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Horizontal and Vertical Technology Spillovers from FDI in Eastern Europe*

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Abstract

The aim of our paper is to empirically estimate the direction and magnitude of technological spillovers from FDI using a plant level dataset of Romanian firms for the period 1999-2007. We use the Levinsohn Petrin (2003) methodology in order to estimate total factor productivity and compute several measures of spillover effect based on time varying Input-Output tables. We find local suppliers to benefit from positive backward spillovers while local clients are negatively affected by forward spillovers. Using several measure of absorptive capacity like human capital or R&D does not change our results. On the other hand, a large technological gap favors the capture of technological spillovers. Labor mobility is the only significant horizontal spillovers. We also find that labor mobility changes direction according to different human capital levels. We finally show that local firms buying inputs from FDI suppliers are negatively affected by a second order vertical spillover.

Keywords: FDI, spillovers, technology transfer, total factor productivity, absorptive capacity

JEL codes: O33, F23, L22

Résumé

L'objectif de ce papier est d'estimer de manière empirique la direction et l'ampleur des externalités technologiques à partir des IDE, en utilisant un échantillon d'entreprises roumaines pour la période 1999-2007. Nous estimons la productivité totale des facteurs à travers la méthode de Levinsohn et Petrin (2003) et nous calculons plusieurs mesures d'externalités, basées sur des tableaux entrées-sorties variables. Nous trouvons que les fournisseurs locaux bénéficient des externalités en amont positives, tandis que les clients locaux sont affectés par des externalités en aval négative. L'utilisation des différentes mesures de la capacité d'absorption, comme le capital humain ou la R&D, ne change pas les résultats. Pourtant, le décalage technologique important favorise la capture des externalités. La mobilité des employés reste le seul canal d'externalités horizontales viable, malgré le fait qu'elle change de direction selon les niveaux du capital humain. Enfin, nous trouvons que les entreprises locales s'approvisionnant auprès des fournisseurs des IDE sont affectées par des externalités verticales de deuxième ordre négatives.

Mots clés: IDE, externalités, transfert de technologie, productivité totale des facteurs, capacité d'absorption

Classification JEL : O33, F23, L22

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1. Introduction

Technical progress is key factor in economic growth due to its productivity enhancement effect. It is a fact that most innovation and new technologies are created in developed countries and the chance for developing countries, such as those in Eastern Europe, is to import that technology through various channels. FDI has been said to be the cheapest way for developing countries to acquire technology (Blomstrom and Kokko, 1998) and the most effective form of international technology transfer (Campos and Kinoshita, 2002).

Countries of Central and Eastern Europe (CEEC) had a past of industrialized economies, struggling after the fall of communism with an obsolete capital stock. The large technological gap and the need for restructuring required considerable effort, therefore these countries were particularly concerned by the need of technology transfer. In this regard, governments have created special incentives in order to attract FDI, like tax holidays, duty exemptions or corporate taxation. These policies are based on the optimistic idea that multinationals transfer technology to their affiliates and knowledge then spreads over to domestic firms, creating a multiplier effect in the host economy. The perception of universal solution for the problems of transition has led FDI inflows to be particularly encouraged. Since large amounts of public funds have been used in order to attract FDI, it is essential for policymakers to identify the specific conditions that promote technological spillovers. We naturally wonder if the attention given to FDI and the associated externalities is not disproportionate to their actual benefits. Are spillovers important enough to justify the subsidies and fiscal incentives put in place by developing countries in order to attract FDI?

Despite the consistent theoretical arguments (De Mello, 1997; Markusen and Venables, 1999; Keller, 2009), empirical evidence on the spillover effect is much less clear cut. The recent availability of plant level datasets has encouraged research on the microeconomic mechanism of technology transfer. Empirical studies focus on the intra and inter-industry externalities using different measures of foreign presence and often get conflicting results. Rodrik (1999) plastically summarizes the evidence: “today's policy literature is filled with extravagant claims about positive spillovers from FDI, but the hard evidence is sobering”. The explanations for these mixed findings have pointed to methodological issues (Görg and Strobl, 2005; Carkovic and Levine, 2005) and the heterogeneity of industries and local firms

(Lipsey and Sjöholm, 2005). It is therefore difficult to formulate an a priori expectation about the overall effect of FDI on host economies.

The objective of our paper is to determine the existence of technological spillovers from FDI in the Romanian economy and measure their magnitude. In this regard, we identify the main channels through which technology transfer takes place, their intensity and the effects induced on the productivity of domestic firms. We also test potential factors acting as an absorption capacity and investigate the technology gap hypothesis. The main points we will improve compared to previous studies are: the inclusion of a flexible structure of the economy by the use of time-varying input-output tables, the introduction of two alternative channels of technology transfer (the supply-backward channel and the mobility of employees), the application of additional tests on the absorption capacity, the use of an original proxy for human capital, an extension of the study period until 2007 and extension of the sample to the whole economy.

The structure of the paper is as follows: section 2 presents the main theoretical and empirical contributions on technology spillovers with a special interest for the Romanian economy. The construction of spillover variables and data description is presented in section 3. Section 4 contains the results of our estimations, while the final section of the paper highlights the main conclusions.

2. Literature review

The literature considers the technology transfer associated with capital flows as the main contribution of FDI to the economic development of host countries (Lipsey, 2004; De Mello, 1997, Campos and Kinoshita, 2002, Bloningen and Wang, 2004). As the share of foreign capital in host economies increases, the productivity of local firms is expected to rise due to technology and knowledge diffusion (Blomstrom and Kokko, 1998). Depending on the direction of the diffusion, spillovers can occur horizontally or vertically. When technology from FDI spills over to domestic competitors within the same industry, the spillover is horizontal or intra-industry. Vertical spillovers, on the other hand, occur in downstream and upstream industries, when the technology is absorbed by local clients or suppliers. Initially, research was concentrated on horizontal spillovers, trying to establish a link between the share of FDI in an industry and the productivity of domestic firms (Aitken and Harisson, 1999), only later introducing inter-industry spillovers through supplier and customer linkages (Javorcik, 2004).

The literature identifies several channels through which technology spillovers can occur. Increased competition from foreign affiliates may force local competitors to improve their efficiency (Glass and Saggi, 2002). Demonstration effects can encourage local firms to imitate the more advanced production methods of foreign firms (Wang and Blomström, 1992). Not last, labor turnover can benefit local firms by attracting skilled workers trained in multinationals (Fosfouri et al. 2001). Most of these channels work horizontally, however vertical technology transfer has been proven to be much more intensive. Increased demand for intermediate goods allows economies of scale and favors a higher productivity for local suppliers (Javorcik, 2004). It is also possible for foreign affiliates to deliberately transfer technology to local producers and assist them in meeting quality standards (Blalock and Gertler, 2005).

The theoretical and empirical strands of literature have developed rather separately. Besides the gap between the scarce amount of theoretical work and the numerous empirical studies, the findings of the two strands of literature are not fully convergent. Despite some consensus on the fact that foreign affiliates benefit from a direct technology transfer from the multinationals (Aitken and Harrison, 1999; Girma et al., 2002), there is no clear evidence as to the effects on domestic firms.

The main theoretical contributions come from Markusen and Venables (1999), Alfaro and Rodriguez-Clare (2004) and Keller (2009). These studies take into account both vertical and horizontal FDI and model their implications for the competitive structure of host industries. Given that multinationals generally operate in industries characterized by oligopolistic competition, Markusen and Venables (1999) show that their market penetration increases competition, thereby inducing a horizontal crowding-out effect on local competitors. Alfaro and Rodriguez-Clare (2004) emphasize the role of multinationals in increasing demand for local suppliers. In their model, the entry of multinationals in downstream sectors encourages input diversification, which benefits domestic firms from other sectors as well. Keller (2009) sets up a complex mechanism by which technology transfer takes place both at intra and inter-industry level. They also separate spillovers in pecuniary externalities and pure technological transfer, and model specific effects on the labor market. The different predictions of the theoretical models lead us to believe that the clarification of the FDI impact is ultimately an empirical question.

