# The innovative performance of German multinationals abroad

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Evidence from the European Community Innovation Survey

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## Abstract

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**Key words:** Internationalization of innovation, German multinational firms, innovation performance, Community Innovation Survey

**JEL classification:** O320; O330; F230

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# 1 Introduction

In recent decades firms increasingly decentralized their innovation activities. In 2007, affiliates of multinational enterprises (MNEs) account for around 20% of total business R&D in France, Germany and Italy; between 30% and 50% in Canada, Portugal, the Slovak Republic, Sweden and the United Kingdom; and more than 50% in Austria, Belgium, the Czech Republic, Hungary and Ireland (OECD, 2010, p. 87). This process of decentralization of innovation activities has been labeled as 'internationalization of innovation'. A considerable number of studies have examined this trend in recent years (Dunning and Narula, 1995; Kuemmerle, 1999; von Zedtwitz and Gassmann, 2002; Ambos, 2005; Cantwell and Mudambi, 2005; Narula and Zanfei, 2005; UNCTAD, 2005).

This literature has followed a number of different approaches. Two of them are important for this paper: First, various authors relate R&D and innovation activities abroad to market- and knowledge-seeking strategies of multinational firms (examples include Patel and Vega, 1999; Cantwell and Piscitello, 2002; Edler, 2004; Ambos, 2005; Cantwell and Piscitello, 2005). This approach assumes that firms plan innovation efforts abroad in response to the locational advantages of potential host countries; strong market growth will pose a considerable incentive for a MNE to increase innovation efforts in this country. The main question of this literature is how location shapes innovation activities of foreign-owned firms in various countries. These studies, however, tell only very little how firm characteristics, such as size or sectoral affiliation, are related to innovation activities of foreign-owned firms. Heterogeneity in these factors accounts for a huge share of the variation in innovation behavior between firms (Cohen, 1995; OECD, 2009).

A second stream of the literature on internationalization investigates the role of foreign ownership in explaining innovation performance of firms (Ebersberger and Lööf, 2005; Sadowski and Sadowski-Rasters, 2006; Frenz and Ietto-Gillies, 2007). Here, foreign ownership is typically one among various firm characteristics variables that shape innovation behavior. The vast majority of studies that look at firm characteristics, however, include only observations from one country. Hence, they implicitly assume that there are no differences with respect to the analyzed home countries and results gained from one country can be generalized. In contrast, Dunning and Narula (1995) point out that there is

considerable variance in the innovative activities of foreign-owned enterprises across borders even within Europe.

Only a small number of studies capture both, locational advantages and firm characteristics, in one analysis. Two examples are the articles by Ito and Wakasugi (2007) and Schmiele (2009). Despite the large number of publications on the internationalization of R&D in recent years, we still know only little about how the innovation performance of foreign-owned enterprises differs between countries and how these differences can be explained from the interplay of locational advantages and firm characteristics.

The aim of this paper is shed light on the interplay between location, firm characteristics and foreign ownership. We analyze cross-country differences in the innovation behavior of subsidiaries of German MNEs in various European host countries. Innovation covers a wider range of activities compared to research and development; innovation, however, is in many ways crucial for the commercialization of R&D results.

Innovation activities of firms abroad depend to a considerable degree on their technological strengths and capabilities build up at home (Patel and Pavitt, 1999; le Bas and Sierra, 2002). By including only German-owned subsidiaries, we eliminate possible effects from home country specialization on the innovation performance of the subsidiary. We test cross-country variance with data from the Community Innovation Survey 4 (CIS4). The CIS4 provides information on the characteristics of innovation activity at enterprise level. The independent variables employed in our regressions capture both firm-specific characteristics, as size, market orientation, sectoral affiliation, etc. and country-specific characteristics that describe the innovation system of the host country. The data covers 16 European countries.

The paper is structured as follows: Section 2 discusses our hypotheses; Section 3 describes the data employed in this paper and the variables of the empirical analysis. Section 4 comprises the econometric model. Section 5 presents the results of the descriptive analysis. We mainly focus on innovation activity, innovation input and output intensity, the dependent variables from the multivariate analysis. Section 6 investigates the determinants of innovation behavior of German-owned firms. Conclusions and policy implications derived from the analysis follow in Section 7.

# 2 Research Hypotheses

The aim of this paper is to explore the association between firm characteristics, host country characteristics and the innovation behavior of German-owned subsidiaries in Europe. A first, very general hypothesis is that these variations are associated with both, firm-level characteristics such as size or industrial sector, and the incentives and disincentives posed by various host countries. Indications for the importance of these factors can be found in the literature that analyzes the determinants of innovativeness at the firm-level (Cohen, 1995; Kleinknecht and Mohnen, 2002; OECD, 2009). This leads us to the following hypothesis:

***Hypothesis 1:*** *Country characteristics and firm characteristics are both associated with innovation performance of German MNEs.*

Moreover, we assume a relationship between various characteristics of the host country and the innovativeness of the firm. Competitive pressure from other firms may force German subsidiaries to increase innovation inputs to the level of other enterprises in the country. In addition, potential spillovers may be richer in innovation-intensive environments, which in turn may be an incentive for German-owned subsidiaries to spend more on innovation. We may therefore assume that:

***Hypothesis 2:*** *German subsidiaries spend more on innovation in countries with high average innovation input intensity.*

Germany is among the most technologically advanced and R&D intensive countries in the world. In the context of multinational enterprises, this indicates that German MNEs may possess considerable intangible assets which can be commercialized by their overseas subsidiaries and give them an advantage over domestic competitors and other foreign-owned firms in the country. The advantage German-owned subsidiaries can generate from these assets may be largest in countries which have the largest technology gap to Germany.

