Research and development activity of foreign affiliates: Firm-level evidence from the Czech Republic

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Abstract

The paper focuses on effects of foreign ownership on research and development (R&D) activity carried out by innovative firms in the Czech Republic. The analysis is based on firm-level data from the third Community Innovation Survey. It is shown, using a Heckman's sample selection model, that foreign affiliates tend to engage less in intramural R&D compared to domestic owned firms. The finding is sustained after controlling for a number of other firm, industry and region-specific factors and turns out to be robust across different specifications of the model. Scale effects at the firm level as well as industry and region specific factors, particularly associated to their technology and skills content, also come out as relevant explanatory factors of intramural R&D activity. The analysis further indicates that firm's patenting activity and expenditure on acquisition of extramural R&D, market introduction of innovations and design are complementary to intramural R&D. However, the effect of external acquisition of R&D differs in foreign affiliates and domestic owned firms. Only external R&D sourcing from labs and universities in the host country seems to be complementary to intramural R&D in foreign affiliates, while sourcing of R&D from abroad appears not to be relevant in this context.

Keywords: Foreign affiliates, research and development, innovation strategy.

JEL classification: D21; L16; F23; O23

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1. Introduction

Transnational corporations (TNCs) 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, TNCs are also increasingly important players in generation of new knowledge abroad. A sizeable part of private research and development (R&D) activity is in fact concentrated in large TNCs, which are dominant players in their home base innovation systems as well as enhance technological capabilities through direct investment into R&D in host countries (Narula and Zanfei 2004). It is the latter aspect of international business activity, which is the main focus of this paper.

A lot 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. Despite a strong theoretical reasoning in favour of spillovers, however, the evidence is mixed at best (Görg and Greenaway 2002). 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 on technology spilling over to the host country is rare and in fact rather crowding-out of non-affiliated firms is often detected. In order to provide fresh insights along these lines, we need more direct evidence on innovation activities of foreign affiliates and improve our understanding of particular channels through which spillovers occur.

Availability of evidence from R&D surveys and Community Innovation Surveys triggered extensive research on firm's innovative activities since the beginning of the nineties. Still the literature using large firm-level datasets on innovation activities of foreign affiliates in econometric framework remains relatively small and limited to analyses of Cassiman and Veugelers (2002), Veugelers and Cassiman (2004), Balcet and Evangelista (2004) and Knell and Srholec (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 on innovation activities in latecomer countries, not mentioning data particularly for foreign affiliates.

A complementary line of research emphasizes industry and regional specificity of innovation activity (Malerba and Orsenigo 1993, Audretsch and Feldman 1994). A firm is not seen an island separated from other firms and its social surroundings by "deep waters" of anonymous and homogenous market forces (Richardson 1972 and Lundvall 1988). 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 doesn't undermine but quite on the contrary put forward the importance of firm's ability to capitalize on locally concentrated and embedded tacit knowledge (Maskell and Malberg 1999). Global business with regional home base(s) seems to be the phenomena under question here.

It is one of the core insights of the Schumpeterian literature; furthermore, that innovation differs across industries (Castellacci 2004). Firm's innovative behaviour is seen in the context of strategies pursued by their competitors and partners, which are given by industry-specific technology opportunities and trajectories. Besides the role of firm-specific characteristics, these perspectives underline a joint role of industry and region-specific factors for explaining

firm's behaviour; in particular 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, which determines firm's innovation strategy? Is there a reason for policymakers to be concerned about the impact of foreign investment on local technology 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 investigates 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 on innovation activities separately for foreign and domestic owned firms as well as allows us to take into account role of the industry and region-specific factors. The Czech economy is a fascinating laboratory in this respect. Similarly to the other new EU-members, it 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 econometric framework. The key concern is the role of foreign ownership, while controlling for 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 firm's innovation strategies beyond the intramural R&D activity into the analysis. Section 6 concludes and puts the findings into a general perspective.