Empirical studies that address this issue are much more numerous than the theoretical ones. The findings of these studies are very diverse: some find positive spillovers (Damijan et al, 2003; Kolassa, 2008; Nicolini and Resmini, 2010), others find negative spillovers (Aitken and Harrison, 1999; Javorcik, 2004) while a third category reveals no significant spillover effect (Girma et al. 2002; Kinoshita, 2002). Most empirical studies converge to two conclusions. The first one is that vertical technology transfer is more intense than horizontal transfer, due to multinationals incentives to upgrade local suppliers (Javorcik, 2004; Javorcik and Spatareanu, 2008). The second idea emphasizes the role of firm and industry characteristics in influencing technology absorption. It is widely believed that the extent to which local firms benefit from positive spillovers depends on their absorptive capacity. Among the factors found to influence the magnitude of spillovers, the literature identifies: human capital, innovation efforts, ownership structure, technological gap, firm size or export orientation (Castelanni and Zanfei, 2003; Kolasa, 2008; Nicolini and Resmini, 2010).

We will shortly discus some studies that focus on the Romanian economy. Schoors and Merlevede (2007) use a sample of Romanian firms for the period 1996-2001, and conclude that vertical spillovers dominate technology transfer. Local suppliers are negatively affected, while downstream externalities provide increased productivity for local firms. They show a positive horizontal effect given by the mobility of employees. Javorcik and Spatareanu (2008) investigate the ownership structure of FDI and the way it influences technology transfer. Considering the period 1998-2003, their results show that only joint ventures are associated with positive vertical spillovers, due to lower costs in finding local suppliers and better market knowledge. The authors also identify a negative horizontal effect, due to competition from both joint ventures and wholly owned subsidiaries. Using the same study period, Nicolini and Resmini (2010) extend the sample to also include Bulgarian and Polish firms and arrive at somewhat different results. They argue that domestic firms have benefited from both horizontal and vertical spillovers. The only negative effect they identify is a horizontal competition effect limited to high-tech sectors. They also show that a large technological gap prevents domestic firms from taking full advantage of technology spillovers.

In the present paper, we analyze the impact of horizontal and vertical FDI spillovers on the productivity of domestic firms. We separate horizontal spillovers in a competition effect and a labor market effect, and introduce a second order forward spillover in line with the theoretical work of Markusen and Venables (1999). Since firm heterogeneity seems to influence the capture of spillovers, we test several measures of absorptive capacity, like human capital, research-development and technological gap.

3. Data and methodology

The methodology of identifying technology spillovers is based on observing changes in the productivity of domestic firms following their interaction with FDI. Therefore, the dependent variable will be total factor productivity at plant level and among the explanatory variables we will include several measures of foreign presence, as proxies for the spillover effects. We start with the classical spillover variables used in the literature (horizontal, backward and forward) and then add two alternatives measures, virtually absent from empirical studies (labor mobility and supply-backward spillover).

3.1 Sample description

For this study we use a sample of Romanian firms extracted from the AMADEUS database[3]. Financial information is based on balance sheet data. The selection criteria are active status and a minimum of 50 employees in the latest available year[4]. The data is organized as an unbalanced panel spanning over the period 1999-2007.

We classified firms into 33 industries according to the 2-digit NACE Rev. 2 classification. Manufacturing has the largest representation in the sample, followed by trade and constructions. Since more than half of foreign companies are installed in the tertiary sector (WIIW), we extend the sample to the whole economy. Previous studies limited the analysis to the manufacturing sector, but restriction ignores most of the FDI operating in Romania. In addition, services have a high spillover potential due to their strong orientation towards the

[3] www.amadeus.bvdep.com Amadeus is a pan-European database, developed by Bureau van Dijk. It contains financial information on more the 7 million public and private companies throughout 38 European countries. For Romania, data are reported by the Chamber of Commerce and Industry.

[4] Given the fact that the AMADEUS database ranks companies in decreasing order of turnover, our sample consists mainly of medium and large companies.

domestic market. As a geographical location, we classified firms into eight regions. A third of foreign firms are found in the capital region, while the rest are evenly distributed among the other seven regions.

Regarding ownership, AMADEUS provides information on the percentage and origin of each shareholder. A total share of foreign ownership above 10% classes the firm into the FDI category (according to UNCTAD and OECD methodologies). Out of the initial sample of 3500 firms, due to missing data in key variables like foreign ownership and NACE code, we are left with 1856 firms. 41% of these firms are FDI and the rest are local companies (with a share of foreign ownership below 10%). As expected, the largest share of FDI is located in capital region, followed by the West and lowest in the Northeast and Southeast. Tables 6 and 7 in appendix present the industrial and regional distribution of firms in the sample.

3.2 The dependent variable

The dependent variable in our analysis is total factor productivity (TFP) at plant level. The purpose of calculating TFP is to identify changes in output that cannot be attributed to changes in inputs. Most studies determining TFP start from a logarithmic production function of the form:

$$y_{it} = \beta_0 + \beta_K k_{it} + \beta_L l_{it} + \upsilon_{it} \quad (1)$$

Where y_{it} is firm's *i* value added at time *t*, k_{it} is capital, l_{it} labor. TFP could then be naturally determined as a residual from the above equation, considering labor and capital as exogenous. OLS estimation is however problematic in this case due to a simultaneity bias. The decision of input allocation made by the firm is conditional on knowing her own productivity or at least a part of it. Therefore, we can split the υ_{it} term in a white noise component ε_{it} and a time varying productivity shock ω_{it}. The latter term, even though unknown to the econometrician, is known to the firm and correlated with inputs.

Applying OLS to such a production function will yield an underestimated capital coefficient and an overestimated labor coefficient (van Beveren, 2012). For this reason, recent studies make use of semi-parametric methods that allow firm-specific productivity differences to exhibit idiosyncratic changes over time. The intuition behind these methods is to find a proxy variable that monotonically reproduces productivity dynamics. Olley and Pakes (1996) consider investment as function of unknown productivity. However, their method requires strictly positive investment and in our case it would mean losing 31% of observations. Since firms rarely report zero input consumption, the Levinsohn Petrin (2003) methodology is preferable in this regard. Observations with zero investment, on the other hand, also raise a theoretical problem. Because of adjustment costs, investment retains a certain inertia and might not react monotonically to productivity shocks. We have therefore chosen for our analysis the Levinsohn Petrin (2003) methodology. They model material inputs as a monotonic function of unobserved productivity. The complete description of the methodology is presented in appendix.

Data used to compute TFP is based on balance sheets. Given the time dimension of the data, we use deflators to discount all the financial variables to the same base year 2000. Output data is deflated with industry specific producer price index from Eurostat. The capital stock is proxied by the value of fixed assets, deflated with a composite price index. As suggested by Javorcik (2004) and Merlevede et al. (2011), we construct this index as an average of five deflators, namely: Manufacture of machinery and equipment (29), Manufacture of office, accounting and computing machinery (30), Manufacture of electrical machinery (31), Manufacture of motor vehicles, trailers and semi-trailers (34) and Manufacture of other transport equipment (35). Labor is proxied by the total number of employees, while material inputs are approximated by the firms' material costs. Following the capital deflator, material inputs are also discounted by a composite price index. For each industry, we calculate the index as a weighted average of the deflators of all supplying sectors. The weights are sector specific and determined based on varying input-output tables.

Given the fact that the technology used and the input substitution are likely to be sector specific, we estimate a different production function for each sector. Using the efficient coefficients obtained for K and L, we calculate TFP as the difference between the actual and the predicted output, according to the formula:

$$TFP_{it} = y_{it} - \beta_K k_{it} - \beta_L l_{it} \tag{2}$$

Descriptive statistics of the TFP values obtained are presented in Table 1. In order to validate our results, we also run a simple OLS and a translog estimation[5]. Results are comparable with those obtained by Laenerts and Merlevede (2011) for Romania.

[5]Translog production functions were used by Blalock and Gertler (2008) and Javorcik and Spătăreanu (2008).

Table 1. Descriptive statistics for TFP – different estimation methods

	Total sample		FDI firms		Local firms	
Variable	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev
ln(TFP) - LevPet	3.584	1.804	3.605	2.011	3.552	1.653
ln(TFP) - OLS	2.187	1.139	2.242	1.298	2.151	1.020
ln(TFP) - Translog	1.678	1.767	1.687	1.896	1.665	1.677

Note: Estimations are done separately for each sector, according to the Levinsohn Petrin (2003) methodology (LevPet), the standard OLS and a translog function. Even though the differences in ln(TFP) levels between the two groups of firms are not very high, it should be kept in mind these are expressed in logarithmic scale.

