

# **Research and development activity of foreign affiliates in the Czech Republic**

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### **Abstract**

Using firm-level data from the third Community Innovation Survey, the paper investigates effects of foreign ownership on research and development (R&D) activity carried out by innovative firms in the Czech Republic. It is shown that foreign affiliates tend to engage less in internal R&D compared with domestic-owned firms. The finding is sustained after controlling for a number of other firm, industry and region-specific factors and across different specifications of the model. Only external acquisition of R&D from labs and universities in the host country appears to be complementary to internal R&D activity in foreign affiliates, while sourcing of R&D from abroad is not.

Keywords: R&D; Multinational corporation; Foreign affiliate; Czech Republic.

JEL classification: D21; L16; F23; O23



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## 1. Introduction

Multinational corporations (MNCs) are important actors in knowledge diffusion across national borders through imports of knowledge embodied in capital goods, licensing of foreign technology and application of their organizational and marketing know-how worldwide. Besides facilitating diffusion of knowledge, MNCs are also increasingly important players in the generation of new knowledge abroad. A sizeable part of private research and development (R&D) activity is in fact concentrated in large MNCs, which are dominant players in their home-based innovation systems as well as enhancing technological capabilities through direct investment in R&D in host countries (Narula, 2003; Narula and Zanfei, 2004). It is the latter aspect of international business activity that is the main focus of this paper.

Much has been written on the possibility that the diffusion of knowledge through foreign direct investment offers an avenue for various spillover effects between foreign affiliates and the host economy (Blomström and Kokko, 1998). Despite strong theoretical reasons to expect spillovers, however, the evidence is mixed at best. The empirical literature, typically using indirect measures of technology in the production function framework, finds strong support for direct technology transfer from the parent to the foreign affiliate, but evidence for technology spilling over to the host country is rare, and in fact crowding out of non-affiliated firms is often detected (Görg and Greenaway, 2002). In order to provide fresh insights along these lines, we need more direct evidence for innovation activities of foreign affiliates and to improve our understanding of particular channels through which spillovers occur.

Availability of evidence from R&D surveys and Community Innovation Surveys have triggered extensive research on firms' innovative activities since the beginning of the 1990s. Still, the literature using large firm-level datasets on innovative activities of foreign affiliates from the Community Innovation Surveys in econometric frameworks remains relatively small and limited to the analyses of Balcet and Evangelista (2004), Cassiman and Veugelers (2002), Knell and Srholec (2004) and Veugelers and Cassiman (2004). Apart from the latter study, moreover, the literature has been primarily concerned with evidence from developed countries, which is a consequence of limited availability of direct firm-level evidence for innovation activities in latecomer countries, let alone data specifically on foreign affiliates.

A complementary line of research emphasizes the industry and regional specificity of innovation activity (Asheim and Gertler, 2004; Audretsch and Feldman, 1994; Feldman, 2000; Malerba, 2002; Malerba and Orsenigo, 1993; Pavitt, 1984). A firm is not seen as an island separated from other firms and its social surroundings by "deep waters" of anonymous and homogenous market forces (Lundvall 1988; Richardson, 1972). The ability of firms to pool resources with other organizations in order to exploit synergies from networking proves to be among the core aspects of corporate competitive advantage. The increasingly global reach of business activities does not undermine but on the contrary emphasizes the importance of a firm's ability to capitalize on locally

concentrated and embedded tacit knowledge (Maskell and Malmberg, 1999). Global business with regional home base(s) seems to be the phenomenon under question here. It is one of the core insights of the Schumpeterian literature, furthermore, that innovation differs across industries (Castellacci, 2004). A firm's innovative behaviour is seen in the context of strategies pursued by their competitors and partners, which are given by industry-specific technological opportunities and trajectories.

Besides the role of firm-specific characteristics, these perspectives underline a joint role of industry and region-specific factors for explaining a firm's behaviour; in particular, the localization of R&D activities. Does it truly matter for the extent of R&D activities whether firms are foreign owned or is it rather the nature of industry and environment in the particular location that determines firms' innovation strategy? Is there a reason for policy makers to be concerned about the impact of foreign investment on local technological capabilities? Should the government rather target specific sectors irrespective of the source of investment or direct the limited resources for innovation policy into nurturing the local milieu?

This paper examines these questions using evidence from the Czech Republic. The analysis is based on a large sample of business firms from the third Community Innovation Survey, which provides rich evidence for innovation activities separately for foreign and domestic-owned firms as well as allowing us to take into account the role of industry and region-specific factors. Similarly to the other new EU members, the Czech Republic has experienced fundamental systemic transformation since the early nineties, which has been accompanied by a rapid shift from high autarky towards extreme openness to inflow of foreign goods, capital and ideas. Nowadays it is integrated into the Single European Market and maintains one of the highest penetrations of foreign ownership in the economy within the enlarged EU area.

The paper is organized as follows. In Section 2, we briefly discuss reasons for firms to engage in R&D activity abroad and survey the existing evidence. Section 3 gives a short descriptive overview of the firm-level data. Section 4 applies a simple model of R&D activity on the firm-level data in an econometric framework. The key concern is the role of foreign ownership, while controlling for the influence of other relevant firm, industry and region-specific factors and a possible sample selection bias. Section 5 broadens the picture by including selected characteristics of firms' innovation strategies beyond the internal R&D activity into the analysis. Section 6 concludes and puts the findings into a general perspective.

## **2. Theory and evidence for R&D activity of foreign affiliates**

The literature on foreign direct investment traditionally expected R&D to be concentrated near the headquarters of the firm. The idea that firms invest abroad to take advantage of technology developed in their home base is the core thesis of the "eclectic paradigm" (Dunning, 1988) and it is also the assumption underlying international diffusion of technology in earlier versions of the product cycle theory (Vernon, 1966).

The purpose of R&D in affiliates is expected to be limited to facilitating implementation of technology generated in the home base. The transfer of technology is viewed as one directional, to the host country, in order to improve the utilization of technology developed elsewhere.

Nevertheless, dispersion winds for location of R&D are in place as well. The traditional perspective has been challenged by evolutionary approaches suggesting that the technological bases of MNCs are not limited to any single country, but rather emerge from a variety of sources on a global scale (Kogut and Zander, 1993). The tacit and “sticky” nature of knowledge implies that it is less costly (or otherwise impossible) to transfer some aspects of knowledge within a firm’s ownership boundaries rather than through market transactions. As geographical and cultural proximity might be necessary for sharing knowledge, foreign firms attempt to narrow the divide by “organizational” proximity through direct ownership. Furthermore, firms need to nurture a diversified knowledge base in order to prevent themselves from being locked into a narrow (location-specific) technology path (Cohen and Levinthal, 1990). The greater the variety of knowledge at a firm’s disposal, the greater the opportunity for innovation to arise. Firms therefore invest in R&D abroad to tap into specific technology competencies embedded in foreign locations (Cantwell, 1995).

