

How and By How Much does Foreign Direct Investment Increase the Productivity of Domestic Firms?

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Abstract

We analyze productivity spillovers from MNC subsidiaries to domestic Romanian companies, both within (horizontal spillovers) and across industries (vertical spillovers). We separate labor market spillovers from other horizontal spillovers and define the supply-backward linkage spillover that runs from foreign investors over domestic suppliers to local users of domestic inputs. In our panel of Romanian firms, labor market effects differ from other horizontal effects, vertical spillovers dominate horizontal spillovers and the newly defined supply-backward spillover is economically and statistically significant. The spillovers studied raise total factor productivity between 20% and 50% in the period 1998-2001, depending on the firm's initial level of technology.

Keywords: FDI, spillovers, absorptive capability, firm size, ownership structure

JEL: F2

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1. Introduction

When a firm invests in a foreign country, it often brings with it proprietary technology to compete successfully with indigenous firms (Markusen, 1995). Believing that this transferred technology will be adopted by domestic firms, host country policymakers may try to implement policies to attract foreign direct investment (FDI). Unfortunately, such faith in the positive spillover effects of FDI contrasts starkly with the empirical evidence (Rodrik, 1999). The literature surveys of Görg and Greenaway (2004), Smarzynska Javorcik (2004), and Crespo and Fontoura (2007) conclude that there is no clear evidence of aggregate positive spillovers from FDI.

Looking at the literature more closely, however, we see a distinction between spillovers to firms in the same industries (intra-industry or horizontal spillovers) and spillovers to firms in linked industries (inter-industry or vertical spillovers). Horizontal spillovers have received widespread attention, while the vertical spillover discussion launched by McAleese and McDonald (1978) and Lall (1980) languished for two decades until its recent revival by Schoors and van der Tol (2002) and Smarzynska Javorcik (2004). Schoors and van der Tol (2002) and Smarzynska Javorcik (2004) distinguish vertical spillovers that occur through contacts between foreign firms and their local suppliers in upstream industries (backward spillovers) from those that occur through contacts between foreign firms and their downstream customers (forward spillovers). Both studies suggest that spillovers between industries dominate spillovers within industries. Since then there has been several papers that aim at identifying vertical spillovers. Kugler (2006) finds evidence in a sample of Colombian manufacturing firms for the propagation of technology between industries, suggesting that MNCs outsourcing relationships with local upstream suppliers are the main channel of diffusion. Gorodnichenko et al. (2007) find for a sample of

firms in 17 Central and Eastern European countries that backward spillovers (stemming from supplying a foreign firm in the host country or exporting to a foreign firm) are consistently positive.

Our contribution is twofold. We separate labor market spillovers from other horizontal spillovers and we introduce a new inter-industry spillover effect – the supply-backward spillover. Markusen and Venables (1999) theorize that “FDI may also create demands for local output and these ‘backward linkages’ may strengthen supply industries, this in turn feeding (via forward linkages) to other local firms” (Markusen and Venables, 1999, pp. 336-37). In a two-sector model, they show how foreign investment may fuel demand for locally produced intermediate products, encouraging local suppliers to produce inputs conforming to higher foreign quality standards and eventually making local producers in downstream industries more productive through the availability of better inputs. We try to capture precisely this effect by the supply-backward spillover.

In a sample of domestic Romanian companies we find that horizontal labor market spillovers can be distinguished from other horizontal spillovers and that vertical spillovers are economically more important than horizontal spillovers. The presence of a supply-backward spillover is strongly supported by the data. This paper continues as follows. In section 2, we provide a short overview of the spillover literature. Section 3 lays out the data and the estimation strategy. Results and interpretation are provided in section 4. Section 5 concludes.

2. Spillovers of foreign investment to local firm productivity

Figure 1 illustrates how the spillovers from foreign direct investment run through the host economy’s production chain.

<INSERT FIGURE 1 >

Horizontal spillovers run from a foreign firm to a host country firm in the same industry. Teece (1977) suggests two main channels for horizontal spillovers: mobility of workers trained by foreign firms (see Fosfuri et al., 2001, and Görg and Strobl, 2005) and technology imitation (the demonstration effect). Foreign entry may also fuel competition in the domestic market. Fiercer competition urges host country firms to either use existing technologies and resources more efficiently or adopt new technologies and organizational practices, which provides another important channel of horizontal spillovers (see Aitken and Harrison, 1999, and Glass and Saggi, 2002). None of these effects is necessarily positive, however. Labor market dynamics may entail negative spillovers such as a brain drain of local talent to foreign firms to the detriment of local firm productivity (Blalock and Gertler, 2004) or an overall increase in wages irrespective of productivity improvements caused by foreign firms paying higher wages (Aitken et al., 1996). Where foreign technology is easily copied, the foreign investor may choose to avoid leakage costs on state-of-the-art technology by restricting its technology transfer to technology that is only marginally superior to technology found in the host country (see Glass and Saggi, 1998). Such policies obviously limit the scope for horizontal spillovers via demonstration effects. The higher productivity of foreign affiliates may also lead to lower prices or less demand for the products of domestic competitors. If domestic firms fail to raise productivity in response to the increased competition, they will be pushed up their average cost curves. Ultimately, domestic producers may not merely fall behind, but fall by the wayside, driven out of business by the shock of foreign entry (see Aitken and Harrison, 1999, on this market-stealing effect). These partial effects are hard to disentangle empirically. We identify labor market spillovers by

including a measure that accounts for labor market effects next to a measure that incorporates the net effect of all other spillovers.

As seen from the top panel in Figure 1, backward spillovers go from the foreign firm to its upstream local suppliers. Thus, even if foreign firms attempt to minimize their technology leakage to direct competitors (horizontal effect), they may still want to assist their local suppliers in providing inputs of sufficient quality in order to realize the full benefits of their investment. In other words, they want the inputs from the host country to be lower cost yet similar in quality to inputs in the home country.¹ If the foreign firm decides to source locally, it may transfer technology to more than one domestic supplier and encourage upstream technology diffusion to circumvent a hold-up problem. Rodriguez-Clare (1996) shows that the backward linkage effect is more likely to be favorable when the good produced by the foreign firm uses intermediate goods intensively and when the home and host countries are similar in terms of the variety of intermediate goods produced. Under reversed conditions, the backward linkage effect could even damage the host country's economy.

Figure 1 also suggests how a forward spillover goes from the foreign firm to its downstream local buyer of inputs. The availability of better inputs due to foreign investment enhances the productivity of firms that use these inputs. However, there is also a danger that inputs produced locally by foreign firms are more expensive and less adapted to local requirements. In this case there would be a negative forward spillover.