Descriptive statistics show us that multifactor productivity is systematically higher in the group of foreign firms than for domestic firms. This is a first confirmation of the fact that foreign firms are generally more productive than local ones. In addition, foreign companies seem to be more heterogeneous, with greater deviation from the average productivity. A complete table with all the estimated factor coefficients for every sector is presented in appendix.

3.3 The explanatory spillover variables

In order to construct the proxies for technological spillovers, we used the methodology developed by Javorcik (2004)[6]. For each sector *j*, we construct three variables of foreign presence. The first variable represents the foreign presence within an industry (*Horizontal*), while the other two variables take into account the intensity of inter-industry linkages and therefore measure potential vertical externalities (*Backward* and *Forward*). The horizontal spillover variable is a straightforward and longstanding measure in the literature, as follows:

$$Horizontal_{jt} = \sum_{i=1}^{n_j} (\rho_i * Sales_{it}) / \sum_{i=1}^{N_j} Sales_{it} \qquad (3)$$

where ρ_i is the share of foreign capital in firm *i*, n_j is the number of foreign firms in industry *j* and N_j is the total number of enterprises in industry *j*. The foreign capital share ρ_i varies between 10 and 100% (as defined by

[6]This methodology is used by most recent studies like Laenerts and Merlevede (2011) or Javorick and Spatareanu (2008).

UNCTAD). Thus, the variable *Horizontal* increases both with the share of foreign ownership within the sector and with the sales of foreign firms within the same sector[7].

The proxy for backward spillovers is given by the foreign presence in the downstream sectors, weighted by the share of foreign capital in each of these sectors:

$$Backward_{jt} = \sum_{j \neq k} (\alpha_{jkt} * Horizontal_{kt}) \quad (4)$$

where α_{jkt} is the share of industry's *j* output used as an input by industry *k* at time *t*. The Backward variable measures the presence of foreign investors in *k* sectors supplied by sector *j*. Its purpose is capturing the linkages between FDI and their local suppliers. The shares α_{jkt} are obtained on the basis of NACE 2 digits input-output tables. They are calculated by excluding the final consumption, imports of intermediate goods and sales within the same sector (which are already included in the *Horizontal* variable). The value of the *Backward* variable increases with the share of intermediate consumption sold to sectors with high foreign presence and the relative importance of foreign investors in these sectors.

The variable that takes into account the role of FDI as suppliers of intermediate goods and thus measures forward technological spillovers is given by:

$$Forward_{jt} = \sum_{j \neq k} (\sigma_{jkt} * Horizontal_{kt}) \quad (5)$$

Where σ_{jkt} is the share of sector's *j* inputs that are supplied by sector *k* at time *t*. By measuring the share of foreign production in upstream sectors, the Forward variable is supposed to capture the linkages between FDI and their local clients. The σ_{jkt} shares are calculated based on the same input-output tables, while considering only the production of intermediate goods sold to the domestic market, therefore excluding exports. The *Forward* variable increases with the share of inputs provided by sectors with strong foreign presence and the relative importance of foreign investors in these sectors.

The input-output tables used in this study are expressed in euro, at constant prices and refer to the years 2000, 2003, 2004, 2005, 2006, 2007[8]. This allowed us to calculate time-varying

[7] A similar methodology was used by Aitken and Harrison (1999), using the share of FDI in employment. Blalock (2002) and Schoors and van der Tol (2002) considered the sales of firms with at least 10% of foreign capital, without weighting by the share of foreign capital in each firm. We prefer the Javorcik (2004) version because it allows greater variance and better captures the implications of foreign capital on productivity.

trade coefficients, which is a significant improvement compared to previous studies who use constant ones (Javorcik 2004; Schoors and van der Tol, 2002). Merlevede and Schoors (2007) is the only study we are aware of that uses time varying Input-Output tables. Given the fact that methodology does not allow us to empirically distinguish the pure technology transfer from pecuniary spillovers or economies of scale, we use the spillover term in its broader sense.

3.4 Empirical specification

Since our objective is to analyze the effect of technology transfer on the productivity of domestic firms, the basic equation we estimate is the following:

$$TFP_{ijt} = \beta_0 + \beta_1 Horizontal_{jt} + \beta_2 Backward_{jt} + \beta_3 Forward_{jt} + \beta_5 Control_{ijt} + \alpha_j + \alpha_r + \alpha_t + \varepsilon_{ijt} \quad (6)$$

TFP is total factor productivity at plant level obtained by the Levinsohn Petrin (2003) methodology. *Horizontal*, *Backward* and *Forward* are sector specific variables defined above. *Control* is a vector of control variables introduced in order to isolate the effect of technology transfer from other factors affecting productivity. We have included here a Herfindahl index of market concentration, the demand expressed by downstream sectors, the share of imports, export orientation and firm size. We shortly present a description of these variables and justify their introduction in the empirical specification.

We consider the degree of *market concentration* to be one of the major factors influencing productivity and conditioning the reaction of domestic firms to FDI activity. In this purpose, we use a Herfindahl concentration index for all companies in a given sector[9]. The entry of FDI should naturally increase competition and force domestic firms to improve their efficiency. However, the short-run market stealing effect could be important enough to cause a decrease in productivity. Most empirical studies find a negative relationship between market concentration and productivity gains (Sjoholm, 1999; Javorcik and Spatareanu, 2008).

[8] There are three Input-Output tables missing for years 1999, 2001, 2002 (they were not reported by the Romanian Statistical Institute). We therefore used for the years 1999 and 2001 the coefficients related to the 2000 I-O table and for 2002 the coefficients related to the 2003 I-O table.

[9] Javorcik (2004) uses a Herfindahl concentration index calculated only for the first four companies in each sector. We find however our measure to be better suited.

To the extent that foreign firms buy local inputs, their entry may increase *demand* addressed to local suppliers. This may favor economies of scale, thereby increasing productivity levels. On the contrary, if FDI prefer buying from external markets, a decrease in demand will force producers to spread their fixed costs over a smaller volume of production, leading to decreased productivity. Similar to the intra-industry competition effect, it is therefore necessary to separate the effect of technology transfer from the quantitative effect of increased demand[10]. In line with Javorcik (2004) we construct the demand control variable as: $Demand_{jt} = \sum_k a_{jkt} * Y_{kt}$, where a_{jkt} represents the quantity of good *j* needed to produce one unit of good *k* at time *t* while Y_{kt} represents the total output of industry *k*.

Firm's *size* is an important variable determining productivity, because it captures economies of scale and firm's market power. A large company benefits from high production volumes which ensure a low unit cost. Therefore, we expect a positive relationship between firm size and productivity.

Especially with regard to backward spillovers, an important factor worth considering is the share of *imports* in the total supply of intermediate goods. To the extent that imported products are similar to those produced locally, imports can crowd-out local suppliers. More imports are associated lower contact with local suppliers and therefore less incentives for efficiency improvement. On the other hand, Shojolm (1999) showed that sectors with high import penetration show a stronger competition than sectors with less imports and this may force local producers to work more effectively and improve their productivity.

Export orientation is another factor influencing the productivity of domestic firms by the so called learning-by-exporting phenomenon. Blalock and Gertler (2004) showed that knowledge flows from international buyers help improve efficiency levels of exporting firms. We expect firms in exporting sectors to already be used to the competition in international markets and react faster to changing market conditions.

[10] Van Biesebroeck (2007) offers a second argument for the introduction of a demand control variable. He suggests that information on value added and inputs are only sufficient to determine productivity if the company does not have enough market power to influence the market price. If this is not the case, it is necessary to separate the variation in quantities from price changes. As most often information on unit prices is not available at firm level, the practical solution is to introduce a demand variable. We consider this all the more necessary in our sample, since most companies are large and expected to have strong market power.

