability.

## **4.2 Data and Empirical Implementation**

### **4.2.1 Data**

For the empirical test of our hypotheses we need firm-level information about corporate R&D activities in the home and host countries and data about the development of firm profitability. Appropriate data sources for our purpose are the official German innovation surveys, called Mannheim Innovation Panel (MIP). In 2006, the survey was sent out to 17,395 firms in Germany and inquires about innovation efforts, innovation success and other innovation related topics. A response rate of about 30% is achieved. The 2006 survey includes detailed questions on R&D activities outside the home country. Since the MIP is designed as a panel, it allows us to merge firm-level information across different waves, using distinct identifying numeric codes for surveyed firms.

In the present chapter we make use of two survey waves from the MIP panel. We gather information about firms' innovation activities abroad in year 2005 from the 2006 survey. In this survey firms were asked what type of innovation activity they perform abroad, dividing between different categories (R&D, implementation of new processes, conception/design/construction of new products, manufacturing of new products, sales of new products). Firms were furthermore requested to name in a free text field the countries in which they predominantly perform the different

types of innovation activities. The 2009 survey provides us with information about firms' profitability in the year 2008.

#### 4.2.2 Dependent Variable

We aim at measuring the impact of international R&D activities on future profitability. Since it takes time to translate research efforts into new products or processes, success variables like profitability need to be measured in appropriate time after the operations, to be evaluated where executed. In order to create a sufficient time lag between the R&D activities abroad and the performance indicator, we employ the latest available survey data to measure profitability. That is, we use the 2009 survey that includes firm profitability in 2008. Since empirical evidence has pointed towards the fact that firms tend to carry out rather applied instead of basic R&D at foreign locations, a three-year time lag between research efforts and performance indicator seems to be reasonable. This approach might also alleviate potential endogeneity problems due to *simultaneity* of the decision to locate R&D and profitability that would arise in a cross-sectional analysis.

Profitability is measured using profit margins, more precisely the earnings before taxation as a share of total sales in 2008. The return on sales has been captured in the survey by offering the respondents the possibility to choose their answer from a set of eight possible categories (<0%, 0% - <2%, 2% - <4%, 4% - <7%, 7% - <10%, 10% - <15%, >=15%, unknown). By using this information we create a time lag of three years between our dependent variable (profitability in year 2008) and the foreign R&D activities in 2005.

#### 4.2.3 Explanatory Variables

##### *Measuring Domestic and International R&D Activities*

The main focus of this chapter is to evaluate firms' strategies to locate R&D activities abroad. In order to do so, we include two binary variables: The first dummy indicates firms that concentrate their R&D activities at their home location (*firms with domestic R&D only*). The second dummy variable equals one if the firm carries out national and international R&D activities (*firms with foreign R&D*). Because only one firm reports foreign but no domestic R&D activities, we cannot test for complementarity between the two strategies.

As already pointed out in the literature review, the total benefits and costs may vary with the extent of foreign R&D activities. For instance, on the one hand a

greater number of R&D locations abroad imply a better chance to source knowledge from a wider range of locations. On the other hand, it may increase coordination costs. In order to be able to investigate the effect that international R&D intensity exerts on firm performance we also include three dummy variables that capture the degree of R&D internationalisation. We define the degree of R&D internationalisation analogue to previous studies in the research field of firm internationalisation and firm performance, by using the number of countries in which the firms run R&D laboratories. We receive the information about the number of countries in which the firms operate their R&D activities from the MIP survey. We distinguish between *centralised*, *medium decentralised* and *decentralised foreign R&D activities* in accordance with a situation in which a firm carries out R&D in one, two to three and more than three foreign countries.

Furthermore, note that we employ a representative sample of all firms – but not all firms have conducted R&D in 2005. We construct two additional dummy variables to identify two different groups of non-R&D performing firms. The first group comprises firms that are engaged in innovation activities but without carrying out own R&D activities (*innovative firms without R&D*). The second group indicates firms with no innovation activities in 2005 (*firms without innovation activities*). In the estimates, *innovative firms without R&D* present the reference category.

### ***Control Variables***

The estimation additionally includes a number of firm-level control variables that previous research had linked to profitability. We create a dummy variable that indicates whether the firm exports to foreign markets in the year 2005 (*exporter*). By and large, the literature on exports and firm performance provides evidence that a positive correlation between exports and firm performance is due to the fact that the best performing domestic firms self-select into international markets (Bernard and Jensen 1999; De Loecker, 2007). A similar argument might be effective in case of international R&D. Past profitability is likely to be correlated with future profitability (Geroski and Jacquemin, 1988) and it might also be correlated with the decision to perform R&D abroad in a sense that the most profitable firms self-select into the sample of international R&D performing firms. In this case, omitting past profitability would render the variable *international R&D* endogenous. We account for *past profitability* by including eight dummy variables that measure firms' profit margins in 2005.

Another set of controls are two dummy variables that are intended to capture the effect of *marketing* and *organisational innovations* on firm profitability. Marketing efforts of firms have been proved to enhance the operational performance of multinational firms (Kotabe et al., 2002). The introduction of new brands, sales channels, designs and pricing strategies might enable firms to distinguish their products from competitors and as a result to reap higher profits. Similarly, organisational innovations such as (changes in) knowledge management, customer relationship and alliance management might stimulate firm profitability. Table 21 summarises all variables and provides more details on the definitions of all control variables.

In the estimation, we additionally control for different aspects of the competitive environment in which firms operate and that may influence profitability. First, we included two binary variables that capture whether firms face *strong international competitors* and whether technological competition is characterised by fast outdated products (*fast obsolescence*). We expect a negative sign of the first variable whereas the sign of the second variable is a priori unclear. Firms operating in markets where products become rapidly obsolete due to strong technological competition might charge higher prices and earn higher profits since the expected time to reap benefits from innovative products is shorter. However, strong competition might prevent them from earning higher profits. We further include the firm's *market share* that reflects market power. Higher market shares are expected to alter the level of sales and profitability and therefore need to be accounted for. Since firms could tick a box in the survey if their market share is below 0.1%, we set the market share to zero for these firms and additionally create a dummy variable to account for the truncation effect (*market share truncated*). Similarly, we create a dummy variable for those firms for which this information is missing (*market share missing*).

In addition, we control for *firm size* (number of employees in 2005), the *degree of diversification* of firms' production and the *capital intensity*. The capital intensity points to the level of assets which, when they are used efficiently, contribute to firm performance (Harris, 1988). We measure capital intensity by the ratio of the value of fixed assets to employees in year 2005. Other control variables account for the type of ownership. We distinguish between *unaffiliated firms* (reference group) and firms that either belong to a *national group*, *international group with a German headquarter* or an *international group with headquarter abroad*. The latter firms might be more likely to have R&D at their foreign sites close to their head offices. Dummies for firms belonging to *high R&D-intensive manufacturing*,

*medium R&D-intensive manufacturing, low R&D-intensive manufacturing, knowledge-intensive services and other services* (reference category) allow us to control for industry effects. The categorization of industries has been done following the method of Legler and Frietsch (2007) for the Federal Ministry of Education and Research to distinguish industries by their level of R&D intensity and knowledge intensity.



Table 21: Definition of Explanatory Variables

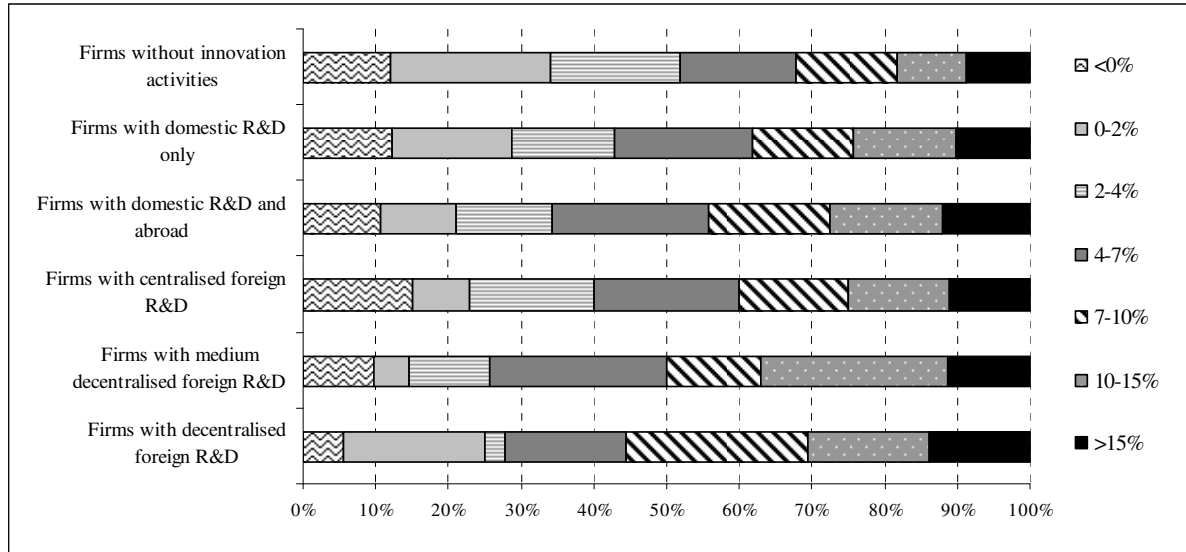
<b>Innovation activities in year 2005</b>	<b>Definition</b>
Firms without innovation activities	1 if the firm has no R&D and no innovations (in year 2005)
Firms with domestic R&D only	1 if the firm has R&D labs in Germany only
Firms with domestic R&D and abroad	1 if the firm has R&D labs in Germany and at least one R&D lab abroad
Firms with centralised foreign R&D	1 if the firm has an R&D lab in only 1 country abroad
Firms with medium decentralised foreign R&D	1 if the firm has R&D labs in 2 or 3 countries abroad
Firms with decentralised foreign R&D	1 if the firm has R&D labs in 4 or more countries abroad
Firms with foreign R&D x Strong international competition	1 if the firm has R&D labs in Germany and at least one R&D lab abroad and experienced strong international competition due to foreign competitors
Reference Group = Innovator without R&D	1 if the firm has innovations but no R&D activities
<b>Control Variables related to year 2005</b>	<b>Definition</b>
Firm size	No. of employees (in log)
Degree of diversification	1 divided by the share of sales with the most important product
Capital Intensity	Ratio of firms' tangible fixed assets to total employees
Exporter	1 if firm is having exports
National group	1 if firm is a national group
Intern. Group with German HQ	1 if firm is an international group headquartered in Germany
Intern. Group with HQ abroad	1 if firm is an international group headquartered abroad
Previous profits <i>i</i>	Firms' return on sales ratio in year 2005; ( <i>i</i> has one of eight values: <0%; 0-2%; 2-4%; 4-7%; 7-10%; 10-15%; >15%; information unavailable. The reference category is <0% )
<b>Industry</b>	<b>Definition</b>
High R&D-intensive manufacturing	1 if firm belongs to the industry classification of knowledge-intensive manufacturing sectors following Legler and Frietsch (2007)
Medium R&D-intensive manufacturing	1 if firm belongs to the industry classification of Other (than the previous category) knowledge-intensive manufacturing sectors following Legler and Frietsch (2007)
Low R&D-intensive manufacturing	1 if firm belongs to the industry classification of not knowledge intensive manufacturing sectors following Legler and Frietsch (2007)
Knowledge-intensive services	1 if firm belongs to the industry classification of knowledge-intensive Services sectors following Legler and Frietsch (2007)
<b>Control Variables related to years 2006-2008</b>	<b>Definition</b>
Marketing innovation	1 if firm had at least one marketing innovation (improved design, advertising techniques / media, sales channels, price policy)
Organisation innovation	1 if firm had at least one organisation innovation (efficient process organisation, work organisation, external relationship management)
<b>Control Variables related to year 2008</b>	<b>Definition</b>
Market share	Market share of most important product
Dummy: Market share truncated	1 if market share is below 0.1%
Dummy: Market share missing	1 if market share information has not been specified
<b>Competitive Environment</b>	<b>Definition</b>
Competition: Fast Obsolescence	1 if firms have stated that the competition indicator: product/services are fast obsolete, is very relevant or relevant
Competition: Strong international competitors	1 if firms have stated that the competition indicator: strong competition due to foreign competitors, is very relevant or relevant

#### 4.2.4 Descriptive Statistics

Our estimation sample that we retain from merging the information of two surveys and removing firms with missing values consists of 1364 firms. Table 25 in the appendix shows the distributional characteristics of the estimation sample with respect to size, industry and innovator status. It turns out that the distributions quite well reflect the ones of the total samples in 2005 and 2008 and do not give any obvious cause for selectivity concerns in this respect.

