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**R&D AND TECHNOLOGY
SPILLOVERS THROUGH
FDI: INNOVATION AND
ABSORPTIVE CAPACITY**

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ABSTRACT

R&D and Technology Spillovers through FDI:
Innovation and Absorptive Capacity*

This Paper examines the effects of two faces of R&D (innovation and development of absorptive or learning capacity) and technology spillovers from FDI (foreign direct investment) on a firm's productivity growth.

Using firm-level panel data on Czech manufacturing firms between 1995 and 1998, I find that:

1) The learning effect of R&D is more important than the innovative effect of R&D in explaining the productivity growth of a firm

2) Technology spillovers from FDI occur for firms that are more R&D intensive

3) Spillovers from foreign joint ventures are insignificant for Czech manufacturing firms

4) The extent of technology spillovers is greater in oligopolistic sectors (electrical machinery and radio and television) than in non-oligopolistic sectors (food, non-metallic minerals, and other manufacturing).

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NON-TECHNICAL SUMMARY

Technological change is one of the driving forces of economic growth. New technology can be acquired from deliberate innovative activity called research and development (R&D) or learning from the existing technology generated by others. It is generally believed that R&D plays a dual role – 'innovation' and 'learning' – in both avenues. That is, R&D activity not only stimulates innovation but also develops the firm's ability to identify, assimilate and exploit outside knowledge. This second role of R&D is considered important in assessing the extent of technology spillovers from others.

This is because technology spillovers may not take place automatically where the recipient's absorptive capacity is insufficient.

This Paper examines the relative importance of two faces of R&D, 'innovation' and 'learning' (or building up the absorptive capacity) for the firm's productivity growth when a carrier of new technology is foreign direct investment (FDI). Among various channels through which technology spills over internationally, FDI is thought of as one of the most effective ways because it transfers technology that is embodied in human capital. Intangible assets possessed by multinational firms such as know-how in management and advertisement can be transferred via FDI but not via other channels such as trading goods and services and licensing agreements.

The data I use for this study is firm-level panel data in the Czech manufacturing sector between 1995 and 1998. Compared to other transition economies such as Hungary and Poland, the Czech Republic had been more conservative in attracting foreign capital. A rush of foreign investors in the manufacturing sector had flown in the country only after the mid-1990s. The advantage of using the Czech data is that I can follow the changes of productivity over time since an onset of FDI inflow.

Comparing our sample firms by ownership – foreign and local firms – in each industry group, it is shown that foreign firms are more productive on average in most industry groups. Foreign firms do not, however, necessarily grow faster than local firms. Particularly, in electrical machinery and radio and television, local Czech firms were less productive than foreign firms in 1995 and they had caught up with foreign counterparts by 1998, which implies the presence of technology spillovers from foreign investment in these sectors.

In the empirical model I examine, productivity growth of a firm occurs either by R&D investment or by technology spillovers from FDI. Next, two faces of R&D are differentiated as innovative and absorptive R&D. Innovative R&D is a direct effect of a firm's R&D investment on its productivity growth. Absorptive R&D is captured through the degree of technology spillovers from knowledge embodied in foreign investment. Technology spillovers take place when a firm

has a foreign joint venture partner or it is operating in the sector with great foreign presence.

The rate of return to innovative R&D is found to be about 14% for firms in our sample. Once I include absorptive R&D as an explanatory variable, innovative R&D becomes less important in accounting for productivity growth. It is found that those firms, which engage in R&D activity, benefit more from technology spillovers from FD and also grow faster. In the case of Czech firms, the main role of R&D investment is to facilitate the absorption of advanced incoming technology from foreign firms rather than to innovate.

It is also observed that in oligopolistic sectors (electrical machinery and radio and television), innovative R&D has a higher return and there seems to exist greater technology spillovers from FDI than in non-oligopolistic sectors (food, non-metallic minerals, and other manufacturing). This suggests that firms have to first invest in R&D knowledge in order to benefit from technology spillovers.

Several policy implications are drawn for the recipient country of FDI. First, local firms should build up the absorptive capacity by investing in R&D activity in order to maximize the extent of technology spillovers from FDI. Thus, R&D subsidies or tax breaks should be accompanied by the promotion of foreign investment. Second, it might be beneficial for the host government to attract FDI particularly in oligopolistic sectors in which the potential technology spillovers are greater than in other sectors.

1   Introduction

The accumulation of knowledge is one of the key determinants for the economic growth of a country. The stock of knowledge or technology can be increased by deliberate investment in R&D capital or by the diffusion of existing technology. Innovations generated by R&D activities and technology spillovers from the stock of knowledge are both important in enhancing firms' productivity as well as being closely related to each other.