***Hypothesis 3:*** *German-owned subsidiaries gain a higher turnover from innovations in countries with a low average R&D intensity compared to Germany.*

We will test these three assumptions in the subsequent sections of this paper. The descriptive and multivariate analyses will be presented in Section 5 and 6.

# 3 Data and Variables

***The Community Innovation Survey***

We draw on data from the fourth wave of the Community Innovation Survey (CIS 4). CIS is a survey based on a harmonized questionnaire administered by Eurostat and national statistical offices or research institutes in all EU member states, Iceland and Norway. CIS aims at assessing various aspects of the innovation behavior and performance of enterprises and follows the definitions laid down in the OECD Oslo Manual (OECD, 2005). The CIS 4 covers the period 2002-2004.

The data set employed in this paper includes more than 2.000 German subsidiaries from 16 European countries. To allow cross-country comparisons, we matched firm level CIS data from different countries, depending on authorization of use by these countries. CIS data has been accessed via the SAFE Center at the premises of Eurostat in Luxembourg. The data contains information about the subsidiary's host country as well as the corresponding home country of the parent enterprise. The figure below (Figure 1) gives an overview of the sample.

[Figure 1 about here]

The data has some important limitations. First, there is no information about the age of the firm and the time of ownership change. This may be a possible source of endogeneity; more productive and more innovative firms may be the preferred acquisition targets of German multinational firms, and these firms may maintain this advantage after ownership change. Second, we cannot identify the parent enterprise and are not able to draw direct comparisons between subsidiaries and their parent enterprises. Furthermore, regional differences (e.g. at the NUTS3 level) cannot be included in the analysis. Another limitation results from the the innovation variable. Innovations cover products and processes new to the firm during the period under review; for CIS4, these are the years 2002 to 2004. Hence, a possible time lag between research and market introduction cannot be taken into account.

***Dependent Variables***

Our model includes innovation input and innovation output intensity as dependent variables. We measure *innovation input intensity* by innovation expenditures of the enterprise as a share of turnover for the reference year 2004. Innovation expenditures include internal and external R&D expenditures, and innovation-related expenditures for machinery, equipment, software, other external knowledge and training (OECD, 2005). Compared to R&D expenditures, innovation expenditures cover a wider range of activities. Some of them are not R&D, but nevertheless are important for the introduction of new products and processes. This wider focus accounts for the fact that the innovation activities of foreign-owned firms in many cases have a non-R&D character and comprise of the adaptation of existing technology to new markets. *Innovation output intensity* is measured by the share of products new to the firm on turnover introduced between 2002 and 2004.

[Table 1 about here]

The paper employs a Heckman Selection model with two equations (see Section 4) in the multivariate analysis. Innovation activity (technological innovations) and product innovations respectively are the dependent variables in the selection equation.

***Independent Variables***

Independent variables differ between the two equations. For the selection equation the independent variables need to be available for all enterprises surveyed in the CIS4. In the function equation, independent variables only need to be available for enterprises with innovation activities.

Table 2 below summarizes all independent variables. The *size* of the enterprise is measured by the number of employees and the number of employees squared to allow a non-linear relationship between size and innovation behavior. There is evidence of a U-shaped relationship between innovativeness and firm size (Cohen, 1995; OECD, 2009; Cohen, 2010). In addition, Belderbos (2001) shows that medium-sized firms Japanese firms have a higher propensity to internationalize R&D than small- or large-sized firms.

[Table 2 about here]

The variable *international market orientation* identifies enterprises which are mainly engaged at international markets. An international market orientation enlarges the potential market for an innovation and thus gives an incentive for higher innovation efforts. Empirical evidence reveals, for example, a positive relationship of innovation behavior and export level (Lachenmaier and Wößmann, 2006; Harris and Li, 2009). Affiliates which are not only active in their host country but also act as representatives for their group in other countries may therefore have a higher innovation intensity.

Besides size, size$^2$ and international market orientation, the selection equation includes three variables indicating that the enterprise has faced obstacles in the innovation process: *Knowledge factors hampering innovation* indicates if the enterprise has faced obstacles related to the availability of knowledge; *cost factors hampering innovation* describes enterprises faced with obstacles related to unexpected high innovation costs and the availability of funding; *market factors hampering innovation* incorporate obstacles related to market acceptance of the innovation.

We also include a variable that identifies enterprises with intramural (in-house) R&D activity during the period 2002-2004. The literature stresses the fact that firms with own R&D activities have also higher abilities to absorb and utilize the results of research done by other organizations (Cantner and Pyka, 1998; Phene and Almeida, 2008). Hence, intramural R&D also points to the absorptive capacity of a firm (Cohen and Levinthal, 1989, 1990), enabling the firm to create new knowledge as well as absorbing knowledge from external sources. Moreover, we include the variable *public funding* which indicates that the enterprises have received public financial support for innovation.

To account for influences from the sectoral level, we employ a new taxonomy of innovativeness at the sectoral level proposed by Peneder (2010). We feel that this taxonomy is better suited to reflect sectoral characteristics than other taxonomies, because it has been constructed with firm-level data and includes both, manufacturing and service industries. Peneder classifies sectors according to cumulativeness of the knowledge base, appropriability conditions, technological opportunity and creative vs. adaptive strategies. *None, low*, *med*, and *high* are sectoral dummies which refer to different levels of sectoral innovativeness according to this taxonomy. The reference category is *none*, which indicates sectors with very little of no innovation activity.