The descriptive statistics elicit the degree of internationalisation in German companies. Despite the increasing trend to internationalise R&D in Germany (Rammer and Schmiele, 2008), it turns out that firms still predominately perform R&D in their home country. 28% of the firms carried out R&D activities only within Germany whereas 17% of the sample firms conducted R&D activities in their home country as well as abroad. Nearly 50 % of the firms that have established R&D facilities abroad run one foreign R&D centre (8% of sampled firms). About 5% of firms with international R&D activities have two or three countries as sources of new knowledge and approximately 3% of the sampled firms set up R&D laboratories in four or more countries abroad. The sample further includes about 38% firms without any innovation activities. The reference group in our estimations represents firms that are involved in innovation activities without own R&D (18%). The estimated average return on sales is 5.6% in our sample. Figure 5 indicates the distribution of firms without innovation activities, with R&D in the home country and firms with R&D in host countries in the given thresholds of return on sales.

Figure 5: Return on Sales Thresholds



### 4.2.5 Estimation Method

Let  $y_i^*$  denote firm’s profitability. We assume that it depends on the observables explanatory variables explained in section 4.2.3 and summarised in the row vector  $x_i$  and on observable variables summarised in the idiosyncratic error  $\varepsilon_i$  in the following way:<sup>15</sup>

$$y_i^* = x_i\beta + \varepsilon_i \quad i = 1, \dots, N \quad \text{and} \quad \varepsilon_i | x_i \sim N(0, \sigma^2)$$

$N$  is the number of firms. Unfortunately, we do not observe true  $y_i^*$ , but only the interval-coded profitability  $y_i$ . The structure of our endogenous variable thus determines the estimation method. An ordered probit model would have been a possible way to estimate the influence of domestic and foreign R&D activities on the return of sales. But since the thresholds of profit margins are given in the survey, we do not need to estimate them as an ordered probit estimation would do. Therefore, it is eligible to use an interval regression with known thresholds. In this model, the parameters  $\beta$  and the variance  $\sigma^2$  can be estimated by maximum likelihood (for more details, see Wooldridge 2002, p. 508). The main advantage of this approach is that, given the threshold values, the estimated coefficients can be directly interpreted as marginal effect like in a linear regression model and unlike in ordinal probit models with unknown thresholds, where the estimated

<sup>15</sup> For simplicity, we neglect the time indices of all variables.

parameters are always scaled by the normalised variance (Czarnitzki and Kraft, 2010).

To check for the robustness of the estimated coefficients, we estimate the model by gradually enhancing the model specification. The first estimation model is our baseline model, which observes the effects of innovation strategy (*foreign R&D*, *domestic R&D* and *no technological innovation activities*) on firm profitability, when we only control for firm size. In the second model we include additional firm-level variables such as marketing and organisation innovation activities, market share information, range of product diversity, capital intensity, firm ownership status and engagement on international markets. In the third model, firm level information about the competitive nature of the market and industry dummies are included. In the fourth estimation model we additionally account for past profitability. Specification five tests the hypothesis H3 by interacting *foreign R&D* and *strength of foreign competition*. The final specification subdivides firms with international R&D by their extent of international R&D activities into three categories and keeps all other variables from the fourth estimation.

### 4.3 Empirical Results

The results of the six different estimation models are shown in Table 22. The first striking result is that both firms with domestic R&D activities as well as firms with international (domestic & foreign) R&D activities show a significantly higher profitability as measured by the return on sales. It can be seen that these profitability effects are consistently significant across all model specifications I-V, even after controlling for firm size, past profitability and many other firm-level variables. Whereas the magnitude of the effect of domestic R&D is nearly unaltered as a result of the inclusion of additional explanatory variables, the effect of foreign R&D is getting somewhat smaller (it declines from 2.99 to 1.87). This implies that the observed higher profitability of firms with foreign R&D activities in the first specification can in part be explained by other variables such as past profitability, group status, industry or market share. As already explained, in the ordered probit model with known thresholds the estimated coefficients can be interpreted as marginal effects like in the standard linear regression model. Based on model IV, the results demonstrate that purely domestic R&D activities raise return on sales by roughly 1% point. Firms performing R&D activities also abroad achieve a profit margin that is roughly 1.9% points higher compared to innovative firms without own R&D. To assess whether this effect is large we compare it with

the average return on sales. Estimating the model with a constant only yields an estimate of the average unconditional profitability which in our sample amounts to 5.57%. Compared to that overall figure, an increase of 1.9% point seems to be relatively large. This is also true compared to the effect of other binary variables such as ownership or export.

More importantly with respect to our research question, the positive profitability effect is significantly stronger for firms with both domestic and global R&D activities than for firms carrying out solely domestic R&D. As depicted in Table 23, we tested on statistical equality of both coefficients but rejected the hypothesis that they are equal. The dominant influence of foreign R&D is consistent across all models I-IV. The results thus confirm Hypothesis 1a in which we assumed that the benefits of international knowledge sourcing outweigh the operational costs of foreign R&D activities as well as the risks of IP losses.

Based on their theoretical model, Sanna-Radaccio and Veugelers (2007) stated that the risk of knowledge leakage increases and thus profitability declines with strong product market competition in foreign markets. To test this Hypothesis 3, we interact foreign R&D activities with a variable indicating the strength of foreign competitors in model V. We find the expected negative sign of the interaction term; however it turns out to be not significant. Hence, we cannot support Hypothesis 3.

In our last model VI we examine the effect of international dispersed R&D activities on firm profitability. The estimation elicits some interesting results. Only medium-centralised firms with two or three R&D locations abroad and decentralised firms with R&D in four or more countries make significantly higher profits out of their international R&D ventures. Compared to firms conducting purely domestic R&D, this difference is again significantly larger. On the contrary, we do find a positive but not significant effect for firms having just one foreign R&D site. Firms with centralised foreign R&D activities do not outperform domestic R&D performers, and they perform significantly worse compared to firms with medium centralised and decentralised foreign R&D.<sup>16</sup> Our finding indicates that firms with just one R&D location abroad either absorb less knowledge from their foreign environment and/or that they failed to establish efficient knowledge transfer and coordination mechanisms. Since the data at hand does not provide information on such mechanisms we admittedly cannot differentiate between these explanations. But obviously, firms with more R&D

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<sup>16</sup> Compared to firms with decentralised R&D, the effect is significant only at the 12% level.

locations abroad have learned how to effectively manage those ventures. By and large, our results are consistent with Hypothesis H2a postulating that profitability increases with the number of foreign R&D locations.

Another interesting finding is that the gain in profitability is larger for firms with two or three R&D locations abroad, which we labelled medium centralised foreign innovators (+3.5 % points), than for firms that innovate in four or more different countries (+2.7% points). Though we cannot prove that this difference is statistically significant in our small sample, it gives at least some indication that the relationship between the degree of R&D internationalisation and profitability might be inverse u-shaped. This would be consistent first with the observation of Gassmann and Von Zedtwitz (1999) who reported that MNEs tend to recentralise international R&D activities and rather establish an integrated R&D network with a smaller number of leading R&D labs and second with a recent finding showing that the relationship between innovation outcome and the degree of internationalisation is inverse u-shaped (Peters and Schmiele 2010). All in all, this question needs to be addressed in future research.

As for our control variables, we find that firm performance is negatively related to firm size. This result seems surprising since the literature provides evidence that firm size increases the likelihood of doing innovation activities abroad (Schmiele, 2011) but reduces the outlook of a higher return of sales. The estimation further provides evidence that firm profitability is highly persistent over time. The coefficients of past profitability are highly significant and increasing in magnitude across the profitability categories. Hence, firms with a higher profitability in the past also make significantly higher return on sales in the current period 2008. We also find that firms operating in markets where products become rapidly obsolete due to strong technological competition earn smaller profit margins. However, firms having a higher market share and a more diversified product range can enhance their performance. The results furthermore demonstrate that firms belonging to a group with headquarters abroad show higher profitability than all other firms. It is not surprising that they outperform unaffiliated firms or firms belonging to a national group since it is likely that the best performing foreign firms enter the German market by acquiring German firms and that they transfer efficiency gains to their subsidiaries in Germany (Dunning 1981; Helpman et al. 2004). Based on this rationale, however, it is surprising that they perform much better than firms belonging to German multinationals. The coefficients of the industry dummies show that in general firms from all three manufacturing

industries achieve higher return on sales than service firms, including knowledge-intensive services firms.





Table 23: Tests on Equality of the Estimated Coefficients

Tests of equality for the estimation coefficients for the respective equation	I	II	III	IV	V	VI
domestic R&D = foreign R&D	0,002 ***	0,034 **	0,061 *	0,098 *	0,111	
domestic R&D=centralised foreign R&D	-	-	-			0,867
domestic R&D=medium decentralised foreign R&D	-	-	-			0,003 ***
domestic R&D=decentralised foreign R&D	-	-	-			0,075 *
centralised foreign R&D=medium decentral. foreign R&D	-	-	-			0,009 ***
centralised foreign R&D=decentralised foreign R&D	-	-	-			0,120
med.decent. foreign R&D=decentralised foreign R&D	-	-	-			0,423

Note: \*, \*\* and \*\*\* indicate significance at the 10%, 5% and 1% level.

To check the robustness of our results, we perform several sensitivity analyses which are summarised in Table 24. First, we investigate whether the results hold when we choose a different time lag. It turns out that the main conclusions still hold when we use a two-year lag for profitability. However, the estimated effect of foreign R&D is smaller compared to our previous results. This is not surprising because, as already said, it takes some time to translate research efforts into innovation outcome and thus to make profits out of R&D activities. Interestingly, firms with domestic R&D show a positive but not significant coefficient in this estimate. This could point towards the fact that foreign R&D also increases the speed of translating research into new products or processes. Using a one-year time lag, it turns out that neither domestic nor foreign R&D activities raise profitability. This is again consistent with the view that R&D is a long-term investment.

Second, we check what happens when we exclude German firms that belong to a foreign multinational group. Foreign R&D activities of those firms might be quite different and might drive our previous results on the effectiveness of foreign R&D. However, we find the result of a stimulating effect of foreign R&D activities confirmed in the reduced sample. Next, we exclude very small firms (less than 100 employees). These firms rarely have foreign R&D activities and though we control for firm size in our main specifications, the results on foreign R&D activities might in part also reflect a size effect. However, the results corroborate our previous findings. Finally, we check for heteroskedasticity. We specify group-wise multiplicative heteroskedasticity of the form  $\sigma_i = \sigma \exp(z_i \gamma)$ , where  $z$  denotes a vector of variables possibly causing heteroskedasticity. Originally, we use all survey stratification variables (i.e. dummy variables for East Germany, 25 industries and 8 size classes), since stratification of the survey leads

to heteroskedastic error terms. However, it turns out that the dummy for East Germany was not significant and we decide to leave it out. In the heteroskedastic ordered probit model the parameters  $\gamma$  have to be estimated as well. The Likelihood Ratio test rejects the assumption of homoskedasticity. However, the overall results are nearly unaltered compared to the homoskedastic model.