The former reasons for venturing into R&D abroad have been dubbed an asset (or home base) exploiting R&D, while the latter has been labelled an asset (or home base) augmenting R&D (Dunning and Narula, 1995; Kuemmerle, 1997, 1999; Narula and Zanfei, 2004). As a consequence, a typology of three innovation strategies of foreign affiliates may be defined as follows (see also Balcer and Evangelista, 2004; Le Bas and Sierra, 2002).

1) *Imitative strategy*. The affiliate develops no internal R&D capabilities. Innovation activity is fully based on application of existing foreign technology, which requires no additional expenditure on R&D in the host country in order to be used effectively. Most innovation expenditure is spent on arms-length purchase of technology in the form of rights to use externally developed inventions, licences, trademarks or software, on the acquisition of technology embodied in capital goods and on training of local labour to employ the “ready-to-use” foreign technology. The affiliate aims at exploiting non-technological comparative advantages of the host country such as cheap labour, low transport costs to the final market or flexible regulations. If any R&D is necessary, it is carried out by the parent, and only the solution is communicated to the affiliate.

2) *Adaptive R&D strategy*. The affiliate maintains modest R&D capabilities in order to adjust foreign technology to preferences of local customers or host country regulations. The main objective of R&D is to facilitate smooth exploitation of technological advantages created abroad. The direction of technology transfer is only from the parent to the affiliate with very limited or no contribution of local R&D to further development of the core technology. The local R&D activity is a mere extension of efforts undertaken outside of the host country, which implies purchase of technology from abroad and a limited patenting record of the affiliate (or only local patents). The

regional market-seeking focus is the key distinctive feature of the adaptive strategy, so that a large proportion of innovation expenditure is devoted to market introduction of innovations.

3) *Augmenting R&D strategy*. The affiliate is deeply engaged in internal R&D activity and has an extensive patenting record. The local R&D activity contributes to the core technology of the foreign owners, so that the affiliate still complements its research by acquisition of R&D from the parent. However, the direction of technology flows is essentially both ways: from parent to the affiliate and vice versa. The main objective is to develop new technologies at the global frontier.

Any regional clustering with technology content is not expected in the case of foreign affiliates pursuing the imitative strategy, but a pool of “blue collar” labour and infrastructure in industrial parks might attract imitative focus into certain regions. Absorptive capacity of the local environment, such as availability of skilled engineers, is important if adaptation of the foreign technology is necessary. A proximity to the market may also play a role for localization of foreign affiliates with adaptive R&D expenditure.

On the other hand, the augmenting motive for investing into R&D abroad requires the foreign innovation system to offer certain location-specific technology content, which foreign firms seek to internalize. A pool of highly educated labour, specialized suppliers and state-of-the-art scientific infrastructure strongly supports the localization of affiliates following this strategy, which suggests that agglomeration effects in close proximity to science parks and technical universities are important for their regional clustering. One has to bear in mind, moreover, that establishment of an R&D unit in a foreign location requires considerable time and effort, but once deeply embedded in the host country research system, it is less costly to maintain. Thus, investment into R&D tends to be “sticky” in locations where sophisticated innovation systems are already in place, and considerable path dependency – and inertia - in localization of R&D activities should be expected (Gertler, Wolfe and Garkut, 2000; Narula, 2002; Narula and Zanfei, 2004). Even if firms develop networks of R&D units in multiple locations, the importance of location-specific factors suggests that most of it tends to be highly concentrated in space (Cantwell and Iammarino, 1998; Verspagen and Schoenmakers, 2004).

Apart from agglomeration effects, the clustering tendency of foreign investment into R&D is further reinforced by the deepening fragmentation of value chains across the globe (Arndt and Kierzkowski, 2001). As a consequence of gradual liberalization of investment and trade on one hand and rapid progress in ICT and transport technologies on the other, individual phases of value chains can be increasingly separated from each other (in space or ownership or both), which allows firms to focus on exploiting the core elements of their competitive advantage and outsourcing the rest. The flip side is that certain fragments of value chains with high skills and technology demands, such as R&D activity, increasingly gravitate towards different areas compared with fragments intensive on other endowments, such as manufacturing activity.

The empirical research on R&D in foreign affiliates broadly confirms these expectations. A typical conclusion of the early literature in this vein has been that the adaptive focus of R&D is predominant among foreign affiliates, while more recent evidence suggests that the core technology augmenting R&D shows an increasing trend (Almeida, 1996; Archibugi and Michie, 1995; Cantwell, 1995; Cantwell and Noonan, 2002; Dunning and Narula, 1995; Florida, 1997; Odagiri and Yasuda, 1996; Patel and Vega, 1999; Pearce and Papanastassiou, 1999; Kuemmerle, 1999; Zander, 1997). Heightened global competition encourages firms to engage more in adaptive R&D to customize products to local needs, but the increasing specialization and complexity of technological development also increases the pressure to search for knowledge outside of the home base to keep pace with foreign competition.

Still, there is abundant evidence that internationalization of R&D does not keep pace with internalization of manufacturing (see, for example, the survey of large MNCs by UNCTAD, 2001). Le Bas and Sierra (2002) confirm that different innovation strategies can be detected in patent data, but the augmenting motive is frequent mainly in the technologically most advanced regions. There seems to be a trend for manufacturing activities to spread to countries behind the technology frontier, while the technologically most advanced segments of value chains remain concentrated and possibly cluster even more into certain areas. The ultimate outcome is that even though foreign direct investment into R&D increases, most of it remains concentrated in the home countries of the largest MNCs - within the triadic or a broader OECD area. In a broader regional context, the path-dependent nature of R&D localization seems to prevail, which is reflected in the increasing technological lead of the frontier countries and poses substantial challenges for technological upgrading in the latecomers (Fagerberg et al. 2005).

A latecomer country needs to reach a certain minimum threshold of location-specific factors, which has to be similar to conditions in the frontrunner countries, in order to attract foreign affiliates pursuing the core technology-augmenting R&D strategies (Narula and Zanfei, 2004). Indeed, this is extremely difficult to achieve with limited resources and the other location-specific disadvantages that most of the latecomer countries face. The path-dependent nature of internalization of R&D activities is clearly fortunate for regions on the frontier, while the deepening fragmentation further undermines the advantages of those coming from behind to attract the R&D-intensive fragments of value chains.

A key matter of concern for countries that currently find themselves somewhat in the middle ground between the technology frontier and most of the developing world, such as the Czech Republic, is whether the adjustment path is likely to be towards increasing engagement of foreign affiliates in R&D in the country or whether technology will tend to be increasingly sourced from abroad. What is the effect of having foreign owners on internal R&D activity in the Czech firms? Does foreign ownership contribute to upgrading, or to hollowing out of the local technology capabilities?