This paper studies the effects of both R&D investment and technology spillovers from foreign direct investment (FDI) on a firm's productivity growth. I pay special attention to "the two faces of R&D"—innovation and 'absorptive' or 'learning' capacity—as Cohen and Levinthal (1989) and Leahy and Neary (1999) propose. That is, R&D not only stimulates innovation but also develops the firm's ability to identify, assimilate, and exploit outside knowledge. This second role of R&D is considered to be very important particularly for assessing the extent of technology spillovers from others. Technology diffusion is not an automatic consequence from the presence of others' knowledge stock. It also requires that the recipient possesses the ability to absorb and adopt the technology and that R&D activities will help increase the incidence of technology spillovers by enhancing the firm's absorptive capacity.

In this study, R&D affects the productivity growth of firms via two channels. First, it directly increases the technology level by adding more new information (innovation). Second, R&D increases the absorptive capacity of the firm and induces a greater extent of technology spillovers indirectly. The empirical set-up for this study is drawn from Griffith, Redding, and Van Reenen (2000). They examine the two roles of R&D in explaining the productivity convergence of 13 OECD countries at the industry level. They find innovative and absorptive R&D equally important.

The other branch of the literature I draw upon is technology spillovers through FDI. Among many channels of technology diffusion[1], FDI is one of the most important vehicles[2] because FDI can transfer technology embodied

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[1]International trade is another important avenue for international technology diffusion. [Grossman and Helpman (1991), Coe and Helpman (1995), and Keller (1997)] Technology is also transmitted via reading and exchanging scientific journals or commercially obtained by licensing agreements. [Eaton and Kortum (1996)]

[2]There are four channels through which technology spills over from foreign to lo-

in human capital which would not be transferred otherwise[3]. Also in the theoretical literature of technology transfer from foreign to domestic firms, Wang and Blomstrom (1992) point to the importance of the learning efforts or the absorptive capacity of host country firms in increasing the rate of technology transfer.

In the empirical studies of technology diffusion via FDI, the evidence is rather mixed despite its premise of potential gains from FDI particularly at the firm- and plant-levels. For example, Haddad and Harrison (1993) and Blomstrom and Sjoholm (1999) find no evidence of technology spillovers at both firm and industry level for Moroccan and Indonesian manufacturing firms, respectively. Djankov and Hoekman (1998) report similar results for Czech manufacturing and non-manufacturing firms. In the Venezuelan manufacturing sector, however, Aitken and Harrison (1999) show that there are benefits of foreign investment but they are captured by foreign joint ventures but not by foreign presence in the industry. These contradictory findings suggest that the incidence of technology spillovers may be dependent on the initial level of technology of local firms relative to that of foreign firms. Kokko (1994) confirms this point from his results on Mexican manufacturing firms by stating that the incidence of technology spillovers are conditional on the technology level of local firms relative to that of foreign firms.

In this study, I explicitly introduce R&D investment as a part of the learning efforts by the host country firm. The empirical set-up in this study is manufacturing firms operating in the Czech Republic between 1995 and 1998. Total factor productivity (TFP) growth of these firms is determined by three factors: R&D, FDI, and the firm's absorptive capacity. I find that: (i) the learning effect of R&D is more important than the innovative effect in explaining the productivity growth of a Czech manufacturing firm; (ii) technology spillovers from FDI occur for firms thaht are more R&D intensive; (iii) spillovers from foreign joint venture are insignificant for Czech manufacturing firms; and (iv) the extent of technology spillovers is greater in oligopolistic sectors (electrical machinery and radio&TV) than in non-oligopolistic sectors (food, non-metallic minerals, and other manufacturing).

This paper is organized as follows. In the next section, empirical specifica-

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cal firms: (1) demonstration-imitation effects, (2) competition effects, (3) foreign linkage effects, and (4) training effects. See Kokko (1992) and Kinoshita (1999) for further discussion.

[3]Mansfield (1980) reports that FDI conveys newer technology than trade.

tions are discussed in light of the theoretical literature. In section 3, the data and summary statistics are described and regression results are examined in section 4. Finally, section 5 concludes my findings.

2   Framework

2.1   R&D and productivity growth

Suppose the production function of firm i is expressed as:

$$Y_{it} = A_{it} L_{it}^{\alpha} K_{it}^{1-\alpha} \tag{1}$$

where Y_{it} is value-added, A_{it} is total factor productivity (TFP) or Solow residual, L_{it} is labor input, and K_{it} is physical capital stock. A_{it} is related to R&D capital stock as follows:

$$A_{it} = B_{it} R_{it}^{\rho} \tag{2}$$

where R_{it} is the stock of R&D capital and B_{it} is other factors that influence TFP. R_{it} can be considered as a firm's intangible assets and thus it is unobservable. It is accumulated over time by investments in knowledge and technology.

