R&D and Technology Spillovers via FDI: Innovation and Absorptive Capacity

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Working Paper Number 349
November 2000

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November 2000

Abstract

Two faces of R&D (innovation and learning) and technology spillovers from FDI (foreign direct investment) on a firm's productivity growth are examined in this paper.

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

(i) the learning effect of R&D is far more important than the innovative effect in explaining the productivity growth of a firm,

(ii) there is no evidence of technology spillovers to local firms from having a foreign joint venture partner,

(iii) positive spillovers from FDI are found in electrical machinery and radio&TV sectors, which are also active investors in innovative R&D.

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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) 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 though FDI. Among many channels of technology diffusion[1], FDI is one of the most important vehicles[2] because FDI can transfer technology embodied

[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 local firms: (1) demonstration-imitation effects, (2) competition effects, (3) foreign link-

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 far more important than the innovative effect in explaining the productivity growth of a firm; (ii) there is no evidence of technology spillovers from having a foreign joint venture partner to local firms; and (iii) positive spillovers from FDI are found in electrical machinery and radio&TV sectors, which are also active investors in innovative R&D.

This paper is organized as follows. In the next section, empirical specifications are discussed in light of the theoretical literature. In section 3, the data and summary statistics are described and regression results are examined in

age 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.

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):

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

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 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:

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

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

[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.

[7] $\rho = \frac{\partial Y}{\partial R} \cdot \frac{R}{Y}$ by definition and $\rho \frac{\triangle R}{R} = \frac{\partial Y}{\partial R} \cdot \frac{R}{Y} \cdot \frac{E}{R} = \eta \frac{E}{Y}$.

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 to or greater than 50% and 0 otherwise.[9] According to this classification,

[8] See Kokko (1992) and Kinoshita (1999) for further discussion.

[9] The cut-off level of foreign shares used in many studies at the firm level is usually 5% or 10%. This definition of 50% or greater is given by the Czech Statistical Office in the question on ownership structure. The effect of foreign ownership on productivity growth may be underestimated due to the difference in definitions of foreign ownership in comparison with the existing studies.

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 $\frac{\triangle B_{it}}{B_{it}}$.

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

where d_j is a sectoral dummy and d_t is a year dummy to control for cross-sectional and time-series differences. Substituting (8) into (7), I get:

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

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:

$$\begin{aligned} \frac{\triangle Y_{it}}{Y_{it}} &= \alpha_0 + \alpha \frac{\triangle L_{it}}{L_{it}} + (1-\alpha)\frac{\triangle K_{it}}{K_{it}} + \eta \frac{E_{it}}{Y_{it}} \\ &\quad + \mu_1 FORGN_{it} + \mu_2 FOR_{j(i)t} + d_j + d_t + \varepsilon_{it} \end{aligned} \tag{10}$$

It should be noted that this 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.

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:

$$\begin{aligned} \frac{\triangle Y_{it}}{Y_{it}} &= \alpha_0 + \alpha\frac{\triangle L_{it}}{L_{it}} + (1-\alpha)\frac{\triangle K_{it}}{K_{it}} + \eta\frac{E_{it}}{Y_{it}} + \mu_1 FORGN_{it} + \mu_2 FOR_{j(i)t} \\ &\quad + \mu_3(\frac{E_{it}}{Y_{it}})FORGN_{it} + \mu_4(\frac{E_{it}}{Y_{it}})FOR_{j(i)t} + d_j + d_t + \varepsilon_{it} \end{aligned} \tag{11}$$

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 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

[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.

[12]Notable examples include Volkswagen (German) in motor vehicle, Continental (Ger-

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 there is no clear correlation between R&D propensity and foreign presence. If R&D propensity implies a level of technological complexity in the sector, then FDI in the Czech Republic is not necessarily going into low-tech sectors with low R&D intensity. Motor vehicle is an exception since it is relatively more R&D intensive and receives a lot of FDI as well.

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 superiority of foreign technology. One explanation for this is that local firms had already caught up in technology and surpassed foreign firms prior to 1995.

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

man) 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

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 what I saw in TFP level comparisons. Foreign firms do not necessarily grow faster than local firms on average. Combining the information on growth rate 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 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 Local firms	Foreign firms	TFP growth difference
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 results of OLS regressions 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.[13] 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 dummies. The rate of return to R&D investment is 0.031 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 output by 3.1%. Thus, R&D investment indeed contributes to the generation of new knowledge but the rate of return is lower than that in the studies done in other countries.[14] The significance of R&D remains robust throughout regressions in table 1 after including sector and time dummies.

The results for foreign variables are somewhat disappointing. FORGN carries a negative sign throughout regressions, although not statistically significant. The effect of FOR is positive as I expected. But the size of the coefficient is lessened as I control for sector and time differences.[15]

A glance at table 3 indicates that there is no evidence of technology spillovers from FDI once I include the firm's R&D investment in the model. Since table 1 shows that average foreign firms are not actively engaging in R&D activities, there may be some substitutability between R&D and FORGN.