### 3. Descriptive overview of the sample

The empirical analysis is based on firm-level data provided by the Czech Statistical Office. The data have been obtained from a compulsory survey, which asked firms about their innovative activities over the years 1999 to 2001. The survey was conducted as a part of the third Community Innovation Survey organized by Eurostat and was fully harmonized with the methodology of the Oslo Manual (OECD 1997).

The questionnaire was distributed to a representative sample of 5,829 Czech enterprises with more than 10 employees. The response rate was 65%. About 38% of the respondents were successful innovators over the period (introduced a new product or process).<sup>1</sup> Only the innovators were asked for further details of their innovation activities, such as R&D activity. The Czech business register provides information on foreign ownership only for incorporated and non-financial firms (about 85% of the respondents and 93% of the innovators). Hence, we restricted the analysis to a sample of 1 295 innovating firms in industry and market services.

The data give firm-specific information on size, ownership, industry, location and direct evidence on innovation activities. Besides the traditional focus on internal R&D, the innovation survey also provides rich evidence on other aspects of innovation activity such as acquisition of technology from external sources (including other affiliated firms), expenditure on acquisition of machinery and equipment to implement innovations, expenditure on the market introduction of innovations or the patenting records of the firms (see Appendix 1 for a complete list and formal definitions of the indicators).

Table 1 provides a descriptive overview of the firm-level data. About a third of the firms are foreign owned, which is broadly in accord with other official statistics. The foreign affiliates engage less in internal R&D, even though they enjoy scale advantages because of their larger size compared with domestic-owned firms. The propensity to conduct R&D internally on a permanent basis is about 6 percentage points lower in foreign affiliates. Internal R&D expenditure per employee is on average approximately 25% lower, and the proportion of R&D employees in the total firm workforce is lower by more than 40% in the foreign affiliates.

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<sup>1</sup> After adjustment of the firm-level data, the official share of innovative firms published by the Czech Statistical Office drops to 29% (CZSO, 2003). Although some limited evidence on R&D activities of foreign affiliates based on annual R&D surveys is available from the OECD AFA Database or national sources, to the best of the author's knowledge, no data from the third Community Innovation Survey have been officially published separately for foreign and domestic owned firms, by either Eurostat or the Czech Statistical Office.

**Table 1: Overview of the firm-level sample from the third Community Innovation Survey**

	All firms	Domestic-owned firms	Foreign affiliates
Number of firms	1295	914	381
Number of employees:			
Average number of employees	477	473	488
Median number of employees	150	150	225
% of total employment	100	69.9	30.1
Internal R&D on a permanent basis and employment:			
% of firms with permanent R&D activity	42.0	43.7	38.0
% of R&D employees in total workforce	6.8	7.4	5.2
Average innovation expenditure per employee ( <i>% of firms engaged in the activity</i> ):			
Average R&D expenditure	25.5 (66.2)	26.8 (68.1)	22.1 (61.3)
Acquisition of external R&D	5.8 (25.7)	3.8 (23.4)	11.0 (31.7)
Acquisition of other external knowledge	4.4 (29.1)	3.7 (28.9)	6.2 (29.6)
Acquisition of machinery and equipment	27.9 (60.2)	22.4 (60.0)	41.8 (60.6)
Training	3.3 (49.9)	3.4 (47.5)	3.0 (56.0)
Market introduction of innovations	14.5 (54.8)	14.4 (55.9)	15.0 (52.1)
Design and other	3.3 (29.3)	3.6 (28.9)	2.3 (30.3)
Patenting activity:			
% of firms reporting patent application	11.0	11.1	10.8
Average of applications per 1,000 employees	3.5	2.6	5.5

Note: The data for R&D employment and innovation expenditure refer to 2001, while the other data correspond to the period 1999–2001. Because of missing values, the number of observations differs for the particular indicators (1,223 for permanent R&D department, 1,222 for R&D employment, 1,014 for innovation expenditure and full coverage on the information on patents).

Source: Own computations based on firm-level data from the Czech Statistical Office.

Internal R&D activity is an important source of new knowledge, but knowledge obtained from other sources and/or from outside of a firm's borders is also an essential input into the innovation process. In order to capture the broader context of innovation activities, firms were also asked to estimate other related expenditures on innovation beyond the internal R&D. These innovation expenditures are grouped into the following categories: (i) acquisition of external R&D (including other affiliated firms), (ii) purchase of other external knowledge (rights to inventions, licences, trademarks, software etc.), (iii) machinery and equipment purchased specifically to implement innovations, (iv) training for employees directly aimed at development and/or implementation of innovations, (v) marketing activities directly aimed at market introduction of innovations and (vi) design and other preparations for production and deliveries.

The survey confirms that distribution of resources devoted to innovation differs between foreign and domestic-owned firms. Although foreign affiliates spend more on average

on innovation expenditure relative to their size, the bulk of the innovation budget is typically devoted to obtaining knowledge from external sources. The difference is most striking in the acquisition of external R&D, for which foreign affiliates spend three times as much per employee compared with their domestic-owned counterparts; much of the difference probably reflects purchases from other affiliated firms abroad. The difference is also apparent in budgets for spending on acquisition of other external knowledge and investment in machinery and equipment, although the frequency of spending on these items is fairly similar. Not much difference is observed in expenditure on market introduction of innovations, design and training, with the exception of a higher share of foreign affiliates spending on the latter.

The firms were also asked whether they applied for patents to protect inventions or innovations developed by the enterprise and were asked to indicate the number of patent applications. The evidence reveals that approximately one in ten firms filed a patent application with any apparent difference along the ownership lines, whereas patenting intensity in terms of the number of applications per employee was almost two times higher in foreign affiliates. It seems that the foreign affiliate firms more than counterbalance their lower internal R&D activity by access to the knowledge base of the group, and they emerge with a superior patenting record.

One has to interpret the patenting record with caution, however, as it is not clear whether the patent applications are filed internationally to protect entirely new inventions (such as EPO or USPTO patents) or whether the purpose is rather to protect the core technology of the firm's group locally by applications to the Czech Patent Office. It is also well known that appropriability conditions through patents differ considerably across industries. Thus, the difference might easily mirror the distribution of foreign affiliates skewed towards industries with a higher propensity to patent new inventions. It is one of the main concerns of the following analysis to explore the extent to which foreign ownership, compared with industry and regional factors, matters for innovation activity in the Czech context.

#### **4. A simple model of R&D activities**

Although the descriptive analysis indicates the main patterns, it can only give tentative answers on the specific role of foreign ownership. The fact that foreign affiliates pursue a particular strategy can be a consequence of other factors, such as firm size, industry or location, which might have little to do with the fact that the firm has foreign owners. It can also be a subject of sample selection bias since only innovating firms answered the questions on R&D. Is it primarily the dominant innovation strategy pursued by foreign affiliates irrespective of differences in size, industry distribution and regional clustering, that should be attributed to their lower internal R&D intensity compared with domestic-owned firms? In order to address the issue, we develop a simple model of R&D activity that considers the factors outlined above.