Time-differentiating equation (2), I get:

$$\frac{\triangle A_{it}}{A_{it}} = \frac{\triangle B_{it}}{B_{it}} + \rho \frac{\triangle R_{it}}{R_{it}} \tag{3}$$

where ρ is the elasticity of value-added with respect to R&D capital stock. In order to estimate the series of R&D capital stock directly, I need additional assumptions. Following Griliches (1980), Nadiri (1980), and Goto and Suzuki (1989), the evolution of R&D capital stock over time can be described as follows (the i th subscript is dropped):

$$R_t = \sum_{k=1}^{\infty} \mu_k E_{t-k} + (1-\delta) R_{t-1} \tag{4}$$

That is, R&D capital stock at time t is the sum of all past R&D expenditures $\{E_{t-k}\}$ and depreciated R&D capital at time t-1 where μ_k is a distributed

3

lag and δ is a rate of obsolescence of R&D capital. For the first term in (4), I need to specify the lag structure. (e.g. R&D expenditures in time t-τ constitute the increase in R&D capital at time t.) In the literature, people often use the average lag τ and $\mu_k = 1$ if $k = \tau$ and $\mu_k = 0$ if $k \neq \tau$. (4) then becomes:

$$R_t = E_{t-\tau} + (1 - \delta)R_{t-1} \tag{5}$$

The rate of obsolescence of R&D capital, δ, is somewhat similar to the rate of depreciation of physical capital. The main difference is, however, that R&D capital also depreciates as knowledge diffuses to people other than the innovator. The estimation of δ requires some information on patent renewal data.[4] In the absence of patent renewal data, it is not possible to estimate a series of R&D capital stock directly. One way to derive the rate of return on R&D investment without estimating the rate of obsolescence is to assume that δ is small enough. If δ is computed as an inverse of the length of time a patent generates royalty revenue as in Goto and Suzuki (1989), then I am implicitly assuming that the average life span of patents is long enough.[5] The other conventional way to avoid the estimation of the rate of obsolescence is to set δ to a plausible level, say, 10% as some researchers do. In this paper, I choose the first approach to compute the rate of return to R&D capital.[6]

Assuming that δ is small and that the average lag is one year ($\tau = 1$) in (5), I get:

$$\frac{\triangle R_t}{R_t} = \frac{E_t}{R_t} \tag{6}$$

The substitution of (6) into (3) yields:

$$\frac{\triangle A_{it}}{A_{it}} = \frac{\triangle B_{it}}{B_{it}} + \eta \frac{E_{it}}{Y_{it}} \tag{7}$$

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[4]One can compute the net profit of a patent as a discounted sum of the revenue from a patent (royalty) minus the patent renewal fee. See Bosworth (1978), Pakes and Shankerman (1984), and Goto and Suzuki (1989) for more details.

[5]This is true for industries that are not so technology-intensive.

[6]Griliches and Mairesse (1984) and Griffith, Redding, and van Reenen (2000) use this approach as well. Hall and Mairesse (1995) report that the choice of depreciation rate for R&D capital makes little difference to R&D elasticity estimates in the study of French manufacturing firms.

where η is marginal product of R&D or the rate of return on R&D investment.[7]

2.2 Technology spillovers from FDI and productivity growth

Another focus of this analysis is FDI as an engine of the productivity growth of a firm. Foreign investment can be considered here as the inflow of advanced knowledge from foreign firms. In particular, among many channels through which foreign knowledge spills over to a country, FDI is one of the most effective forms of international technology transfer because FDI can convey not only technology embodied in goods and services but also intangible assets such as managerial skills that would not be transferred through other avenues.

At the firm level, local firms in the host country can benefit from FDI via roughly four channels.[8] First, foreign technology embodied in FDI can be transferred from foreign to local firms as local firms imitate what foreign firms do. Firms invest abroad in order to exploit firm-specific capabilities and they are thus typically characterized as efficient firms that possess intangible assets. Second, the productivity growth of local firms may be affected by competitive pressures due to the entry of efficient foreign firms. Third, by purchasing intermediate inputs from foreign suppliers or by selling output to foreign producers of final goods, local firms may be able to produce output with a higher standard or be forced to use more efficient technology, respectively. Finally, foreign firms may engage in training workers in local firms especially when they are joint venture partners.

It is, however, difficult to distinguish one from the other since the mechanism of technology spillovers from FDI is complex and often interdependent. Nevertheless, within the limitation of available data, I use two variables that reflect the degree of technology spillovers through FDI in the current empirical set-up.

The first variable is the foreign ownership dummy $FORGN_{it}$ at time t. The past studies often use this variable as a proxy for intra-firm technology spillovers from FDI. $FORGN_{it}$ is 1 if shares owned by foreign firms are equal

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[7]$\rho = \frac{\partial Y}{\partial R} \cdot \frac{R}{Y}$ by definition and $\rho \frac{\triangle R}{R} = \frac{\partial Y}{\partial R} \cdot \frac{R}{Y} \cdot \frac{E}{R} = \eta \frac{E}{Y}$.
[8]See Kokko (1992) and Kinoshita (1999) for further discussion.

to or greater than 50% and 0 otherwise.[9] According to this classification, I define only firms with foreign majority shares as foreign-owned firms (e.g. firms with $FORGN_{it} = 1$).