We measure impacts from host countries with country dummies. To account for the fact that elements of the innovation process become transnational and global, or regional, rather than national (Fischer 2001), and no data is available on regional level, countries are aggregated at two different levels. We aggregated countries in five groups, Northern Europe (Denmark, Norway, Finland), Southern Europe (Spain, Portugal, Italy), Western Europe (Luxembourg, France), and two Eastern European groups. These are on the one hand Bulgaria, Hungary, Romania, Slovenia and on the other hand Czech Republic, Estonia, Latvia, Lithuania, and Slovakia. The northern European countries are used as reference category. To proof for sensitivity we further aggregated these countries in old (EU15 including Norway) and new member countries with Romania as reference category. Descriptive statistics not reported here indicate that there are substantial differences between these country groups in business R&D intensity, human resources in science and technology or publication intensity from which we assume that they influence innovation behavior of German-owned subsidiaries.

# 4 Model Specification

The multivariate analysis investigates the relationship of innovation input and output intensity and various firm and host country characteristics. Using ordinary least squares (OLS) instead of a selection model may lead to biased inferences when the data is not a representative sample of the population. Taking into account only the innovative enterprises discards the enterprises not active in innovation. This implicates that the estimation results may not hold for the population as a whole, as they are based on a non-randomly selected subset leading to an overestimation of the variables. Including all the enterprises from the sample, whether they are active in innovation or not, would in turn lead to an underestimation of innovation input and output intensity. Therefore, a model accounting for these data / variable restrictions – the Heckman Selection Model – needs to be employed in the analysis.

The Heckman Selection Model (Greene, 2002; Wooldridge, 2002; Kennedy, 2003) is appropriate because data is incidentally truncated due to the questionnaire design. Sample selection is a special form of censoring, but one in which truncation occurs, when the likelihood that an observation appears in the sample is a stochastic function of the dependent variable. Incidental truncation, moreover, implicates that no information is available for the units excluded from the sample (Breen, 2003; Fu et

al., 2009). This model is a standard tool in various evaluation studies, for example in the evaluation of labor market programs. The bias that arises from using least squares in a model with nonrandom sample selection is characterized as an estimator applicable to such models. This estimator amounts to estimating the omitted variable and using least squares including the estimated omitted variable as a regressor (for a formal derivation see below) (Heckman, 1976, 1979).

We observe some variables such as size, main market, location and sectoral affiliation for all enterprises. A number of other variables such as innovation expenditure, however, can only be observed for innovative enterprises. Thus, the availability of most dependent variables – and therefore the composition of the sample - depends on whether or not the enterprises have introduced an innovation. The group of enterprises for which we have data on innovation behavior constitute a non-random, self-selected sub-sample of the whole population (Blundell and Costa Dias, 2000).

Formally, we can write the model as follows: Let the equation that determines the sample selection be

$$z_i = \begin{cases} 1 & \text{if} \quad z_i^* = X_{1i}\beta_0 + \varepsilon_{1i} > 0 \\ 0 & \text{if} \quad z_i^* = X_{1i}\beta_0 + \varepsilon_{1i} \le 0 \end{cases} \tag{1}$$

$$\text{Prob}(z_i = 1 \mid X_{1i}) = \Phi(X_{1i}\beta_0) \tag{2}$$

$$\text{Prob}(z_i = 0 \mid X_{0i}) = 1 - \Phi(X_{0i}\beta_0) \tag{3}$$

and let the equations of primary interest be

$$y_{2i} = y_{2i}^* = X_{2i}\beta_2 + \varepsilon_{2i} \qquad \text{if} \quad z_i = 1 \tag{4}$$

$$y_{3i} = y_{3i}^* = \alpha_1 y_{2i}^* + X_{3i}\beta_3 + \varepsilon_{3i} \quad \text{if} \quad z_i = 1 \tag{5}$$

The selection equation (1) identifies the determinants of being innovative while the function equations [(4) and (5)] relate various independent variables to innovation behavior, i.e. to innovation input intensity ( $y_{2i}$ ) and innovation output intensity ( $y_{3i}$ ). Let $z_i^*$ be our latent variable, ascertaining the firm's probability of being innovative, which we cannot observe. The probability depends on some observable explanatory variables $X$ containing firm characteristics (as e.g. size of the enterprise and market-orientation), factors hampering innovation activities, dummies for a sectoral taxonomy and on unobservable variables summarized in the error term ( $\varepsilon_{1i}$ ). If $z_i^*$ is larger than zero, we observe that

firm i engages in innovation activities. $z_i$ is a binary variable, taking the value 0 for non-innovative firms and 1 otherwise. With the stipulation that a firm is innovative, the amount of resources devoted to innovation activities ( $y_{2i}$ ) can be observed. Innovation input intensity is measured by innovation expenditures as a share of turnover. Innovation output intensity ( $y_{3i}$ ), measured as the share of products new to the enterprise on turnover, results from innovation expenditure ( $y_{2i}$ ) and the explanatory variables $X$ .

Estimating the probit equation (selection equation) by maximum likelihood, we obtain estimates of $\beta_0$ and thus the nonselection hazard – what Heckman (1979) referred to as the inverse of the Mill's ratio, $\hat{\lambda}_i$ :

$$\hat{\lambda}_i = \frac{\phi(X_{1i}\hat{\beta}_0)}{\Phi(X_{1i}\hat{\beta}_0)} \tag{6}$$

We obtain $\hat{\beta}$ by augmenting the regression equation with the nonselection hazard $\hat{\lambda}_i$ . Hence, regressors become $[X \ \lambda]$ with the additional parameter estimate $\beta_\lambda$ on the variable containing the nonselection hazard.