The bottom panel of Figure 1 shows how the supply-backward spillover runs from the foreign firm through its local suppliers to the local customers of these suppliers. Markusen and Venables

¹This incentive is qualified, of course. First, when transportation costs between the home and host country are low enough, MNCs can source inputs in their home country rather than in the host country. Second, MNCs can put pressure on uncooperative local suppliers by inducing suppliers from their home country to invest in the host country, creating an isolated enclave of mutually linked foreign firms.

suggest a trade-off between increased product market competition, which they claim had an adverse effect on productivity, and inter-industry linkage effects, which are said to be positive. When vertical linkage effects are strong enough, foreign investors can stimulate demand for locally produced intermediate products. This demand stimulus encourages local suppliers to invest and produce inputs conforming to higher quality standards (see also Blomström and Kokko, 1998). This may not only exert a positive effect on the productivity of local intermediate good producers, but may also stimulate the productivity of their local customers.²

The existence, direction, and magnitude of spillovers may depend on the firm-specific level of technology. Findlay (1978) constructs a dynamic model of technology transfer through FDI from developed to developing countries. He argues that there is a positive connection between the distance to the world's technological frontier and economic growth. Findlay's model implies that productivity spillovers are an increasing function of the technology gap between foreign and domestic firms. Acemoglu et al. (2002) and Aghion et al. (2005) on the other hand use a Schumpeterian model to predict that firms that are close to the efficiency frontier benefit more from foreign presence than firms that are far from the frontier. This is the absorptive capability hypothesis. While Findlay suggests that spillovers are a negative function of the level of technology, the absorptive capability interpretation suggests a positive relation. Figure 2 suggests roughly how these competing hypotheses might give rise to non-linear relationships. In line with these competing hypotheses, Girma and Görg (2005) offer a U-shaped relationship between productivity growth and their horizontal spillover variable interacted with the level of technology. Girma (2005) observes that horizontal spillovers increase with absorptive capability up to a threshold level, beyond which the increase is much less pronounced.

²Because Markusen and Venables consider a two-sector model, local customers are always in the same industry as

< INSERT FIGURE 2 >

The existence, direction, and magnitude of spillovers may also depend on firm size. If larger firms have greater resources with which to exploit innovative opportunities, they should be able to benefit more from foreign technology. On the other hand, small and medium-sized firms are often important sources of innovation. Small firms make important contributions to innovation because they are less bureaucratic and exploit innovations that might otherwise appear insignificant to large firms (Sinani and Meyer, 2004). Grouping firms according to their size makes sense for a transition economy like Romania where large enterprises are typically former state enterprises that remain clumsy at adopting new technologies or adapting to change market conditions.

3. Empirical approach, data and variables

3.1 Empirical approach

We use a two-step procedure. The first step consists in the estimation of a standard production function. The second step relates the estimated total factor productivity to measures of FDI spillovers and several control variables.

Our initial problem is that firms react to firm-specific productivity shocks that are not observed by the researcher. For example, a firm confronted with a large positive productivity shock might respond by using more inputs. Griliches and Mairesse (1995) provide a detailed account of this foreign firms. We extend their idea to all local customers.

problem and make the case that inputs should be treated as endogenous variables since they are chosen on the basis of the firm's unobservable assessment of its productivity. OLS estimates of production functions therefore yield biased estimates of factor shares and biased estimates of productivity.³ We thus employ the semi-parametric approach suggested by Olley and Pakes (1996) and subsequently modified by Levinsohn and Petrin (2003). While details on the methodology appear in Appendix A, it is sufficient here to note that it allows for firm-specific productivity differences that exhibit idiosyncratic changes over time. We estimate domestic industry production functions for each industry j in the period 1998–2001, excluding foreign firms from the estimation. A measure of total factor productivity tfp_{it} is obtained as the difference between value added and capital and labor inputs, multiplied by their estimated coefficients:

$$\forall j : tfp_{it} = va_{it} - \beta_l l_{it} - \beta_k k_{it} \quad (1)$$

In the second step, we relate tfp_{ijrt} to a vector of spillover variables, **FDI**, a concentration index, H , and industry, region, and time dummies (α_j , α_r , and α_t). Note that we pool industries for the estimation of (2), whereas (1) is an industry-specific estimation.

$$tfp_{ijrt} = \alpha_i + \Psi_1 f(\mathbf{FDI}_{jt}, T_{ijrt}) + \alpha_2 H_{jt} + \alpha_j + \alpha_r + \alpha_t + \varepsilon_{ijrt} \quad (2)$$

Concentration (H_{jt}) is measured by the Herfindahl concentration index. The theoretical literature is inconclusive as to the impact of competition on productivity. Nickell (1996) finds a positive impact of competition on firm performance, which suggests a negative sign for α_2 . The vector of

³Specifically, the coefficient of labor is biased upwards, while the capital coefficient is biased downwards.

spillover variables (\mathbf{FDI}_{jt}) covers different transformations of the horizontal and vertical spillovers. We first look at the spillover variables traditionally considered in the literature. Next, we add the horizontal labor market spillover and the supply-backward spillover. We then interact the spillover variables with the firm-specific level of technology (T_{ijrt}) in a non-linear way. Finally, we consider whether the degree of foreign ownership and firm size play a role. Specification (2) is first differenced and estimated as a fixed effects model:

$$\Delta tfp_{ijrt} = \beta_i + \Omega_1 \Delta f(\mathbf{FDI}_{jt}, T_{ijrt}) + \beta_2 H_{jt} + \beta_t + \varepsilon_{ijrt} \quad (3)$$

The fixed effects control for all time-invariant firm-specific unobservables driving productivity growth, including region and industry effects. The first-differenced time dummies still control for the business cycle. Because \mathbf{FDI}_{jt} and H_{jt} are defined at the industry level, while estimations are performed at the firm level, standard errors need to be adjusted (see Moulton, 1990). Standard errors are clustered for all observations in the same industry and year.

3.2 Data description and variable definitions

Romanian firm-level data for 1996–2001 are drawn from the Amadeus database published on DVD and CD by Bureau Van Dijk. The entire Amadeus series is used to construct a database of time-specific foreign entry in local Romanian firms.⁴ The sample is unbalanced due to firms entering in later years, both because of increased coverage and new start-ups. Industry price level

⁴Amadeus DVDs are released each year. They provide a pan-European database of financial information on public and private companies. Specific entries, however, only indicate the most recent ownership information. Since ownership information is gathered at irregular intervals, we do not have ownership information for all years and firms. Ownership changes tend to show up *ex post* in the database. Therefore, if a given firm has any gaps in its ownership series, we fill the gaps with the information from the following year.

data at Nace 2-digit level are taken from the Industrial Database for Eastern Europe from the Vienna Institute for International Economic Studies and from the Statistical Yearbook of the Romanian National Statistical Office (RNSO). Our industry classification follows the classification used in the Romanian input-output (IO) tables. This classification is then linked to the Nace classification scheme. IO tables for the period 1995–2001 were obtained from the RNSO.

The matrix **FDI** in (3) contains measures of foreign presence to capture the different spillovers described above. We classify a firm as foreign ($Foreign = 1$) when foreign participation exceeds 10%.⁵ The horizontal spillover variable $Horizontal_{jt}^X$ captures the degree of foreign presence in sector j at time t and is measured as:

$$Horizontal_{jt}^X = \frac{\sum_{i \in j} Foreign_{it} * X_{it}}{\sum_{i \in j} X_{it}} \quad (4)$$

where X_{it} refers to either employment L_{it} for the horizontal labor market spillover, and real output Y_{it} for the net other horizontal spillover. $Horizontal_{kt}^{Y(L)}$ is industry k 's share of output (labor) produced (employed) by foreign-owned firms.