The different aggregation levels (some of the variables are firm specific while others are industry specific) raises some heteroskedasticity concerns. The solution suggested by Moulton (1990) is clustering standard errors at industry-year level. In order to cope with omitted variables, we also include three sets of fixed effects, for industry α_j, region α_r and time α_t. This also allows us to control for foreign investors clustering in more productive industries or regions.

4. Results

In this section we will present our main results concerning the spillover effects. We start with the classical spillover channels, we continue by investigating labor turnover and a combination of backward and forward spillover and finally address the absorptive capacity of local firms.

4.1 Horizontal and vertical FDI spillover effects

The objective of our empirical estimation is twofold. On one hand we are interested whether the productivity of local firms in influenced by high within-industry foreign penetration. On the other hand, we want to observe if domestic firms that sell to or supply from foreign companies benefit from an increased productivity. To this end, we estimate equation (6) using the sample described in section 3.1. The main results are presented in Table 2. In order to depict differences between domestic and foreign firms, we estimate the model both on the total sample (column 1), as on the two separate sub-samples (column (2) for foreign firms, and columns (3)-(6) for domestic firms).

For estimates on the total sample, we wanted to highlight a potential productivity differential between FDI and local firms. We thus introduced the dummy variable *Dummy_FDI*, which takes the value 1 if the share of foreign ownership exceeds 10% and 0 otherwise. As opposed to the indirect spillover effects, this variable allows us to capture the direct technology transfer from multinationals to affiliates. A positive and significant coefficient for this variable would be an indication of a correlation between FDI status and higher productivity[11].

[11] However, the coefficient on *Dummy_FDI* should be interpreted with caution since it is subject to upward bias. Foreign investors have a tendency to self-select themselves towards larger and more productive firms, thereby the productivity differential could be overestimated.

We observe in column (1) that foreign firms have indeed a higher productivity levels than Romanian companies, with a premium around 12%. This is a confirmation of the direct technology transfer and represents at the same time a premise for potential spillovers to domestic firms.

We are also wondering whether, beyond FDI status, does the actual share of foreign ownership have an impact on direct technology transfer. Therefore, we replace the dummy by a continuous variable (called *FDI)*, which ranges between 10% and 100%. As this variable is only relevant for foreign firms, we restrict the sample accordingly (column 2 of Table 2). Results indicate that a larger share of foreign ownership results in a slightly higher productivity. However the marginal effect is quite low.

Since we are mainly interested by the impact of foreign firms' activity on the performance of domestic companies, we further limit the estimation to the sample of local firms. As pointed out by Javorcik and Spatareanu (2011), this restriction also avoids potential endogeneity problems caused by self-selection. The model specified in equation (6) is then progressively estimated by introducing all control variables (columns 3 - 6 of Table 2). We first concentrate our interpretations on columns 1-3, and then continue with the full set of controls.

Concerning the spillover variables, our results confirm previous studies in the literature in the sense that vertical technology transfer is much more intense than horizontal one. The status of supplier of FDI companies, whether local or foreign, favors increased productivity levels due to an upward technology transfer. We observe that the benefits are even greater for local suppliers than for other foreign suppliers (coefficient of 0.96 versus 0.72 in columns 3 and 2). Domestic firms situated in downstream industries suffer however from a sizeable decline in productivity. This complex nature of inputs supplied by foreign producers may cause difficulties in integrating them into the production chain. Nonetheless, better quality inputs are often accompanied by higher supplying costs, which generate a loss of efficiency. The negative *Forward* effect seems to be more important that the positive *Backward* spillover. If we turn our attention to foreign firms in downstream industries, the negative *Forward* effect is not significant. This confirms that foreign firms are better equipped to using more complex inputs.

No intra-industry spillover is highlighted, as the *Horizontal* variable is insignificant. We still observe a positive coefficient for foreign firms (column 2) and a negative coefficient for local firms (columns 3-6). Though not significant, this result suggests that foreign firms, as opposed to local ones, could benefit from increased market competition. The remark seems particularly relevant since the Herfindahl index of market concentration is significant only for foreign companies. In highly concentrated industries, foreign companies are negatively affected by the lack of competition, while Romanian companies show no response. It seems that foreign firms are the only ones reacting to increased competition by productivity improvements. Demand is positively correlated with productivity gains in all cases, results in line with our expectations.

Table 2. FDI technology spillovers and total factor productivity

VARIABLES	Total sample (1)	Foreign (2)	Domestic (3)	Domestic (4)	Domestic (5)	Domestic (6)
Dummy_FDI	0.121***					
	(0.000)					
FDI		0.001***				
		(0.000)				
Horizontal	-0.020	0.240	-0.176	-0.045	-0.009	-0.017
	(0.148)	(0.268)	(0.170)	(0.150)	(0.149)	(0.150)
Backward	0.846***	0.720**	0.966***	0.854***	0.789***	0.754***
	(0.192)	(0.333)	(0.217)	(0.227)	(0.226)	(0.221)
Forward	-0.882***	-0.247	-1.523***	-1.756***	-1.633***	-1.590***
	(0.309)	(0.502)	(0.388)	(0.359)	(0.355)	(0.359)
Herfindahl	-0.406*	-1.137***	0.155	-0.053	0.069	0.071
	(0.236)	(0.345)	(0.310)	(0.265)	(0.272)	(0.273)
Demand	0.128***	0.191***	0.103***	0.059***	0.045***	0.044***
	(0.015)	(0.030)	(0.017)	(0.015)	(0.015)	(0.015)
Size				0.208***	0.206***	0.206***
				(0.015)	(0.015)	(0.015)
Import					-0.073***	-0.071***
					(0.019)	(0.019)
Export						-0.024
						(0.018)
Constant	3.148***	1.323**	3.813***	3.126***	3.309***	3.332***
	(0.363)	(0.660)	(0.424)	(0.410)	(0.412)	(0.407)
Observations	13,416	5203	8,213	8,213	8,213	8,213
R^2	0.81	0.82	0.82	0.86	0.86	0.86

Note: the dependant variable is ln(TFP) obtained by the Levinsohn Petrin (2003) method. Cluster robust standard errors are reported in brackets. *** p<0.01, ** p<0.05, * p<0.1. The estimation method is random effects GLS. All estimations include industry, region and year fixed effects.

The successive introduction of other control variables confirms the initial results. A high foreign presence in consumer sectors is positively associated with increased productivity in upstream sectors. Romanian firms producing inputs improve their productivity following the imposition of strict quality standards by FDI. We argue that backward technology transfer has an important deliberate component. Thus, it often can be described as a voluntary transfer rather than an externality, since foreign firms are directly interested to buy better quality inputs. On the contrary, the foreign presence in upstream sectors is associated with a decrease in productivity for local firms that supply upon FDI. Our results are similar to those obtained by Laenarts and Merlevede (2011) for Romania, Schoors and van der Tol (2002) for Hungary or Javorcik (2004) for Lithuania.

The lack of horizontal spillovers has several explanations. First, it is very difficult to separate the positive effect of technology transfer from the negative competition effect. What we practically capture in empirical studies is the net horizontal effect. Secondly, it is possible for domestic firms not to have the absorptive capacity necessary to assimilate foreign knowledge. Finally, in situations where the technology is relatively easy to imitate by local competitors, the foreign investor may restrict the transfer to a technology just marginally superior to the local one. This considerably reduces the potential for spillovers (Glass and Saggi, 1998). Damijan et al. (2003) and Nicolini and Resmini (2010) are the only studies to find a horizontal positive effect for Romania. Most studies either fail to obtain conclusive results or even find negative horizontal spillovers (Javorcik and Spatareanu, 2008, Konigs, 2001).

Changes in the degree of market concentration do not seem to impact the economic efficiency of local firms. Similar conclusions were reached by Gorodnicenko et al. (2007) and Javorcik and Spatareanu (2011). This suggests a lack of responsiveness of local firms and a poor adaptation to changing market conditions[12]. Firm size, measured by its total assets, contributes to higher productivity. Large firms are more efficient because they enjoy economies of scale. At the same time, they have a stronger market power, including their ability to easily cope with competition. Higher imports, as expected, lead to lower productivity of local suppliers due to a market-stealing effect. Although we expect exports to favor greater economic efficiency, we note that local companies in exporting sectors do not

[12] Even though it is not significant, we keep the Herfindahl index as a control variable while we change the specification of spillovers. This ensures us that the impact of our interest variables is the result of technology transfer and not a mere consequence of competition.

show a higher productivity than those in local-oriented sectors. This result is explained by the low added value of exported goods. Additionally, Hunya (2002) actually showed that FDI in Romania did not change the structure of exports, but followed the country's comparative advantage in low value added sectors.