# 5 Differences in innovation behavior of German-owned firms between countries

We will first analyze cross-country differences in innovation behavior of German subsidiaries and compare German subsidiaries with all enterprises in their host countries.

[Figure 2 about here]

We find considerable performance differences between German-owned subsidiaries and all other enterprises located in the various host countries. In all countries, German subsidiaries have a higher propensity to innovate than the total country sample. This may reflect, one the one hand, the internal transfer of knowledge and other advantages subsidiaries of MNEs enjoy in innovation. On the other hand, cross-country differences may also be explained by self-selection; the group of foreign-owned firms constitutes a non-random sample, since only the most productive firms go abroad. Similar findings not reported here are obtained for product innovation.

We measure innovation input intensity by innovation expenditures as a share of turnover. The figure below (Figure 3) shows innovation input intensity of German-owned subsidiaries in various countries. We display mean innovation input intensity for both, German subsidiaries and the entire firm population.

[Figure 3 about here]

The relationship between innovation input intensity of German subsidiaries and the innovation input intensity of all enterprises in a country is more ambiguous. German-owned subsidiaries in Norway for example exhibit the highest innovation intensities, while innovation input intensity for all enterprises is one of the lowest. A similar result turns out for Portuguese enterprises. The opposite is true for Denmark. German-owned subsidiaries reach relatively low innovation intensities in contrast to the national average of firms in Denmark, which are on top of all observed countries. From these findings, hypothesis 2 can neither be rejected nor verified, thus findings from the multivariate analysis are required.

Our second dependent variable used in the function equation is innovation output intensity. A comparison between German-owned subsidiaries and all enterprises in various host countries is given by figure 4 below.

[Figure 4 about here]

In contrast to innovation input intensity, we can see that in all countries, except Portugal, German-owned subsidiaries achieve higher innovation output intensity than the entire firm population. In the majority of countries, innovation output intensity of German-owned subsidiaries is even higher than for enterprises located in Germany. It is striking that highest turnovers with new products are achieved mainly in Eastern European host countries (14.39%) (besides Spain) whereas lowest turnovers are gained mainly in Western European host countries (10.33%). Regarding in contrast all firms surveyed in the CIS4, innovation output intensity in Eastern European countries is marginally lower (5.8%) than in Western European countries (7.68%).

To sum up, descriptive statistics reveal that German-owned subsidiaries behave differently in different countries; in general, they are more innovative than the total enterprise population. In about half of the countries, they spend less on innovation than the average enterprise. In contrast, innovation output intensity of German-owned subsidiaries is in all but one country higher than the innovation output intensity of the average enterprise.

These results may be caused by two factors: first, German subsidiaries in these countries differ in their firm characteristics; these differences, in turn, are related to different innovation performance. Second, characteristics of the host countries may lead to a higher or lower innovation performance of German subsidiaries. Hypothesis 1, assuming that country characteristics as well as firm characteristics are associated with innovation performance of German-owned subsidiaries, can therefore be verified. We will disentangle these two factors in the next section with multivariate analysis.

# 6 Determinants of innovation behavior of German-owned firms

We analyze first the results from the selection equations (see equation (1)). The table below (Table 3) shows results for the selection equations for innovation input (selected by product and process innovations) and output intensity (selected by product innovations) of the Heckman model.

[Table 3 about here]

The likelihood of an enterprise being active in innovation increases significantly with size and international market orientation of the enterprise. The small influence of firm size could suggest a decreasing marginal effect of this variable. Moreover, we find a positive, but quite usual coherence between the likelihood of an enterprise being active in innovation and the presence of hampering factors such as the lack of knowledge, too high innovation cost and too little market acceptance. This can be attributed to the subjective rating of the aforementioned hampering factors. An enterprise might not be able to appraise an obstacle in a realistic way until it had not been confronted with factors hampering innovation. It is assumed that enterprises not engaged in innovation underestimate these hampering factors. With respect product and process innovations, only cost factors and knowledge factors result significant; to product innovations, additionally market factors result significant. The likelihood of enterprises to be innovative increases with sectoral innovation intensity measured by the sectoral taxonomy of Peneder (2010). Significant results are obtained for medium and high innovation intensities. For enterprises in industries with low innovation intensity we found no significant difference to the base case.

Results for the function equations are given in Table 4 below. The results for innovation input intensity show a highly significant, U-shaped relationship between innovation input and size. International market orientation, in contrast, has no significant association with innovation input intensity that goes beyond the effects of the selection equation. There is also a significant association between innovation input intensity and public funding, which points to the importance of incentives set by policy to stimulate innovation in foreign-owned firms. Higher innovation input intensity is also associated with

the decision of the firm to engage in internal R&D activities. There is, however, no significant influence of innovation co-operation on innovation input intensity.

[Table 4 about here]

Enterprise size is marginally less important for innovation output intensity compared to innovation input intensity. A U-shaped relationship between size and innovativeness, however, is also confirmed for innovation output intensity. Large multidivisional firms enjoy a much broader range of possible applications for new knowledge, which may further increase their advantages in the commercialization of new products (Rosenberg, 1990). There is a significant and positive relationship between innovation output intensity and co-operation agreements of the firm which could not be found for innovation input. We conclude that German subsidiaries use co-operation mainly as a tool to gain knowledge that helps them to adjust their products to the host market, rather than as a tool to create new knowledge. Public funding has no significant impact on the turnover from innovations new to the enterprise. This result can be seen as a sign for the uncertainty associated with the market introduction of new products. It may also be a caused by the fact that most innovation policy schemes support innovation input (in particular R&D funding) or the presence of IPR regulations, but not commercialization and innovation output of firms.