In this view, internal R&D activity may emerge as a distinctly firm-specific attribute, but it may also be embedded in the local environment or it may be driven by technological opportunities provided by the industry-specific context. The regional innovation system can be a gravity centre for R&D activities because of agglomeration effects, where sizeable knowledge externalities arise, and the industry can experience a scientific breakthrough, which opens up windows for a new technology trajectory with high payoffs for those pushing the frontier. Given this logic, the presence of internal R&D in a firm is likely to reflect sets of characteristics that are:

- 1) *firm-specific*,
- 2) *industry-specific*, and
- 3) *location-specific*.

In the following econometric analysis, dependent variables will be the indicators of internal R&D activity from the innovation survey: the dummy variable for permanent R&D activity, expenditure on internal R&D and the number of employees involved in internal R&D. A closer inspection of the data suggests the presence of some outliers in the sample, which would bias the results. Therefore, we use the variables on expenditure and employment in logs to limit a possible influence of measurement errors and short-term surges in a firm's R&D activity.<sup>2</sup>

The dummy explanatory variable for foreign ownership will be the main focus of our interest in the analysis. A negative coefficient of the variable would suggest that the foreign-owned firms tend to use technology developed externally, while a positive sign would suggest that foreign ownership is associated with superior internal R&D capabilities. Large firms can enjoy economies of scale of various kinds, so we control for scale effects by including number of employees. We expect larger firms to have more resources available to engage in R&D and a higher likelihood of reporting permanent R&D activity. The size variable also appears in logs to limit influence of outliers.

We can account for industry and location-specific factors by computing some aggregated averages from the firm-level dataset and claim that these represent properties bound to industries and regions. These average figures, however, would partly reflect attributes of the industries as such, but partly also properties of the industries specifically in the Czech Republic (because of the other firm and location-specific factors). Of course, the latter should be avoided as we ideally want to use explanatory factors that are exogenous to the dependent variable and unrelated

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<sup>2</sup> As some of the firms did not engage in internal R&D activity - reported as "0" - we added "1" to all observations before computing the natural logarithm. It should be further noted that the proportions between the average figures for foreign and domestic owned firms reported in the previous section do not appear to be generally influenced by the presence of outliers in the sample (and the same applies to the other types of innovation expenditure).

(uncorrelated) to each other. Instead of using information derived from the Czech sample itself, therefore, we use patterns that are characteristic for the specific industries in a general context - as defined by the OECD taxonomy of industries by technology intensity (Hatzichronoglou, 1997) and industry averages for the whole OECD area. Similarly, we do not use regional aggregates from the sample, but include general attributes of regions from the Czech regional datasets. Although some of the regional data still can be related to the location of particular (large) firms, factors associated with geography are among the most exogenous variables to single firms that an economist can hope for (see Appendix 1 for details on the indicators).

As already noted, the results can be influenced by a sample selection bias since only the innovative firms give details of R&D activity in the innovation surveys, and also because the foreign affiliates turn out to be more likely to innovate. In order to correct for the possible bias, we use a two-step Heckman's procedure to estimate the model, particularly a probit-specific procedure for the binary dependent variable of permanent R&D activity (Heckman, 1976, 1979). The correction for sample selection of innovative firms can be identified only by variables that are available for the total sample of firms that answered the innovation survey. Besides the dummy for foreign ownership, therefore, the data allow us to test whether certain obstacles prevent firms from innovation. We take into account only obstacles to innovation given by factors mostly external to a firm, such as general economic factors, regulations or lack of customer interest, to curtail a potential endogeneity problem. It comes out that the various obstacles are highly intercorrelated, so we use their factor score in the estimation. A battery of industry dummies at two-digit level of NACE (rev. 3) is further included to correct for any industry-specific innovation opportunities. The Heckman's correction for innovation activity is well identified by these factors (see Appendix 2 for results and details of the identification).

Table 2 presents the results if each of the dependent variables is regressed against the firm-specific factors, industry dummies for the OECD taxonomy and regional dummies for Prague and other districts with technical universities. In the first column, the Heckman's probit model gives us estimates of the probability that a firm engages in activity of interest conditional on the independent variables. The results indicate that - all else being equal - having foreign owners reduces the probability of engaging permanently in internal R&D by 32%. The variable for foreign ownership also turns out to be highly significant and negative in all of the remaining estimates, which shows that the average difference from domestic-owned firms observed in the previous section cannot be clearly attributed to industry or region composition effects. The size variable comes out with significant and positive coefficient in all estimates as well, which confirms that scale effects matter for internal R&D activity. The concern about the selection bias is also well justified, as the Heckman's procedure yields a significant correction coefficient.

**Table 2: Regression results with industry and region-specific factors**

	Research and experimental development (R&D)					
	Perm- anent	Emp- loyees	Expen- diture	Perm- anent	Emp- loyees	Expen- diture
Constant	0.02 (0.16)	0.90*** (4.34)	4.52*** (7.47)	-0.14 (0.88)	0.56*** (2.72)	4.01*** (6.50)
<u>Firm-specific factors:</u>						
Foreign ownership	-0.27*** (4.09)	-0.54*** (5.84)	-0.94*** (3.38)	-0.29*** (4.05)	-0.52*** (5.84)	-0.84*** (3.07)
Log of size	0.13*** (5.76)	0.36*** (13.68)	0.70*** (8.57)	0.15*** (5.93)	0.40*** (15.07)	0.75*** (9.02)
<u>Industry-specific factors (standardized scores based on OECD averages):</u>						
Foreign ownership	0.03 (0.95)	0.05 (1.09)	0.24* (1.70)	-0.05 (1.11)	-0.10* (1.82)	-0.09 (0.54)
Technology opportunity	..	..	..	0.15*** (3.26)	0.28*** (5.56)	0.54*** (3.43)
Technology trajectory	..	..	..	0.07** (2.17)	0.17*** (4.21)	0.11 (0.85)
<u>Region-specific factors (standardized scores based on Czech regional datasets):</u>						
Foreign ownership	0.05 (1.62)	0.14*** (3.62)	0.32*** (2.70)	-0.0001 (0.00)	-0.04 (0.54)	-0.01 (0.06)
Stock of human capital	..	..	..	0.04 (0.72)	0.15** (2.30)	0.34* (1.61)
Heckman's correction for innovators	-1.22*** (8.69)	-0.64*** (16.60)	-3.15*** (7.60)	-1.08*** (7.60)	-1.18*** (7.78)	-2.94*** (7.11)
Wald $\chi^2$	42.36	216.32	89.63	49.77	283.29	107.40
Number of observations	1223	1222	1014	1223	1222	1014

Note: Absolute value of robust and Heckman's two-step z-statistics in brackets; \*, \*\*, \*\*\* denote significance at the 10, 5 and 1 percent levels. The number of observations differs because of missing data for some variables.