To test the robustness of the results, we proceeded to two verifications. As it has been suggested that a potential time frame might be required for the technological externalities to appear, we first repeat the estimations by using lagged spillover variables. Second, we successively remove one of the control variables in order to see whether the sign or the significance of spillover variables changes in the absence of controls. The results of these analyzes are presented in Table 11 and Table 12 in Appendix. The results remain the same, as the *Backward* and *Forward* spillovers are very robust, while the *Horizontal* spillover remains with no significant effect.

4.2. Additional channels for technology transfer. Supply-backward and labor mobility

Besides the three classical measures of technological spillovers conventionally used in the empirical research, the theoretical literature identifies two additional channels. These are the supply-backward spillovers (Markusen and Venables, 1999; Pack and Saggi, 2001) and labor mobility (Fosfuri et al. 2001).

In the theoretical model developed by Markusen and Venables (1999), FDI increases the demand addressed to local suppliers, favoring economies of scale and encouraging the production of higher quality inputs. In addition, other firms in downstream sectors can also benefit from the improved supply of inputs, free-riding the initial backward technology transfer. This can be interpreted as a second-order backward effect, which Markusen and Venables (1999) call a supply-backward spillover. The theoretical aspect is further developed by Pack and Saggi (2001). They suggest that multinationals, in order to avoid the risk of relying on a sole supplier, will widely transfer technology, either by direct transfer to additional suppliers or by encouraging spillovers from the original recipient. This will stimulate new entry into the upstream industry, thereby increasing competition and lowering prices. As suppliers also sell their inputs to other firms in downstream markets, this will increase productivity levels, profits and encourage entry in downstream markets as well. In this way, foreign firms cannot internalize the entire benefit of supplier upgrading. Provided new competition is not too great, the benefits of a competitive supply base compensate the rents lost to free-riders (Pack and Saggi, 2001).

The only two studies we are aware of to test the supply-backward hypothesis are Schoors and Merlevede (2007) and Blalock and Gertler (2008)[13]. They both show positive second-order spillovers down the supply chain from the adoption of foreign technology. We construct our *Supply_Back* in line with these studies as:

$$Supply\_Back_{jt} = \sum_{j \neq k} (\sigma_{jkt} * Backward_{kt}) \quad (7)$$

Where σ_{jkt} is the share of industry's *j* inputs supplied by industry *k* and the $Backward_{kt}$ variable indicates the presence of foreign investors in downstream *j* industries[14]. Therefore, the newly created *Supply_Back* variable captures the influence of FDI on domestic firms situated in other sectors *k*, downstream as well from sector *j*. Basically, this mechanism combines a first *backward* flow (from FDI in industry *k* to suppliers in industry *j*) with a second stage *forward* flow (from local suppliers in sector *j* to other local clients in sectors *k*).

The results obtained by introducing this additional variable are presented in columns (1) - (2) of Table 3 .We observe a high significance of the variable *Supply_Back*, however, associated with a negative sign. Firms that purchase their inputs from suppliers of FDI companies are affected by a negative spillover effect. This result can be explained by higher quality standards imposed by FDI to its suppliers, which are usually accompanied by price increases. From a technical point of view, this result could be expected since it is a combination of *Backward* and *Forward* effects. Having different signs and magnitudes, the one that prevails is the negative *Forward* spillover.

The fact that the benefits associated with upstream technology transfer cannot be exploited by other downstream firms raises some concerns related to the social return on technology transfer. The purpose of the multinational is to transfer technology to its suppliers so that they are able to produce higher quality inputs and eventually lower its non-labor costs. If the FDI

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[13]Schoors and Merlevede (2007) focus on productivity spillovers, while Blalock and Gertler (2008) seek aggregate welfare gains over the supply chain.

[14] Schoors and Merlevede (2007) argue that the separate identification of this effect is only possible as long as the share of the industry's *k* output supplied to industry *j* is different from the share of industry's *j* inputs bought from industry *k*.

firm is the only one internalizing this upgrading, the benefits become private (Blalock and Gertler, 2008). Therefore there should be no obvious reason for public subsidies to directly encourage technology transfer from multinationals.

Table 3. The Supply-Backward spillover and the mobility of employees

VARIABLES	(1)	(2)	(3)	(4)
Horizontal	0.074	0.062	-0.158	-0.161
	(0.163)	(0.166)	(0.200)	(0.200)
Horizontal_L			0.416**	0.407**
			(0.171)	(0.176)
Backward	0.734***	0.710***	0.681***	0.668***
	(0.224)	(0.219)	(0.227)	(0.221)
Forward	-1.490***	-1.466***	-1.456***	-1.442***
	(0.335)	(0.337)	(0.330)	(0.334)
Supply_Back	-0.956*	-0.897*	-1.127**	-1.089*
	(0.567)	(0.580)	(0.565)	(0.582)
Herfindahl	0.020	0.024	0.126	0.126
	(0.278)	(0.279)	(0.277)	(0.277)
Demand	0.060***	0.059***	0.058***	0.057***
	(0.019)	(0.019)	(0.019)	(0.019)
Size	0.204***	0.204***	0.204***	0.204***
	(0.015)	(0.015)	(0.015)	(0.015)
Import	-0.078***	-0.077***	-0.095***	-0.094***
	(0.019)	(0.019)	(0.020)	(0.020)
Export		-0.018		-0.011
		(0.018)		(0.019)
Constant	3.544***	3.548***	3.584***	3.586***
	(0.429)	(0.427)	(0.431)	(0.429)
Observations	8,213	8,213	8,213	8,213
R^2	0.86	0.86	0.86	0.86

Note: The dependant variable is ln(TFP), obtained by the Levinsohn Petrin (2003) method. Cluster robust standard errors are presented in brackets. *** p<0.01, ** p<0.05, * p<0.1. The estimation method is random effects GLS. All estimations include industry, region and time dummies.

According to the analysis conducted so far, horizontal technology transfer seems to be insignificant for the productivity of domestic firms. However, this result could be explained by opposite effects compensating each other. There is always the risk that an increase in productivity generated by labor turnover might be canceled by adverse competition effects

(Blalock and Gertler, 2004). The majority of empirical studies do not distinguish between these two channels of horizontal spillovers, arguing that what is relevant is the net effect. By only analyzing the net effect, we actually don't know whether the two effects are insignificant, or are both important but with an opposite sign.

Fosfuri et al. (2001) were the first to address labor turnover as an explicit channel for knowledge spillovers. In their theoretical model, a firm wishing to engage in international trade has to choose between FDI and exporting. If it decides to create a foreign affiliate, the company has to train local employees. Once the training completed, the foreign company and the domestic firms will "bid" to obtain the services of employees. Knowledge transfer takes place to the extent that domestic firms win the bidding and trained employees migrate from FDI to domestic firms. Fosfuri et al. (2001) state that this phenomenon occurs when market competition is not very important and knowledge is less specific. As in Schoors and Merlevede (2007), we define the variable for horizontal labor spillovers as:

$$Horizontal\_L_{jt} = \sum_{i=1}^{n_i} (Dummy\_FDI * L_{it}) / \sum_{i=1}^{N_i} L_{it} \qquad (8)$$

Where *Dummy_FDI* was defined before and L_i represents the number of employees of firm *i*, n_i is the number of foreign firms in industry *j*, and N_i the total number of firms in industry *j*. This variable weights the share of foreign firms in the total employment at the industry level.

We wish to emphasize the difference between the horizontal variable based on sales and the horizontal variable based on employment. Apart from the support indicator, the difference lies in the way we take into account the foreign presence. The first one uses continuous values of the share of foreign ownership, while the *Horizontal_L* variable uses discrete values 0/1 to distinguish employees of foreign companies from those of domestic firms. We make this distinction because we believe the accumulation of knowledge by its employees is not a linear function of the share of foreign capital of a firm. Thus, we consider that all employees of foreign firms are exposed to new technologies and are able to accumulate and use that knowledge in the event of transfer to a local company.