Table 24: Robustness Checks

	Only Firms with innovation activities in 2005		Only Firms with more than 100 employees		Profits 2 years ahead		Heteroskedasticity estimation	
Firms without innovation activities	-	-	1.187 *	1.085	0.178	0.157	0.070	0.042
			(0.671)	(0.673)	(0.380)	(0.380)	(0.378)	(0.380)
Firms with domestic R&D only	1.101 **	1.144 **	1.010	0.979	0.484	0.484	0.806 **	0.837 **
	(0.462)	(0.463)	(0.654)	(0.655)	(0.397)	(0.397)	(0.407)	(0.409)
Firms with domestic R&D and abroad	2.080 ***	-	-	2.553 ***	1.464 ***	-	1.696 ***	-
	(0.641)			(0.766)	(0.541)		(0.551)	
Firms with centralised foreign R&D	-	1.270 *	-	1.745 ***	-	1.265 **	-	1.143 *
		(0.721)		(0.857)		(0.632)		(0.643)
Firms with medium decentralised foreign R&D	-	3.765 ***	-	3.523 ***	-	1.776 **	-	3.117 ***
		(0.920)		(1.019)		(0.775)		(0.833)
Firms. with decentralised foreign R&D	-	3.014 ***	-	2.994 ***	-	2.075 **	-	2.304 **
		(1.012)		(1.084)		(0.872)		(1.036)
domestic R&D=foreign R&D	0.076 *	-	0.013 **	-	0.037 **	-	0.070 *	-
domestic R&D=centralised foreign R&D	-	0.847	-	0.298	-	0.171	-	0.609
domestic R&D=medium decentralised foreign R&D	-	0.002 ***	-	0.004 ***	-	0.076 *	-	0.004 ***
domestic R&D=decentralised foreign R&D	-	0.048 **	-	0.036 **	-	0.054	-	0.140
centralised foreign R&D=medium decentralised foreign R&D	-	0.005 ***	-	0.051 *	-	0.515	-	0.024 **
centralised foreign R&D=decentralised foreign R&D	-	0.078 *	-	0.213	-	0.347	-	0.268
med.decent. foreign R&D=decentralised foreign R&D	-	0.469	-	0.603	-	0.751	-	0.466
<i>ln sigma</i>								
Industry dummies							chi2(24)= 91.42 ***	chi2(24)=84.07 ***
Size dummies							chi2(7)=17.64 **	chi2( 7)=19.79 ***
LR-Test							chi2(31)=109.04 ***	chi2(31)=104.38 ***
No. of observations	853	818	585	553	1361	1326	1364	1329

Note: \*, \*\* and \*\*\* indicate significance at the 10%, 5% and 1% level. The full set of control variables was included in the regressions but not reported. Ln sigma indicates the results for the variance estimation. We only report tests on joint significance of industry and size dummies of this equation.

## 4.4 Conclusion

This chapter aimed to evaluate the relationship between costs and benefits that result from international R&D activities. From the theoretical point of view there is no clear indication whether the gains of R&D activities abroad in terms of a presumably increasing innovation output and additional knowledge creation outweigh the pains of R&D internationalisation related to financial, organisational costs, foregone economies of scale and scope and outgoing knowledge spillovers. We have utilised a comprehensive data set which incorporates cross section and time series information to carry out an empirical analysis on this matter. R&D internationalisation is a firm strategy that is adapted and extended by an increasing number of firms. Hence, we investigated how firms that have spread their R&D activities across multiple countries differ in their profitability in comparison to firms that have chosen a moderate number of countries in which they operate R&D activities.

All in all, our results tell a rather clear story. We consistently find that R&D activities abroad are conducive to firms' profitability. We likewise ascertain a stimulating effect for firms with purely domestic R&D activities. But the results confirm that firms with both domestic and international R&D experience a stronger effect on return on sales. We can therefore conclude that firms which innovate globally are not only able to realise the benefits of these international ventures but that they are also able to limit the costs and risks. We furthermore provide evidence that firms with internationally more dispersed R&D operations achieve higher return on sales. Though due to data limitations the evidence is admittedly weak, the estimation results lead us furthermore to the conclusion that a moderate number of R&D locations abroad seems to be most conducive to profitability. Firms which have established R&D laboratories in two or three countries receive the highest return from their foreign R&D efforts. Firms with four or more R&D locations abroad seem to achieve lower profitability gains than medium centralised firms, but the gain is still about twice as large as the one of firms performing solely domestic R&D. As already pointed out, further research on the hypothesis of an inverse u-shaped relationship between the degree of R&D internationalisation and profitability seems to be necessary.

One aspect of the analysis is worthy to be noted. In our sample, international R&D performers always carry out R&D at home as well. This implies that the observed higher profitability of firms pursuing an international R&D strategy

might be attributed to two different sources. Either R&D abroad itself is more beneficial than domestic R&D or foreign R&D is as beneficial as domestic R&D but firms may realise additional synergy (complementarity) effects if they perform R&D at home and abroad. Due to the above mentioned data constraints we unfortunately cannot distinguish between these two sources. This is an open question that remains for future research.

One academic intention of this chapter was to fill an essential gap in the literature. Our results draw attention to the extensive research about the motives, organisation and management of international R&D. So far there have been few efforts to describe the benefits of global R&D centres but these attempts have often used patent data which has several limitations to measure benefits (Griliches, 1990). Furthermore, these studies have been narrowly focussed either on the costs or on the benefits of international R&D. This study was aimed to combine both views and to provide empirical evidence to managers who face both perspectives in their business. To conclude, R&D location matters for profitability. Sourcing knowledge abroad is beneficial to firms' operational profits and indicates that firms which undertake global R&D efforts may also grow faster than firms that rely on domestic R&D. However, there is a threshold in the number of locations beyond which firms cannot increase their profitability anymore (and might experience a decrease in profits)

## 4.5 Appendix

Table 25: Distributional Characteristics of Samples

Distribution	Sample		
	2005	2008	Estimation
<i>by size</i>			
<10	17.31	18.47	15.25
10-19	15.73	16.22	14.22
20-49	16.89	18.14	14.88
50-99	11.49	13.43	11.88
100-249	12.74	12.70	12.02
250-499	7.25	5.61	6.45
500-999	5.73	4.42	4.55
>1000	12.86	11.00	20.75
<i>by industry</i>			
high R&D-intensive manufacturing	7.52	6.94	7.33
medium R&D-intensive manufacturing	10.89	11.88	12.76
low R&D-intensive manufacturing	40.04	38.89	39.59
knowledge-intensive services	20.36	21.33	20.89
and other services	21.19	20.96	19.43
<i>by innovation activities</i>			
no innovation activities	37.96	35.71	37.49
with innovation activities	62.04	64.29	62.51

Notes: Samples of 2005 and 2008 includes 5187 and 7662 observations. The estimation sample 1364.

Table 26: Descriptive Statistics

No.	Explanatory Variables	Mean	Std. Dev.	Min	Max
1	Firm without innovation activities	0.375	0.484	0	1
2	Innov. with domestic R&D only	0.276	0.447	0	1
3	Innov. with foreign R&D	0.171	0.376	0	1
4	Innov. with centralised foreign R&D	0.075	0.264	0	1
5	Innov. with medium decentralised foreign R&D	0.047	0.211	0	1
6	Innov. with decentralised foreign R&D	0.027	0.162	0	1
	Innovator without R&D (reference group)	0.181	0.385	0	1
7	Foreign R&D x Strong international competition	0.065	0.246	0	1
8	Firm size	4.671	2.447	0	13.041
9	Marketing innovation	0.359	0.480	0	1
10	Organisation innovation	0.374	0.484	0	1
11	Exporter	0.535	0.499	0	1
12	Capital Intensity	-2.642	1.894	-9.551	3.827
13	Market share	14.550	25.868	0	100
14	Dummy: Market share truncated	0.192	0.394	0	1
15	Dummy: Market share missing	0.278	0.448	0	1
16	Degree of diversification	1.693	1.623	1	50
	National firm, unaffiliated (reference group)	0.565	0.496	0	1
17	National group	0.163	0.369	0	1
18	Intern. Group with German HQ	0.191	0.394	0	1
19	Intern. Group with HQ abroad	0.081	0.272	0	1
20	Industry: High R&D-intensive Manufacturing	0.073	0.261	0	1
21	Industry: Medium R&D-intensive Manufacturing	0.128	0.334	0	1
22	Industry: Low R&D-intensive Manufacturing	0.396	0.489	0	1
23	Industry: R&D-intensive Services	0.209	0.407	0	1
	Industry: Low R&D-intensive services (ref. group)	0.194	0.396	0	1
24	Competition: Fast Obsolescence	0.147	0.354	0	1
25	Competition: Strong international competitors	0.315	0.464	0	1
26	Previous profits up to 2%	0.175	0.380	0	1
27	Previous profits up to 4%	0.160	0.367	0	1
28	Previous profits up to 7%	0.164	0.371	0	1
29	Previous profits up to 10%	0.104	0.306	0	1
30	Previous profits up to 15%	0.100	0.300	0	1
31	Previous profits more than 15%	0.084	0.277	0	1
32	Previous profits missing	0.101	0.302	0	1
	Previous profits less than 0% (reference group)	0.112	0.316	0	1





## **5 Intellectual Property Infringements Due to R&D Abroad? A Comparative Analysis Between Firms with International and Domestic R&D Activities<sup>17</sup>**

The internationalisation of corporate R&D activities enables firms to better serve customers abroad with customised products. R&D activities in customers' countries allow firms to react more quickly to local demands and supply customers in the host country as an authentic 'local' firm (Porter, 1980). Firms with international R&D centres further benefit from internalising foreign talents and expertise into their knowledge base. Many firms have realised the potential of international R&D activities and contributed to the persistent trend to internationalise their innovation strategies (UNCTAD, 2005). This trend is also spurred by emerging economies that have large numbers of university graduates and a growing importance in firms' market portfolios and therefore appear increasingly as desired corporate innovation locations (Rammer and Schmiele, 2008). The internationalisation of corporate R&D activities is often associated with a looser control over technological knowledge and other core competences. Foreign business environments can be very different culturally and legally in comparison to the home country and challenge the operations of international firms. Especially for firms that carry out R&D activities abroad, the weakness of the intellectual property (IP) protection system can hamper their innovative efforts. The intellectual property right (IPR) standards often do not follow the economic development of some emerging states such as China. Firms have to balance the attractiveness of a greater market size with customised innovative products against the risk of knowledge loss from their innovative efforts.

To evaluate this risk, this chapter analyses whether firms with innovation activities abroad face a higher risk to experience IP infringements from abroad than firms that have R&D and innovation activities solely in their home country.

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<sup>17</sup> This chapter draws on Schmiele (2010).

The main contribution of this chapter is to distinguish between different types of innovation activities abroad (R&D, conception/design of new products, manufacturing of new products, implementation of new processes) and different types of IP infringements (infringement of inventions, product piracy, usage of firm name and designs). In addition, we are able to identify whether the IP infringement by competitors from abroad stems from a firm's innovation host country or from another country abroad. The distinction between host country and non-host country IP infringement can explain whether localised innovation activities, signalling effects or export intensity foster IP infringements.

Prior to the empirical analysis, an explorative study on firms with R&D and business activities abroad was carried out. In interviews, the organisations that hold patents and trademarks told about their experience with IP infringements from abroad. This so-called triangulation approach, the combination of different data sets and research methods, allows gaining a wider and deeper understanding of the topic (Jick, 1979). The qualitative study can lead to conclusions which the empirical analysis would not reveal (Jick, 1979) and can make important contributions to the empirical study.

The outline of this chapter is as follows: Section 2 will introduce previous work and related theoretical approaches in this field of research. In Section 3, we present results of the explorative study and frame the research questions accordingly. Subsequently, an empirical study which is based on a large sample of firms from Germany investigates in Section 5 whether the findings from the explorative study hold for a sample of about 900 innovative firms from Germany of which approximately 500 firms had international innovation activities. Section 6 provides the empirical results and Section 7 provides the conclusions and implications of this research work.

## **5.1 Theoretical Framework**

Firms investing into R&D seek to appropriate the returns of their efforts. Depending on the nature of the innovation outcome, firms have different possibilities to protect their IP. Technological inventions can be legally protected by applying for a patent grant. Non-technical IP can be protected with industrial designs or trademarks. Each type of IPR requires an application at the public authority which can grant an IPR for the territory it is responsible for. The enforcement of IPR is only possible if they are granted for the region in which the

infringement case took place. The following subsections will introduce theoretical concepts which explain the occurrence of IP infringements from abroad.

### **5.1.1 Liabilities of Foreignness**

The internationalisation of business activities such as R&D and other innovation related activities are faced with additional complexity in the business unit abroad. The complexity arises from unfamiliar business environments (Hymer, 1976), which are created by cultural, political and economic differences between home and host country. All costs associated with the newness of the foreign firm in the foreign business environment are summarised as the liabilities of foreignness (Zaheer, 1995). The liabilities of foreignness stem from unexpected situations leading them to flawed decisions and hence expose the firm to extraordinary risks (Lord and Ranft, 2000). Social and cultural laws are not codified and therefore especially ambiguous to foreigners and offer great potential to cause liabilities of foreignness (Jensen and Szulanski, 2004). As for international R&D centres, liabilities of foreignness can be too much trust in formal contracts or local R&D partners, the disrespect of the foreign culture and business etiquette which can result in the loss of authority and resignations of important employees. In certain countries, contracts are rather based on personal relationships and the respect of intellectual properties and their legal enforcement is not that embedded (Yang, 2005). The costs from firms' foreignness also comprise the loss of IP to competitors abroad when they have not taken appropriate measures to protect them. Firms have to undertake efforts to learn and employ strategies of the local legal system to work efficiently against counterfeiting.