2. Theory and evidence on R&D activity of foreign affiliates

The literature on foreign direct investment traditionally expected R&D to be concentrated near 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 to be one-directional to the host country in order to improve 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 technology base of TNCs is 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 firm's ownership boundaries rather than through market transactions. As geographical, cultural and alike 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 diversified knowledge base in order to prevent themselves from being locked in a narrow (location-specific) technology path (Cohen and Levinthal 1990). The

greater is the variety of knowledge at firm's disposal, the greater are the changes for innovation to arise. So firms invest into R&D abroad to tap into specific technology competences embedded in foreign locations (Cantwell 1995).

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

1) *Imitative strategy*. The affiliate develops no intramural R&D capabilities. Innovation activity is fully based on application of existing foreign technology, which requires any additional expenditure on R&D in the host-county in order to use it effectively. Most of innovation expenditure is spent on arms-length purchase of technology in the form of rights to use externally developed inventions, licenses, trademarks or software, on 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 in the parent and only the solution 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 no or very limited contribution of the 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 or technology from abroad and limited patenting record of the affiliate (or only local patents). The regional market-seeking focus is the key distinct 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 highly engaged in intramural R&D activity and reports 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 a 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 the 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 the 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 as well as state-of-

the-art scientific infrastructure strongly supports 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 R&D unit in foreign location requires considerable time and effort, but once deeply embedded in the host country research system it is less costly to maintain. Thus foreign investment into R&D tends to be "sticky" in locations, where sophisticated innovation systems are already in place and a considerable path-dependency in localization of R&D activities should be expected (Narula and Zanfei 2004). Even if firms develop networks of R&D units in multiple locations, the importance of the location-specific factors suggests that most of it remains highly concentrated in space.

Apart from the 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 and ownership or both), which allows firms to focus on exploiting the core elements of their competitive advantage and outsource 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 as compared to 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 these veins has been that the adaptive focus of R&D is predominant among the foreign affiliates (Mansfield, Teece and Romeo 1979), while the more recent evidence suggests that the core technology augmenting R&D is on increasing trend (Archibugi and Michie 1995, Cantwell 1995, Odagiri and Yasuda 1996, Almeida 1996, Florida 1997, Zander 1997, Patel and Vega 1999, Pearce and Papanastassiou 1999, Kuemmerle 1999, Cantwell and Noonan 2002). A heightening global competition encourages firms to engage more in the adaptive R&D to customize products to local needs, but the increasing specialization and complexity of technological development also strengthens the pressure to search for knowledge outside of the home base to keep a pace with foreign competition.

Still there is abundant evidence that internationalization of R&D doesn't keep its pace with internalization of manufacturing to any comparable extent (see for example the survey of large TNCs by UNCTAD 2001). Le Bas and Sierra (2002) confirm that different innovation strategies can be actually 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 towards countries behind the technology frontier, while the technologically most advanced segments of value chains remain concentrated and possibly even more cluster into certain areas. The ultimate outcome is that even though foreign direct investment into R&D increases, most of it remains to be concentrated in home countries of the largest TNCs – 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 increasing technology lead of the frontier countries and poses substantial challenges for technological upgrading in the latecomers (Fagerberg, Srholec and Knell 2005).

It is important to realize that it is the absolute comparative advantage, which determines localization of foreign direct investment. A latecomer country needs to reach a certain

minimum threshold of the location-specific factors, which has to be comparable to conditions in the frontrunner countries, in order to attract foreign affiliates pursuing the core technology augmenting R&D strategies. Indeed, this is extremely difficult to achieve with limited resources and other location-specific disadvantages that most of the latecomer countries face. The path-dependent nature in internalization of R&D activities is clearly fortune for regions on the frontier, while the deepening fragmentation undermines 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 outsourced from abroad. What is the effect of having foreign owners on intramural R&D activity in the Czech firms? Does the foreign ownership contribute to upgrading or rather 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 has been obtained from a compulsory survey, which asked firms about their innovative activities over 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 them were successful innovators over the period (introduced a new product or process).[1] Only the innovators were asked about further details on 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 gives firm-specific information on size, ownership, industry, location and direct evidence on innovation activities. Besides the traditional focus on intramural 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 market introduction of innovations or patenting record of firms (see Appendix 1 for a complete list and formal definitions of the indicators).