The second variable is $FOR_{j(i)t}$, which proxies foreign presence in the sector measured as the share of employment by foreign-owned firms to total employment within the industry. Namely, $FOR_{j(i)t}$ denotes sectoral foreign stock at time t in the j th industry to which the i th firm belongs. This variable is considered to reflect the degree of intra-industry technology spillovers from FDI.

These two variables are incorporated into $\frac{\triangle B_{it}}{B_{it}}$.

$$\frac{\triangle B_{it}}{B_{it}} = \mu_1 FORGN_{it} + \mu_2 FOR_{j(i)t} \qquad (8)$$

Substituting (8) into (7), I get:

$$\frac{\triangle A_{it}}{A_{it}} = \eta \frac{E_{it}}{Y_{it}} + \mu_1 FORGN_{it} + \mu_2 FOR_{j(i)t} \qquad (9)$$

η, μ_1, and μ_2 are expected to be positive and significant if they raise a firm's productivity. Alternatively, I can also run the following regression to get the estimates for the variables of our interest:

$$\begin{aligned}\frac{\triangle Y_{it}}{Y_{it}} &= \alpha_i + \alpha \frac{\triangle L_{it}}{L_{it}} + (1 - \alpha) \frac{\triangle K_{it}}{K_{it}} + \eta \frac{E_{it}}{Y_{it}} \\ &\quad + \mu_1 FORGN_{it} + \mu_2 FOR_{j(i)t} + d_j + d_t + \varepsilon_{it} \end{aligned} \qquad (10)$$

where d_j and d_t are sector and time dummies, respectively. α_i is a firm's fixed effect invariant over time. This model is closely related to the specification that Haddad and Harrison (1993) and Aitkin and Harrison (1999) use in their studies of manufacturing firms in Morocco and Venezuela, respectively. The novelty of this model is that I include R&D investment in the effort level of local firms to increase the stock of knowledge.

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[9]The cut-off level of foreign shares conventionally used is 5% or 10%. The Czech Stastitical Office uses 50% instead for the definition of foreign ownership. Due to this difference in the definition of foreign ownership, the effect of foreign ownership on productivity growth may be understated in this study relative to those found in other studies.

R&D is directly related to TFP growth in the above specification. R&D may also affect the extent of technology spillovers from FDI by increasing a firm's capacity to absorb new technology more effectively. Griffith, Redding, and Van Reenen (2000) distinguish the two faces of R&D—innovation and enhancement of absorptive capacity—and analyze both roles of R&D empirically on productivity growth of industries in OECD countries. They indeed find evidence that R&D not only stimulates innovation but also facilitates the imitation of others' discoveries.

The current study also addresses this issue by relating R&D to the size of technology spillovers. That is, the R&D variable affects via two channels. One is through a direct channel (η) and the other is through the absorptive capacity (μ_1 and μ_2).[10] Equation (10) is extended into the following form:

$$
\begin{aligned}
\frac{\triangle Y_{it}}{Y_{it}} &= \alpha_i + \alpha \frac{\triangle L_{it}}{L_{it}} + (1 - \alpha)\frac{\triangle K_{it}}{K_{it}} + \eta \frac{E_{it}}{Y_{it}} + \mu_1 FORGN_{it} + \mu_2 FOR_{j(i)t} \\
&\quad + \mu_3(\frac{E_{it}}{Y_{it}})FORGN_{it} + \mu_4(\frac{E_{it}}{Y_{it}})FOR_{j(i)t} + d_j + d_t + \varepsilon_{it} \qquad (11)
\end{aligned}
$$

3   Data

Two data sets are used for this study. Both data sets are collected by the Czech Statistical Office. The first data set is the quarterly data that was compiled from firms' balance sheets and income statements from the first quarter of 1993 through the last quarter of 1998. Most of the variables necessary for the estimation were drawn from this data set.

The second data set is the annual survey on R&D and licenses. Since R&D expenditures are reported by firms annually from 1995 through 1998, the quarterly firm-level data was merged into the annual level and then the two data sets were merged according to the firm identifier and year. Finally, the panel data for 1995-1998 has 1217 observations.[11]

Table 1 shows the annual average of two key variables, R&D propensity and foreign presence, for each sector. R&D propensity is defined as a ratio of

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[10]Note that the degree of technology spillovers in Griffith, Redding and Van Reenen (2000) is defined as the distance from technology frontier or the catch-up effect to the leading-edge technology. Kinoshita (1999) uses the initial difference in technlogy level as the degree of technology transfer.

[11]Computing TFP growth rates, the number of observations drops to 704.