Although it is customary in the literature to check for the industry and location-specific factors by using dummies, the phenomena in question are far from being of "black & white" nature in most cases. Dummies are "catch-all" variables for which it is often not entirely clear what they really capture.<sup>3</sup> Having detailed data for regional location and industry classification of each firm in the sample, however, it is only a matter of convenience to employ dummies instead of "real-world" observed characteristics of the specific regions and industries. Hence, we use location, industry and firm-specific classification codes to merge the firm-level data with rich evidence readily available in regional and industrial statistics. Instead of using dummies for regions, for example, we work with university attainment of population by regions. Furthermore, this allows us to include additional variables that directly reflect penetration of foreign ownership at the level of industry and region.

Table 2 shows the results if each of the dependent variables is regressed against the dummy for foreign ownership, the log of firm size and selected industry and region-

<sup>3</sup> In addition, dummies may unnecessarily consume degrees of freedom if they are not significant explanatory factors and may bias the results if too many of them are included in the estimate.

specific factors.<sup>4</sup> In the first set of results, the dummies for industries and regions are replaced by the new variables of foreign penetration represented by the share of foreign affiliates in employment by industry in the OECD area and by share of foreign affiliates in employment in the Czech districts. It is confirmed that the firms with foreign owners have a significantly lower propensity to venture into internal R&D activity compared with domestic-owned firms. In contrast, the variable for the foreign penetration in region twice comes out with significantly positive coefficients, and the variable for the foreign penetration in industry also once shows a marginally significant coefficient. The regional variable turns out to be a particularly relevant explanatory factor for a firm's R&D employment and expenditure, which suggests some externalities for R&D activity because of local clustering of foreign affiliates. It might be that foreign affiliates at least partly outsource R&D to other local firms and/or their competition, demonstration and other effects - well described in the literature on technology spillovers - encourage other local firms to increase internal R&D activity.

In order to test whether it is truly the effect of foreign penetration or rather other industry and region-specific characteristics, we further include variables representing technology opportunity and trajectory of industry and local endowment of human capital. The technology opportunity of industry refers to the level of business expenditure on R&D in terms of value added; the technology trajectory of industry measures the trend in the amount of business expenditure on R&D since the mid-1990s (both in the OECD area); and the local stock of human capital reflects the share of people with university education in total adult population in the district where the firm is located.

The results suggest that the technology content of industries and the local pool of highly educated labour matter for an internal firm's R&D activity much more than the industry- and region-specific penetration of foreign ownership. Once the effect of these factors is controlled for, the variables for internationalization are not significant, with the only exception being foreign ownership by industry in the regression on R&D employment. Attempts to include other internationalization variables for industries and regions, such as the share of foreign affiliates in value added and inflow of foreign direct investment in terms of GDP, also met with little success.

The variables obviously interact with each other, which raises concerns about a possible multicollinearity problem in the estimate. The main bias is because of high correlation between the regional variables on penetration of foreign ownership and the stock of human capital ( $R^2 = 0.70$ ). If the former is dropped from the estimate, the local educational level becomes significant at 1% in the last two regressions. There is also some correlation between the foreign penetration and technology opportunities in industry ( $R^2 = 0.49$ ), but it does not seem greatly to affect the coefficient of the latter. Other correlations are negligible ( $R^2 < 0.10$ ). In any case, we drop the insignificant

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<sup>4</sup> The selected industry and region-specific factors were standardized to a common scale (deducting mean and dividing by standard deviation) before the estimation in order to allow for a direct comparison of the magnitude of coefficients. The standardization affects only the magnitude (not the significance) of the relevant parameters - all other results of the estimate remain intact.

variables on foreign penetration in industry and region from the final regression in the following estimates.

The need to avoid exacerbating multicollinearity problems also prevents us from including more regional variables reflecting technology and skills, such as R&D intensity, wage level and various aspects of infrastructure by regions, which tend to be highly correlated with each other and also with the variable of local human capital (mostly as a consequence of the distinct nature of the Prague agglomeration). Although the stock of human capital turned out to be by far the most relevant explanatory variable among relevant regional factors, the variable probably also at least partly represents a joint effect of the other above-mentioned correlated factors.

## **5. The extension to other aspects of innovation strategies**

The theoretical typology of innovation strategies has suggested that internal R&D of foreign affiliates should be accompanied by certain other features of innovation activity. The descriptive overview also revealed some important differences between foreign and domestic-owned firms, particularly in expenditure on acquisition of external R&D, other external knowledge and in patenting records. Hence, it is natural to examine whether there is any relation of the other observed aspects of innovation strategies with internal R&D by including them directly into the estimate.

For this purpose, we utilize the firm-specific information on the various other innovation expenditures and the number of patent applications from the innovation survey. As in the case of the dependent variables, we apply the logarithmic transformation in the same way because of concerns related to the influence of outliers. The explanatory power of the model did not appear very high for the dummy variable for permanent R&D activity, so that the focus is narrowed on the dependent variables for R&D employment and expenditure hereafter. The latter variables should be also given priority because they provide some information on scale of R&D activity, in contrast to the binary nature of the dummy variable. As already noted above, we shall control for the industry and region-specific factors by including only the variables on technology and skills.

Again we use the Heckman's selection correction procedure to estimate the model. In order to identify differences between foreign and domestic-owned firms, we also split the sample and estimate the model separately for both groups of firms. An additional possible sample selection bias obviously emerges along the divide by ownership. To address the problem, we first generate the relevant inverse Mills' ratio from the correction for innovative firms and include it as a regressor into estimation of the model with a further Heckman's correction for sample selection on the firm's ownership. Essentially we estimate a double selection (or bivariate selectivity) model, which

accounts for both possible selection biases (Heckman and Willis, 1977; Poirier, 1980; Meng and Schmidt, 1985).<sup>5</sup>

The identification of the additional correction for sample selection on ownership is given by the previously used variables of the firm's size in logs, the factor score on obstacles to innovation, penetration of foreign ownership in industry and region and a set of new variables. These include a firm-specific variable of age of the firm measured by the number of days since its registration in the business register and three regional factors that proved to be particularly relevant for location of foreign affiliates: the share of employment in large firms (more than 500 employees) in total employment, the share of employment in industry in total employment and sick-leave rate given by days of incapacity for work on the number of sickness-insured persons (see Appendix 2 for results and details on the identification).<sup>6</sup>

Table 3 gives the results.<sup>7</sup> We first focus on the estimate for the full sample. It is confirmed that foreign ownership at the firm level exerts a significantly negative effect, while the firm's size along with the industry and region-specific factors are positively related to the internal R&D activity. In line with expectations, the number of patent applications is significantly and positively associated with R&D activity. The same applies for acquisition of R&D externally, which suggests that its external sourcing in general actually complements firm's internal R&D efforts. This finding confirms expectations based on the evolutionary and/or resource-based theories of the firm, emphasizing the need to pool knowledge with other organizations to innovate, and previous findings of the empirical literature on the "make or buy" dichotomy (Veugelers 1997; Veugelers and Cassiman, 1999).