Table 1 provides descriptive overview of the firm-level data. About a third of the firms are foreign owned, which is broadly in accord to other official statistics. The foreign affiliates engage less in intramural R&D, even though they enjoy scale advantages due to larger size compared to domestic owned firms. The propensity to conduct R&D internally on a

[1] 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 knowledge of the author any data from the third Community Innovation Survey has not been officially published separately for foreign and domestic owned firms; neither by Eurostat or the Czech Statistical Office.

permanent basis is about 6 percentage points lower in foreign affiliates. Intramural R&D expenditure per employee is on average lower roughly by 25% and share of R&D employees in total employment is lower by more than 40% in the foreign affiliates.

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

	All firms (N = 1,295)	Domestic owned firms (N = 914)	Foreign affiliates (N = 381)
Number of firms	1,295	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
Intramural R&D on a permanent basis and employment			
% of firms with permanent R&D activity	42.0	43.7	38.0
% of R&D employment in total employment	6.8	7.4	5.2
Average innovation expenditure per employee *(% of firms engaged in the activity)*			
Average R&D expenditure per employee	25.5 *(66.2)*	26.8 *(68.1)*	22.1 *(61.3)*
Acquisition of extramural 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 corresponds to period 1999-2001. Due to missing values, the number of observation 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.

Intramural R&D activity is important source of new knowledge, but also knowledge obtained from other sources and/or from outside of firm's borders is essential input into innovation process. In order to capture the broader context of innovation activities, firms have been also asked to estimate other related expenditures on innovation beyond the intramural R&D. These innovation expenditures are grouped into the following categories: i) acquisition of extramural R&D (including from other enterprises within the group), ii) purchase of other external knowledge (rights to inventions, licences, trademarks, software and alike), 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 on average more on innovation expenditure relative to their size, a bulk of the innovation budget is typically devoted to obtain knowledge from external sources. The difference is most striking in acquisition of extramural R&D for which foreign affiliates spend three times as much per employee as compared to their domestic owned counterparts; much of the difference most probably reflects purchase 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, though, the frequency to engage in spending on these items is fairly similar. Not much difference is observed in expenditures 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 further asked whether they applied for patents to protect inventions or innovations developed by the enterprise and indicate number of the patent applications. The evidence reveals that roughly each tenth firm filed a patent application with any apparent difference along the ownership lines, whereas patenting intensity in terms of the number of applications per employees was almost two times higher in foreign affiliates. It seems that the foreign affiliates firms more than counterbalance their lower intramural R&D activity by access to knowledge base of the group to come out with superior patenting record.

One has to interpret the patenting record with a 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 distribution of foreign affiliates skewed towards industries with higher propensity to patent new inventions. It is one of the main concerns of the following analysis to disentangle to which extent the foreign ownership as compared the industry as well as regional factors matter 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's size, industry or their location, which might have a little to do with the fact that the firm has foreign owners. It can also be a subject of a 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, which should be attributed to their lower intramural R&D intensity as compared to domestic owned firms? In order to address the issue, we develop a simple model of R&D activity that brings aboard the factors outlined above.

In this view, the intramural R&D activity may emerge as a distinctly firm-specific attribute but it also may be embedded in the local environment or it may be driven by technological opportunities given by the industry-specific context. The regional innovation system can be a gravity centre for R&D activities due to agglomeration effects, where sizeable knowledge externalities arise, and the industry can experience a scientific breakthrough, which opens up windows for new technology trajectory with high payoffs for those pushing the frontier. Given this logic the presence of intramural 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 intramural R&D activity from the innovation survey: the dummy variable for permanent R&D activity, expenditure on intramural R&D and the number of employees involved in intramural R&D. A closer inspection of the data suggests presence of some outliers in the sample, which would bias the results. So we use the variables on expenditure and employment in logs to limit a possible influence of measurement errors and short-term surges in firm's R&D activity during the period.[2]

The dummy explanatory variable for foreign ownership will be in the centre 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 positive sign would suggest that foreign ownership is associated with superior intramural R&D capabilities. Large firms can enjoy economies of scale of various kinds, so that 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 higher likelihood to report permanent R&D activity. The size variable also appears in logs because we assume non-linearity to be involved in these relations.