R&D expenditure to value-added and foreign presence is measured as a ratio of employment by foreign-owned firms to total employment in the sector.

Foreign presence varies greatly across sectors. Three sectors that attract much FDI are motor vehicle, rubber, and electrical machinery[12]. Basic metal and other transport equipment receive the least FDI in our sample firms. R&D propensity also varies but to a lesser degree. Other transport equipment, radio&TV, and motor vehicle exhibit higher R&D propensity than other sectors.

Note that the sectors with the greater foreign presence do not necessarily exhibit the greater R&D propensity. If R&D intensity implies a level of technological complexity in the sector, then FDI in the Czech Republic is not necessarily going into high-tech sectors. Motor vehicle is the only exception since it is relatively more R&D intensive and receives a lot of FDI on average.

3.1   Comparisons between foreign and local firms

A premise of this study is that foreign firms are more technologically advanced than local firms. As technology spills over from foreign to local firms, local firms adopt the new methods of production or management resulting in higher productivity.

The first two columns in table 2 report the average TFP levels computed for each sector and ownership classification (local and foreign firms). In many sectors, I observe higher productivity levels for foreign firms. The exceptions are textile, chemical, machinery, medical equipment, and other transport equipment. As table 1 indicates, textile, machinery, and other transport equipment have very little foreign presence and the average of foreign firms may not be treated as representative due to too few observations. However, foreign presence is large enough and accounts for 11% in both chemical and medical equipment sectors. In these two sectors, foreign firms are relatively less efficient than local firms. This finding goes against the premise of the technological superiority of foreign firms. One explanation for this is that local firms had already caught up in technology and surpassed foreign firms prior to 1995.

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[12]Notable investments are Volkswagen (German) in motor vehicle, Continental (German) in rubber& plastic, and Matsushita (Japanese) and Siemens (German) in electrical machinery.

Table 1: Annual average of R&D to value-added and foreign employment share by sector (1995-1998)

	R&D / Y	Foreign employment share
food	0.10	0.20
textile	0.03	0.05
wood & paper	0.06	0.10
chemical	0.13	0.11
rubber & plastic	0.15	0.31
non-metallic mineral	0.19	0.21
basic metal	0.05	0.02
fabricated metal	0.08	0.13
machinery	0.20	0.05
electrical machinery	0.10	0.29
radio&TV	0.37	0.23
medical equipment	0.15	0.11
motor vehicle	0.22	0.46
other transport equipment	0.38	0.02
other manufacturing	0.06	0.11
ALL	0.16	0.14

The last column in table 2 shows the differences by sector between the average TFP growth rates for foreign firms and that for local firms. Positive numbers imply that foreign firms grew faster than local counterparts on average. Negative numbers imply that local firms grew faster than foreign firms on average. There is no observation for foreign firms in some sectors and in these sectors the TFP growth difference is not available.

The picture here looks different from TFP level comparisons. Foreign firms do not necessarily grow faster than local firms on average. Combining the information on growth rates with the information on productivity levels, there are four categories in which I can classify sectors.

In the first group (food, non-metallic mineral, and other manufacturing), foreign firms are more productive in levels and also continue to grow faster than local firms. In the second group (electrical machinery and radio&TV), foreign firms are more productive but local firms are catching up with them. On the contrary, in the third group (textile), local firms are more productive but foreign firms are catching up. Finally, in the last group (chemical, machinery, medical equipment, and other transport equipment), local firms are more productive and grow faster than foreign counterparts. For the remaining sectors, there is no difference in TFP growth between foreign and local firms, or, the figure is not available due to lack of foreign observations. I will not discuss these non-grouped sectors here.

The most interesting case is the second group. In electrical machinery and radio&TV, the superiority of foreign technology is observed and so is the presence of technological catch-up by local firms. There seem to be indeed some positive productive spillovers to local firms from FDI in this case. On the other hand, in the first group (food, non-metallic mineral, and other manufacturing), local firms failed to benefit from the presence of foreign advanced technology. Finally, in the last two groups, the absence of the technological superiority of foreign firms is simply interpreted as a lack of enough information due to little foreign presence in these sectors.

In the next section, I attempt to examine various factors that made a difference between domestic firms in the first and second groups in whether or not they caught up with foreign firms.

Table 2: Average TFP levels and TFP growth differences by sector and ownership(1995-1998)

| | TFP level | | TFP growth difference |
	Local firms	Foreign firms	
food	0	0.30	0.04
textile	–0.03	–0.17	0.03
wood & paper	0.02	0.36	—
chemical	0.16	0.05	-0.03
rubber & plastic	-0.12	0.34	0
non-metallic mineral	0.12	0.38	0.02
basic metal	0.07	0.76	—
fabricated metal	0.04	0.34	0
machinery	-0.10	-0.11	-0.01
electrical machinery	0.07	0.22	-0.01
radio&TV	-0.12	1.06	-0.04
medical equipment	-0.05	-0.36	-0.09
motor vehicle	-0.17	0.40	0
other transport equipment	-0.01	-1.70	-0.17
other manufacturing	-0.04	0.22	0.02
ALL	-0.02	0.19	0

Notes:

(1) TFP level $= \ln VA - \alpha_k \ln K - \alpha_l \ln L$.