The results of introducing the *Horizontal_L* variable are presented in columns (3)-(4) of Table 3. As a consequence, the initial *Horizontal* variable (based on sales) is now interpreted as the effect of other channels of horizontal transfer, besides worker mobility. Given the fact that we already controlled for most of the competition, this variable then tends to measure pure technology transfer. Horizontal transfer was not significant until now and it still remains insignificant once labor mobility is taken into account. This leads us to believe that foreign firms are quite efficient in protecting their technology from local competitors.

On the contrary, the intra-industry transfer in the form of labor market spillovers proves to be very important. The variable *Horizontal_L* shows a positive and significant coefficient. The tendency of multinationals to invest in human capital is well known, both through employees training and better management practices. By migrating to domestic companies, these workers also transfer the knowledge and the skills they have acquired. The transfer is not without a certain cost, as domestic firms usually have to offer some form of wage compensation. This compensation is however much less costly as if they would develop the training internally. Our results therefore indicate that the only channel for intra-industry technology spillovers remains the mobility of employees.

4.3 Technological spillovers and the absorptive capacity of local firms

The mixed results of empirical studies have led economists to question the existence of specific factors conditioning FDI spillovers (Lipsey and Sjoholm, 2005). This implies a potential non-linear effect in the mechanism of technology transfer. Typically, the observed negative effects for developing countries are explained by a lack of adequate absorption capacity. Campos and Kinoshita (2002) argue that CEEC have a relatively backward technology, being far from the world technological frontier. However, they have a high potential of positive spillovers mainly due to their skilled labor force.

The theoretical literature emphasizes the role of firm heterogeneity in international trade (Helpman et al., 2004), and studies that investigate technology transfer are becoming increasingly interested in catalyst factors for spillovers. It is assumed that domestic firms need a minimum level of absorptive capacity in order to reap positive spillovers (Glass and Saggi, 1998, Blomstrom and Kokko, 1998; Nicolini and Resmini, 2010). Most of these studies focus on the characteristics of domestic firms, although there are exceptions that analyze the characteristics of foreign investors as well (Javorcik and Spatareanu, 2008). Thus, in this study we consider the absorptive capacity of local firms as given by human capital, R&D investment and the technological gap. We briefly describe the measures being used.

The role of *human capital* as an absorptive capacity was initially stated by Borensztein et al. (1998), in the context of FDI growth effects. Plant level studies are often constrained by the lack of information on skill levels and thus can rarely consider this aspect of the absorptive capacity. Exceptions like Gorodnicencko et al. (2007) and Blalock and Gertler (2009) use specific survey datasets[15] and proxy human capital by the share of employees with higher education. They find that firms with highly educated employees adopt more foreign technology than others.

The Amadeus database does not contain information on the skill structure of employment. We are thus forced to seek alternative measures to approximate human capital. Assuming that wages are correlated with the skill level, higher labor costs are equivalent to a higher human capital stock (for the same number of workers). Based on this assumption, we recalculate labor by dividing the total labor cost of firms by the minimum wage for each industry, region and year[16]. We then obtain a measure for labor expressed in "equivalent" workers. By calculating the ratio of “equivalent” workers to the actual number of employees we obtain a measure of the human capital stock. The larger this ratio, the larger the human capital stock of the firm. This reasoning is summarized as follows:

$$HumanCapital_{ijt} = [Cost\_L_{ijt} / \min_{jrt}(Wage_{ijt})] / L_{ijt} \qquad (9)$$

The second variable used to measure absorptive capacity is *R&D investment*[17]. Own innovation effort facilitates domestic firms’ capability to assimilate and exploit foreign knowledge. Kinoshita (2002) conducted a study on Czech firms and concluded that technology transfer has no significant effect on domestic firms, except for those that invest heavily in R&D. In their study on several transition countries, Damijan et al. (2003) reached mixed conclusions. If FDI in general has no spillover effect on domestic firms, when R&D investment is taken into account, spillovers turn out to be negative in Poland and the Czech Republic and positive in Romania. Focusing on Poland, Kolasa (2008) investigates several measures of innovation and find that the stock of intangible assets helps to increase the

[15] An example of widely used survey dataset is the Business Environment and Enterprise Performance Survey provided by the World Bank. However, for most developing countries, it does not allow a panel format as different firms are surveyed each year.

[16] There is no available data on average wage, thus we compute it as the total labor cost divided by the number of employees.

[17] Studies that used R&D to proxy absorptive capacity are Kinoshita (2002), Damijan et al. (2003), Kolasa (2008).

benefits from foreign presence. In line with these earlier studies, we proxy R&D by the stock of intangible assets, as a share of total fixed assets:

$$R\&D_{ijt} = IntgAssets_{ijt} / FixedAssets_{ijt} \tag{10}$$

A third measure we use for absorptive capacity is the *technological gap*. There are studies that show that the ability of domestic firms to reap positive spillovers is higher if the technological gap with respect to foreign firms is not too large (Girma, 2005; Kolassa, 2008; Nicolini and Resmini, 2010). Other studies, on the contrary, argue that a high gap leaves rooms for significant improvements and pressures firms to restructure. Thus, the larger the gap, the more likely is the firm to benefit from positive spillovers (Campos and Kinoshita, 2002; Grifith et al. 2004; Blalock and Gertler, 2009). An additional argument in investigating the role of technological gap in the transmission of spillovers is that it has been rarely studied at inter-industry level, most studies focusing on its capacity to overcome horizontal competitive pressure.

For each domestic firm we compute the technological gap as the ratio between maximum productivity of foreign firms within the industry and its own productivity[18]. In doing so, we assume that the most productive foreign firm operates on the production possibilities frontier, and the gap proxies the distance of domestic firms towards this frontier. We have constructed our measure of technological gap based on Girma (2005):

$$Gap_{ijt} = \max_{j}(TFP_{ijt}^{FDI}) / TFP_{ijt} \tag{11}$$

We introduce all the three measures of the absorptive capacity in our estimation of equation (6), together with interaction terms with spillover variables. Results are presented in Table 4. The first two columns use human capital as a proxy for absorptive capacity, while columns (3) and (4) use R&D and the technological gap.

Human capital proves to be a significant determinant of TFP, as expected. We also note that vertical technology transfer is not affected by human capital, none of the two interaction terms being significant. The only type of spillovers that depends on human capital is the *Horizontal* one. However, unlike the sign we would expect (positive), we obtain a negative coefficient for

[18] There are studies that indentify the maximum TFP levels from the total number of firms within a sector, without distinguishing between domestic and foreign firms (ex. Griffith et al. 2004). Since we are interested in the effect of knowledge spillovers from FDI, we find it more relevant to approximate the productivity frontier by the maximum TFP recorded by foreign firms only.

Table 4. FDI spillovers and the absorptive capacity of local firms

Absorptive capacity given by	Human Capital		R&D	Gap
	(1)	(2)	(3)	(4)
Horizontal	0.740**	-0.441	-0.235	-0.013
	(0.362)	(0.508)	(0.210)	(0.150)
Backward	0.767***	0.738***	0.862***	0.758***
	(0.222)	(0.229)	(0.275)	(0.221)
Forward	-1.486***	-1.418***	-1.203***	-1.584***
	(0.353)	(0.345)	(0.467)	(0.359)
*Horizontal*Absorptive*	-0.128***	0.037	0.733**	0.165**
	(0.050)	(0.070)	(0.334)	(0.078)
*Backward*Absorptive*	0.075		-0.105	0.328*
	(0.066)		(0.293)	(0.169)
*Forward*Absorptive*	0.032		0.186	0.100***
	(0.085)		(0.317)	(0.024)
Horizontal_L		1.779***		
		(0.466)		
*Horizontal_L*HumanCapital*		-0.247***		
		(0.067)		
Human Capital	0.066***	0.098***		
	(0.024)	(0.023)		
R&D			-0.005	
			(0.005)	
Gap				-0.052***
				(0.011)
Demand	0.047***	0.040**	0.069***	0.044***
	(0.015)	(0.016)	(0.021)	(0.015)
Herfindahl	0.074	0.186	-0.175	0.206***
	(0.275)	(0.272)	(0.342)	(0.015)
Size	0.193***	0.190***	0.212***	-0.070***
	(0.019)	(0.019)	(0.018)	(0.019)
Import	-0.069***	-0.082***	-0.061***	-0.025
	(0.019)	(0.020)	(0.022)	(0.018)
Export	-0.021	-0.014	-0.016	-0.015
	(0.018)	(0.018)	(0.018)	(0.018)
Constant	2.938***	2.772***	2.593***	3.421***
	(0.399)	(0.398)	(0.481)	(0.408)
Observations	8,213	8,213	5,068	8,213
R^2	0.86	0.86	0.88	0.86

Note: The dependant variable is ln(TFP), obtained by the Levinsohn Petrin (2003) method. Cluster robust standard errors are presented in brackets. *** p<0.01, ** p<0.05, * p<0.1. The estimation method is random effects GLS. All estimations include industry, region and time dummies.

the variable *Horizontal*HumanCapital*. At the same time, we notice that the horizontal transfer has become positive and significant. This is an indication that domestic firms enjoy positive intra-industry spillovers only at medium levels of human capital. The higher the human capital stock of local companies, the more likely are the firms to be affected by negative horizontal externalities.