The simplest possibility to account for the industry and location-specific factors is to compute some aggregated averages from the firm-level dataset and claim that these represent properties bounded to industries and regions. These average figures, however, would partly reflect attributes of the industries as such but also partly property of the industries specifically in the Czech Republic (due to 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 also unrelated (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 patterns still can be related to location of particular (large) firms, factors associated to

[2] As some of the firms didn't engage in intramural R&D activity – reported „0" –, we had 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 don't appear to be generally influenced by the presence of outliers in the sample (and the same applies to the other innovation expenditure).

geography are among the most exogenous variables to single firms 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 on R&D activity in the innovation surveys and in addition since the foreign affiliates turns 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 (a probit-specific procedure for the binary dependent variable on permanent R&D activity). The correction for sample selection on innovative firms can be identified only by variables that are available for the total sample of firms, which answered the innovation survey. Besides the dummy for foreign ownership, therefore, the data allows 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's interest, to curtail a potential endogeneity problem. It comes out that the various obstacles are highly correlated to each other, so we use their factor score in the estimation. A battery of industry dummies at 2-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 on the identification).

Table 2 presents 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 university. 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 equal - having foreign owners reduces the probability to engage permanently in intramural 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 plainly 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 intramural R&D activity. The concern about the selection bias is also well justified as the Heckman's procedure yields significant correction coefficient.

In the first set of estimates we include only the industry dummies by technology intensity. There seems to be a relatively clear divide between medium-high and high-tech sectors on one hand and the other half of the spectrum towards the low-tech edge on the other hand. The dummy for high-tech services directly covers – among some others – firms with R&D as their principal business activity, so it is in line with expectations that it turns out with highly significant and positive coefficient. It is somehow surprising to see, however, that the medium-high tech industries seem to have higher propensity to engage in intramural R&D activity than the sector of high-tech industries. A closer look at the data reveals that this is primarily due to relatively sophisticated innovation system in the Czech automotive industry, whereas electronics - the prime branch of high-tech manufacturing in most countries - falls short of expectations. In particular foreign affiliates in electronics, mostly contractual manufacturers attracted by low labour costs and investment incentives, maintain R&D intensity, which is substantially lower than in their domestic owned counterparts and in fact even below the average of the Czech manufacturing.

Table 2: Econometric results with dummies for industries and regions

Dependent variable:	*Research and experimental development (R&D)*					
	Perm-anent	*Emp-loyees*	*Expen-diture*	*Perm-anent*	*Emp-loyees*	*Expen-diture*
Constant	-0.94***	-0.07	1.02	-0.95***	-0.14	0.89
	(2.99)	(0.28)	(1.25)	(2.95)	(0.52)	(1.07)
Firm-specific factors:						
Foreign ownership	-0.32***	-0.47***	-0.70***	-0.32***	-0.47***	-0.72**
	(3.76)	(5.88)	(2.86)	(3.76)	(5.90)	(2.96)
Log of size	0.19***	0.39***	0.76***	0.19***	0.40***	0.77***
	(6.17)	(14.97)	(9.21)	(6.15)	(15.02)	(9.27)
Industry dummies:						
High-tech industry	0.59***	0.47***	2.10***	0.59***	0.48***	2.12***
	(3.00)	(2.60)	(3.78)	(3.00)	(2.66)	(3.82)
Medium-high-tech industry	0.64***	0.61***	2.39***	0.65***	0.64***	2.48***
	(3.68)	(4.15)	(5.15)	(3.67)	(4.29)	(5.29)
Medium-low-tech industry	0.05	-0.29**	0.20	0.06	-0.26*	0.31
	(0.34)	(2.20)	(0.47)	(0.39)	(1.92)	(0.72)
Low-tech industry	-0.06	-0.29**	-0.23	-0.06	-0.26**	-0.14
	(0.54)	(2.55)	(0.64)	(0.46)	(2.19)	(0.37)
High-tech services	0.88***	1.04***	3.15***	0.87***	1.02***	3.10***
	(4.20)	(6.12)	(5.97)	(4.15)	(5.96)	(5.85)
Regional dummies:						
Prague	..	..	..	0.03	0.12	0.37
	..	..	..	(0.28)	(1.25)	(1.23)
Other districts with technical university	..	..	..	0.01	0.06	-0.02
	..	..	..	(0.05)	(0.68)	(0.07)
Heckman's correction for innovators	-0.45**	-0.62***	-0.86*	-0.45**	-0.63***	-0.90*
	(2.32)	(3.40)	(1.67)	(2.33)	(3.46)	(1.75)
Wald χ^2	67.90	364.83	175.02	67.58	366.46	177.00
Number of observations	1,223	1,222	1,014	1,223	1,222	1,014