(2) TFP growth difference $=$ (average TFP growth rate)$_{foreign}-$ (average TFP growth rate)$_{domestic}$.

4 Estimation Results

Table 3 presents the regression results of fixed-effects model[13] with innovative R&D and two foreign variables. The dependent variable is $\ln \frac{Y_{it}}{Y_{it-1}}$. The coefficient of R&D measures the a direct impact of R&D investment on productivity growth and I call it here innovative R&D as opposed to absorptive R&D. The coefficient of R&D is also the rate of return to R&D investment. All regressions include the intercept and the changes of capital and labor.

FORGN and FOR are the variables that represent spillovers within the firm and within the industry, respectively. FORGN is a foreign ownership dummy and, if foreign joint venture has any effect on productivity growth, I would expect it to be positive. This variable reflects the demonstration effect and possibly includes the linkage and training effects of technology spillovers from FDI.[14] FOR is a proxy for foreign presence in the industry measured as the employment share of foreign firms to that of all firms in the industry and mainly reflects demonstration and competition effects.

Column I reports the result without sector and time dummies. The rate of return to R&D investment is 0.141 at 1% level of significance. This implies that one more unit of R&D, in this case, one more CZK spent on R&D will lead to an increase of value-added by 14.1%. Thus, R&D investment indeed contributes to the generation of new knowledge but the rate of return is somewhat lower than in the past studies for other countries.[15] The size of R&D coefficieint is strengthened as I control for sector and time differences in column II and III with the same significance level.

On the other hand, the results for foreign variables are disappointing. Both FORGN and FOR carry a negative sign throughout regressions. This implies that firms with foreign ownership tend to grow slower than local firms and that firms in the sector with great forreign presence also grow slower than the others. But these differences are not significant as the coefficients are statistically insignificant.

The results in table 3 show that productivity growth of the firm is ex-

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[13]I run both random-effects and fixed-effects regressions. The Hausman test rejects the null hypothesis in favor of the fixed-effects model. I do not report the random-effects estimators here.

[14]See footnote 2 on page 1.

[15]Goto and Suzuki (1989) report that the rate of return on R&D for Japanese manufacturing firms is about 30%.

Table 3: Innovative R&D and FDI: Fixed-effects model

	I	II	III
R&D/Y	.141***	.148***	.149***
	(.021)	(.022)	(.022)
FORGN	-.016	-.007	-.007
	(.019)	(.019)	(.019)
FOR	-.024	-.047	-.024
	(.055)	(.096)	(.104)
sector dummies	no	yes	yes
time dummies	no	no	yes
N	704	704	704
N of cross-sections	353	353	353
R^2	.2102	.2545	.2605

Notes:

(1) Dependent variable = Change in log of value-added.

(2) Intercept, changes in capital and labor are included in regressions
 but is not reported here.

(3) Parentheses are standard errors. *** indicates 1% significance level.

plained mostly by the firm's own R&D investment and that there is no evidence of technology spillovers from foreign investment both at the firm and sector levels.

The limited impact of foreign investment is reported by other authors in firm- and plant-level studies. Using two variables similar to FORGN and FOR, Haddad and Harrison (1993) find no positive effects of these variables on productivity growth. Aitken and Harrison (1999) find a positive effect of the foreign joint venture variable but a negative effect of foreign stock in the industry. Kokko (1994) examines the effect of foreign presence within the industry on labor productivity and concludes that technology spillovers are found only in sectors in which technology gaps between foreign and local

firms are not too large. More recently, Blomstrom and Sjoholm (1999) draws a similar conclusion and finds that technology spillovers were restricted to non-exporting local firms.

There are a few studies on the effects of FDI in transition countries. Djankov and Hoekman (1998) use the Czech data with coverage of manufacturing and non-manufacturing firms and also find no spillovers from FDI. Rather, imports seem to be the driving force of productivity growth of these firms. Konings (2000) in a study of Poland, Bulgaria, and Romania reports that there are even negative spillovers from FDI in some cases.

All these studies point to the fact that technology spillovers from FDI are not at all automatic consequences from the mere presence of foreign firms. If there are any spillovers at all, they may be conditional on some factors endogenous to the recipient firms or industries such as absorptive capacity in the host economy.