For the measurement of the backward spillover variable $Backward_{jt}$, one possibility might be to employ the share of firm output sold to foreign firms. However, this information is unavailable from our dataset. Moreover, the share of firm output sold to foreign-owned firms may cause endogeneity problems if the latter prefer to buy inputs from more productive domestic firms. We thus measure $Backward_{jt}$ as:

$$Backward_{jt} = \sum_{k|k \neq j} \gamma_{jkt} * Horizontal_{kt}^Y \quad (5)$$

where γ_{jkt} is the proportion of industry j 's output supplied to sourcing industry k at time t . The γ s are calculated from the time-varying IO tables for intermediate consumption. In the calculation of γ , we explicitly exclude inputs sold within the firm's industry ($k \neq j$) because this is captured by $Horizontal_{jt}^Y$. Since firms cannot easily switch between industries for their inputs, we avoid the problem of endogeneity by using the share of industry output sold to downstream domestic markets k with some level of foreign presence $Horizontal_{kt}^Y$. In the same spirit, we define the forward spillover variable $Forward_{jt}$ as:

$$Forward_{jt} = \sum_{l|l \neq j} \delta_{jlt} * Horizontal_{lt}^Y \quad (6)$$

where the IO tables reveal the proportion δ_{jlt} of industry j 's inputs purchased from upstream industries l . Inputs purchased within the industry ($l \neq j$) are again excluded, since this is already captured by $Horizontal$.

The variable $SupplyBackward_{jt}$, which captures the hypothesis of Markusen and Venables, is constructed as:

$$SupplyBackward_{jt} = \sum_{l|l \neq j} \delta_{jlt} * Backward_{lt} \quad (7)$$

where δ_{jlt} reveals again the proportion of industry j 's inputs purchased from upstream industries l that in turn supply the downstream industries of foreign firms as measured by $Backward_{lt}$. Identification is possible as long as the share of industry a 's output supplied to its downstream industry b , i.e. γ_{ab} , is sufficiently different from the share of industry b 's inputs purchased from upstream industry a , i.e. δ_{ba} . This is the case for our IO tables.

⁵This threshold level is commonly applied (e.g. by the OECD) in FDI definitions.

Our measure of the level of technology needs to reflect the relative technical capabilities of a domestic firm vis-à-vis the efficiency frontier embodied by foreign firms' efficiency in the same industry. In constructing the measure T_{it} , we apply the Levinsohn-Petrin technique on earlier years of the full sample of both domestic and foreign firms to avoid endogeneity. The estimated relation is then used to derive total factor productivity measures φ_{it} for all firms. T_{it} is defined in (8) as the distance between firm i 's lagged productivity level, φ_{it-1} , and the lagged “foreign frontier” in its industry. The latter is defined as the mean productive efficiency of the 25% most productive foreign firms in industry j ($\bar{\varphi}_{jt-1,FOR}$). More productive firms have higher values of T .

$$T_{it} = \frac{\varphi_{it-1}}{\bar{\varphi}_{jt-1,FOR}} \quad (8)$$

We integrate the level of technology in the analysis by considering the interaction of T with *Horizontal*, *Backward*, *Forward*, and *SupplyBackward*. Since the above discussion suggests possible non-linearities, we consider interactions with the squared level of technology (T^2). Table 1 gives summary statistics for the variables described here.

< INSERT TABLE 1 >

4. Results

4.1 Labor market and supply-backward spillover

< INSERT TABLE 2 >

In Table 2, we introduce the horizontal labor market spillover and the supply-backward spillover. Panel A reports the results for all industries. We report different combinations of the variables. In contrast to Konings (2001), we find that local firm productivity is enhanced by horizontal labor market spillovers. This finding is robust throughout the paper and confirms the findings of Görg and Strobl (2005). Other net horizontal spillovers exert no positive effect on local firm productivity. Inspection of the coefficients of the vertical spillover variables reveals that the supply-backward spillover is economically more important than horizontal spillovers. The estimated coefficient for the supply-backward spillover is consistently positive and is inclined to be statistically significant. This lends support to the hypothesis of Markusen and Venables (1999). Forward linkages to foreign firms are found to fuel total factor productivity of domestic firms, while backward linkages to foreign firms appear detrimental to total factor productivity. In panel B, we repeat our estimations for manufacturing industries only. We employ reduced IO tables for manufacturing to recalculate the spillover variables. The results change drastically. Most spillovers are no longer statistically different from zero. Only the backward spillover retains its statistical significance. The economic conclusion is now in line with earlier findings: backward links of local manufacturing firms to foreign firms are now beneficial to total factor productivity. This reversal of results should not come as a surprise. According to Romania's

National Trade Register Office,⁶ 4% of all foreign affiliates in Romania were located in the primary sector, 19% in the secondary sector, and 77% in the tertiary sector at the end of 2002. Limiting the analysis to manufacturing ignores the lion's share of foreign affiliates operating in Romania. Many are upstream service industries, and neglecting the effect of their improved productivity on the rest of the economy could well lead to inappropriate conclusions. Therefore we will consider all industries in the remainder of the paper.

4.2 Level of technology

< INSERT TABLE 3 >

< INSERT TABLE 4 >

< INSERT FIGURE 3 >

In Table 3, we allow non-linear interactions of the spillover variables with the level of technology.⁷ The first column gives the results for all firms, while further columns give results for three split samples: small, medium-sized, and large firms. The implied non-linear relation between the spillovers and the level of technology is shown in Figure 3. In table 4 we report joint significance tests for all spillover variables and their interactions with the firm-specific level of technology T . The interactions between spillover variables and the level of technology can generally not be rejected. Even the output-based horizontal spillover exhibits a significant interaction with the level of technology for small and medium-sized firms. The interaction with the level of technology turns out to be non-linear, except for supply-backward spillovers to medium-sized and large firms.

⁶Data reported in the World Investment Report 2005, UNCTAD.

Firm size plays an important role. Generally, spillover effects seem to be larger for small and medium-sized firms than for large firms in both directions. On one hand, smaller firms may more easily adapt to newer and better inputs and find it easier to adjust their production processes, allowing larger positive spillovers. On the other hand, they may be less resilient to potential negative spillovers as they face harder budget constraints. This could be specifically true for Romania. Most large enterprises are former state enterprises that, while poor at adopting new technologies, are well connected to the sources of soft finance.