### **5.1.2 Signalling Effects of International R&D**

Previous studies provide empirical evidence that firms that innovate both in their home country and abroad are more successful in generating innovative products and achieve higher sales growth due to these new products compared to firms that innovate only domestically (Peters and Schmiele, 2010a; 2010b). This suggests that firms with international R&D units are highly competitive and more successful market actors. From this point of view, it can be assumed that firms are not so much at risk to experience IP infringements because of their international innovation activities abroad itself but from the success the firm gains from these activities.

### 5.1.3 International R&D Spillovers

Firms that carry out R&D activities are very likely to generate knowledge spillovers to third parties (Jaffe, 1986, Acs et al., 1992, 1994) which benefit and exploit these assets. International spillovers from innovation activities can occur because of the imperfect appropriability of innovations (Macdissi and Negassi, 2002). International knowledge spillovers can take place via different channels such as trade, foreign direct investment (FDI) or cooperations. FDI seems to play a particular role (Hejazi and Safarian, 1999). Knowledge spillovers from internal R&D activities abroad can be transmitted by reverse engineering, labour market mobility (Görg and Strobl, 2001; Maliranta et al., 2009), user-supplier relations (Javorcik, 2004; Markusen and Venables, 1999) or technology transfer (Macdissi and Negassi, 2002). The geographical proximity increases the chances of knowledge flows between producers and receivers of spillovers (Marshall, 1920; Jaffe et al., 1993; Branstetter, 2001; Audretsch and Feldman, 1996).

An important aspect for the translation of R&D spillovers into a benefit for the receiving firms is that the receiving entity is able to productively use the information. The receiver requires absorptive capabilities (Cohen and Levinthal, 1989) in terms of pre-existing knowledge in the relevant technology field in order to be able to use the incoming spillovers. If a country or firm does not possess the necessary extent of absorptive capabilities, the knowledge spillovers cannot be fully utilised. For developing countries, the lower level of education can be a barrier to transferring the spillovers into sophisticated products. Spillovers are often used to produce rather crude imitations (Macdissi and Negassi, 2002), simple designs or to copy firm names but rarely to develop competitive products. In this vein, innovation activities in countries with low knowledge levels might be less risky for foreign-owned firms' IP.

The macroeconomic view on spillovers emphasises the positive effects of international spillovers on the economic development of the receiving host country. Host countries benefit twofold from foreign R&D activities. Firstly, the direct benefits result from the learning from new products, materials, processes and the organisation, while indirect benefits stem from the imports of products and services of the foreign firms into the host country (Coe and Helpman, 1995). The incoming knowledge spillovers contribute to the accumulation of the domestic R&D, which is evidently increasing national productivity (Griliches, 1988). The relation of foreign innovation activities and host country productivity growth has also been shown by several scholars (Keller and Yeaple, 2003; Coe and Helpman, 1995). R&D of foreign-owned firms does also stimulate the R&D

expenditures in many host countries (Lonmo and Andersen, 2003; Costa and Filippov, 2008; UNCTAD, 2005). Following this perspective, foreign-owned firms can benefit from technological developments that are initiated by international spillovers. The technological development of host countries goes hand in hand with the local market development for foreign-owned firms' products.

To reduce outgoing spillovers, firms invest into knowledge protection mechanisms by applying formal and strategic protection methods (Arbussa and Coenders, 2007). These methods can vary in their efficiency for products and processes as well as across industries (Levin et al., 1987; Mansfield, 1986; Arundel, 2001). While strategic appropriability methods such as secrecy enable firms to hide firm knowledge to outsiders, patents have the unique property to be defendable in court. The extent of knowledge spillovers is not only moderated by corporate R&D appropriability measures but also by the effectiveness of legal IPR regimes (Belderbos et al., 2008). For R&D activities in developing countries, the use of formal protection methods can be ineffective since weak IPR systems restrict effective enforcement of the intellectual property rights. A mix of legal, operational and strategic activities (Yang and Jiang, 2007; Yang et al., 2008) or de-facto strategies which make use of cultural laws in host countries (Keupp et al., 2010) can be more effective against IP infringements. The following explorative study reveals some of these strategies implemented in German firms in China.

## 5.2 Explorative Study

For the explorative study, interviews with five German firms in China from different industries have been carried out as well as one interview with a legal advisor for intellectual property protection from a German public institution. For Germany, as an export-driven economy, China is a very attractive market which often urges firms to adapt their domestic products to Chinese tastes and standards. The adaption of products as well as the development of new products for the Chinese market or for global demand involves innovation and R&D activities. Most of the firms which have been interviewed expressed that they are having localised R&D activities in order to meet customer preferences, being able to react more quickly to local demands and become a 'total local firm' which operates all parts of its value chain at the foreign location. Table 28 gives an overview of the organisations that participated in the study.

*Table 28: Overview of Interviewed German Organisations in China*

Firms	Industry / Products	Firm size	R&D in China
A	Chemistry	>20000	Yes
B	Chemistry	>20000	Yes
C	Oil Processing	< 5000	Yes
D	Machinery	>10000	Yes
E	Machinery	< 5000	No
F	Public institution / Legal Advisory	< 200	-

The interview partners were the General Manager or Managing Directors in smaller firms and heads of patent and trademark functions as well as R&D managers in larger firms. The case F interview partner is a legal advisor predominantly for small and medium sized German firms which are planning business operations in China or are already active in China. Case F explains that the Chinese government wants to improve China's technological performance by attracting R&D intensive foreign direct investments. In the past, there have been national rules of local content requirements, which urged foreign firms and their suppliers to produce a larger share of their products within China. Greater corporate investments were connected to the demand for local development centres in China (Schüller, 2006). However, the surveyed firms expressed that they did not set up R&D facilities to meet public requirements but customer demand. Further insights from the interviews are presented in the following paragraphs.

### **5.2.1 Insights from Interviews**

#### *Corporate IP Protection Strategies*

All firms (cases A-E) have used formal protection methods to be able to carry out legal actions when firm technology, names, logos or designs have been used by competitors. These IP protection strategies have been put into place before the firms entered China. This trend to carefully manage IP and its protection was confirmed by case F. The legal advisor expressed that German firms entered the Chinese market very well prepared in terms of IP protection issues. Not surprisingly, especially firms in the chemical and pharmaceutical industry (A, B) emphasised the importance of patents for the appropriation of IP. For the other

firms, the importance of formal strategies was not as high, case C even argued that patents had no additional value to copyrights and trademarks in China. They draw their attention to strategic IP protection methods. An effective way to avoid product piracy has been the import of product parts from the home country or other global centres which are essential to the product but not developed or produced in the host country. In this vein, case B started the initiative to define the 'crown jewels' of the firm and develop specific disclosure actions. Following the secrecy method, firms limit the number of people that know all about the product or developed a code system for their suppliers to hide the origins of the ingredients. Once the product is available on the market, firms do not rely on the product solely to win and keep customers. Similarly important is to offer distinct services and infrastructures which are harder to imitate by product pirates. Apart from products, manpower has a great potential for knowledge leakages. To prevent employees from taking firm knowledge from the present firm to direct competitors when leaving the company, firms use anti-compete contracts, extra compensations as well as social pressure to emphasize the employees' responsibilities towards its previous employer.

### ***Firms' Experience with IP-infringements***

Interview partners denied that their R&D activities in China increased the occurrence of IP infringements. Firm E, which has no R&D activities in China yet, would not expect a rise in IP infringements either if they were to establish R&D activities in China. However, all firms (A-E) reported infringements of firm names and trademarks. Patent infringements have been experienced by case A and case B. Further, case B argues that the risk of infringement is most pronounced for their most prestigious and successful products. Firms A and C state that their infringements all stem from local rivals, not from international market players. Firm E, which reported few cases of firm name infringements, assumes that firm reputation is a driving factor for IP infringements and explains: "we are not famous enough to be copied".

### ***Firm Reactions to IP Infringements***

The legal and strategic reactions of firms in case of IP infringements vary according to their level of IP infringements. Firm E, which has few firm name infringements, does not carry out any legal actions. Firms A and B employ a team of lawyers that follow up on patent infringements. Although the compensation from these infringement cases is marginal, each infringement incident in firm C is

prosecuted with the aim to keep infringers busy. Firm B also uses press releases about successful patent infringement cases in court in order to discourage potential IP infringers. Firm D tries to get hold of IP infringers with the help of custom raids on fairs in Europe. Strategic decisions and reactions after IP infringements were the relocation of critical business processes back to the home country in firm C, while case A and B did not use backward relocation of operations as a method of IP protection.

### ***Importance of IP Infringements and Financial Effects for Firms***

Although most of the firms have experienced IP infringements, the respective firms judge that these cases are manageable and occur to a moderate extent (3 cases per month in firm C). Due to the limited number of cases, IP issues in China are of minor importance to the surveyed firms. Since the costs of legal cases are low, the overall monetary loss is low as well. Firm D, for example, has experienced product piracy for outdated machinery products from which they had received only little sales.

## **5.3 Research Questions**

The conclusions emerging from the interviews with German firms in China about their experience with IP infringements and local R&D activities are: all firms have experienced IP infringements, firms do not expect a rise of IP infringements due to their R&D activities in China and the majority of the IP infringements concerns the usage of firm names and trademarks.

These interview results oppose in some parts the results from the literature introduced in Section 2. The firms reported a manageable extent of IP infringements that cause relatively few costs. From the spillover literature or the liabilities of foreignness perspective, more costs and risks would have been expected to result from international R&D activities. However, one has to keep in mind that infringers from China might not have the technological potential to successfully copy technological inventions which reduces the amount and severity of infringements (low absorptive capabilities) from this particular country. Furthermore, firms which operate internationally are aware of their core competences and the differences in IP rights and their enforcements. They consequently develop and use strategies and methods to protect their products and technologies.



With these results from the explorative study which was carried out in a country with weak intellectual property rights (Zhao, 2006; Park, 2008), the following research questions are formulated:

- *Research Question 1: Do firms which have R&D activities in countries with weak intellectual property rights have a higher probability to be infringed by local competitors than firms which predominantly innovate in countries with strong IPR?*
- *Research Question 2: Due to lower absorptive capabilities in developing countries: Are IP infringements mainly targeting firm names and designs in these countries?*

Based on the theoretical assumption about the liabilities of foreignness and signalling effects, research question 3 is framed as:

- *Research Question 3: Are firms with international R&D activities more at risk to experience intellectual property infringements than firms that innovate only in their home country?*

With respect to the signalling theory, research question 4 is put down as:

- *Research Question 4: Will firms with international R&D activities increase their risk to experience IP infringements from countries in which they do not have R&D units?*

## **5.4 Empirical Study**

The explorative study contributed to the understanding of how firms are affected and deal with IP infringements abroad. The aim of this part of the chapter is to analyse the research questions based on a larger number of observations and thus lead to results which are representative and allow generalisations.

The intention of the empirical study is to find statistically significant evidence whether international R&D activities impose a higher risk on firms' intellectual properties. We observe firms with national R&D activities only and firms with international R&D activities and distinguish the type of IP infringement that these two groups of firms experienced. In a second empirical approach, we test whether the host country of a firm's R&D activities abroad itself is the origin of infringement or if firms with international innovation activities have experienced IP infringements from countries in which they do not innovate. The following

sections introduce the data and the estimation methods used for the empirical analysis.

### 5.4.1 Data

For the empirical investigation of our research questions, we need firm-level information about corporate R&D activities in the home and host countries as well as data about the infringement of firms' intellectual properties abroad. For this study the Mannheim Innovation Panel (MIP) survey waves from years 2006 and 2008 are used since these two waves contain relevant data for the research questions. Table 29 gives an overview of the employed single data samples and the sample size after merging the two survey waves.

*Table 29: Overview of the Employed Data Samples*

	MIP 2006	MIP 2008	Combined Sample
Gross Sample	17,395	19,080	n.a.
Net sample	5,187	6,624	5,166
thereof: innovators	2,843	3,484	2,018
thereof: international innovators	842	n.a.	552
thereof: infringements from abroad	n.a.	444	94

The following paragraphs will further describe the survey information that is used to compute the estimation variables.