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 due to missing data for some variables.

It is interesting to note that the OECD taxonomy proves to be in general problematic to use in the context of latecomer countries, in particular the newly industrialized areas in the East Asia (Srholec 2006). The Czech evidence also confirms that particularly the deep fragmentation of value chains in electronics makes it difficult to interpret the category of high-tech manufacturing in countries somewhat lower at the technology ladder. Yet, the dummies for medium-low-tech and low-tech manufacturing appear with insignificant or significantly negative parameters, which suggests that there is some systematic pattern along the broad taxonomic categories in our sample. It can well be that the OECD taxonomy might not be an appropriate tool for a broad cross-country comparisons but still keeps most of its substance for cross-industry comparisons within countries.

Not much has changed after including the regional dummies. The capital of Prague is the gravity centre of business activity in the Czech Republic, which is clearly reflected in regional statistics, but location of firms in this area doesn't matter for intramural R&D activity. The

other regional dummy also fails to be significant, so any agglomeration effects related to presence of a technical university don't seem to materialize in the Czech regions.[3] It should be mentioned that we have further tested a battery of other dummies for NUTS-2 regions (nine in total in the Czech Republic), but majority of them didn't come out significant and the results for other variables in the model remained intact. The only robust result from this exercise is that the Northwest region – near the German border – is not attractive for localization of R&D activity.

Although it is customary in the literature to check for the industry and location-specific factors by using dummies, the phenomena in question is 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.[4] 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, in the next step, we use the location and industry firm-specific classification codes to merge the firm-level data with rich evidence readily available in regional and industrial statistics. Instead of using simple dummies for regions, for example, we work with university attainment of population by regions. Furthermore, it allows us to include additional variables that directly reflect penetration of foreign ownership at the level of industry and region.

Table 3 shows results if each of the dependent variables is regressed against the dummy for foreign ownership, the log of firm's size and selected industry and region-specific factors.[5] In the first set of the 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 significantly lower propensity to venture into intramural R&D activity as compared to domestic owned firms. In contrast, the variable for internationalization of region twice comes out with significantly positive coefficient and the variable for internationalization of industry also once shows up with marginally significant coefficient.

[3] Roughly a quarter of the firms in the sample is registered in Prague and another quarter in one of the districts with technical university.

[4] 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 – consider, for example, inclusion of 50 dummies for districts in the previous estimate.

[5] The selected industry and region-specific factors were standardized to a common scale (deducting meand and dividing by standard deviation) before the estimation in order to allow for a direct comparison of their coefficient's magnitude. The standardization affects only magnitude (not significance) of the relevant parameters – all other results of the estimate remain intact.