The horizontal labor market spillover seems to be very positive, although the relation is not highly stable across size classes. F-tests in table 4 reject zero labor market effects. The non-linear interaction with the level of technology (small firms excluded) is not rejected. This lends support to the absorptive capability hypothesis. Access to higher skilled labor through foreign presence in the industry is positive for all domestic firms, though most of the benefits go to firms that were already more productive. The backward spillover is found to be mainly negative, but the interaction with the level of technology is not very stable across size classes. Forward spillovers in turn are not rejected in any size class by the F-tests. The results reveal a U-shape relation between the level of technology and the contribution of forward spillovers to total factor productivity. This relation is very robust across size classes, lending support to the conjecture that both the Findlay and the absorptive capability hypothesis are at work. Nevertheless, the exact shape of the relation suggests that the access to better inputs because of foreign direct investment mainly benefits the more productive domestic firms. The supply-backward spillover is strongly detected for small firms, and less convincingly for medium-sized and large firms. Better inputs through foreign presence in not directly related industries mainly benefits small firms, provided

⁷The results for manufacturing only are available on request.

that their level of technology is high enough to absorb these better inputs.

4.3 Economic significance

< INSERT TABLE 5 >

Most spillover studies limit themselves to the presentation of statistically significant spillover channels, as presented in Figure 3. Figure 3 merely portrays the contribution of the spillovers to TFP as a function of the firm's level of technology at the average values of the spillover variables.⁸ This neither reveals what actually happened to Romanian firms, nor provides a sound basis for FDI policy.⁹ Since firms are subject to all spillover effects at the same time, the correlations between the spillover variables will matter to understand the precise economic effects. Moreover, the spillover variables, their correlation structure, and the firm's level of technology change over the time period considered. To present the economic significance of spillover effects for the domestic Romanian firms in the period 1998-2001 we use the results of Table 3 to calculate the total net effect of foreign presence on domestic firms. We predict the contribution to total factor productivity of the different spillovers at the firm level by multiplying the estimated coefficients with the actual values of the variables concerned. Table 5 shows the spillovers' contribution to total factor productivity growth during the period 1998–2001, averaged over firms for different ranges of their initial level of technology. The breakdown in technology ranges is based on the 1998 level of technology percentiles.

⁸ Note also that firms are not uniformly distributed over the horizontal axis in figure 3.

⁹ One firm's horizontal effect is also the basis for another firm's vertical effect. What is then the policy advise if

Results in table 5 reveal that the average Romanian firm enjoyed positive total net spillovers at any initial level of technology during the period 1999-2001. The average contribution to total factor productivity ranges from 21% (firms with the lowest initial level of technology) to 47% (firms with the highest initial level of technology). This hints at the importance of absorptive capability to assess the economic impact of our results. The supply-backward spillover is an important contributor to the productivity growth of Romanian firms. It accounts for more than 40 percent of total net spillovers on average and is especially important for small and medium-sized firms and the technologically most advanced firms. The forward spillover, in contrast, is highly positive for technologically less advanced firms, while the effect is smaller, but still positive, for technologically more advanced firms. The strong combined effect of the forward and the backward spillover suggest that better inputs in some way or other explain the lion's share of FDI-fuelled productivity growth. Backward spillovers are detrimental across the board, and especially for smaller firms. It is unclear as why foreign clients seem less eager to transfer technology to small local firms. This may be due to a lack of awareness or a greater worry over technology leakage. Note however that backward spillovers turn positive, in line with the rest of the literature, if we restrict the sample to manufacturing firms (results available on request). Interestingly, horizontal labor market spillovers are always positive and dominate the other net horizontal spillovers. Labor market spillovers are especially beneficial to small firms, and nearly zero for large firms, confirming the F-tests above. Small firms seem to benefit most from foreign technology diffusion through the local labor market. The other horizontal spillovers are not only smaller than labor market spillovers, but also often negative, certainly for large firms. Large firms appear to have suffered most from market-stealing.

horizontal effects are negative and vertical effects positive?

5. Conclusions

This study analyzes horizontal and vertical productivity spillovers of foreign direct investment on domestic Romanian companies from 1998 to 2001, a period when the Romanian economy experienced substantial structural changes. We therefore employ a series of input-output tables for the calculation of vertical spillovers. Since the lion's share of foreign affiliates operates in the services sector, we do not restrict our sample to manufacturing. Our main contribution is the identification of two new spillovers effects, the horizontal labour market spillover and the supply-backward spillover. Since competing hypotheses exist about the interaction between the level of technology and spillover effects, we include non-linear interaction effects between all spillover variables and the firm-specific level of technology.

Horizontal labor market spillovers tend to be positive, while net other horizontal spillovers tend to be insignificant, with the exception of a market-stealing effect for large firms. The established result that vertical spillovers are economically more important than horizontal spillovers is confirmed. This is certainly the case for the newly defined supply-backward spillover: buying goods from firms that also supply to foreign firms in a different industry was found to enhance total factor productivity greatly, lending support to the theory of Markusen and Venables (1999). Forward spillovers were generally positive and exhibited a U-shaped relation with the level of technology across size classes. This lends support to the conjecture that both the Findlay and the absorptive capability hypothesis are at work. Backward spillovers are generally detrimental, but positive backward spillovers are found among manufacturing industries. When all spillover effects are accounted for, the average Romanian firm enjoys economically large positive total net spillovers at any initial level of technology. The effect is distinctly positive for firms with the

highest level of technology. Together the newly introduced horizontal labor market and supply-backward spillovers account for half of the positive impact of foreign entry on Romanian domestic firms' total factor productivity.

References

Acemoglu, D., Aghion, P., and Zilibotti, F., 2002. Vertical Integration and Distance to Frontier. *Journal of the European Economic Association, Papers and Proceedings*.

Aitken, B., Harrison, A., 1999. Do Domestic Firms Benefit from Direct Foreign Investment? Evidence from Venezuela. *American Economic Review* 89(3), 605-618.

Aitken, B., Harrison, A., and Lipsey, R., 1996. Wages and Foreign Ownership: A Comparative Study of Mexico, Venezuela and the United States. *Journal of International Economics* 40, 345-371.

Aghion, P., Bloom, N., Blundell, R., Griffith, R., Howitt, P., 2005. Competition and Innovation: An Inverted U Relationship. *Quarterly Journal of Economics* 120(2), 701-.

Blalock, G., Gertler, P., 2004. Firm Capabilities and Technology Adoption: Evidence from Foreign Direct Investment in Indonesia. *Mimeo*.

Blomström, M., Kokko, A., 1998. Multinational Corporations and Spillovers. *Journal of Economic Surveys* 12(3), 247-277.

Bureau van Dijk Electronic Publishing, *Amadeus Database*, Brussels, Belgium, various issues.

Caves, R., 1974. Multinational Firms, Competition and Productivity in Host-Country Markets. *Economica* 41(162), 176-193.

Crespo, N., Fontoura, M.P., 2007. Determinant Factors of FDI Spillovers – What Do We Really Know? *World Development* 35(3), 410-425.

Findlay, R., 1978. Relative Backwardness, Direct Foreign Investment, and the Transfer of Technology: A Simple Dynamic Model. *Quarterly Journal of Economics* 92(1), 1-16.

Fosfuri, A., Motta, M., Rønde, T., 2001. Foreign Direct Investment and Spillovers through Workers' Mobility. *Journal of International Economics* 53(1), 205-222.