Now I introduce "absorptive R&D" interacted with both foreign spillover variables. In the first column in table 4, the interaction of R&D with FORGN is added. The direct effect of R&D invesment or innovative R&D remains significant. But the indirect effect of R&D investment via foreign ownership (R&D*FORGN) is negative. The rate of return to R&D is smaller, though insignificant, for foreign-owned firms. The contribution of foreign ownership to productivity growth becomes negligibly small. Here the firm's learning effect from being a foreign-owned firm is found absent.

On the other hand, column II shows that absorptive R&D via foreign presence in the sector increases productivity growth significantly. Innovative R&D is 0.136 while absorptive R&D from foreign presence in the industry (R&D*FOR) is 0.317, which is much greater than the direct effect of innovative R&D. In other words, absorprtive R&D in learning from foreign firms in the sector is more important than innovative R&D in explaining productivity growth differentials. Notice that unconditional spillovers from foreign presence in the industry (FOR) are not found. Only the spillover effect emerges only when it is conditioned on the firm's own R&D activity.

Finally, column III reports the estimation of equation (11) including all relevant variables. The result obtained frmo column II remains robust after including two types of absorptive R&D.

I find in table 4 that the role of R&D in increasing absorptive capacity is much greater than the conventional role of innovation. Only when the firm performs R&D actively are there positive spillovers from foreign presence in

the industry. This finding is consistent with aggregate-level studies emphasizing the importance of human capital of the recipient country. Borensztein, De Gregorio, and Lee (1998) find that FDI has a positive effect on economic growth only when it is interacted with the level of human capital in the host country. The level of human capital is a proxy for absorptive capacity of the recipient country. At the firm level, R&D can be considered as such a proxy.

In table 5, I divide the sample by ownership into local and foreign firms. The result from table 4 still holds for local firms. Innovative R&D is outweighed by absorptive R&D via spillovers from foreign presence in the industry. This confirms that local Czech firms benefitted from foreign presence in the industry given that they also engage in R&D activity. For foreign firms, although the rate of return to R&D is 0.239 and much greater than that of local firms, the contribution of absoprtive R&D is not observed. We infer that foreign firms are the active innovators while local firms are successful imitators of foreign technology as long as they also participate in R&D activities.

Table 4: Innovative and absorptive R&D and FDI: Fixed-effects model

	I	II	III
R&D/Y	.151***	.136***	.138***
	(.022)	(.023)	(.023)
FORGN	.0005	-.006	.002
	(.023)	(.019)	(.022)
FOR	-.022	-.079	-.078
	(.104)	(.106)	(.106)
(R&D/Y)×FORGN	-.102	—	-.114
	(.148)		(.147)
(R&D/Y)×FOR	—	.317**	.321**
		(.134)	(.135)
sector dummies	yes	yes	yes
time dummies	yes	yes	yes
N	704	704	704
N of cross sections	353	353	353
R^2	.2615	.2727	.2741

Notes:

(1) Dependent variable = Change in log of value-added.

(2) Intercept, changes in capital and labor are included in regressions
 but are not reported here.

(3) Parentheses are standard errors. *** and **indicate 1% and 5%
significance levels, respectively.

Table 5: Local and foreign firms: Fixed-effects model

	Local firms	Foreign firms
R&D/Y	.136***	.239
	(.023)	(.164)
FOR	-.128	.296
	(.114)	(.390)
(R&D/Y)*FOR	.358***	-.983
	(.139)	(1.327)
sector dummies	yes	yes
time dummies	yes	yes
N	633	71
N of cross-sections	319	38
R^2	.2938	.4919

Notes:

(1) Dependent variable = Change in log of value-added.

(2) Intercept and changes of capital and labor are included
in regressions.

(3) Parentheses are standard errors. *** indicates 1% significance level.

Table 6: Non-oligopolistic and oligopolistic sectors

	Non-oligopolistic sectors	Oligopolistic sectors
R&D/Y	-.025	.068***
	(.113)	(.022)
FORGN	.021	-.016
	(.030)	(.044)
FOR	.026	.037
	(.115)	(.107)
time dummies	yes	yes
N	84	69
N of cross-sections	46	37
R^2	.1766	.3992

Notes:

(1) Dependent variable = Change in log of value-added.

(2) Intercept and changes of capital and labor are included

in regressions.

(3) Parentheses are standard errors. *** indicates 1% significance level.

(4) Non-oligopolistic sectors=food, non-metallic mineral, others;

Oligopolistic sectors=electrical machinery, radio&TV.

Sectoral differences introduced as sector dummies are not jointly significant. Nevertheless, the distribution of foreign firms as well as R&D propensity across sectors is uneven as seen in table 1. In table 6, I pay special attention to sectors with a relatively large foreign presence. The two groups of sectors I will focus on are based on the observation from table 2. The first group of sectors are those in which foreign firms exhibit higher efficiency, yet local firms fail to catch up with them. Food, non-metallic mineral, and other manufacturing are included in the first group, also called as non-oligopolistic sectors. The second group is oligopolistic sectors which include electrical machinery and radio&TV. In these sectors, foreign firms show higher pro-

ductivity and local firms succeed in catching up with them. In both groups, there exist foreign firms equipped with superior technology. But what made the difference in the outcome of local firms' productivity?