### 5.4.2 Dependent Variables

The aim of the chapter is to analyse the factors that influence the probability that a firm's IP is being infringed by competitors from abroad. We focus on IP of firms from Germany. In the 2008 MIP survey, firms were asked whether they had experienced infringements of their IP in the years 2005-2007. The respondents had the opportunity to specify whether the kind of IP infringement targeted technological inventions, product or business model piracy or the usage of firm names or designs. For each kind of IP infringement, the respondents could declare whether the origin of the infringing firm resulted from national or foreign firms. The countries from which the infringements originated had to be specified in a free text field. Based on this information a total of five dependent variables have been defined. The definitions of the dependent variables are shown in Table 30 below.

Table 30: Definition of Dependent Variables

<i>Dependent variables</i>	<i>Definition / Data years: 2005-07</i>
<i>1st analysis</i>	
Technology infringements	1 if firm experience copying of technological inventions from abroad
Product piracy	1 if firm experienced product piracy or piracy of business models from abroad
Usage of firm names or designs	1 if firm's name, logo, designs have been used by foreign firms
<i>2nd analysis</i>	
Infringements from host countries	1 if firm's innovation host countries are also the origin of IP infringements
Infringements from no-host countries	1 if IP infringements stem from other than firm's innovation host countries

In order to answer all research questions two different analyses will be carried out. For the first empirical analysis, the kind of foreign IP infringement is of primary interest, therefore, three kinds of foreign IP infringement from abroad are distinguished as dependent variables: *technology infringements, product or business model piracy and the usage of firm names or designs*. The descriptive results in Table 35 illustrate that about 9% of the sample firms had foreign technological infringements while 7% experienced the piracy of products or business models from foreign infringers and about 8% of the firms reported that foreign firms used their firm name or designs. The specification for the first empirical analysis consists of three-equations (the estimation method section will elaborate further in this matter):

$$[1] \quad \text{Type of Infringement}_{ik} = \alpha_k + \beta_k X_i + \chi_k Y_i + \varepsilon_{ik} \quad \text{for } k = \{1,2,3\}$$

$$\text{Cov}(\varepsilon_1, \varepsilon_2) = \rho_1$$

$$\text{Cov}(\varepsilon_1, \varepsilon_3) = \rho_2$$

$$\text{Cov}(\varepsilon_2, \varepsilon_3) = \rho_3$$

where X is the vector for the explanatory variables and Y the vector for the control variables.

For the second empirical analysis, it is tested whether the location of international innovation activities of the infringed firms are linked to the location of the infringing competitor. Two dependent variables are defined: infringements by competitors from host countries and infringements from competitors located in countries where the infringed firm has no innovation activities (no-host countries). These variables were created by linking infringement information from the 2008 survey with information on a firm's innovation activities abroad which are collected in the 2006 survey. In this survey firms were asked to provide a list of countries with main innovation activities in 2005, differentiated by the type of

innovation activity (R&D, conception/design of new products, manufacturing of new products, new process implementation). The second analysis comprises two equations which are specified as follows:

$$[2] \quad \text{Origin of Infringement}_{ij} = \alpha_j + \beta_j X_i + \chi_j Y_i + \varepsilon_{ij} \quad \text{for } j = \{1,2\}$$

where X is also the vector for the explanatory variables and Y the vector for the control variables. The descriptive results show that among firms which have innovation activities abroad, about 3% experienced infringements from their innovation host countries and about 10% reported infringements from no-host countries. Table 35 and Table 37 in the appendix section display all descriptive results.

### 5.4.3 Explanatory Variables

The 2006 survey contains information to construct the explanatory variables employed in both empirical analyses. Table 31 lists the variables and their measurement. The most interesting explanatory variables to answer the research question in this chapter are those that capture the location of corporate R&D activities. There are the two basic categories: firms that concentrate their R&D activities in their home country and firms which also have international R&D activities.

The first analysis also investigates whether certain countries drive the occurrence of IP infringements. The host countries were grouped into the following regions, each of them is represented by an indicator in analysis [1]: China, India, Western Europe, Eastern Europe, North America. In a further variant, the host countries of firms' foreign R&D activities have been categorised into countries with weak or strong IPRs, following the Park (2008) index<sup>18</sup>. Since some firms had specified more than one R&D location abroad, variables were created that express the relation of the number of weak and strong IPR countries to the total number of host countries where a firm conducts R&D abroad.

In the second analysis [2], the aim is to analyse the influence of the host countries of innovation activities on IP infringements. For this model, more information about innovation-related activities abroad is used. Beside R&D activities abroad, the conception and design of new products as well as the production of new

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<sup>18</sup> Countries with a Park (2008) index greater than 4.10 have been declared as strong IPR countries. The consideration behind this numeric range was that China has an index of 4.08 and is frequently mentioned as a country with low IPR protection system while Norway, which is characterized as a strong IPR regime by Zhao (2006), has an index of 4.17.

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products and the implementation of new processes are considered as further types of innovation activities in the host country, since these activities might increase the effect of international IP infringements, too. The descriptive statistics demonstrates that 55% of the sample firms have R&D activities abroad, 66% have design activities abroad and 82% produce innovations abroad. Different interaction terms between these three types of international R&D activities are included to observe likely complementary effects of different innovation activities abroad. For a country specific view of IP infringements from host or no-host countries, we distinguish international innovation activities by host country. The descriptive results show that 16% of firms have innovation activities in China, 5% in India, 25% in Eastern Europe, 30% in North America and nearly every second firm with innovation activities abroad operated them in the Western European region. The results of the descriptive statistics are presented in Table 37 in the appendix section.

Table 31: Definition of Explanatory and Control Variables

<i>Explanatory variables</i>	<i>Definition / Data year: 2005</i>
<b>Explanatory variables 1st analysis</b>	
Domestic R&D only	1 if the firm has R&D activities in Germany only
Domestic R&D and abroad (iR&D)	1 if the firm has R&D activities in Germany and at least one R&D lab abroad
R&D in China	1 if firm has R&D activities in China
R&D in India	1 if firm has R&D activities in India
R&D in Western Europe	1 if firm has R&D activities in Western Europe
R&D in Eastern Europe	1 if firm has R&D activities in Eastern Europe
R&D in North America	1 if firm has R&D activities in North America
R&D in Rest of the World	1 if firm has R&D activities in the Rest of the world
R&D in Countries with weak IPR	Number of R&D locations in countries with weak IPRs in total sum of R&D locations abroad
R&D in Countries with strong IPR	Number of R&D locations in countries with strong IPRs in total sum of R&D locations abroad
<b>Explanatory variables 2nd analysis</b>	
Innovation conception/design abroad (iKON)	1 if firm undertakes design/conception activities of new products abroad
Innovation Production abroad (iPROD)	1 if firm manufactures innovations abroad
iR&D x iKON	1 if firm has R&D and design/conception activities abroad
iR&D x iKON x iPROD	1 if firm has R&D, design/conception and innovation manufacturing activities abroad
iR&D x iPROD	1 if firm has R&D and innovation manufacturing activities abroad
iKON x iPROD	1 if firm has conception/design and innovation manufacturing activities abroad
Innovation active in China	1 if firm has one of the observed innovation activities* located in China
Innovation active in India	1 if firm has one of the observed innovation activities* located in India
Innovation active in Eastern Europe	1 if firm has one of the observed innovation activities* located in Eastern Europe
Innovation active in Western Europe	1 if firm has one of the observed innovation activities* located in Western Europe
Innovation active in North-America	1 if firm has one of the observed innovation activities* located in North America
<b>Control Variables for both analyses</b>	
Intern. Group with German HQ	1 if firm is an international group headquartered in Germany
Intern. Group with HQ abroad	1 if firm is an international group headquartered abroad
High-Skilled Employees	No. of graduated employees per total number of employees
Export intensity	Share of exports to total sales
Firm age	ln (time between the year of market entry and 2005)
Firm size	No. of employees (in log)
Firm in East Germany	1 if firm is located in Eastern Germany
Competition: Technology	Average importance of technological advantage as indicator of competition (at NACE 3 industry level)
Industry: Knowledge-intensive Manufacturing	1 if firm belongs to the industry classification of Knowledge-intensive manufacturing sectors following Legler and Frietsch (2007)
Industry: Other Knowledge-int. Manufacturing	1 if firm belongs to the industry classification of Other (than the previous category) Knowledge-intensive manufacturing sectors following Legler and Frietsch (2007)
Industry: Other Manufacturing	1 if firm belongs to the industry classification of not knowledge intensive manufacturing sectors following Legler and Frietsch (2007)
Industry: Knowledge-intensive Services	1 if firm belongs to the industry classification of Knowledge-intensive Services sectors following Legler and Frietsch (2007)

\* innovation activities: R&D, Conception/design of new products, Manufacturing of new products, New process implementations

#### 5.4.4 Control Variables

For both empirical analyses, the same set of control variables is included. They include firm size, firm age, the share of graduated employees, export intensity and the firm location within Germany. Furthermore, a variable is included that captures the importance of technology rivalry in the firm's business environment.

Other control variables are the firms' ownership structure and industry variables. We distinguish five types of industries according to their level of R&D intensity and knowledge intensity following Legler and Frietsch (2007).

#### **5.4.5 Estimation Method**

##### ***International R&D and Different Types of IP Infringements***

For the first empirical analysis, firms were included in the sample that reported either domestic or international innovation activities and provided information on IP infringements (including firms that stated that none of their IP was subject to infringements from abroad). The sample size amounts to 908 observations. Since the occurrence of infringements of different types of IP (technology, products, names and designs) can be correlated, a trivariate probit estimation was carried out. The correlation coefficients between the equations for the three dependent variables support this assumption, they are highly significant. The estimation strategy comprises three model variants. Model (1), the base model, estimates the effects of domestic and international R&D activities on the likelihood to experience different IP infringements. Model (2) substitutes the variable for international R&D activities by two variables that indicate the share of low and strong IPR-countries among the R&D host countries. In model (3), different host countries and regions of firms' R&D activities abroad are included as dummy variables and replace the variables for strong and weak IPR host countries.

##### ***International Innovation Activities and Infringements from Host Countries***

To observe the influence of international innovation activities on the likelihood of IP infringements from firms' host countries and no-host countries, the sample has been restricted to firms with at least one innovation activity abroad. The observable innovation activities abroad hereby comprise R&D, design and production of innovations and the implementation of new process technology abroad.

For this second empirical analysis, country information of firms' innovation locations abroad have been matched with the country information of IP infringements by competitors from abroad. Each time a firm's innovation host country was identical with the country of the reported IP infringement the dependent dummy variable *infringement from host country* has been set 1 (otherwise: 0). The same approach has been done to compute the dependent

variable *infringement from no-host country*. Hereby, this variable is 1 for each innovation host country that is not on the list of countries from which the firm reported IP infringements. Firms naming more than one host country of innovation activities or more than one country from which their IP have been infringed were duplicated in the data set each time the different host countries and infringement origins matched. The number of duplications has been used as a frequency weight for a weighted probit estimation.

A previous test of correlation between the estimation equations for “infringements from host countries” and “infringements from no-host countries” resulted in non-significant correlation coefficients, therefore, the estimations for the dependent variables were performed separately. For each of the two dependent variables, seven model variants with different perspectives on international R&D activities were estimated. Model (1) is the base model and includes variables that indicate whether firms have only domestic R&D activities or both domestic and international R&D activities. The second model further incorporates variables that capture other innovation related activities abroad. Models (3) to (6) include interaction terms between international R&D activities and other international innovation activities to observe likely complementary effects of e.g. innovation production activities and R&D activities on the probability to receive IP infringements from the host country. Model (7) adds country dummies of international R&D and innovation activities.

## **5.5 Results**

### **5.5.1 International R&D and Different Types of IP Infringements**

In the theory section, it has been anticipated that international R&D activities will lead to an increased risk of IP infringements in comparison to firms conducting R&D only in their home country (in our sample: Germany). The estimation results in Table 32 show that this is the case for infringements which target technological inventions of the firm. This finding partly answers research question 3 in which we were questioning the influence of foreign R&D activities on the occurrence of IP infringements in comparison with firms that conduct R&D only in their home country. Most importantly, international R&D activities foster infringements of technological knowledge which is critical for firms' competence. The test of statistical equivalence between the marginal effects of only domestic and also foreign R&D activities is statistically significant. However, this weak significant



effect is the only significant influence of international R&D activities on IP infringements.