We recall that horizontal spillovers mostly occur through increased competition (expected negative effect) or through the mobility of employees (expected positive effect). We thus suspect that the lack of any significant horizontal effect might be due to compensation between these two. If the competition effect were to dominate, the *Horizontal* variable should have a negative sign and the interaction with human capital should be positive. Our results indicate just the opposite. Consequently, we expect a dominance of horizontal labor market externalities. In order to validate this hypothesis, we introduce in column (2) the *Horizontal_L* and its interaction with human capital.

The results fully confirm our expectations. Only horizontal labor spillovers are significant, the net effect of other channels being insignificant. Local firms benefit from a significant increase in productivity due to employee mobility from foreign to local firms. The coefficient is also quite large, exceeding the classic negative forward spillover. The interaction with human capital however, illustrates a surprising fact. Horizontal proximity to FDI harms domestic firms with a significant human capital stock. Foreign affiliates, disposing of additional financial resources, are known to pay higher wages to equivalent workers (Aitken et al. 1996). They can therefore afford to recruit the best employees on the market, "stealing" them from local firms that have invested in their training. Thus, at high human capital levels, labor turnover actually acts in the reverse direction, going from domestic firms to FDI. Human capital, although a significant determinant of productivity, increases the risk of losing skilled workers in favor of FDI.

R&D investment does not significantly influence the productivity of local firms. This result is probably explained by the very low values of R&D investment performed by local firms[19]. Concerning its influence on the spillover channels, the only significant interaction is with horizontal spillovers. At average values of R&D, horizontal spillovers have no effect on the productivity of domestic firms (as obtained in previous estimations). However at high R&D values, local firms develop the ability to access and exploit the stock of foreign knowledge within the sector.

[19] For most domestic firms the share of intangible assets ranges from 0 to 2% of fixed assets.

In what follows if we turn to the third conditioning factor, namely the technological gap. We are interested to see whether the more advanced local firms benefit more from FDI induced spillovers, or is it the backwarded firms that reap most of the benefits. The results following the introduction of the technological gap and its interactions with spillover variables are presented in column (4) of Table 4. As a general remark, a large technological gap is associated with a lower productivity. Instead, all interaction variables are positive and significant, which means that technology transfer is facilitated by a large technological gap.

Horizontal spillovers had on average no effects on the productivity of local firms (as confirmed by previous estimates). Surprisingly, firms with an important technological gap enjoy a positive and significant spillover effect, following with foreign firms in the same sector. At average levels of technology, downstream local firms were negatively affected by linkages with foreign suppliers (negative sign of the *Forward* variable). Nevertheless, low technological levels mitigate this negative spillover (the overall effect still doesn't become positive, but it reduced). The Backward variable on the other hand, remains positive and significant, so is its interaction with the gap. FDI are actively involved technological upgrading of their suppliers, in order to help them fulfill quality standards and later benefit from better inputs.

Table 5. Main results of interactions between spillovers and absorptive capacity

		Spillovers conditioned by		
	Average Spillovers	Human Capital	R&D	Technological Gap
Horizontal	0	-	+	+
Backward	+	0	0	+
Forward	-	0	0	+

Note: The table is constructed based on results in Table 4. The symbols we use are 0 (zero) for an insignificant interaction effect, + (plus) for a positive interaction effect and – (minus) for a negative interaction effect.

Table 5 regroups the main results obtained by relating the technology transfer to different firm level characteristics. Human capital does not have absorptive role. Moreover, it generates a negative horizontal effect due to the loss of the best employees in favor of foreign firms. Research and development activities have a limited role as well, facilitating technology transfer only at intra-industry level. Thus, the absorptive capacity hypothesis is not valid for vertical transfer (at least for the variables we considered). Regarding firm technological level, a large gap seems to favor both upstream and horizontal spillovers, while downstream externalities are being mitigated.

5. Conclusion

The empirical analysis in this study was focused on the direction and intensity of FDI productivity spillovers in the Romanian economy. We employed a large plant level dataset comprising all sectors of the economy for the period 1999-2007. By using the Levinsohn Petrin (2003) technique we were able to obtain efficient TFP estimates and relate them to several spillover measures. For the vertical spillovers we have used time varying input-output tables, which allowed us to consider a changing structure of the economy. This is a significant improvement compared to previous studies. We distinguished five measures of spillovers, two horizontal and three vertical. As opposed to most of the literature, we separated the horizontal spillover in pure technology transfer and labor market externalities. We also computed a combination of backward and forward spillovers in order to identify second round vertical transfer. Conditioning the spillover effects by plant level characteristics like human capital, R&D or technological gap revealed more insights into the FDI effects on domestic firms' productivity.

Our results confirm previous studies on indirect technology transfer, in the sense that vertical spillovers are strongly confirmed, while horizontal ones are insignificant. Additionally, vertical transfer is also much less sensitive to the presence of absorptive factors. Being in the supplier position brings in significant productivity gains, foreign companies being directly interested by the quality of supplied inputs. Moreover, the benefits associated with backward spillovers are more important for domestic suppliers than other foreign suppliers, probably due to a higher technological gap. For clients in downstream sectors instead, the situation appears less favorable. The complexity of new inputs, combined with higher prices, frequently generates efficiency losses in downstream sectors. The magnitude of negative forward spillovers is higher than that of positive backward spillovers. Therefore, local clients who buy their inputs from the same suppliers as FDI are at the end affected by a second order negative spillover. The free-rider hypothesis is thus invalidated for Romanian economy.

The mobility of employees is the only horizontal channel at work in Romania. Following recruitment of experienced staff working in multinationals, domestic firms take advantage of their skills and enjoy an increase in productivity. However, at high levels of human capital, labor turnover is reversed and foreign firms are those taking the highly qualified employees from domestic firms. Human capital does not act as an absorptive capacity as it does not encourage positive externalities and even generates a negative horizontal effect. This negative effect can partially be compensated by research and development investment, which facilitates horizontal technology transfer. A final conclusion confirms that the technological gap favors positive spillovers at all levels. The less advanced is a firm's current technology, the more likely is the firm to gain by engaging in trade with FDI. Since foreign firms deliberately transfer technology and know-how to their suppliers, local producers are particularly favored by the important gap.

Our results show that the benefits associated with upstream technology transfer cannot be exploited by other downstream firms besides the FDI. This raises some concerns related to the social return on technology, casting doubt on the justification of public subsidies to directly encourage technology transfer. Contrary to Schoors and Merlevede (2007) we do not find that the average Romanian firm enjoys positive net spillovers. On the contrary, we find that the position in the vertical supply chain is crucial.

From a policymaker's point of view, the objective would be to minimize the negative spillovers and maximize the positive ones. Since sectors mostly affected by negative spillovers are those that rely heavily upon FDI suppliers, a solution would be to encourage the entry of new firms, using measures like credit facilities, tax reductions or creation of industrial parks. Significant productivity gains in upstream sectors call for policies that strengthen linkages between foreign firms and local suppliers, such as minimum local content.