Glass, A., Saggi, K., 1998. International Technology Transfer and the Level of Technology. *Journal of Development Economics* 55, 369-398.

Glass, A., Saggi, K., 2002. Multinational Firms and Technology Transfer. *Scandinavian Journal of Economics* 104(4), 495-513.

Görg, H., Greenaway, D., 2004. Much Ado About Nothing? Do Domestic Firms Really Benefit from Foreign Direct Investment? *World Bank Research Observer* 19, 171-197.

Görg, H., Strobl, E., 2005. Spillovers from Foreign Firms through Worker Mobility: An Empirical Investigation. *Scandinavian Journal of Economics* 107(4), 693-709.

- Gorodnichenko, Y., Jan Svejnar, J., Terrell K., 2007, When does FDI have positive spillovers? evidence from 17 emerging market economies, CEPR Discussion Paper 6546.
- Griliches, Z., Mairesse, J., 1995. Production Functions: The Search for Identification. National Bureau of Economic Research, NBER Working Paper: No. 5067.
- Girma, S., 2005. Absorptive Capacity and Productivity Spillovers from FDI: A Threshold Regression Analysis. *Oxford Bulletin of Economics and Statistics* 67(3), 281-306.
- Girma, S., Görg, H., 2005. Foreign Direct Investment, Spillovers and Absorptive Capability: Evidence from Quartile Regressions. The Kiel Institute for the World Economy, Kiel Working Paper: No. 1248.
- Kokko, A., Tansini, R., Zejan, M., 1996. Local Technological Capability and Productivity Spillovers from FDI in the Uruguayan Manufacturing Sector. *The Journal of Development Studies* 32(4), 602-611.
- Konings, J., 2001. The Effects of Foreign Direct Investment on Domestic Firms – Evidence from Firm-Level Panel Data in Emerging Economies. *Economics of Transition* 9(3), 619-633.
- Kugler, M., 2006, Spillovers from foreign direct investment: Within or between industries? *Journal of Development Economics* 80, 444—477.
- Lall, S., 1980. Vertical Interfirm Linkages in LDCs: An Empirical Study. *Oxford Bulletin of Economics and Statistics* 42(3), 203-226.
- Levinsohn, J., Petrin, A., 2003. Estimating Production Functions Using Inputs to Control for Unobservables. *Review of Economic Studies* 70(2), 317-341.
- McAleese, D., McDonald, D., 1978. Employment Growth and Development of Linkages in Foreign-owned and Domestic Manufacturing Enterprises. *Oxford Bulletin of Economics and Statistics* 40(4), 321-339.
- Markusen, J., 1995. The Boundaries of Multinational Enterprises and the Theory of International Trade. *Journal of Economic Perspectives* 9(2), 169-189.
- Markusen, J., Venables, A., 1999. Foreign Direct Investment as a Catalyst for Industrial Development. *European Economic Review* 43(2), 335-356.
- Moulton, B., 1990. An Illustration of a Pitfall in Estimating the Effects of Aggregate Variables on Micro Units. *Review of Economics and Statistics* 72(2), 334-338.
- Nickell, S., 1996. Competition and Corporate Performance. *Journal of Political Economy* 104(4), 724-746.
- Organization for Economic Cooperation and Development (OECD), 2002. OECD Economic Survey Romania. *OECD Economic Surveys* 2002(17).
- Olley, S., Pakes, A., 1996. The Dynamics of Productivity in the Telecommunications Equipment

Industry. *Econometrica* 64(6), 1263-1297.

Petrin, A., Poi, B., Levinsohn, J., 2004. Production Function Estimation in Stata Using Inputs to Control for Unobservables. *The Stata Journal* 4(2), 113-123.

Rodríguez-Clare, A., 1996. Multinationals, Linkages, and Economic Development. *American Economic Review* 86(4), 852-873.

Rodrik, D., 1999. The New Global Economy and Developing Countries: Making Openness Work. Overseas Development Council (Baltimore, MD), Policy Essay No. 24.

Romanian National Statistical Office (RNSO), 2005. Statistical Yearbook. Bucharest, Romania.

Schoors, K., van der Tol, B., 2002. Foreign Direct Investment Spillovers within and between Sectors: Evidence from Hungarian Data. Ghent University Faculty of Economics and Business Administration Working Paper: No. 02/157.

Sinani, E., Meyer, K., 2004. Spillovers of Technology Transfer from FDI: The Case of Estonia. *Journal of Comparative Economics* 32(3), 445-466.

Sjöholm, F., 1999. Level of Technology, Competition and Spillovers from Foreign Direct Investment: Evidence from Establishment Data. *Journal of Development Studies* 36(1), 53-73.

Smarzynska Javorcik, B., 2004. Does Foreign Direct Investment Increase the Productivity of Domestic Firms? In Search of Spillovers Through Backward Linkages. *American Economic Review* 94(3), 605-627.

Teece, D., 1977. Technology Transfer by Multinational Firms: The Resource Cost of Transferring Technological Know-how. *Economic Journal* 87(346), 242-261.

United Nations Conference on Trade and Development (UNCTAD), 2005. World Investment Report. Transnational Corporations and the Internalization of R&D. United Nations, New York.

Vienna Institute for International Economic Studies, 2004, Industrial Database Eastern Europe. Vienna, Austria.

Yudaeva, K., Kozlov, K., Melentieva, N., Ponomareva, N., 2003. Does Foreign Ownership Matter? Russian Experience. *Economics of Transition* 11(3), 383-410.

APPENDIX A: Production function estimation

We estimate the following production function sector by sector to derive sector-specific labor and capital intensities.

$$\forall j : \ln VA_{irt} = \beta_0 + \beta_l \ln L_{irt} + \beta_k \ln K_{irt} + \omega_t + \eta_t \quad (9)$$

where subscripts irt stand for firm i and region r at time t , and j stands for sector j . VA stands for real value added of the firm, L is the freely variable input labor and K is the state variable capital. The error has two components, the transmitted productivity component given as ω , and η , an error term that is uncorrelated with input choices. The key difference between ω and η is that the former is a state variable and hence impacts the firm's decision rules. ω is not observed by the econometrician; instead the firm immediately adjusts its freely variable input L in response. We focus on value added rather than sales because it is a better measure of firm performance. Consider the following version where small cases refer to variables in logs and firm and region subscripts have been dropped.

$$va_t = \beta_0 + \beta_l l_t + \beta_k k_t + \omega_t + \eta_t \quad (10)$$

Levinsohn and Petrin (2003) start by assuming that the demand for the intermediate input, materials m_t , depends on the firm's state variables k_t and ω_t :

$$m_t = m_t(k_t, \omega_t) \quad (11)$$

Making mild assumptions about the firm's production technology, it can be shown that the demand function is monotonically increasing in ω_t . This allows inversion of the intermediate

demand function, so ω_t can be written as a function of k_t and m_t .¹⁰

$$\omega_t = \omega_t(k_t, m_t) \quad (12)$$

The unobservable productivity term is now expressed solely as a function of two observed inputs. Following Olley and Pakes (1996), Levinsohn and Petrin (2003) make a final identification restriction by assuming that productivity is governed by a first-order Markov process:

$$\omega_t = E[\omega_t | \omega_{t-1}] + \xi_t \quad (13)$$

where ξ_t is an innovation to productivity that is uncorrelated with k_t (but not necessarily with l_t ; this is part of the source of the simultaneity problem). The estimation routine itself starts with transforming (10).