Firms conducting their R&D activities only in the home country are more likely to suffer from product or business model piracy. This result indicates that also purely domestic innovators have to fear counterfeiting of their products. Results with stronger statistical significance are achieved in the second trivariate estimation model. Here, firms that have their international R&D activities in a higher share of countries with weak IPR protection increase their chances of all observed IP infringements. A higher share of strong IPR countries among firms' innovation locations abroad increases the risk of technological infringements significantly. It leads to the conclusion that strong IPR regimes, which are established in countries with elaborate absorptive capabilities, impose a stronger risk on technological firm knowledge. This finding answers the first research question of the chapter. The effect of R&D activities in strong IPR regimes on technology infringements is lower than for the share of weak IPR host countries but both effects do not vary statistically from each other. However, both significant effects differ statistically from the effects retained for national innovating firms.

The country specific effects on the different types of IP infringements from abroad are negligible. Only firms which have R&D activities in China show a higher probability to be subject to illegal usage of their firm names and designs. This weak significant effect supports our second hypothesis, namely that developing nations with limited technological capabilities are more likely to use foreign trademarks. The significant effect of R&D in China varies also statistically from the effect of domestic R&D activities.

Among the control variables, export intensity shows strong and robust significant effects for all three kinds of IP infringements. Firms with strong export activities mirror their success with products or services on foreign markets. Their international competitiveness may result in signalling effects which, as indicated by the estimation results, foster any kind of IP infringement from abroad.

Firm size shows a positive influence on technology infringements. A technology driven business environment also increases the probability of technology infringements by foreign competitors. Firms which are headquartered in Eastern Germany or abroad are significantly less likely to experience infringements of their technological inventions.

Table 32: Marginal Effects from the Influence of International R&D on Different Types of IP Infringements

	Technology Infringement			Product Piracy			Firm name/design usage		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Domestic R&D only	0.018 (0.018)	0.017 (0.017)	0.013 (0.016)	0.032 * (0.019)	0.034 * (0.018)	0.016 (0.017)	0.020 (0.018)	0.016 (0.017)	0.012 (0.016)
Domestic R&D and abroad	0.084 * (0.046)	-	-	0.065 (0.043)	-	-	0.065 (0.042)	-	-
R&D in weak IPR countries	-	0.070 ** (0.030)	-	-	0.080 ** (0.033)	-	-	0.076 ** (0.030)	-
R&D in strong IPR countries	-	0.050 ** (0.024)	-	-	0.040 (0.028)	-	-	0.024 (0.026)	-
R&D in China	-	-	0.254 (0.173)	-	-	-0.036 (0.022)	-	-	0.374 * (0.212)
R&D in India	-	-	0.281 (0.406)	-	-	0.335 (0.290)	-	-	0.469 (0.411)
R&D in Western Europe	-	-	0.028 (0.037)	-	-	-0.015 (0.024)	-	-	0.003 (0.027)
R&D in North America	-	-	0.101 (0.078)	-	-	0.094 (0.086)	-	-	0.034 (0.054)
R&D in Eastern Europe	-	-	0.036 (0.051)	-	-	0.009 (0.042)	-	-	-0.020 (0.021)
R&D in RoW	-	-	-0.020 (0.029)	-	-	-0.016 (0.045)	-	-	0.112 (0.145)
Export intensity	0.109 *** (0.027)	0.106 *** (0.027)	0.109 *** (0.027)	0.116 *** (0.028)	0.103 *** (0.028)	0.116 *** (0.028)	0.114 *** (0.028)	0.119 *** (0.028)	0.114 *** (0.028)
Intern. Group with German HQ	0.004 (0.015)	0.004 (0.015)	0.009 (0.016)	-0.001 (0.016)	-0.001 (0.016)	0.006 (0.018)	0.001 (0.015)	0.001 (0.015)	0.010 (0.016)
Intern. Group with HQ abroad	-0.027 ** (0.012)	-0.027 ** (0.012)	-0.023 * (0.013)	-0.005 (0.021)	-0.005 (0.021)	-0.000 (0.023)	-0.014 (0.017)	-0.015 (0.016)	-0.009 (0.017)
High-Skilled Employees	0.021 (0.036)	0.022 (0.036)	0.021 (0.036)	-0.044 (0.043)	-0.047 (0.043)	-0.044 (0.043)	-0.057 (0.041)	-0.065 (0.042)	-0.057 (0.041)
Firm size	0.010 *** (0.004)	0.010 *** (0.004)	0.009 ** (0.004)	0.002 (0.004)	0.002 (0.004)	0.002 (0.005)	0.005 (0.004)	0.006 (0.004)	0.005 (0.004)
Firm age	-0.001 (0.007)	-0.001 (0.007)	-0.001 (0.007)	-0.008 (0.008)	-0.009 (0.008)	-0.010 (0.008)	-0.010 (0.008)	-0.011 (0.007)	-0.010 (0.007)
Competition: Technology	0.035 ** (0.014)	0.036 ** (0.014)	0.036 *** (0.014)	0.013 (0.015)	0.013 (0.015)	0.018 (0.015)	0.008 (0.014)	0.009 (0.013)	0.007 (0.013)
Firm in East Germany	-0.032 ** (0.013)	-0.034 ** (0.013)	-0.032 ** (0.014)	-0.022 (0.015)	-0.022 (0.015)	-0.023 (0.015)	-0.020 (0.015)	-0.021 (0.014)	-0.021 (0.014)
Ind: Knowledge-int. Manu.	0.044 (0.071)	0.044 (0.071)	0.054 (0.086)	-0.013 (0.029)	-0.011 (0.029)	-0.024 (0.024)	0.108 (0.094)	0.120 (0.101)	0.187 (0.158)
Ind: Other Knowl.-int. Manu.	0.085 (0.087)	0.083 (0.087)	0.106 (0.107)	0.011 (0.038)	0.014 (0.039)	0.004 (0.035)	0.169 (0.108)	0.184 (0.115)	0.274 (0.175)
Ind: Other Manufacturing	0.070 (0.050)	0.071 (0.050)	0.085 (0.059)	-0.007 (0.026)	-0.004 (0.027)	-0.012 (0.026)	0.074 (0.047)	0.082 * (0.050)	0.117 (0.073)
Ind: Knowledge-int. Services	0.031 (0.057)	0.031 (0.057)	0.047 (0.071)	-0.036 (0.024)	-0.035 (0.024)	-0.042 * (0.022)	0.021 (0.053)	0.026 (0.056)	0.051 (0.084)
dom. R&D=R&D abroad	0.016 **			0.016 **			0.016 **		
dom.R&D=weak IPR countries	0.049 **			0.049 **			0.049 **		
dom.R&D=strong IPR countries	0.067 *			0.067 *			0.067 *		
strong=weak IPR countries	0.504			0.504			0.504		
dom.R&D= R&D in China	0.031 **			0.031 **			0.031 **		
dom.R&D= R&D in India	0.313			0.313			0.313		
dom.R&D= R&D in WEU	0.666			0.666			0.666		
dom.R&D= R&D in N. America	0.115			0.115			0.115		
dom.R&D= R&D in E. Europe	0.621			0.621			0.621		
dom.R&D= R&D in ROW	0.463			0.463			0.463		
No. of observations	908	908	908	908	908	908	908	908	908
Athanhro for equ. (1) , (2) , (3)	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***

Standard errors in parentheses; \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

### **5.5.2 International Innovation Activities and Infringements from Host Countries**

The aim of the second analysis is to estimate the risk of infringement by competitors from the host countries of firms' innovation activities abroad. Table 33 presents the marginal effects of the probit estimations. The corresponding tests between the effects for statistical equality are presented separately in Table 38 in the appendix section.

The results of the base model show that firms with international R&D activities have no significant effects on infringements from their R&D host countries. The addition of further innovation related activities leads to strong positive results for the production of innovations abroad. In model (3), the interaction of international R&D and the design of new products abroad lead to weak significant effects. However, the tests of statistical equivalence between the effects from this interaction term and the effect from domestic R&D activities are significant and therefore differ from each other. Firms which have R&D, innovation production and design capacities abroad show mild positive significant effects and also differ significantly from the effects for domestic R&D activities. The combination of R&D and innovation production facilities abroad leads to a higher probability of IP infringements from host countries. Firms with innovation design and innovation production activities abroad have a weaker but positive significant effect. Overall, the results lead to the impression that the more innovation processes the firms has located overseas, the more they experience infringements of their intellectual assets from host country competitors.

The last model incorporates tests on how innovation activities in various countries and regions contribute to the occurrence of IP infringements from these host countries. Hereby, innovation activities in China and North America significantly increase the probability of IP infringements by competitors from these locations. The effects of innovation activities in China or North America are significant but do not vary statistically from the effects of domestic R&D activities.

Export intensity has a low significant or even no effect in this empirical analysis. This indicates that IP infringements from countries in which the firm operates innovation activities are fostered particularly by these operations. The results for the influence of technology driven business environments are also not robust across the different models variants. Firms with headquarters in Germany show a significant negative probability to experience IP infringements from their innovation host countries. Knowledge intensive and other manufacturing sectors

are also significantly less likely to be infringed from innovation host countries than firms in the service sectors.

Table 33: Marginal Effects: Infringements from Innovation Host Countries

	Dep. Var.: IP infringements from host country						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Domestic R&D only	-0.016 (0.029)	0.007 (0.038)	0.030 (0.035)	0.022 (0.027)	0.018 (0.029)	0.006 (0.042)	-0.003 (0.010)
Domestic R&D and abroad (iR&D)	0.011 (0.031)	0.040 (0.040)	-	-	-	0.025 (0.041)	-
Inno. conception/design abroad (iKON)	-	0.008 (0.019)	-	-	0.002 (0.021)	-	-
Innovation production abroad (iPROD)	-	0.051 *** (0.014)	0.043 *** (0.013)	-	-	-	-
iR&D x iKON	-	-	0.090 * (0.046)	-	-	-	-
iR&D x iKON x iPROD	-	-	-	0.111 ** (0.044)	-	-	-
iR&D x iPROD	-	-	-	-	0.083 ** (0.040)	-	-
iKON x iPROD	-	-	-	-	-	0.041 * (0.022)	-
Innovation active in China	-	-	-	-	-	-	0.169 *** (0.052)
Innovation active in India	-	-	-	-	-	-	0.070 (0.052)
Innovation active in Eastern Europe	-	-	-	-	-	-	-0.004 (0.011)
Innovation active in Western Europe	-	-	-	-	-	-	-0.003 (0.009)
Innovation active in North America	-	-	-	-	-	-	0.060 ** (0.029)
Export intensity	0.052 * (0.028)	0.045 (0.028)	0.039 (0.025)	0.048* (0.028)	0.046 (0.030)	0.045 (0.031)	0.035 ** (0.017)
Intern. Group with German HQ	-0.045 *** (0.015)	-0.033 ** (0.015)	-0.030 ** (0.014)	-0.034 ** (0.016)	-0.037 ** (0.017)	-0.039 ** (0.017)	-0.017 * (0.009)
Intern. Group with HQ abroad	0.006 (0.023)	-0.003 (0.019)	-0.006 (0.015)	-0.003 (0.020)	-0.002 (0.021)	0.004 (0.023)	0.017 (0.020)
High-Skilled Employees	0.008 (0.043)	0.034 (0.041)	0.039 (0.036)	0.036 (0.042)	0.026 (0.044)	0.033 (0.046)	-0.023 (0.024)
Firm age	0.004 (0.008)	0.007 (0.008)	0.007 (0.007)	0.007 (0.008)	0.007 (0.009)	0.008 (0.009)	0.003 (0.005)
Firm size	0.005 (0.004)	0.002 (0.004)	0.001 (0.003)	0.001 (0.004)	0.003 (0.004)	0.004 (0.004)	-0.005 * (0.003)
Firm in East Germany	-0.016 (0.019)	-0.006 (0.020)	-0.005 (0.018)	-0.009 (0.020)	-0.007 (0.022)	-0.004 (0.024)	-0.004 (0.011)
Competition: Technology	0.033 ** (0.016)	0.028 * (0.016)	0.023 (0.014)	0.026 (0.016)	0.029 * (0.017)	0.026 (0.017)	0.012 (0.009)
Ind: Knowledge-int. Manu.	-0.048 *** (0.015)	-0.038 ** (0.019)	-0.033 ** (0.017)	-0.035 * (0.021)	-0.040 * (0.021)	-0.040 * (0.023)	-0.027 *** (0.010)
Ind: Other Knowl.-int. Manu.	-0.072 *** (0.021)	-0.056 ** (0.025)	-0.048 ** (0.024)	-0.053 ** (0.026)	-0.061 ** (0.027)	-0.061 ** (0.028)	-0.041 *** (0.016)
Ind: Other Manufacturing	-0.065 *** (0.025)	-0.048 * (0.027)	-0.038 (0.025)	-0.040 (0.029)	-0.049 * (0.030)	-0.049 (0.031)	-0.037 ** (0.016)
Ind: Knowledge-int. Services	-0.036 * (0.021)	-0.014 (0.030)	-0.012 (0.027)	-0.013 (0.032)	-0.015 (0.033)	-0.015 (0.034)	-0.014 (0.011)
Observations	579	508	508	516	508	508	579

Standard errors in parentheses; \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

### **5.5.3 International Innovation Activities and Infringements from No-Host Countries**

When comparing the results from the analysis of IP infringements from innovation host countries with the results of IP infringements from countries in which the firm has no innovation activities some differences are obvious. The empirical results in Table 34 show that international R&D activities have a weak significant effect in model variant (2). This finding answers the last research question of whether signalling effects are created by corporate R&D activities abroad and lead to infringements from no-host countries.