Table 3: Regression results with industry and region-specific factors

Dependent variable:	*Research and experimental development (R&D)*					
	Perm-anent	*Emp-loyees*	*Expen-diture*	*Perm-anent*	*Emp-loyees*	*Expen-diture*
Constant	0.02	0.90***	4.52***	-0.14	0.56***	4.01***
	(0.16)	(4.34)	(7.47)	(0.88)	(2.72)	(6.50)
Firm-specific factors:						
Foreign ownership	-0.27***	-0.54***	-0.94***	-0.29***	-0.52***	-0.84***
	(4.09)	(5.84)	(3.38)	(4.05)	(5.84)	(3.07)
Log of size	0.13***	0.36***	0.70***	0.15***	0.40***	0.75***
	(5.76)	(13.68)	(8.57)	(5.93)	(15.07)	(9.02)
Industry-specific factors (standardized scores based on OECD averages):						
Foreign ownership	0.03	0.05	0.24*	-0.05	-0.10*	-0.09
	(0.95)	(1.09)	(1.70)	(1.11)	(1.82)	(0.54)
Technology opportunity	..	..	..	0.15***	0.28***	0.54***
	..	..	..	(3.26)	(5.56)	(3.43)
Technology trajectory	..	..	..	0.07**	0.17***	0.11
	..	..	..	(2.17)	(4.21)	(0.85)
Region-specific factors (standardized scores based on Czech regional datasets):						
Foreign ownership	0.05	0.14***	0.32***	-0.0001	-0.04	-0.01
	(1.62)	(3.62)	(2.70)	(0.00)	(0.54)	(0.06)
Stock of human capital	..	..	..	0.04	0.15**	0.34*
	..	..	..	(0.72)	(2.30)	(1.61)
Heckman's correction for innovators	-1.22***	-0.64***	-3.15***	-1.08***	-1.18***	2.94***
	(8.69)	(16.60)	(7.60)	(7.60)	(7.78)	(7.11)
Wald χ^2	42.36	216.32	89.63	49.77	283.29	107.40
Number of observations	1,223	1,222	1,014	1,223	1,222	1,014

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 due to missing data for some variables.

The variable for foreign penetration by region turns out to be particularly relevant explanatory factor for firm's R&D employment and expenditure, which suggests some externalities for R&D activity due to local clustering of foreign affiliates. Indeed, it is the first indication of a positive influence of foreign ownership on the indigenous Czech technology capabilities detected by our analysis (and in fact the only one as shall be seen below). 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 intramural 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 by industry and local endowment by 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-nineties (both in the OECD area); and the local stock of human capital reflects the share of people with university education in total population in the district, where the firm is localized.

The results suggest that the technology content of industries and the local pool of highly educated labour matter for intramural 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 fail to be significant, with the only exception of 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, were also not met with much success.

The variables obviously interact with each other, which raises concerns about a possible multicollinearity problem in the estimate. The main bias is due to 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 doesn't not seem to much affect coefficient of the latter. Other correlations are negligible (R^2<0.10). In any case, we drop the insignificant variables on foreign penetration in industry and region from the final regression in the following estimates.

The need not to escalate the problems with multicollinearity 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 to each other and to the variable of local human capital (mostly as the consequence of the distinct nature of the Prague agglomeration). Albeit the stock of human capital turned out to be by far the most relevant explanatory variable among relevant regional factors, the variable probably also represents at least partly 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 intramural 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 record. Hence it is natural to examine whether there is any relation of the other observed aspects of innovation strategies to the intramural R&D by including them directly into the estimate.

For this purpose we utilize the firm-specific information on the various other innovation expenditure 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 due to concerns related to influence of outliers. As noted, we control for the industry and region specific factors by including only the variables, which proved to be significant previously. We further narrow the focus on the dependent variables on R&D employment and expenditure, which reflect some information on the scale of the activity and because the explanatory power of the model for the dummy for permanent R&D activity didn't appear to be very high.

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 the further Heckman's correction for sample selection on the firm's ownership. Essentially we estimate a double selection model, which accounts for both possible selection biases.

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 on 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 sickleave 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). [6]

Table 4 gives the results. We first focus on the estimate for the full sample. It is confirmed that foreign ownership at the firm-level exerts significantly negative effect; while the firm's size along with the industry and region-specific factors are positively related to the intramural 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 external R&D, which suggests that its external sourcing actually in general complements firm's in-house 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 relevance of the "make or buy" dichotomy (Veugelers 1997 and Veugelers and Cassiman 1999).