$$\begin{aligned} va_t &= \beta_0 + \beta_l l_t + \beta_k k_t + \omega_t + \eta_t \\ &= \beta_l l_t + \phi_t(k_t, m_t) + \eta_t \end{aligned} \quad (14)$$

where

$$\phi_t(k_t, m_t) = \beta_0 + \beta_k k_t + \omega_t(k_t, m_t) \quad (15)$$

By substituting a third-order polynomial approximation in k_t and m_t for $\phi_t(k_t, m_t)$, it is possible to consistently estimate parameters as

¹⁰Due to possible correlation with labor and capital, direct FDI participation in the firm may distort the estimation. We focus here solely on domestic firms. What about the spillovers? Since we estimate a production function for each sector separately and because the spillover variables are sector-specific, there is only variation in the time dimension. The correlation between spillover variables on one hand, and labor and capital on the other, is fairly low (below 0.2 for almost all spillovers in all sectors). Furthermore, the possible correlation will to some extent be accounted for in the analysis. If ω_t is a function of foreign presence, this will be reflected in material input choice as $m_t = m_t(k_t, \omega_t(\text{foreign}))$. The inverted function would read $\omega_t = \omega_t(k_t, m_t(\text{foreign}))$.

$$va_t = \delta_0 + \beta_l l_t + \sum_{g=0}^3 \sum_{h=0}^{3-h} \delta_{gh} k_t^g m_t^h + \eta_t \quad (16)$$

where β_0 is not separately identified from the intercept of $\phi_t(k_t, m_t)$. This completes the first stage of the estimation routine from Levinsohn and Petrin (2003), from which an estimate of β_l and an estimate of ϕ_t (up to the intercept) are available. The second stage of the estimation procedure begins by computing the estimated value for ϕ_t using

$$\hat{\phi}_t = va_t - \beta_l l_t \quad (17)$$

$$= \hat{\delta}_0 + \sum_{i=0}^3 \sum_{j=0}^{3-i} \delta_{ij} k_t^i m_t^j \quad (18)$$

For any candidate values β_k^* , one can compute (up to a scalar constant) a prediction for ω_t for all periods t using

$$\hat{\omega}_t = \hat{\phi}_t - \beta_k^* k_t \quad (19)$$

Taking the $\hat{\omega}_t$'s for all t , a consistent (non-parametric) approximation to $E[\omega_t | \omega_{t-1}]$, say $E[\hat{\omega}_t | \omega_{t-1}]$, is given by the predicted values from the regression

$$\hat{\omega}_t = \gamma_0 + \gamma_1 \hat{\omega}_{t-1} + \gamma_2 \hat{\omega}_{t-1}^2 + \gamma_3 \hat{\omega}_{t-1}^3 + \varepsilon_t \quad (20)$$

Given β_l , β_k^* , and $E[\hat{\omega}_t | \omega_{t-1}]$ the sample residual of the production function can be written as

$$\hat{\eta}_t + \xi_t = va_t - \beta_l l_t - \beta_k^* k_t - E[\hat{\omega}_t | \omega_{t-1}] \quad (21)$$

The estimate $\hat{\beta}_k$ of β_k can then be defined as the solution to¹¹

$$\min_{\beta_k^*} \sum_t \left(va_t - \beta l_t - \beta_k^* k_t - E \left[\hat{\omega}_t \mid \omega_{t-1} \right] \right)^2 \quad (22)$$

Since each of the two main stages of estimation involves a number of preliminary estimators, the covariance matrix of the final parameters must account for the sampling variation introduced by all of the estimators used in the two stages. Although deriving an analytic covariance matrix may be feasible, this calculation is not trivial. Instead, Levinsohn and Petrin (2003) substitute computational power for analytic difficulties, employing the bootstrap method to estimate standard errors.¹²

For the estimation the data are taken from the Amadeus database, described in the main text. Value added is calculated as real output Y , measured as sales deflated by producer price indices of the appropriate Nace industry minus real material input M , measured as material costs deflated by a weighted intermediate input deflator where the industry-specific weighting scheme is drawn from the IO tables. Labor L is expressed as the number of employees. Real capital K is measured as fixed assets, deflated by the average of the deflators for the following five Nace industries: machinery and equipment (29); office machinery and computing (30); electrical machinery and apparatus (31); motor vehicles, trailers, and semi-trailers (34); and other transport equipment (35). This approach follows Smarzynska Javorcik (2004).

¹¹A golden-section search algorithm is used to minimize (22).

¹²Given the use of panel data, sampling occurs with replacement from firms, using the entire time series of observations for that firm in the bootstrapped sample when the firm's ID-number is randomly drawn. A bootstrapped sample is complete when the number of firm-year observations (closely) equals the number of firm-year observations in the original sample. The variation in the point estimates across the bootstrapped samples provides an estimate for the standard errors of the original point estimates (see Petrin *et al.*, 2004).

Table 1: Summary statistics for the full and domestic sample

	full sample		domestic sample	
	mean	st. dev.	mean	st. dev.
ln real value added	8.308	2.052	8.149	1.989
ln real capital	7.366	2.460	7.185	2.407
ln labor	1.823	1.457	1.737	1.407
ln TFP	5.338	1.201	5.284	1.176
level of technology	0.171	0.190	0.160	0.179
Herfindahl	0.025	0.046	0.024	0.044
Horizontal ^Y	0.256	0.156	0.248	0.153
Horizontal ^L	0.190	0.149	0.183	0.145
Backward	0.257	0.074	0.256	0.076
Forward	0.303	0.073	0.303	0.073
SupplyBackward	0.266	0.039	0.265	0.039

Table 2: Effect of introducing of the horizontal labor market spillover and the supply-backward spillover variables

<i>Panel A - Results for all industries</i>					
	(1)	(2)	(3)	(4)	(5)
Δ Horizontal ^Y	-0.020 [0.04]	-0.142 [0.25]	-0.041 [0.07]	-0.389 [0.66]	-0.334 [0.57]
Δ Horizontal ^L		0.749 [2.30]**	0.799 [2.41]**	0.761 [2.23]**	0.690 [2.16]**
Δ Backward	-0.701 [2.56]**	-0.676 [2.81]***	-0.619 [2.52]**		-0.562 [2.28]**
Δ Forward	1.183 [2.02]**	1.325 [2.22]**	1.489 [2.60]***	1.196 [1.99]**	
Δ SupplyBackward	2.767 [2.16]**	2.073 [1.64]		1.695 [1.37]	3.027 [2.59]***
N	150626	150626	150626	150626	150626
# firms	68233	68233	68233	68233	68233
R ²	0.02	0.02	0.02	0.02	0.02
<i>Panel B - Results for manufacturing industries</i>					
	(1)	(2)	(3)	(4)	(5)
Δ Horizontal ^Y	-0.106 [1.11]	-0.076 [0.81]	-0.069 [0.77]	-0.041 [0.42]	-0.078 [0.85]
Δ Horizontal ^L		-0.208 [1.19]	-0.218 [1.25]	-0.192 [1.10]	-0.214 [1.14]
Δ Backward	0.501 [2.20]**	0.523 [2.32]**	0.530 [2.38]**		0.533 [2.33]**
Δ Forward	0.103 [0.46]	0.038 [0.20]	0.034 [0.17]	0.140 [0.70]	
Δ SupplyBackward	0.361 [0.68]	0.266 [0.51]		0.325 [0.61]	0.262 [0.51]
N	55629	55629	55629	55629	55629
# firms	25096	25096	25096	25096	25096
R ²	0.01	0.01	0.01	0.01	0.01