In models (3) and (4), further significant marginal effects emerge from the interaction effects from international R&D and the design of new products abroad as well as from firms that have R&D, the design and production of new products located abroad. Table 38 shows that these two interaction terms vary both statistically from the effects for domestic R&D activities. In addition to the results for the innovation host country IP infringements, the results from model (7) indicate that firms which innovate in China, North America or India are significantly more at risk to be infringed from others but these innovation host countries than firms that innovate in the rest of the world. Contrary to the results of the analysis about innovation host country infringements, innovation activities and in specific the production of innovative goods abroad do not have similarly strong significant effects as for the innovation host country infringements.

The estimation results show that export intensity plays a major role as a driver for infringements from countries in which the infringed firms did not have innovation activities. The marginal effects for export intensity are robust across all estimation models. The signalling assumption can serve here as a possible explanation. Firms ease the way for competitors to learn about their products by exporting even if the firm itself is not innovation active in the country where the infringing party stems from.

Firms whose business environment is characterised by technological product competition are more at risk to receive IP infringements from no-host countries. These results are more robust than for host country infringements. Firms which are headquartered in the eastern part of Germany are significantly less at risk to be infringed from innovation no-host countries. The results from the industry sectors are somewhat less robust. Firms in the knowledge intensive manufacturing sector seem to have a lower probability to lose intellectual properties to firms from countries where they have no firm internal innovation activities.

Table 34: Marginal Effects: Infringements from No-Host Countries

	Dep. Var.: IP infringements from no-host country						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Domestic R&D only	0.036 (0.060)	0.074 (0.076)	0.046 (0.051)	0.006 (0.038)	0.007 (0.041)	0.071 (0.076)	-0.015 (0.028)
Domestic R&D and abroad (iR&D)	0.080 (0.055)	0.119 * (0.070)	-	-	-	0.114 (0.070)	-
Inno. conception/design abroad (iKON)	-	0.023 (0.034)	-	-	0.022 (0.035)	-	-
Innovation production abroad (iPROD)	-	0.035 (0.032)	0.021 (0.034)	-	-	-	-
iR&D x iKON	-	-	0.125 ** (0.054)	-	-	-	-
iR&D x iKON x iPROD	-	-	-	0.090 * (0.046)	-	-	-
iR&D x iPROD	-	-	-	-	0.067 (0.047)	-	-
iKON x iPROD	-	-	-	-	-	0.026 (0.032)	-
Innovation active in China	-	-	-	-	-	-	0.131 ** (0.053)
Innovation active in India	-	-	-	-	-	-	0.212 ** (0.094)
Innovation active in Eastern Europe	-	-	-	-	-	-	0.004 (0.030)
Innovation active in Western Europe	-	-	-	-	-	-	-0.003 (0.027)
Innovation active in North America	-	-	-	-	-	-	0.074 * (0.043)
Export intensity	0.138 *** (0.047)	0.149 *** (0.053)	0.148 *** (0.052)	0.156 *** (0.052)	0.153 *** (0.053)	0.149 *** (0.052)	0.141 *** (0.045)
Intern. Group with German HQ	-0.005 (0.029)	-0.004 (0.033)	-0.004 (0.033)	-0.001 (0.032)	-0.003 (0.033)	-0.004 (0.033)	0.032 (0.031)
Intern. Group with HQ abroad	-0.032 (0.033)	-0.038 (0.035)	-0.040 (0.035)	-0.035 (0.035)	-0.037 (0.036)	-0.037 (0.036)	-0.002 (0.038)
High-Skilled Employees	-0.060 (0.077)	-0.039 (0.084)	-0.023 (0.083)	-0.020 (0.082)	-0.030 (0.084)	-0.042 (0.085)	-0.094 (0.075)
Firm age	0.020 (0.014)	0.024 (0.016)	0.024 (0.016)	0.022 (0.016)	0.023 (0.016)	0.024 (0.016)	0.022 (0.014)
Firm size	-0.002 (0.007)	-0.002 (0.008)	-0.003 (0.008)	-0.002 (0.008)	-0.002 (0.008)	-0.001 (0.008)	-0.015 ** (0.007)
Firm in East Germany	-0.086 *** (0.027)	-0.073 ** (0.032)	-0.072 ** (0.032)	-0.079 ** (0.031)	-0.077 ** (0.032)	-0.074 ** (0.032)	-0.077 *** (0.026)
Competition: Technology	0.081 *** (0.027)	0.075 ** (0.030)	0.073 ** (0.030)	0.078 *** (0.030)	0.079 *** (0.030)	0.075 ** (0.030)	0.067 ** (0.026)
Ind: Knowledge-int. Manu.	-0.099 *** (0.037)	-0.095 * (0.052)	-0.090 * (0.053)	-0.078 (0.056)	-0.083 (0.057)	-0.094 * (0.053)	-0.096 *** (0.033)
Ind: Other Knowl.-int. Manu.	-0.096 ** (0.048)	-0.075 (0.068)	-0.063 (0.070)	-0.055 (0.070)	-0.060 (0.071)	-0.074 (0.068)	-0.082 * (0.046)
Ind: Other Manufacturing	-0.090 * (0.050)	-0.066 (0.067)	-0.052 (0.068)	-0.042 (0.069)	-0.050 (0.069)	-0.064 (0.068)	-0.073 (0.048)
Ind: Knowledge-int. Services	-0.069 (0.049)	-0.029 (0.074)	-0.020 (0.077)	-0.016 (0.078)	-0.016 (0.079)	-0.030 (0.075)	-0.044 (0.053)
Observations	579	508	508	516	508	508	579

Standard errors in parentheses; \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

## 5.6 Conclusions

This chapter investigated the relationship between international innovation activities and their propensity to provoke intellectual property infringements from foreign firms. The literature offers a stream of research studies about how R&D creates international spillovers and that the foreign business environment inhibits extraordinary risks which lead to higher costs due to foreign-owned firms' foreignness.

In an explorative study in China we found that firms have been experiencing IP infringements but that these cases are manageable. The results from two empirical analyses show that international R&D activities of firms have only weak significant effects and only for technology infringements. Of course, technological knowledge is most important in many sectors but can also not be avoided by carefully choosing the host innovation countries. Weak intellectual property regimes significantly ease the way to all kinds of IP infringements while strong IPR countries are territories for technology infringements. But even firms which have only national innovation activities are significantly more at risk to experience foreign product piracy. China, Russia and India are worldwide the main sources of counterfeit and pirated products (OECD, 2008). And also in our empirical analysis, the foreign-owned R&D activities in China lead to firm name infringements while innovation activities in China but also in North America lead to infringements from these host countries.

A larger scope of international R&D and other innovation related activities abroad has significantly stronger effects on IP infringements from innovation host countries than single innovation activities. Following the results, one conclusion that can be drawn is that firms which only have R&D centres abroad to develop new technologies and products are less at risk to be infringed than firm that embody their innovative knowledge in products abroad. About 10% of the firms with international innovation activities in our data set experienced IP infringements from countries in which they have localised innovation activities. The results of this chapter explain this occasion with the strong effects of firms' export intensity.

The analyses in this chapter have some limitations. Within this research framework it would have been interesting to analyse different types of IP infringements from certain countries and how they are influenced by R&D and



innovation activities in these countries. However, due to data constraints, it is not possible to split the data set by two dimensions, location and type of IP infringement. Another limitation is that some firms reported international R&D and innovation activities but did not specify the foreign locations. Consequently, the direct match between foreign innovation locations and the origin of IP infringements is often not possible and leads to smaller numbers of dependent variables for the second analysis. The survey information does not allow to draw conclusions about the type of R&D, in the sense of knowledge augmenting or knowledge exploiting (Kuemmerle, 1997) activities that have been carried out in the foreign R&D departments.

## 5.7 Appendix

*Table 35: Descriptive Statistics of First Data Sample: Types of Foreign IP Infringements*

No.	Dependent and Explanatory Variables	Mean	Std. Dev.	Min	Max
	Technology Infringement	0.088	0.283	0	1
	Product Piracy	0.069	0.254	0	1
	Firm name/design usage	0.081	0.274	0	1
1	Domestic R&D only	0.558	0.497	0	1
2	Domestic R&D and abroad	0.151	0.358	0	1
3	R&D in China	0.011	0.106	0	1
4	R&D in India	0.007	0.086	0	1
5	R&D in Western Europe	0.068	0.252	0	1
6	R&D in North America	0.042	0.200	0	1
7	R&D in Eastern Europe	0.022	0.146	0	1
8	R&D in RoW	0.016	0.125	0	1
9	R&D in strong IPR countries	0.099	0.295	0	1
10	R&D in weak IPR countries	0.036	0.181	0	1
11	Intern. Group with German HQ	0.259	0.438	0	1
12	Intern. Group with HQ abroad	0.102	0.303	0	1
13	High-Skilled Employees	0.230	0.244	0	1
14	Export intensity	0.227	0.291	0	1
15	Firm size	4.526	1.956	0	13.041
16	Firm age	2.699	0.871	-0.693	6.378
17	Competition: Technology	3.434	0.731	1	6
18	Firm in East Germany	0.313	0.464	0	1
19	Industry: Knowledge-int. Manu.	0.111	0.314	0	1
20	Industry: Other Knowl.-int. Manu.	0.150	0.357	0	1
21	Industry: Other Manufacturing	0.393	0.489	0	1
22	Industry: Knowledge-int. Services	0.222	0.416	0	1

Table 36: Correlation Matrix of Explanatory Variables for Data Sample [1](by No., see previous table)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
1	1.000																						
2	-0.427	1.000																					
3	-0.120	0.260	1.000																				
4	-0.088	0.192	0.178	1.000																			
5	-0.288	0.642	0.070	0.086	1.000																		
6	-0.225	0.487	0.181	0.189	0.272	1.000																	
7	-0.165	0.357	0.052	0.080	0.049	0.064	1.000																
8	-0.128	0.277	0.161	0.224	0.210	0.262	0.079	1.000															
9	-0.365	0.806	0.055	0.062	0.777	0.581	0.320	0.187	1.000														
10	-0.154	0.464	0.449	0.294	0.020	0.028	0.202	0.262	-0.018	1.000													
11	0.009	0.044	0.014	-0.017	0.037	-0.016	0.027	-0.047	0.024	0.049	1.000												
12	-0.003	0.101	0.029	-0.004	0.092	0.031	-0.013	0.008	0.115	0.011	-0.198	1.000											
13	0.062	0.072	0.033	0.013	0.048	0.052	0.020	0.019	0.070	0.026	-0.069	-0.038	1.000										
14	0.079	0.278	0.094	0.069	0.201	0.223	0.086	0.104	0.267	0.123	0.076	0.172	-0.026	1.000									
15	-0.015	0.284	0.089	0.107	0.233	0.295	0.083	0.100	0.292	0.045	0.233	0.204	-0.236	0.301	1.000								
16	-0.057	0.042	0.032	0.013	0.031	0.063	0.019	0.021	0.035	0.020	0.028	-0.013	-0.172	0.064	0.216	1.000							
17	0.652	0.176	0.061	0.056	0.131	0.143	0.068	0.090	0.168	0.053	-0.067	0.120	0.207	0.329	-0.011	-0.112	1.000						
18	0.065	-0.102	-0.020	-0.025	-0.093	-0.078	0.001	-0.028	-0.098	-0.001	-0.035	-0.090	0.187	-0.152	-0.244	-0.238	0.038	1.000					
19	0.059	0.079	0.025	0.077	0.073	0.091	0.028	0.062	0.084	0.021	-0.039	0.068	0.076	0.147	0.034	-0.054	0.315	0.001	1.000				
20	0.051	0.160	0.037	0.041	0.111	0.126	0.039	0.080	0.141	0.058	0.012	0.100	-0.068	0.318	0.135	0.036	0.422	-0.033	-0.147	1.000			
21	0.067	-0.095	-0.027	-0.050	-0.074	-0.086	-0.002	-0.046	-0.083	-0.024	0.036	-0.003	-0.340	-0.004	-0.003	0.010	-0.220	-0.005	-0.285	-0.339	1.000		
22	-0.039	-0.017	-0.021	-0.010	-0.019	-0.028	-0.026	-0.027	-0.019	-0.027	-0.062	-0.078	0.513	-0.223	-0.148	-0.022	-0.069	0.003	-0.186	-0.221	-0.430	1.000	