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 the technology fully developed by others doesn't seem to require much (if any) intramural R&D capability, while certain absorptive capacity of firms is needed to use the external R&D sourcing. The expenditure on market introduction of innovations turns out with significant and positive parameter, which shows that it also appears in tandem with intramural 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, thought it is related only to R&D employment. The expenditure on training of personnel doesn't seem to be relevant in this context.[7]

[6] It should be noted that we have also tested the role of firm's age (both in logs and without logs) directly for intramural R&D activity in the previous estimates. The age variable was expected to capture 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 pick-up a possible difference between recently established greenfield projects and (privatization) mergers and acquisitions. Nevertheless, the age variable didn't come out as significant explanatory factor for R&D activity nor influenced results of the other variables, so these results are not reported in the paper.

[7] Any multicollinearity problems arise in the estimates (see Appendix 3 for correlation table). So as the industry and region specific factors, the variables on the other aspects of innovation strategies have been standardized (deducting meand 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 magnitude (not significance) of the relevant parameters – all other results of the estimate remain intact.

Table 4: Regression results with industry and region-specific

Dependent variable:	*Research and experimental development (R&D)*					
	R&D employees			*R&D expenditure*		
Sample:	*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)
Firm-specific factors:						
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)***
Other aspects of firm's innovation strategies (standardized scores on patents / innovation expenditure):						
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)**
Industry and region-specific factors (standardized scores):						
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)
Heckman's selection correction for firm's:						
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 χ^2	376.96	423.34	136.33	195.83	267.36	93.12
Number of observations	1,009	726	283	1,014	730	284

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 due to missing data for some variables.

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 extramural acquisition of R&D reinforces intramural R&D activity in domestic owned firms, whereas it has not any 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 as compared to domestic owned firms, though the extra efforts are not complementary to their intramural 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 purchase of other external knowledge though rights to use or embodied in fixed investment. Indeed, this finding might be of a paramount importance for understanding the nature of technology sourcing in foreign affiliates and for formulation of relevant innovation policies.

Unfortunately we are not able to directly identify from the innovation survey whether the external R&D is acquired from the parent or from other sources neither whether it is obtained from the host country or from abroad. [8] Nevertheless, the survey includes a set of questions on 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 for innovation with relevant partners. Table 5 gives results of the exercise in the sub-sample of foreign affiliates if interaction terms with a dummy for cooperation with 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 are included in the model (see Appendix 1 for definition of the variables). It comes out that the combination of spending on external R&D and cooperation with the local scientific partners is complementary to intramural R&D in foreign affiliates, though any support for such a conclusion is offered for cooperation with abroad. It 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 as compared to relations with partners abroad.

[8] The first innovation survey included a distinction between innovation expenditure from within the country and from abroad, which was unfortunatelly not maintained in the third round of innovation surveys.

Table 5: Regression results with industry and region-specific

Sample:	*Foreign affiliates*	
Dependent variable:	*R&D employees*	*R&D expenditure*
Constant	-0.89 (0.98)	-1.23 (0.47)
Firm-specific factors:		
Log of size	0.43 (4.96)***	1.01 (4.02)***
Other aspects of firm's innovation strategies (standardized scores):		
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)
Industry and region-specific factors (standardized scores):		
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)
Heckman's selection correction for firm's:		
Innovation	-0.85 (3.18)***	-2.22 (2.84)***
Foreign ownership	0.61 (1.70)*	1.90 (1.81)*
Wald χ^2	136.02	106.65
Number of observations	259	260

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 due to missing data for some variables.

6. Conclusions

The paper examined factors behind firm's intramural R&D activities using firm-level data from innovation survey in the Czech Republic. The aim was to find out whether foreign affiliates are more likely to engage in intramural R&D as compared to domestic owner firms, while controlling for other firm, industry and region-specific factors. It has been shown that

i) All else equal, foreign affiliates tend to engage less in intramural R&D activity. The result is robust across different specifications and estimates.
ii) Scale effects at the firm level as well as industry and region specific factors, particularly associated to their technology and skills content, are also relevant explanatory factors of firm's intramural R&D activity.
iii) Firm's patenting activity and expenditure on acquisition of extramural R&D, market introduction of innovations and design are complementary to intramural R&D.
iv) However, the effect of external acquisition of R&D differs in foreign affiliates and domestic owned firms. Only external R&D sourcing from labs and universities in the host country seems to be complementary to intramural R&D in foreign affiliates, while sourcing of R&D from abroad appears not to be relevant in this context.