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<sup>5</sup> The double selection approach is often used in the applied literature on labour economics. In this paper we analyse within a sequential framework whether firms are innovative or not and subsequently foreign or domestic owned, which is analogous to workers' decisions to participate in labour and employers' decisions to hire them (Mohanty, 2001) and their observed earnings (Amemiya, 1985), married women's decisions to participate in the labour force (Heckman and Willis, 1977) or women's' decisions to work and their subsequent choice of occupation (Sorensen, 1989) and whether to attend a college (Fische et al. 1981).

<sup>6</sup> It should be noted that we have also tested the role of a firm's age (both in logs and without logs) directly for internal R&D activity in the previous estimates. The age variable was expected to capture the maturity (life-cycle) of the firm because established firms are more likely to be engaged in R&D activity. In the specific case of foreign affiliates, the age variable might also detect a possible difference between recently established greenfield projects and (privatization) mergers and acquisitions. Nevertheless, the age variable did not come out as a significant explanatory factor for R&D activity nor did it influence the results of the other variables, so these results are not reported in the paper.

<sup>7</sup> It should be mentioned that little concern about multicollinearity arises in the estimates (see Appendix 3 for a correlation table). As the industry and region-specific factors, the variables on the other aspects of innovation strategies also have been standardized (deducting mean and dividing by standard deviation) before each of the estimations in order to allow for a direct comparison of their coefficient's magnitude. The standardization affects only the magnitude (not the significance) of the relevant parameters—all other results of the estimate remain intact.

**Table 3: Regression results with other aspects of firm's innovation strategies**

	R&D employees			R&D expenditure		
	Total sample	Domestic-owned firms	Foreign affiliates	Total sample	Domestic-owned firms	Foreign affiliates
Constant	0.62 (2.97)***	0.36 (1.60)	-0.92 (1.09)	3.96 (6.56)***	3.64 (5.59)***	-1.27 (0.50)
<u>Firm-specific factors:</u>						
Foreign ownership	-0.54 (6.03)***	..	..	-1.00 (3.87)***	..	..
Log of size	0.38 (13.14)***	0.40 (11.18)***	0.42 (5.12)***	0.72 (8.58)***	0.65 (6.39)***	1.04 (4.21)***
<u>Other aspects of firm's innovation strategies (standardized scores on patents / innovation expenditure):</u>						
Number of patent applications	0.27 (7.79)***	0.22 (5.62)***	0.38 (5.53)***	0.59 (5.83)***	0.61 (5.47)***	0.59 (2.88)***
Acquisition of external R&D	0.11 (2.97)***	0.16 (3.77)***	0.03 (0.34)	0.36 (3.31)***	0.63 (5.12)***	-0.02 (0.08)
Acquisition of other external knowledge	-0.02 (0.55)	-0.01 (0.13)	-0.08 (1.05)	-0.07 (0.67)	-0.11 (0.86)	-0.05 (0.22)
Acquisition of machinery and equipment	-0.01 (0.19)	-0.03 (0.79)	0.04 (0.50)	-0.15 (1.41)	-0.24 (2.02)**	-0.14 (0.63)
Training	0.02 (0.40)	0.02 (0.50)	-0.01 (0.16)	0.16 (1.36)	0.10 (0.74)	0.28 (1.19)
Market introduction of innovations	0.10 (2.56)**	0.09 (1.86)*	0.12 (1.53)	0.39 (3.40)***	0.36 (2.76)***	0.46 (1.94)*
Design and other	0.07 (1.97)**	0.05 (1.16)	0.12 (1.84)*	0.08 (0.76)	-0.05 (0.45)	0.42 (2.07)**
<u>Industry- and region-specific factors (standardized scores):</u>						
Technology opportunity in industry	0.20 (4.82)***	0.25 (5.40)***	0.13 (1.49)	0.41 (3.36)***	0.35 (2.62)***	0.48 (1.91)*
Technology trajectory in industry	0.17 (3.92)***	0.21 (4.56)***	0.05 (0.62)	0.05 (0.39)	0.09 (0.71)	-0.01 (0.03)
Local stock of human capital	0.09 (2.23)**	0.06 (1.34)	0.18 (1.94)*	0.22 (1.86)*	0.30 (2.23)**	0.04 (0.13)
<u>Heckman's selection correction for firms:</u>						
Innovation	-0.91 (7.07)***	-0.85 (6.06)***	-0.94 (3.74)***	-2.69 (7.14)***	-2.56 (6.43)***	-2.61 (3.47)***
Foreign ownership	..	0.19 (0.75)	0.68 (2.02)**	..	0.97 (1.32)	2.07 (2.04)**
Wald $\chi^2$	376.96	423.34	136.33	195.83	267.36	93.12
Number of observations	1009	726	283	1014	730	284

Note: Absolute value of Heckman's two-step z-statistics in brackets; \*, \*\*, \*\*\* denote significance at the 10, 5 and 1 percent levels. The number of observations differs because of missing data for some variables.

The results also confirm that the nature of external R&D sourcing is different from the plain purchase of external knowledge via rights to inventions, licences or software and acquisition of knowledge embodied in fixed investment. Application of technology fully developed by others does not seem to require much (if any) internal R&D capability, while a certain absorptive capacity of firms is needed to use external R&D sourcing. The expenditure on market introduction of innovations turns out to have a significant and positive parameter, which shows that it also appears in tandem with internal R&D and lends some support to the adaptive nature of some R&D as outlined in the theoretical typology. The significant and positive coefficient of expenditure on design and other preparations supports the previous point, although it is related only to R&D employment. The expenditure on training of personnel does not seem to be relevant in this context.

The results for the estimation separately for domestic and foreign-owned firms broadly confirm the previous findings, but also reveal one important difference between the two groups of firms. A higher budget for external acquisition of R&D reinforces internal R&D activity in domestic-owned firms, whereas it has no significant influence in foreign affiliates. As has been shown, the foreign affiliates spent much more on acquisition of external R&D relative to their size compared with domestic-owned firms, although the extra efforts are not complementary to their internal R&D activity. It seems that the acquisition of external R&D is of a truly different nature in the foreign affiliates. It might well be that not much absorptive capacity is needed and not much of the two-directional exchange of knowledge is actually involved in this context, which perhaps makes the external sourcing of R&D in foreign affiliates somewhat closer to the acquisition of knowledge embodied in fixed investment or purchase of other external knowledge through rights to use.