*Table 37: Descriptive Statistics of Second Data Sample: IP Infringements from Host and No-Host Countries*

No.	Dependent and Explanatory Variables	Mean	Std. Dev.	Min	Max
	Infringements from Hostcountries	0.032	0.175	0	1
	Infringements from No-Host countries	0.098	0.297	0	1
1	Domestic R&D only	0.327	0.470	0	1
2	Domestic R&D and abroad (iR&D)	0.550	0.498	0	1
3	Innovation conception/design abroad (iKON)	0.664	0.473	0	1
4	Innovation Production abroad (iPROD)	0.823	0.382	0	1
5	Interaction term: iR&D x iKON	0.468	0.499	0	1
6	Interaction term: iR&D x iKON x iPROD	0.405	0.491	0	1
7	Interaction term: iR&D x iPROD	0.441	0.497	0	1
8	Interaction term: iKON x iPROD	0.541	0.499	0	1
9	Innovation active in China	0.160	0.367	0	1
10	Innovation active in India	0.054	0.225	0	1
11	Innovation active in Eastern Europe	0.254	0.435	0	1
12	Innovation active in Western Europe	0.489	0.500	0	1
13	Innovation active in North-America	0.302	0.460	0	1
14	Intern. Group with German HQ	0.252	0.434	0	1
15	Intern. Group with HQ abroad	0.157	0.364	0	1
16	High-Skilled Employees	0.249	0.242	0	1
17	Export intensity	0.434	0.327	0	1
18	Firm age	2.804	0.994	-0.693	5.173
19	Firm size	6.144	2.419	1.099	13.041
20	Firm in East Germany	0.180	0.385	0	1
21	Competition: Technology	3.585	0.751	1	6
22	Industry: Knowledge-int. Manu.	0.146	0.354	0	1
23	Industry: Other Knowl.-int. Manu.	0.256	0.437	0	1
24	Industry: Other Manufacturing	0.348	0.476	0	1
25	Industry: Knowledge-int. Services	0.173	0.379	0	1

*Table 38: Tests of Statistical Equality between the Marginal Effects of National and International Innovation Activities for Host and No-Host Country Infringements*

Tests between marginal effects	Host country infringements	No-host country infringements
dom. R&D=iR&D	0.167	0.112
dom.R&D=iKON	0.540	0.973
dom.R&D=iPROD	0.660	0.134
dom.R&D=iR&D x iKON	0.031 **	0.011 **
dom. R&D=iR&D x iKON x iPROD	0.032 **	0.004 ***
dom. R&D=iR&D x iPROD	0.144	0.032
dom. R&D=iKON x iPROD	0.581	0.467
dom.R&D=Innovation active in China	0.007 ***	0.000
dom.R&D=Innovation active in India	0.004 ***	0.031
dom.R&D=Innovation active in WEU	0.709	0.962
dom.R&D=Innovation active in N. America	0.047 **	0.006
dom.R&D=Innovation active in E. Europe	0.619	0.971

Table 39: Correlation Matrix of Explanatory Variables for Second Data Sample [2](by No., see Table 37)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25		
1	1.000																										
2	-0.802	1.000																									
3	-0.282	0.345	1.000																								
4	0.070	-0.107	-0.001	1.000																							
5	-0.651	0.812	0.618	0.081	1.000																						
6	-0.549	0.685	0.521	0.375	0.843	1.000																					
7	-0.596	0.744	0.410	0.407	0.759	0.920	1.000																				
8	-0.259	0.322	0.735	0.529	0.525	0.708	0.617	1.000																			
9	-0.061	0.120	0.054	0.151	0.140	0.186	0.190	0.146	1.000																		
10	-0.111	0.159	0.161	0.017	0.191	0.197	0.174	0.147	0.233	1.000																	
11	0.036	-0.021	0.015	0.073	0.004	0.012	0.031	0.038	0.031	0.057	1.000																
12	-0.256	0.309	0.119	0.008	0.255	0.213	0.261	0.114	-0.059	0.050	-0.052	1.000															
13	-0.216	0.282	0.138	0.099	0.268	0.299	0.318	0.195	0.207	0.178	-0.016	0.094	1.000														
14	0.022	-0.024	-0.021	0.022	-0.029	-0.005	-0.019	0.009	-0.014	-0.093	-0.019	-0.030	-0.048	1.000													
15	-0.120	0.168	0.101	-0.015	0.180	0.135	0.153	0.058	0.030	-0.003	-0.006	0.082	0.014	-0.273	1.000												
16	-0.069	0.109	-0.078	-0.208	-0.009	-0.064	-0.033	-0.159	-0.011	0.006	-0.046	-0.012	0.110	-0.065	-0.076	1.000											
17	-0.018	0.137	0.149	0.056	0.178	0.163	0.180	0.151	0.072	0.087	0.069	0.029	0.240	0.078	0.160	-0.049	1.000										
18	-0.030	0.040	-0.035	0.117	0.058	0.113	0.129	0.049	0.109	0.059	0.049	0.049	0.075	-0.021	0.064	-0.107	0.132	1.000									
19	-0.159	0.271	0.195	0.221	0.334	0.412	0.409	0.313	0.198	0.181	0.096	0.213	0.404	0.109	0.136	-0.209	0.323	0.219	1.000								
20	0.080	-0.117	-0.140	-0.077	-0.169	-0.153	-0.153	-0.132	-0.069	-0.040	0.039	-0.067	-0.123	0.026	-0.105	0.161	-0.090	-0.220	-0.307	1.000							
21	0.019	0.128	0.067	-0.074	0.129	0.055	0.050	0.016	0.119	0.076	0.055	-0.011	0.207	-0.035	0.126	0.178	0.201	0.024	0.056	0.023	1.000						
22	-0.052	0.109	0.030	0.070	0.130	0.106	0.108	0.054	0.095	0.040	0.020	0.069	0.131	-0.070	0.071	0.049	0.078	-0.035	0.083	0.049	0.259	1.000					
23	0.011	0.088	0.130	0.020	0.133	0.131	0.120	0.128	0.038	0.123	0.025	-0.025	0.152	0.014	0.085	-0.116	0.229	0.077	0.145	-0.005	0.444	-0.265	1.000				
24	0.109	-0.164	-0.120	0.114	-0.176	-0.135	-0.110	-0.051	-0.027	-0.100	0.097	-0.023	-0.165	0.048	-0.023	-0.379	-0.038	0.023	-0.037	-0.059	-0.416	-0.306	-0.446	1.000			
25	-0.046	0.034	-0.057	-0.240	-0.042	-0.090	-0.099	-0.163	-0.095	-0.051	-0.114	0.001	-0.025	-0.053	-0.083	0.594	-0.223	-0.096	-0.191	0.022	-0.068	-0.195	-0.284	-0.328	1.000		



## 6 Summary and Conclusions

The previous chapters have answered research questions and tested hypotheses related to the three main topics of the dissertation: (1) What motivates and hinders firms to internationalise their innovation activities, (2) What are the corporate benefits from international R&D engagements and (3) What risks impose international innovation activities on firms' intellectual properties? Besides these main topics the thesis looked into effects of different innovation activities abroad as well as of different host countries.

Chapter 3, which targeted the first thematic focus, showed that firm capabilities, in particular absorptive capabilities and previous international business experience resulting from exports and international research cooperation, play a major role in the internationalisation decision. However, the effects vary for different innovation activities abroad. While the likelihood to carry out research abroad is only driven by firm capabilities, the decision to internationalise the production of innovations is also spurred by the shortage of labor and high innovation costs in the home country. Absorptive capabilities are of greater importance for firms that plan to innovate in Eastern Europe and North America. Innovation barriers in the home innovation environment are of minor relevance as internationalisation drivers and rather act as barriers to innovation internationalisation. These results lead to the conclusion that firms which are internationalising their innovation value chain are not pursuing this strategy to overcome limitations in the home country innovation system but to intensify their existing international engagements by setting up R&D and innovation activities abroad in order to strengthen their existing capabilities.

The results of Chapters 4 and 5 are especially interesting to practitioners. Both chapters are devoted to the second main topic and evaluate the benefits of international corporate R&D activities. In Chapter 4, we proved that international innovating firms are more successful in introducing new products, firm and market novelties. Moreover, the market success with new products and firm novelties is higher for firms with international R&D than for firms with only national R&D. The international R&D intensity (measured by the number of R&D

locations abroad) shows an inverse-u shaped relationship in our estimations, indicating that a moderate number of R&D locations abroad has the most positive influence on innovation outcome and innovation success.

In Chapter 5, the aim was to observe the impact of international R&D activities on firm performance. The monetary success of firms is the focal point in this analysis while Chapter 4 was focusing on the innovative outcomes. Thus, this analysis combined both perspectives by analysing the firm profitability: the costs that arise from the international knowledge sourcing activities and the benefits from the innovative outcomes. The results are in line with the conclusions from Chapter 4. Firm profitability receives stronger positive influences from both national and international R&D activities than from only domestic R&D activities. The positive effect of international R&D activities decreases with a large number of R&D locations abroad. A moderate decentralisation of the international R&D organisation is therefore most beneficial to firm profitability.

Chapter 3 has left the reader with the insight that firms with strong capabilities, technological advancedness and international experience are more likely to operate international R&D centres. Chapters 4 and 5 pointed out the positive feedback of international R&D activities in terms of innovation and firm performance compared with firms that innovate only nationally. Chapter 6 complemented these findings with an analysis about the potential knowledge losses due to firms' R&D activities abroad and is related to the third main focus of this dissertation.

The results of Chapter 6 reveal that the risk of intellectual property loss due to international R&D and innovation activities is not as severe as expected. International R&D increases the risk of infringements of technology inventions only weakly. The location of R&D abroad, in weak or strong IPR regimes, does not alter the risk of infringement. Insights from five case studies with German firms in China pointed out the risk of firm name and logo infringements from Chinese competitors. This risk was also evident in the empirical analysis. The econometric results show that innovation activities in China and also North America are likely to create infringements from these host countries. It could be shown that infringements from the foreign innovation host countries do not result from localised R&D activities but rather from the manufacturing of innovative products or a wider scope of innovation activities abroad. Infringements from countries in which firms do not have innovation activities could be traced back to firms' export intensity.



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Implications from the results of this dissertation can be drawn for both policy makers and practitioners. Chapter 3 has revealed barriers for firms to internationalise their R&D and innovation activities. Regulation forms a barrier to those firms that planned to set up innovation facilities in countries with marginal knowledge levels such as China. The lack of international cooperation partners represents also a hampering factor which policy makers could reduce with tailored support programmes. The results also show that firms from the Eastern German region are less likely to internationalise innovation activities. With regard to the encouraging benefits from international R&D activities abroad that have been found in Chapters 4 and 5, these barriers should be minimised.

For practitioners, the results from Chapters 4, 5 and 6 lead to a recommendation for the internationalisation of R&D and innovation activities. These chapters have shown that international R&D is influencing the innovation performance, the market success with innovations as well as the firm performance stronger than purely national R&D activities. Moreover, the risk of intellectual property infringements due to international R&D is manageable. Later-stage innovation activities such as the manufacturing of innovative goods abroad are more risky. Nevertheless, the results clearly state that firms should decentralise their R&D activities carefully. The decision to innovate in countries with strong or weak IPR is not as critical as the number of R&D locations abroad. A moderate number of R&D locations (we found evidence for two or three locations abroad) shows the strongest positive influence on innovation outcome, innovation success and firm profitability.



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