Second-step fixed effect estimates for domestic firms; the dependent variable is firm-level TFP growth based on first-step production function estimates. Robust t-statistics in brackets;*/**/*** denotes significance at 10/5/1 percent.

Table 3: Impact of the interaction of spillover variables with the level of technology (T) and sample splits based on firm size (L) - Results for all industries

	All firms	L<5	5≤L<50	L≥50
Δ Horizontal ^Y	-0.293 [0.50]	-0.503 [0.79]	0.129 [0.25]	-1.054 [2.29]**
Δ (T*Horizontal ^Y)	1.086 [1.17]	4.538 [3.38]***	0.758 [0.82]	1.023 [1.36]
Δ (T ² *Horizontal ^Y)	-0.515 [1.32]	-2.446 [3.82]***	-0.851 [2.23]**	-0.626 [1.38]
Δ Horizontal ^L	0.960 [2.54]**	1.166 [3.17]***	0.686 [2.18]**	0.175 [0.57]
Δ (T*Horizontal ^L)	-1.153 [1.61]	-1.542 [1.59]	-0.950 [1.28]	-1.032 [1.30]
Δ (T ² *Horizontal ^L)	0.756 [2.10]**	0.606 [0.82]	1.227 [2.48]**	1.054 [2.23]**
Δ Backward	-0.893 [3.68]***	-0.989 [3.70]***	-0.785 [3.59]***	-0.507 [1.88]*
Δ (T*Backward)	1.442 [2.07]**	1.106 [0.94]	0.928 [1.26]	1.424 [1.33]
Δ (T ² *Backward)	-1.524 [3.47]***	-1.444 [1.55]	-1.354 [2.56]**	-0.835 [1.22]
Δ Forward	2.328 [3.64]***	2.337 [3.67]***	1.953 [3.11]***	1.728 [3.78]***
Δ (T*Forward)	-4.139 [2.60]***	-3.132 [1.69]*	-2.973 [1.50]	-4.025 [3.56]***
Δ (T ² *Forward)	3.029 [3.38]***	3.390 [3.19]***	3.258 [2.96]***	2.412 [4.78]***
Δ SupplyBackward	1.959 [1.74]*	2.530 [1.87]*	2.801 [2.67]***	-0.484 [0.50]
Δ (T*SupplyBackward)	-4.309 [2.04]**	-12.737 [4.41]***	-4.369 [1.84]*	-0.914 [0.50]
Δ (T ² *SupplyBackward)	0.381 [0.30]	4.465 [2.75]***	-0.072 [0.05]	-1.061 [1.11]
N	120317	56095	53348	10874
# firms	55097	30866	26351	4993
R ²	0.09	0.12	0.11	0.13

Second-step fixed effect estimates for domestic firms; the dependent variable is first-differenced firm level TFP based on the first-step production function estimates. Columns 2-4 are split-samples according to the domestic firm's number of employees, L. Robust t-statistics in brackets; */**/** denotes significance at 10/5/1 percent.

Table 4: Impact of the interaction of spillover variables with the level of technology (T) and sample splits based on firm size (L) - Results for all industries - F-tests

	All firms	L<5	5≤L<50	L≥50
F-tests				
<i>No T-Horizontal^Y</i>	0.87	7.29***	4.10**	1.02
<i>No Horizontal^Y</i>	0.59	5.11***	2.83**	2.26*
<i>No T-Horizontal^L</i>	2.32*	1.50	4.36**	3.32**
<i>No Horizontal^L</i>	3.94***	3.35**	5.32***	2.23*
<i>No T-Backward</i>	6.61***	1.37	4.12**	0.89
<i>No Backward</i>	7.78***	5.35***	6.53***	1.27
<i>No T-Forward</i>	6.26***	6.81***	7.50***	11.62***
<i>No Forward</i>	6.81***	7.69***	6.64***	9.17***
<i>No T-SupplyBackward</i>	6.38***	11.71***	6.61***	4.97***
<i>No SupplyBackward</i>	4.56***	8.36***	6.34***	4.09***

“*No T-Spillover*” is a test for the joint significance of the T and T² interactions with the respective spillover variable, “*No Spillover*” is a test for the joint significance of the T and T² interactions and the level of the respective spillover variables. Columns 2-4 are split-samples according to the domestic firm's number of employees, L.

*/**/** denotes rejection at 10/5/1 percent.

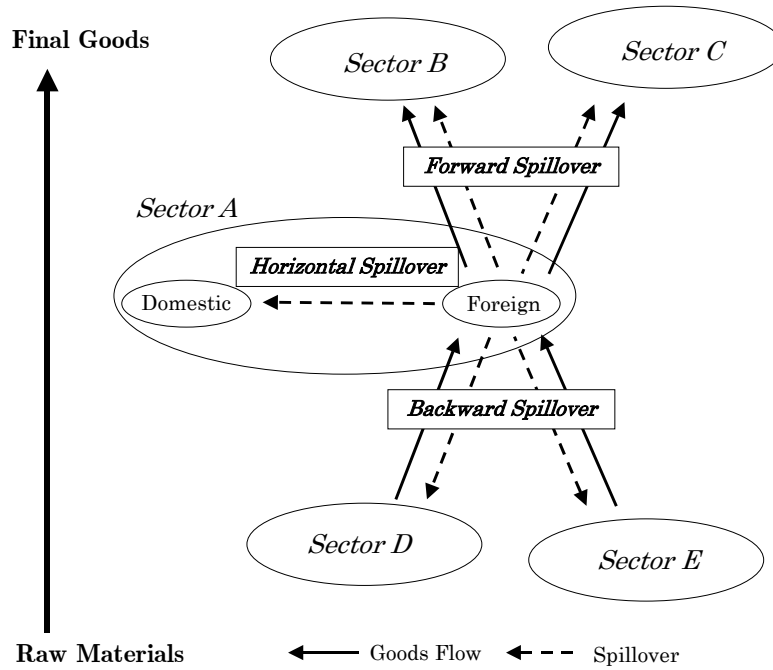
Table 5: Actual domestic firm TFP-increase during 1998-2001 due to spillover effects for different categories of firm size (L) and the initial level of technology in 1998 (T98)