An interesting finding results from the variable indicating that the firm engages in intramural R&D activity. The coefficient is significant in both cases; it has, however, a positive sign for innovation input intensity and a negative sign for innovation output intensity. This may be a result of different strategies pursued by foreign-owned firms. The literature (Kuemmerle, 1999; Cantwell and Mudambi, 2005; Narula and Zanfei, 2005) broadly differs between overseas innovation activities that aim at adapting existing technologies to new markets (market-seeking) and innovation that aims at creating new knowledge (knowledge-seeking). Firms that follow knowledge-seeking strategies may also have internal R&D activities, which is not necessary for firms which mainly follow market-seeking strategies. As a result, internal R&D is positively associated with innovation input intensity, but negatively related to innovation output intensity, because firms that follow market-seeking strategies mainly commercialize existing technologies of the company. Regression results for country group variables

show no significant influence on innovation input intensity of German-owned subsidiaries after correcting for firm characteristics and sectoral affiliation.

In contrast, we can find significant country effects for innovation output intensity. Compared to the base case (the Northern European countries Denmark, Norway and Finland), innovation output intensity is significantly higher in all other regions except Western Europe, holding all other factors constant. This indicates that, compared to Northern European countries, German subsidiaries find it easy to produce novelties in Southern Europe and both Eastern European country groups. We can interpret this as an indication that German subsidiaries find it easier to transfer their intangible assets and technologies into new products in countries where the technology gap between these countries and Germany is relatively high. In contrast to innovation output intensity, we could find no effect of the host country on input intensity.

To sum up, our results clearly show the importance of firm characteristics for innovation behavior of German-owned subsidiaries. The importance of location could only be confirmed for innovation output intensity. Thus, we can only partially confirm hypothesis 1. Moreover, we therefore accept hypothesis 3 and refute hypothesis 2. We cannot rule out that this result is due to the econometric set-up and the use of dummy variables. A more elaborated approach using variables that address particular locational advantages at the regional level may reveal a significant influence of location on input intensity as well. Data at the regional level, however, is not available from the CIS.

# 7 Concluding Remarks

This paper analyzed the innovation activities of subsidiaries of German multinational firms in 16 European countries. Special emphasis was laid on innovation input intensity (innovation expenditure as percentage of turnover) and innovation output intensity (share of products new to the firm on turnover). The analysis revealed that innovation output intensity of the average German-owned subsidiary is higher than innovation output intensity of the average firm in all but one country. This result indicates that subsidiaries of German MNEs are highly innovative and contribute with the introduction of new products and processes to growth and employment of their host countries.

Innovation input intensity, in contrast, is more heterogeneous across countries; German-owned subsidiaries spent more on innovation than the average firm in half of the countries. A comparison of the host countries where input intensity of German-owned subsidiaries is highest suggests that these differences are not related to host country characteristics such as GDP per capita or R&D intensity.

We further investigated the relationship between innovation input and output intensity, firm characteristics and host countries with multivariate analysis. Regression analysis revealed that firm characteristics such as size, intramural R&D activity, international market orientation, or sectoral affiliation are significantly associated with innovation input and output intensity of German-owned subsidiaries. The assumption that the host country plays a decisive role for innovation performance of German subsidiaries is only partly supported by the regression results. Country dummies are significant when we aggregate countries into country groups. Here, we find significant effects of the host country for innovation output intensity.

Innovation output intensity of German-owned subsidiaries is higher in Bulgaria or Romania, Southern European countries or Eastern European countries compared Northern European countries. There is no significant difference between Western and Northern European countries. We interpret this as an indication that German subsidiaries find it easier to transfer their intangible assets and technologies into new products in countries than in high-income countries. In other words, the economic advantages German subsidiaries can generate from intangible assets of their parent companies are largest in countries which have the largest technology gap to Germany.

This seems, at a first sight, a contradiction to the assumption that innovation efforts may be higher in high-income countries due to richer potential spillovers and stronger pressure from competitors that force firms to keep innovation efforts at par with their business environment. The finding is also somewhat at odds with other studies (for example Belderbos *et al*., 2009) which demonstrate that scientific excellence or market size matter for innovation efforts of foreign-owned firms. It is, however, important to consider that we are talking about innovation output, not input. Multinational firms do not necessarily develop and commercialize new products in one and the same country.

In a policy perspective, this result indicates that foreign-owned firms are a valuable source of international technology diffusion. Low-income countries can benefit in particular; first, because new

products introduced by foreign-owned firms may be used as inputs in the production processes of domestically owned firms and raise their productivity. A second channel for spillovers is the imitation of new products by domestically owned firms. Additional spillover effects may arise from the mobility of personnel between foreign-owned and domestically owned firms.

The results also indicate that German MNEs are well integrated into their host country innovation systems and responding to policy incentives; public funding received by the firms is associated with significantly higher innovation input intensity. Benefits from the presence of German-owned subsidiaries, however, do not justify a policy of offering special incentives to attract these firms. We cannot see from our results if similar benefits are also generated by foreign-owned firms from other countries, or if foreign-owned firms perform better than domestic ones. Our results, however, clearly show the importance of firm characteristics for innovation behavior of German-owned subsidiaries. From a policy perspective, this implies that policy should improve the innovation capabilities of foreign-owned firms, rather than offer benefits to attract foreign-owned firms. This is the consensus approach in the policies towards foreign-owned firms in the EU and in OECD countries (OECD, 2008).