Our findings suggest that there are reasons to doubt the extent to which R&D has become spatially dispersed to regions outside the main areas harbouring home bases of TNCs. At least as far as the Czech case is concerned, the home bases of foreign investors generally remain the dominant site for their R&D activity. On the contrary, our results rather lend some support to the "hollowing out" thesis on the effects of foreign direct investment on indigenous technological capabilities in latecomer countries.

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

On the other hand, one has to bear in mind the development context as well. A majority of existing evidence on intramural R&D activities of foreign affiliates has been restricted to data from developed countries so far. A similar firm-level data on innovation strategies of foreign affiliates in medium – not mentioning low – income countries has been hardly analysed in the literature so far. It is one of the major contributions of this paper to provide fresh insights from the former centrally planned and the 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 on the aggregate level suggest (Fagerberg, Srholec and Knell 2005), the technology gap seems to widen and foreign direct investment actually might be one of the main

proponents of the process. 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.

If our findings are representative for countries behind the technology frontier, then they suggest that foreign affiliates don't 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 a paramount importance to capitalize on inflow of foreign direct investment for technological catching-up. The policy-makers in the Czech Republic and elsewhere seem to be increasingly aware of the need to implement innovation policy along these lines. It remains to be seen whether one will be able to conclude that the Czech picture has been reversed as soon as some longitudal data for innovation surveys become available.

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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 ingaged in intramural R&D on a permanent basis
R&D employment	Persons	Number of persons involved in intramural 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 the firm
Innovation expenditure on:		
Intramural 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 laboratiories 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 laboratiories of universities in the Czech Republic

Industry dummies (based on the OECD taxonomy – OECD 2003, pg. 156):

	NACE, rev. 3 codes
High-tech	353, 244, 30, 32, 33
Medium-high-tech	31, 34, 24 excl. 244, 352, 354, 355, 29
Medium-low-tech	351, 23, 25-28
Low-tech	15-22, 36-37
High-tech services	64, 72 and 73

Regional dummies

Prague	The capital city (app. 10% of total population)
Other districts with technical university	NUTS4 with a technical university (except Prague) as follows: Brno, Ostrava, Plzen, Olomouc, Liberec, Hradec Kralove, Usti nad Labem, Ceske Budejovice, Pardubice, Zlin, Opava (besides the capital of Prague, there are 40 other districts in the Czech Republic) .

Industry-specific factors (based on OECD averages):

Foreign ownership	Share of foreing affiliates in employment at 2 and 3 digit NACE (rev. 3) – based on the OECD AFA Database
Technology opportunity	R&D intesity (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 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: 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)
Firm-specific factors:		*Firm-specific factors:*	
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)**
Industry dummies (NACE, rev. 3 codes):		Factor score on ext. obstacles	0.12 (2.86)***
15, 16	0.67 (5.41)***	*Industry -specific factor:*	
17, 18, 19	0.14 (1.47)	Foreign ownership	0.12 (3.00)***
20, 21, 22	-0.05 (0.42)	*Region-specific factors:*	
23, 24 ,25	0.67 (6.22)***	Foreign ownership	0.22 (5.60)***
26	0.99 (7.45)***	Employment in large firms	-1.58 (4.79)***
27, 28	0.14 (1.56)	Employment in industry	0.01 (2.28)**
29	0.83 (7.30)***	Sickleave rate	-0.03 (1.85)*
30, 31, 32, 33	0.63 (6.43)***		
34, 35	0.73 (5.67)***		
36, 37	0.28 (2.27)**		
64, 72, 73	0.28 (2.27)**		
Wald χ^2	347.67	Wald χ^2	102.92
Number of observations	3,221	Number of observations	1,295

Note: Absolute value of robust t-statistics in brackets; *, **, *** denote significance at the 10, 5 and 1 percent levels.

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	3,221

Appendix 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