Unfortunately, we are not able to identify directly from the innovation survey whether external R&D is acquired from the parent or from other sources, nor whether it is obtained from the host country or from abroad.<sup>8</sup> Nevertheless, the survey includes a set of questions on the cooperative behaviour of firms, which can provide some indirect indication along these lines. Hence, we examine interaction terms between the expenditure on external R&D and the propensity to cooperate in innovation with relevant partners. Table 4 gives results of the exercise in the subsample of foreign affiliates if we include in the model interaction terms with dummies for cooperation with the following partners: (i) other firms in the group abroad, (ii) with R&D labs or universities (science) abroad and (iii) with scientific institutions in the host country (see Appendix 1 for definition of the variables).

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<sup>8</sup> The first innovation survey included a distinction between innovation expenditure from within the country and from abroad - at least in Belgium (Veugelers and Cassiman, 2004) - which was unfortunately not maintained in the third round of innovation surveys.

**Table 4: Regression results focused on external R&D sourcing in foreign affiliates**

	R&D employees	R&D expenditure
Constant	-0.89 (0.98)	-1.23 (0.47)
<u>Firm-specific factors:</u>		
Log of size	0.43 (4.96)***	1.01 (4.02)***
<u>Other aspects of firms' innovation strategies (standardized scores):</u>		
Number of patent applications	0.34 (4.86)***	0.45 (2.21)**
Acquisition of external R&D	-0.01 (0.05)	-0.17 (0.63)
ext. R&D * cooperation with other firms in the group abroad	-0.10 (1.03)	-0.23 (0.78)
ext. R&D * cooperation with science abroad	-0.0001 (0.00)	-0.02 (0.07)
ext. R&D * cooperation with science in the host country	0.23 (2.43)**	0.85 (3.03)***
Acquisition of other external knowledge	-0.12 (1.60)	-0.21 (0.91)
Acquisition of machinery and equipment	0.02 (0.29)	-0.29 (1.24)
Training	0.02 (0.29)	0.51 (2.07)**
Market introduction of innovations	0.16 (1.90)*	0.57 (2.32)**
Design and other	0.10 (1.41)	0.32 (1.57)
<u>Industry- and region-specific factors (standardized scores):</u>		
Technology opportunity in industry	0.14 (1.47)	0.65 (2.35)**
Technology trajectory in industry	0.07 (0.72)	-0.06 (0.20)
Local stock of human capital	0.17 (1.70)*	0.002 (0.01)
<u>Heckman's selection correction for firm's:</u>		
Innovation	-0.85 (3.18)***	-2.22 (2.84)***
Foreign ownership	0.61 (1.70)*	1.90 (1.81)*
Wald $\chi^2$	136.02	106.65
Number of observations	259	260

Note: Only sample of foreign affiliates included in the analysis. Absolute value of Heckman's two-step z-statistics in brackets; \*, \*\*, \*\*\* denote significance at the 10, 5 and 1 percent levels. The number of observations differs because of missing data for some variables.

It is revealed that the combination of spending on external R&D and cooperation with the local scientific institutions is positively associated with internal R&D in foreign affiliates, although any support for such a conclusion is offered for cooperation with abroad. In other words, the results suggest that sourcing of R&D from the local economy is complementary to foreign affiliates' own R&D efforts, while cooperation with the parent or scientific institutions abroad seems to have no direct effect on their internal R&D. This should be interpreted with caution, of course, as not every external R&D sourcing is accompanied by innovation cooperation. Still, the results seem to confirm the finding by Knell and Srholec (2004) that there is a difference between domestic and foreign firms as well as between links of the firms established locally compared with relations with partners abroad.

## 6. Conclusions

This paper has examined factors behind firms' internal R&D activities using firm-level data in the Czech Republic. The aim was to find out whether foreign affiliates are more likely to engage in internal R&D compared with domestic-owned firms, while controlling for other firm, industry and region-specific factors. Our findings suggest that there are reasons to doubt the extent to which R&D has become spatially dispersed to regions outside the areas traditionally harbouring headquarters activities of MNCs. All else being equal, foreign affiliates tend to engage less in internal R&D activity. The result is robust across different specifications and estimates. At least as far as the Czech Republic is concerned, the results rather lend some support to the "hollowing out" thesis on the effects of foreign ownership on indigenous technological capabilities in latecomer countries.

It should be emphasized, however, that there is strong evidence that foreign direct investment in R&D is on an increasing trend. Some of the econometric studies using large samples of firms, such as the analysis of Belgian data by Veugelers and Cassiman (2004), show that foreign ownership is positively associated with internal R&D activity in some areas. Therefore, the fact that foreign ownership is negatively related to internal R&D is apparently not a general feature of foreign affiliates as such, but is rather an outcome of certain context-specific factors. There is no doubt that the decision of foreign firms to localize R&D activity is conditional on the complexity of the local innovation system and other characteristics of the locality. It might well be the other way around in the Czech Republic, if appropriate conditions and policies had been put in place.

On the other hand, one has to bear in mind the development context as well. The majority of existing evidence on internal R&D activities of foreign affiliates has been restricted to data from developed countries. Similar firm-level data on innovation strategies of foreign affiliates in medium-income - not to mention low-income - countries has seldom been analysed in the literature so far. It is one of the main contributions of this paper to provide fresh insights from a former centrally planned economy and now a new EU member country. It might well be that the Czech evidence points to a broader divide in the effects of foreign direct investment on indigenous technological capabilities in the frontier and latecomer countries.

As some analyses at the aggregate level suggest (Fagerberg et al. 2005), the technology gap seems to be widening. If our findings are representative for countries behind the technology frontier, then they suggest that foreign affiliates do not appear to grow deep R&D roots in the latecomer economies on their own accord. Hence policies focused on embedding of foreign affiliates into the host economies are, as they always have been, of paramount importance for capitalizing on inflow of foreign direct investment for technological catching up. Admittedly, we need more research on firm-level data from other latecomer countries in order to establish whether the presented findings capture a mere Czech peculiarity or some general pattern along these lines emerging in the global economy.