Future research could improve and refine our results by extending the list of host country variables with indicators for the R&D intensity of the business sector of the country, scientific output of universities, the availability of skilled personnel, and market size and growth.

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**Table 1: Dependent Variables**

| Dependent variables | Indicator |
|---|---|
| **Selection equation** | |
| Innovation activity *(innov)* | 1 if a firm introduced onto the market a new or significantly improved good, service, method of production, logistic delivery or distribution system or supporting activities during 2002-2004; 0 otherwise |
| Product innovation *(inprod)* | 1 if a firm introduced onto the market a new or significantly improved good or service during 2002-2004; 0 otherwise |
| **Function equation** | |
| Innovation Input Intensity *(lintens)* | ln (innovation expenditure as a share of the total turnover); reference year 2004 |
| Innovation Output Intensity *(lturnin)* | ln (% of turnover in new or improved products introduced during 2002-2004 that were new to the firm) |

Source: own illustration, CIS4, EUROSTAT

**Table 2: Independent Variables**

| Independent variables | Indicator |
|---|---|
| **Internal capabilities concerning all enterprises surveyed in the CIS4 (Selection equation)** | |
| Size | ln (total number of employees) in the reference year 2004 |
| International market orientation | 1 if a firm exported goods or services during the years 2002-2004; 0 otherwise |
| Market factors hampering innovation | 1 if innovation was considerably hampered by the market dominance of established enterprises or uncertain demand for innovative goods/services; 0 otherwise |
| Cost factors hampering innovation | 1 if innovation was considerably hampered by a lack of funds within the enterprise or enterprise group, lack of outside funds or too high innovation costs; 0 otherwise |
| Knowledge factors hampering innovation | 1 if innovation was considerably hampered by a lack of qualified personnel, a lack of information on technology, a lack of information on markets, or difficulty in finding co-operation partners for innovation; 0 otherwise |
| **Internal capabilities concerning enterprises with innovation activities only (Function equation)** | |
| Size | ln (total number of employees) in the reference year 2004 |
| $Size^2$ | ln (total number of employees)$^2$ in the reference year 2004 |
| International market-orientation | 1 if a firm exported goods or services during the years 2002-2004; 0 otherwise |
| Public funding | 1 if the firm got public funding for innovation from local or regional authorities, or from central government, or from the EU; 0 otherwise |
| Intramural R&D | 1 if the enterprise is engaged in intramural (in-house) R&D; 0 otherwise |
| Sectoral affiliation *(none, low, med, high)* | Taxonomy of economic sectors (four categories) according to their innovation intensity (Peneder, 2010); sectors are classified according to cumulativeness of the knowledge base, appropriability conditions, technological opportunity and creative vs. adaptive strategies. |

Source: own illustration, CIS4, EUROSTAT

**Table 3: Selection equation results**

| | Product and Process Innovations | | Product Innovations | |
|---|---|---|---|---|
| **Firm-level characteristics** | | | | |
| Size | 0.1935 *** | *0.023* | 0.1815 *** | *0.026* |
| International market orientation | 0.2246 *** | *0.074* | 0.2390 *** | *0.087* |
| Cost factors hampering innovation | 0.1805 ** | *0.077* | 0.1802 ** | *0.083* |
| Knowledge factors hampering innovation | 0.3443 *** | *0.092* | 0.3489 *** | *0.100* |
| Market factors hampering innovation | 0.0863 | *0.082* | 0.2366 *** | *0.090* |
| **Sectoral innovation intensity** | | | | |
| Ref. case: none | | | | |
| low | 0.1601 | *0.139* | 0.3154 * | *0.174* |
| med | 0.4955 *** | *0.137* | 0.7434 *** | *0.170* |
| high | 0.7073 *** | *0.134* | 0.9759 *** | *0.164* |
| cons | -1.7051 *** | *0.176* | -2.4967 *** | *0.213* |
| N | 1881 | | 1718 | |

***, **, * denote statistical significance at the 1%, 5% and 10% test level; Numbers in italics denote the standard error; Number of observations cover innovative and non-innovative firms