	horizontal1	horizontal2	backward	forward	supplyback	Total
<i>All</i>	-0.013	0.045	-0.058	0.195	0.120	0.290
p1<T98<p10	-0.004	0.033	-0.040	0.157	0.073	0.218
p10<T98<p25	-0.006	0.035	-0.053	0.183	0.088	0.246
p25<T98<p50	-0.008	0.037	-0.061	0.183	0.094	0.245
p50<T98<p75	-0.011	0.047	-0.063	0.198	0.109	0.280
p75<T98<p90	-0.021	0.060	-0.066	0.229	0.154	0.355
p90<T98<p99	-0.035	0.063	-0.046	0.222	0.272	0.476
<i>L<5</i>	-0.016	0.055	-0.068	0.202	0.131	0.304
p1<T98<p10	0.006	0.054	-0.053	0.188	0.053	0.248
p10<T98<p25	0.003	0.050	-0.062	0.203	0.070	0.265
p25<T98<p50	-0.001	0.046	-0.073	0.189	0.081	0.243
p50<T98<p75	-0.016	0.054	-0.074	0.205	0.135	0.305
p75<T98<p90	-0.063	0.075	-0.077	0.239	0.267	0.441
p90<T98<p99	-0.116	0.090	-0.053	0.197	0.471	0.589
<i>5 ≤ L < 50</i>	0.014	0.041	-0.056	0.186	0.181	0.367
p1<T98<p10	0.018	0.033	-0.046	0.167	0.095	0.268
p10<T98<p25	0.014	0.037	-0.059	0.196	0.124	0.312
p25<T98<p50	0.016	0.038	-0.060	0.192	0.131	0.317
p50<T98<p75	0.016	0.044	-0.060	0.187	0.154	0.341
p75<T98<p90	0.009	0.046	-0.060	0.200	0.209	0.405
p90<T98<p99	0.011	0.037	-0.034	0.153	0.371	0.537
<i>L ≥ 50</i>	-0.031	0.007	-0.035	0.127	0.022	0.091
p1<T98<p10	-0.010	0.008	-0.021	0.093	0.007	0.078
p10<T98<p25	-0.012	0.004	-0.033	0.113	0.017	0.089
p25<T98<p50	-0.019	0.004	-0.038	0.124	0.009	0.079
p50<T98<p75	-0.033	0.009	-0.039	0.142	0.012	0.090
p75<T98<p90	-0.056	0.014	-0.039	0.154	0.029	0.101
p90<T98<p99	-0.070	0.004	-0.036	0.133	0.093	0.124

Table entries are averaged firm-level predictions of the different spillover's (column headings) contribution to TFP growth during 1998-2001 for different ranges of the 1998 level of technology (T98). pX refers to the Xth percentile of the distribution of *IT*. Predictions are obtained by multiplying the appropriate estimated coefficients with the actual values of the spillover variables concerned. Size classes are based on the number of employees, *L*. The first line for each size class lists the average over all firms.

Figure 1: Spillover schemes

Horizontal, Backward and Forward Spillovers



Supply Backward Spillover

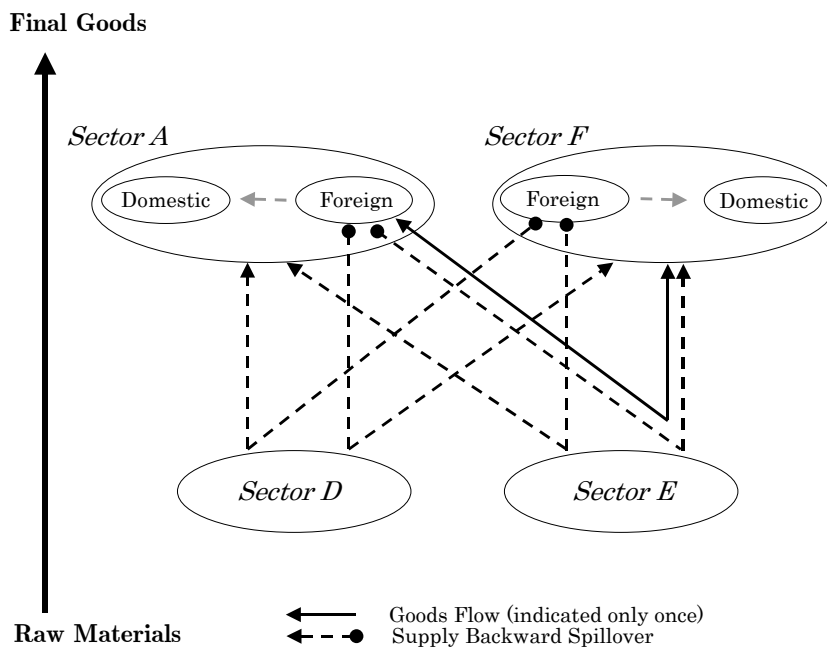


Figure 2: Spillovers as a non-linear function of the level of technology

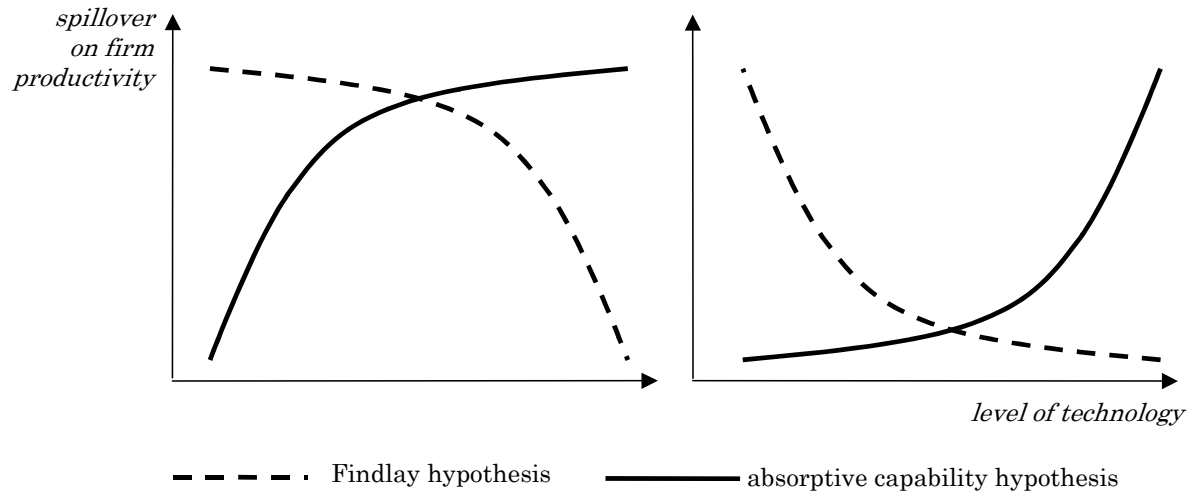


Figure 3: Contribution of spillover effects to firm-level TFP (vertical axis) as a function the level of technology (horizontal axis) for different classes of firm size (L denotes the number of employees) (calculations are based on average values of the spillover variables in the respective subsamples)