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## Appendix 1: Overview of the variables

### Firm specific variables:

Indicators	Scale	Description
Foreign ownership	Binary	Dummy variable with value 1 when the firm is foreign-owned (more than 50% foreign ownership)
Size	Persons	Number of employees
Age	Days	Number of days since registration of the firm in the business register
Permanent R&D activity	Binary	Dummy variable with value 1 if the firm engaged in internal R&D on a permanent basis
R&D employment	Persons	Number of persons involved in internal R&D activities within the firm (full-time equivalent)
Number of patent applications	Patents	The number of applications of the firm (or firm's group) for patents to protect inventions or innovations developed by the firm

### Innovation expenditure on:

Internal R&D	CZK	All creative work undertaken within the firm on a systematic basis in order to increase the stock of knowledge, and the use of this stock of knowledge to innovate
Acquisition of external R&D	CZK	Same activities as above, but performed by other companies (including other enterprises within the group) or other public or private research organisations
Acquisition of other external knowledge	CZK	Advanced machinery, computer hardware specifically purchased to implement innovations
Acquisition of machinery and equipment	CZK	Purchase of rights to use patents and non-patented inventions, licenses, know-how, trademarks, software and other types of knowledge from others for use in the firm's innovations
Training	CZK	Internal or external training for your personnel directly aimed at the development and/or introduction of innovations
Market introduction of innovations	CZK	Internal or external marketing activities directly aimed at the market introduction of innovations (may include preliminary market research, market tests and launch advertising, but exclude the building of distribution networks)
Design and other	CZK	Procedures and technical preparations to realise the actual implementation of innovations not covered elsewhere

### Innovation cooperation:

Cooperation with other firms in the group abroad	Binary	Dummy variable with value 1 for innovative firms that have innovation cooperation with other firms in the group abroad
Cooperation with science abroad	Binary	Dummy variable with value 1 for innovative firms that have innovation cooperation with R&D laboratories of universities abroad
Cooperation with science in the host country	Binary	Dummy variable with value 1 for innovative firms that have innovation cooperation with R&D laboratories of universities in the Czech Republic

### Industry-specific factors (based on OECD averages):

Foreign ownership	Share of foreign affiliates in employment at 2 and 3 digit NACE (rev. 3) – based on the OECD AFA Database
Technology opportunity	R&D intensity (BERD as % of value added) at 2 and 3 digit NACE (rev. 3) – based on the OECD ANBERD Database
Technology trajectory	Average annual growth of BERD in % at 2 and 3 digit NACE (rev. 3) over 1995-2001 – based on the OECD ANBERD Database

Note: The OECD figures are computed by industry (not simple averages across countries), i.e. the sum of BERD across countries divided by sum of value added across the same sample of countries. The coverage of countries depends on data availability and differs for the variables; the data refer to the latest available period until 2001 (see the OECD STAN Database, version of November 2005, and OECD AFA Database, version of January 2005, for the actual coverage for each variable).

### Region-specific factors (based on regional datasets from the Czech Statistical Office):

Foreign ownership	Share of foreign affiliates in total employment at NUTS4
Local stock of human capital	Share of people with university education in total population at NUTS4
Employment in large firms	Share of employment in firms with 500 and more employees in total employment at NUTS4
Employment in industry	Share of employment in industry in total employment at NUTS4
Sickleave rate	Days of incapacity for work on the number of sickness insured persons at NUTS4

## Appendix 2

**Appendix Table 1: The first-step probit estimates for Heckman corrections**

Dependent variable: Successful innovation		Dependent variable: Firm's foreign ownership	
Constant	-0.59 (15.78)***	Constant	-0.38 (0.98)
<u>Firm-specific factors:</u>		<u>Firm-specific factors:</u>	
Foreign ownership	0.21 (3.81)***	Log of size	0.15 (5.10)***
Factor score on ext. obstacles	-0.24 (9.18)***	Age of firm	-0.0001 (2.44)**
<u>Industry dummies (NACE, rev. 3 codes):</u>		<u>Factor score on ext. obstacles</u>	
15, 16	0.67 (5.41)***	0.12 (2.86)***	
17, 18, 19	0.14 (1.47)	<u>Industry -specific factor:</u>	
20, 21, 22	-0.05 (0.42)	Foreign ownership	0.12 (3.00)***
23, 24, 25	0.67 (6.22)***	<u>Region-specific factors:</u>	
26	0.99 (7.45)***	Foreign ownership	0.22 (5.60)***
27, 28	0.14 (1.56)	Employment in large firms	-1.58 (4.79)***
29	0.83 (7.30)***	Employment in industry	0.01 (2.28)**
30, 31, 32, 33	0.63 (6.43)***	Sickleave rate	-0.03 (1.85)*
34, 35	0.73 (5.67)***		
36, 37	0.28 (2.27)**		
64, 72, 73	0.28 (2.27)**		
Wald $\chi^2$	347.67	Wald $\chi^2$	102.92
Number of observations	3221	Number of observations	1295

Note: Absolute value of Heckman's two-step z-statistics in brackets; \*, \*\*, \*\*\* denote significance at the 10, 5 and 1 percent levels.

**Appendix Table 2: Results of the factor analysis on the obstacles to innovation**

	Factor loadings
Excessive perceived economic risks	0.77
Innovation costs too high	0.79
Lack of appropriate sources of finance	0.61
Insufficient flexibility of regulations or standards	0.58
Lack of customer responsiveness to innovation	0.58
Eigenvalue	2.25
Proportion of the first factor in the sum across all eigenvalues	1.17
Number of observations	3221

**Appendix Table 3: Correlation table**

	R&D employment	R&D expenditure	Firm's foreign ownership	Log of size	Technology opportunity in industry	Technology trajectory in industry	Local stock of human capital	Number of patent applications	Acquisition of external R&D	Acquisition of other external knowledge	Acquisition of machinery and equipment	Training	Market introduction of innovations	Design and other
R&D employment	1.00													
R&D expenditure	0.73	1.00												
Dummy for firm's foreign ownership	-0.06	-0.03	1.00											
Log of size	0.41	0.31	0.14	1.00										
Technology opportunity in industry	0.29	0.26	0.04	0.16	1.00									
Technology trajectory in industry	-0.01	-0.06	0.05	-0.27	-0.21	1.00								
Local stock of human capital	-0.05	-0.04	-0.01	-0.31	-0.06	0.30	1.00							
Number of patent applications	0.34	0.28	0.03	0.24	0.14	-0.08	-0.05	1.00						
Acquisition of external R&D	0.16	0.16	0.11	0.03	0.08	-0.01	0.03	0.21	1.00					
Acquisition of other external knowledge	-0.03	-0.03	0.05	-0.06	-0.05	0.11	0.11	0.01	0.12	1.00				
Acquisition of machinery and equipment	0.02	-0.01	0.04	0.04	0.03	-0.07	-0.11	0.03	0.09	0.17	1.00			
Training	-0.06	-0.02	0.09	-0.26	-0.09	0.28	0.16	-0.03	0.11	0.21	0.11	1.00		
Market introduction of innovations	0.01	0.06	0.05	-0.24	-0.04	0.18	0.23	0.00	0.06	0.15	0.01	0.27	1.00	
Design and other	0.08	0.06	0.04	-0.07	0.05	0.01	0.02	0.06	0.12	0.05	0.05	0.08	0.25	1.00