Source: own calculation, CIS4, EUROSTAT

**Table 4: Function equation results**

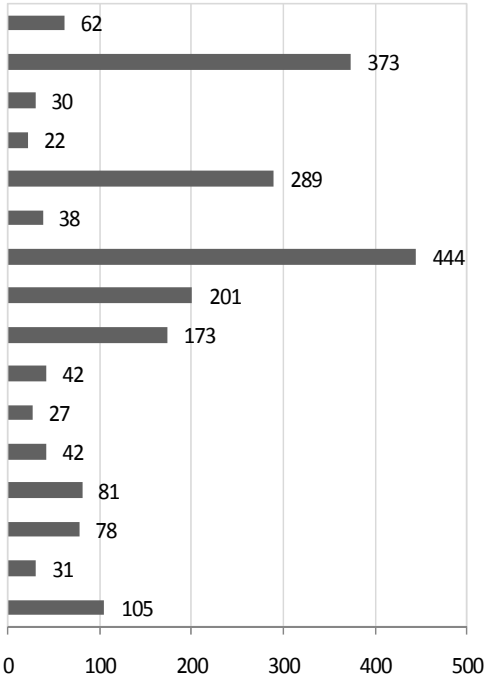
| | Innovation Input Intensity | | Innovation Output Intensity | |
|---|---|---|---|---|
| **Firm-level characteristics** | | | | |
| Innovation Input Intensity | | | 0.1206 *** | *0.029* |
| Size | -1.1606 *** | *0.270* | -0.7050 *** | *0.236* |
| Size$^2$ | 0.0846 *** | *0.024* | 0.0628 *** | *0.022* |
| International market orientation | 0.1887 | *0.182* | 0.5077 *** | *0.156* |
| Cooperation agreements | -0.1042 | *0.116* | 0.3299 *** | *0.100* |
| Public funding | 0.4819 *** | *0.150* | -0.0531 | *0.122* |
| Intramural R&D | 0.2902 *** | *0.130* | -0.3397 *** | *0.118* |
| **Country groups** | | | | |
| Ref. case: DK, NO, FI | | | | |
| ES, PT, IT | -0.3526 | *0.235* | 0.5269 *** | *0.196* |
| LU, FR | -0.3559 | *0.234* | 0.1565 | *0.192* |
| BG, HU, RO, SI | -0.1777 | *0.249* | 0.5909 *** | *0.203* |
| CZ, EE, LT, LV, SK | 0.1127 | *0.240* | 0.3865 ** | *0.197* |
| **Sectoral innovation intensity** | | | | |
| Ref. case: none | | | | |
| low | 0.6801 *** | *0.338* | -0.4520 | *0.345* |
| med | 1.1159 *** | *0.378* | -0.3058 | *0.354* |
| high | 1.5497 *** | *0.411* | -0.3484 | *0.366* |
| cons | -1.5931 | *1.244* | -0.3111 | *0.901* |
| N | 1881 | | 1718 | |
| N uncensored | 966 | | 524 | |
| Wald $\chi^2$ | 120.32 *** | | 80.98 *** | |
| LR test of indep. Eqns. | 2.87 * | | 1.29 | |

***, **, * denote statistical significance at the 1%, 5% and 10% test level; Numbers in italics denote the standard error; Number of observations cover innovative and non-innovative firms; Uncensored observations relate to firms with innovation activities; the $\chi^2$ test is a Wald test that all coefficients in the regression model (except the constant) are 0

Source: own calculation, CIS4, EUROSTAT

**Figure 1: Number of enterprises with innovation activities per country**

| Host Country | (1) % | (2) Number of Observations |
|---|---|---|
| Bulgaria (BG) | 3.04 | 62 |
| Czech Republic (CZ) | 18.30 | 373 |
| Denmark (DK) | 1.47 | 30 |
| Estonia (EE) | 1.08 | 22 |
| Spain (ES) | 14.18 | 289 |
| Finland (FI) | 1.86 | 38 |
| France (FR) | 21.79 | 444 |
| Hungary (HU) | 9.86 | 201 |
| Italy (IT) | 8.49 | 173 |
| Luxembourg (LU) | 2.06 | 42 |
| Latvia (LV) | 1.32 | 27 |
| Norway (NO) | 2.06 | 42 |
| Portugal (PT) | 3.97 | 81 |
| Romania (RO) | 3.83 | 78 |
| Slovenia (SI) | 1.52 | 31 |
| Slovakia (SK) | 5.15 | 105 |
| Total | 100 | 2038 |