[13] See footnote 2 on page 1.

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

[15] Year dummies are added as proxies for changes of aggregate economic and political environments in column III. However, they are jointly rejected in the model.

Table 3: Innovative R&D and FDI

	I	II	III
R&D/Y	.031***	.033***	.033***
	(.007)	(.008)	(.008)
FORGN	-.006	-.007	-.007
	(.007)	(.007)	(.007)
FOR	.030	.023	.026
	(.019)	(.045)	(.060)
sector dummies	no	yes	yes
time dummies	no	no	yes
N	704	704	704
adjusted R^2	.1709	.1734	.1713

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. ***,**, and *indicate 1%, 5% and 10% significance levels, respectively.

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 present, then they are conditional on some factors endogenous to the recipient firms or industries 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. Innovative R&D remains significant and, interestingly enough, R&D*FORGN shows the negative and significant sign. As I deduced from table 1, R&D and FORGN are substitutes in explaining productivity growth. In light of absorptive capacity, R&D does not help increase technology spillovers from foreign ownership but rather decreases the degree of such spillovers.

On the other hand, absorptive R&D becomes more dominant than innovative R&D in column II when I add instead the interaction term R&D*FOR. Thus, R&D helps increase the degree of intraindustry spillovers from FDI significantly. Innovative R&D is no longer significant once I account for this type of absorptive capacity. If I define absorptive or learning R&D as R&D that develops the firm's ability to imitate and exploit outside knowledge, then R&D*FOR may capture the notion of absorptive capacity more appropriately. Since the investor in R&D is identical to that with foreign ownership, the distinction between R&D and R&D*FORGN is less obvious.

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. Borensztein, De Gregorio, and Lee (1998) in the study of FDI and economic growth draws a conclusion consistent with the current result. In their study, FDI is found to have a positive effect on economic growth only when it is interacted with the level of human capital in the country. The level of human capital is a proxy for absorptive capacity of the recipient country. In the present paper, R&D is used in place of human capital.

I divide the sample by ownership into local and foreign firms in table 5. 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. On the other hand, R&D plays no important role for productivity growth of foreign firms. Rather, foreign firms increase their productivity from positive externalities from other foreign firms in the same industry. Such positive externalities are recognized when there are sharable inputs within the industry. For example, foreign firms can hire skilled workers already trained by other foreign firms through labor turnover. This also confirms the agglomeration economies of foreign investors in certain sectors such as motor vehicles, electrical machinery, and rubber&plastic in the Czech Republic.

Table 4: Innovative and absorptive R&D and FDI

	I	II	III
R&D/Y	.036***	.008	.010
	(.008)	(.011)	(.011)
FORGN	.002	-.005	.004
	(.008)	(.007)	(.008)
FOR	.025	-.019	-.018
	(.045)	(.047)	(.047)
(R&D/Y)×FORGN	-.088*	—	-.094**
	(.044)		(.044)
(R&D/Y)×FOR	—	.233***	.240***
		(.079)	(.079)
sector dummies	yes	yes	yes
time dummies	no	no	no
N	704	704	704
adjusted R^2	.1768	.1825	.1865

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%, 5% and 10% significance levels, respectively.

Table 5: Local and foreign firms

	Local firms	Foreign firms
R&D/Y	.007	.008
	(.011)	(.063)
FOR	-.025	.131**
	(.080)	(.064)
(R&D/Y)*FOR	.247***	-.256
	(.080)	(.389)
time dummies	no	no
N	643	61
adjusted R^2	.1783	.3084

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. ** and *indicate 5% and 10% significance levels, respectively.

Table 6: Non-oligopolistic and oligopolistic sectors

	non-oligopolistic sectors	oligopolistic sectors
R&D/Y	-.030**	.038***
	(.013)	(.012)
FORGN	-.019	.006
	(.012)	(.019)
FOR	-.044	.156*
	(.068)	(.087)
sector dummies	no	no
time dummies	no	no
N	84	69
adjusted R^2	.2367	.1023

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. ** and *indicate 5% and 10% significance levels, respectively.

(4) Non-oligopolistic sectors=food, non-metallic mineral, others; Oligopolistic sectors=electrical machinery, radio&TV.

Sectoral differences introduced as fixed effects 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 productivity 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 easily 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 present and the size of the coefficient is large. For group 1, the rate of return to R&D is even negative and there are naturally no spillovers.

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 amount of foreign investment made in the 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 estimated as roughly around 3%. Once I include the learning effect of R&D investment in the model, the direct effect of R&D on productivity growth becomes insignificant. 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 far 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.

[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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