The answer to this question can be found in table 6. For group 2 in column II, R&D investment has a substantial contribution to productivity growth. Technology spillovers from foreign stock in the industry are positive but insignificant. For group 1, the rate of return to R&D is negative and the smaller coefficient on FOR indicates the lesser extent of spillovers from foreign presence in the industry.

For local firms to narrow the technology gap, foreign presence alone is not enough to guarantee the incidence of technology spillovers. Simultaneous efforts to build up their skill base in the form of R&D investment is a necessary condition for technology spillovers from FDI in the sector. And electrical machinery and radio&TV present successful examples. Despite the substantial inflow of foreign investment in these sectors, food, non-metallic mineral and others did not receive spillovers partly because they did not engage in R&D activities.

This result is consistent with the theoretical predictions made by other authors. The interactions between firms in R&D activities are often described in a oligopolistic model. Muniagurria and Singh (1997) show that technology spillovers from a more advanced foreign firm to the home firm are realized only when the home firm conducts its own R&D. In a similar vein, Kamien and Zang (2000) argue that a firm has to enter the R&D race by engaging in R&D, first of all, in order to benefit from spillovers from rival firms in research joint venture. It is natural to assume that these strategic incentives are stronger in an oligopolistic market such as electrical machinery and radio&TV than food, non-metallic, and others.

5 Conclusion

Using unpublished firm-level data on the Czech manufacturing sector between 1995 and 1998, I examined the importance of the firm's R&D and technology diffusion from FDI in explaining productivity growth. In the analysis, I distinguish the two roles of R&D: innovation and increasing the absorptive capacity.

The annual rate of return on R&D investment for pooled samples is es-

timated as around 14%. Both foreign joint venture (FORGN) and foreign presence in the sector (FOR) are found to have no significant effect on the growth of productivity. But only when FOR is interacted with R&D does it have a positive and significant effect. This implies that the indirect effect of R&D via the development of the absorptive capacity is more important than the direct effect of innovative R&D in increasing productivity growth of the firm, and that R&D and intraindustry spillovers from FDI go hand in hand.

The other important finding is that the rate of technology spillovers from FDI varies greatly across sectors. In oligopolistic sectors such as electrical machinery and radio&TV, there exists a significant rate of spillovers from having a large foreign presence. Also, R&D investment has a higher rate of return in these sectors. On the other hand, less oligopolistic sectors such as food and non-metallic mineral show no evidence of spillovers despite the large presence of foreign investors in these sectors.

Based on these results, several policy implications can be drawn. First, for the host country to maximize the degree of technology spillovers from FDI, the home country firms should engage in R&D investment in order to enhance their absorptive capacity. Thus, R&D subsidies or tax breaks should be accompanied by the promotion of foreign investment. Second, it may be beneficial for the host government to target oligopolistic industries to attract FDI because the benefits of spillovers will be greater provided that domestic industries possess competitiveness in research activities.

Appendix. Data description

The first source of the data used in this study is the firm-level survey data drawn from quarterly balance sheets and income statements (6430 observations). The second source is annual R&D data that consists of 1175 observations. After merging the two by firm identifier and year and counting only those that are in both data sets, the number of observations drops to 995. Excluding those without ownership information and industry classification, it drops further to 919. The combined data contains the information on capital stock, capital investment, number of employees by type, total sales, output, value-added, deflators, ownership classification, and R&D expenditures.

Firms with foreign ownership are either wholly or partly foreign-owned. The rest of the firms are defined as locally-owned firms. Among local firms, the majority is privately-owned firms. During the period of 1995-1997, there were few changes in ownership classification among sample firms.

According to the 2-digit ISIC, there are 15 sectors: (15) food & tobacco, (17) textile, apparel & leather, (20) paper, pulp, wood & petroleum, (24) chemical, (25) rubber & plastic, (26) non-metallic mineral, (27) basic metal, (28) fabricated metal, (29) machinery and office machinery, (31) electrical machinery, (32) radio, TV & communication equipment, (33) medical equipment & watches, (34) motor vehicle, (35) other transportation equipment, and (36) furniture & others. Parentheses are the original 2-digit OKEC numbers.

The dependent variable in main regressions is the annual growth rate of value-added. I do not use output, even though it is available, because costs of materials and energy are not available.

The value of fixed assets is reported in company balance sheets. However, due to the revaluation of fixed assets at the beginning of each year, it tends to be overvalued. Instead, I use "depreciated capital" reported in income statements for a proxy of capital stock. [16] For the labor variable, the number of total employees is used.

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[16]Djankov and Hoekman(1998) use energy comsuption for capital utilization. However, the figures on energy are not available in the data.

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