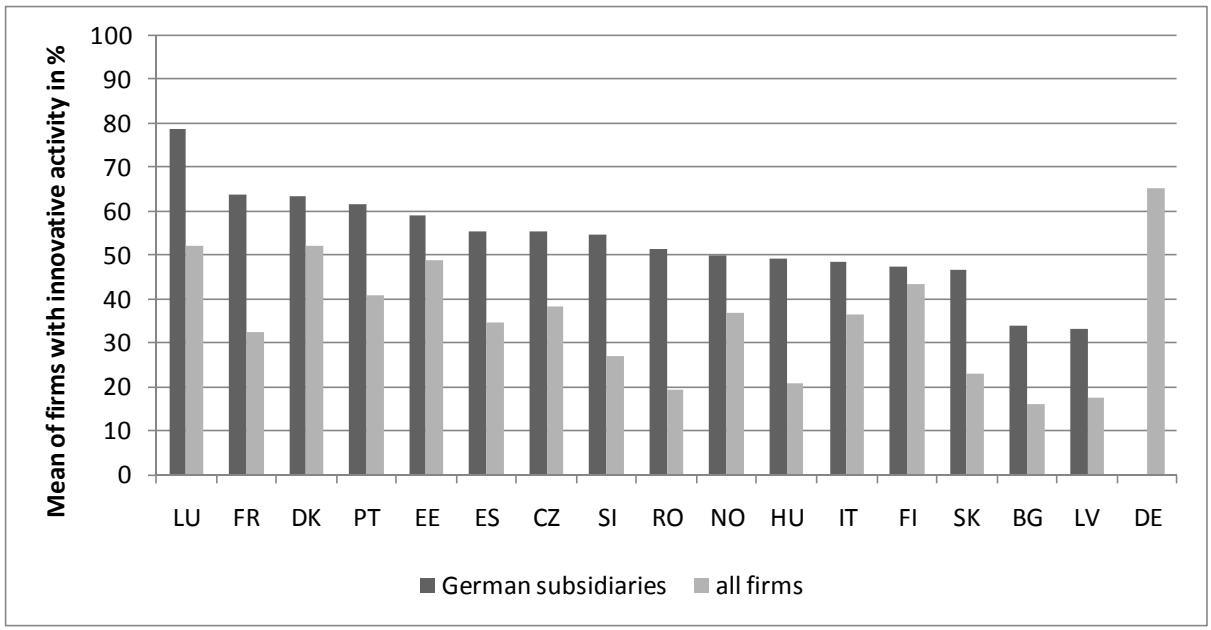



(1) Share of enterprises per country

(2) Observed enterprises in absolute numbers

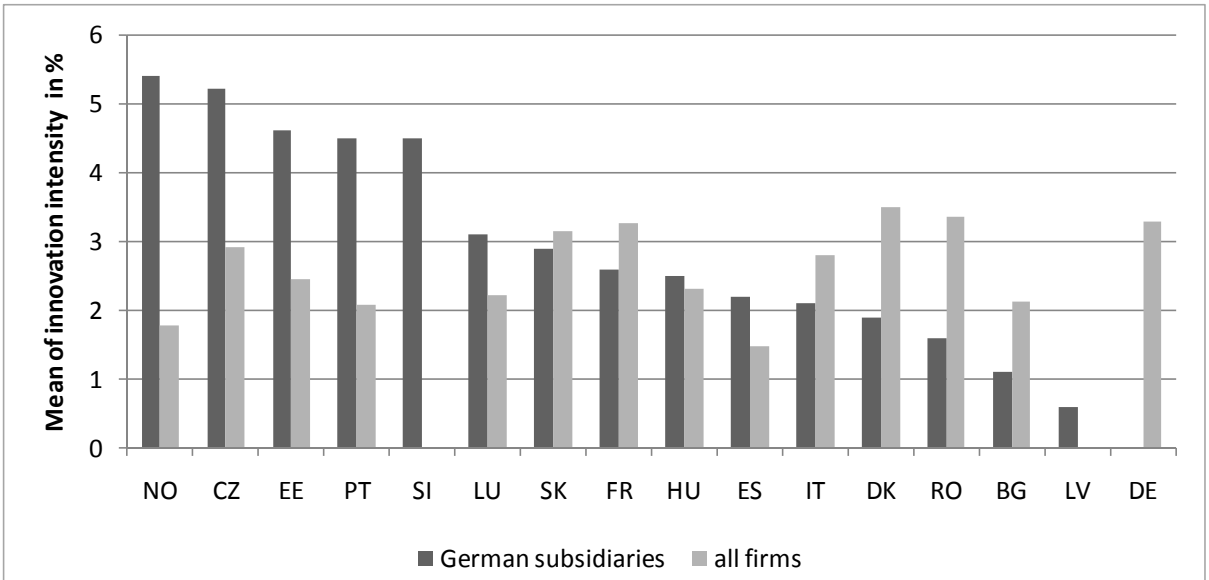
Source: own illustration, CIS4, EUROSTAT

**Figure 2: Firms with innovation activities per country**




Source: own illustration, CIS4, EUROSTAT

**Figure 3: Innovation Input Intensity of firms per country**



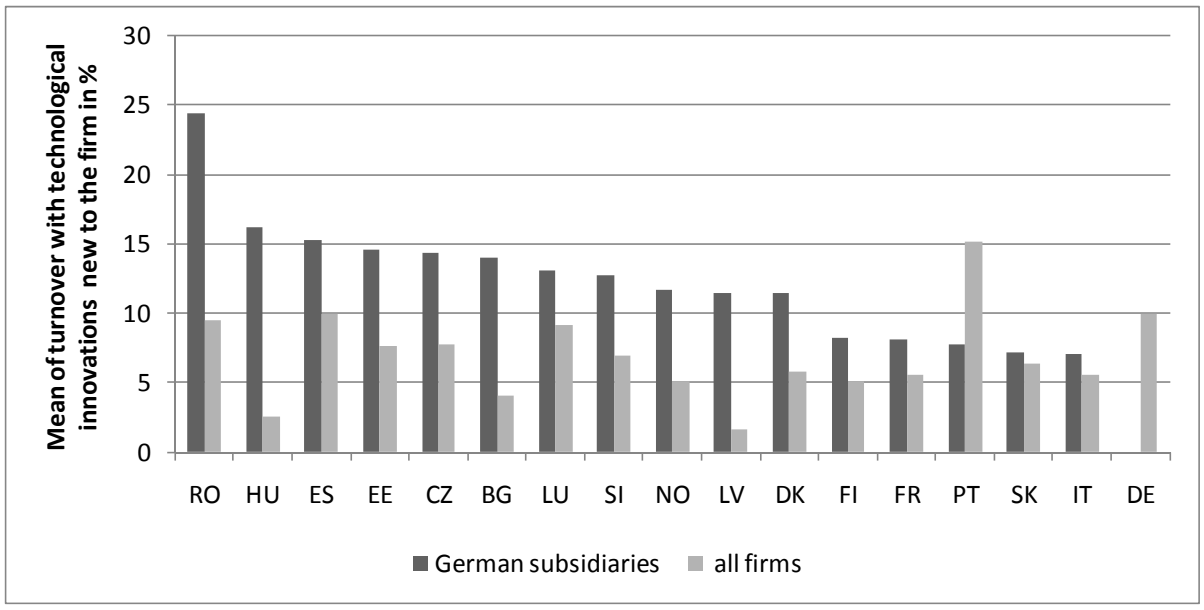

i. Innovation input intensity is measured as share of innovative expenditure on turnover

ii. Innovation input intensity of Finland (FI) cannot be calculated on grounds of the non-authorized value of innovation expenditure. Hence Finland is not included in this analysis.

iii. There are no national population means for Slovenia (SI) and Latvia (LV).

Source: own illustration, CIS4, EUROSTAT

**Figure 4: Innovation Output Intensity of firms per country**




Source: own illustration, CIS4, EUROSTAT