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APPENDIX

The Levinsohn Petrin (2003) methodology for estimating TFP

The Levinsohn petrin (2003) methodology is a non-parametric technique used to compute total factor productivity (TFP) at plant level. Consider to following Cobb-Douglas production function:

$$y_{it} = \beta_0 + \beta_K k_{it} + \beta_L l_{it} + \beta_M m_{it} + \omega_{it} + \varepsilon_{it} \qquad (1)$$

Where y_{it}, k_{it}, l_{it} and m_{it} denote the logarithm of output, capital, labor and material inputs respectively. The term ω_{it} is the productivity while ε_{it} is measurement error or an unexpected productivity shock (that cannot be forecasted during the period in which labor can be adjusted). Both ω_{it} and ε_{it} are unobserved to the econometrician. However, ω_{it} is known to the firm, being a state variable that influences its decision of input allocation. Labor and materials are considered freely adjustable inputs. Given the fact that labor l_{it} and materials m_{it} are allocated at the same time with productivity observation, this gives rise to simultaneity bias. Capital on the other hand is considered a state factor which is subject to an investment process. The firm decides in *t-1* its investment based on expectations of future productivity, given the information available in *t-1*. This means that capital only depends on the distribution of ω conditional on past information. OLS estimation would therefore produce an upwardly biased estimate for labor and materials and a downwardly estimate for capital.

The idea of Levinsohn and Petin (2003) is that the observable characteristics of the firm can be modeled as a monotonic function of unobserved productivity. They suggest material inputs to smoothly react to productivity changes. Therefore $m_{it} = f_t(\omega_{it}, k_{it})$. The monotony assumption allows the inversion of the function, so the unobservable productivity ω_{it} can be written as a function of observable inputs k_{it} and m_{it}. Replacing $\omega_{it} = f_t^{-1}(m_{it}, k_{it})$ in eq. (1):

$$y_{it} = \beta_0 + \beta_K k_{it} + \beta_L l_{it} + \beta_M m_{it} + f_t^{-1}(m_{it}, k_{it}) + \varepsilon_{it} \qquad (2)$$

We further note $\Phi_{it}(m_{it}, k_{it}) = \beta_0 + \beta_K k_{it} + \beta_M m_{it} + f_t^{-1}(m_{it}, k_{it})$ as we replace in eq. (2) :

$$y_{it} = \beta_L l_{it} + \Phi_{it}(m_{it}, k_{it}) + \varepsilon_{it} \qquad (3)$$

The functional forms of $\Phi(.)$ is unknown as the f function is unknown. Levinsohn and Petrin (2003) use a third order polynomial expansion in m_{it} and k_{it} to approximate $\Phi(.)$. Therefore, eq. (3) can be estimated by OLS, obtaining an efficient estimate for $\hat{\beta}_L$ as well as an estimate of $\hat{\Phi} = y_{it} - \hat{\beta}_L l_{it}$. Due to the non-parametric approximation however, $\hat{\beta}_K$ and $\hat{\beta}_M$ cannot be identified in this step because they are collinear with the non-parametric term $\Phi(.)$.

Assuming that ω_t follows a first order Markov process, Levinsohn and Petrin (2003) write ω_{it} as a function of ω_{it-1}, with ξ_{it} being the innovation in ω_{it}. Therefore, firm's expectations of current productivity ω_{it} depend only on past productivity ω_{it-1}:

$$\xi_{it} = \omega_{it} - E[\omega_{it} \mid \omega_{it-1}] \qquad (4)$$

Based on the estimate for the aggregate expression $\hat{\Phi}_{it} = y_{it} + \beta_K k_{it} + \beta_M m_{it} + f_t^{-1}(k_{it}, m_{it})$ obtained from the first step, for any candidate values of the parameters (β_K, β_M) one can compute a prediction for ω_{it} using:

$$\hat{\omega}_{it}(\beta_K, \beta_M) = \hat{\Phi}_{it} - \beta_K k_{it} - \beta_M m_{it} \qquad (5)$$

A consistent estimation for $\hat{E}[\omega_{it} \mid \omega_{it-1}]$ is given by the non-parametric regression of $\omega_{it}(\beta_K, \beta_M)$ on $\omega_{it-1}(\beta_K, \beta_M)$ and a constant

$$\hat{\omega}_{it} = \gamma_0 + \gamma_1 \hat{\omega}_{it-1} + \gamma_2 \hat{\omega}_{it-1}^2 + \gamma_3 \hat{\omega}_{it-1}^3 + u_{it} \qquad (6)$$

Innovations in productivity ξ_{it} are therefore obtained as a residual:

$$\xi_{it} = \omega_{it}(\beta_K, \beta_M) - \hat{E}[\omega_{it} \mid \omega_{it-1}] \qquad (7)$$

Capital in *t* being determined by investment decision in *t-1* is not correlated to productivity shocks ξ_{it}. The condition therefore used to estimate capital coefficient is:

$$E[\xi_{it}, k_{it}] = 0 \qquad (8)$$

However, allocation of material inputs is decided in *t* such that m_{it} is correlated with the productivity level $E[\xi_{it}, m_{it}] \neq 0$. On the other hand, decision to allocate material inputs in the previous period m_{it-1} cannot anticipate present productivity shocks $E[\xi_{it}, m_{it-1}] = 0$. This condition allows estimating the coefficient for material inputs:

$$E[\xi_{it}, k_{it}] = 0 \quad \text{and} \quad E[\xi_{it}, m_{it-1}] = 0 \qquad (9)$$

Since the final estimation is based on several preliminary estimators, the covariance matrix of the final parameters needs to be corrected for sampling variation introduced by all of these estimators. Though the analytic determination of the covariance matrix is feasible, but rather difficult, Levinsohn and Petrin (2003) use bootstrapping to estimate standard errors.

Table 6. Industry distribution of firms in the sample

Industry	No. firms	Foreign firms	Local firms
Agriculture and fishing	50	10	40
Mining and quarrying	24	9	15
Manufacture of food products and beverages	172	72	100
Manufacture of textiles	22	17	5
Manufacture of clothing and apparel	61	30	31
Manufacture of leather and leather products	31	16	15
Manufacture of wood and wood products	32	13	19
Manufacture of pulp, paper and paper products	22	10	12
Manufacture of coke and refined petroleum products	5	4	1
Manufacture of chemical products	43	27	16
Manufacture of rubber and plastic products	40	25	15
Manufacture of other non-metallic mineral products	51	27	24
Manufacture of basic metals	35	26	9
Manufacture of fabricated metal products	70	22	48
Manufacture of office machinery and computers	17	8	9
Manufacture of electrical machinery	38	30	8
Manufacture of machinery and equipment	45	22	23
Manufacture of motor vehicles, trailers and semi-trailers	42	33	9
Manufacture of other transport equipment	25	11	14
Manufacture of furniture	46	26	20
Electricity, gas, steam and hot water supply	42	11	31
Collection, purification and distribution of water	37	12	25
Construction	269	39	230
Sale, maintenance and repair of motor vehicles and motorcycles	52	17	35
Wholesale trade, except of motor vehicles and motorcycles	238	98	140
Retail trade, except of motor vehicles and motorcycles	105	40	65
Transport and auxiliary transport activities	107	31	76
Hotels and restaurants	22	12	10
Telecommunications	28	22	6
Financial intermediation and insurance activities	4	2	2
Real estate activities	8	3	5
Professional, scientific and technical activities	50	28	22
Other business activities	23	8	15
TOTAL	1856	761	1095

Table 7. Regional distribution of firms in the sample

Regions	Number of firms	Share in total	Foreign firms	Local firms
Bucharest-Ilfov	595	32.1	342	253
Center	241	13	86	155
North-East	170	9.2	39	131
North-West	186	10	70	116
South	207	11.1	67	140
South-East	187	10.1	49	138
South-West	93	5	29	64
West	177	9.5	79	98
Total	1856	100 %	761	1095

Table 8. Definition of variables and expected sign

Variable	*Definition*	*Expected sign*
TFP	Logarithm of Total Factor Productivity according to the Levinsohn Petrin (2003) methodology $TFP_{it} = y_{it} - \beta_K k_{it} - \beta_L l_{it} - \beta_M m_{it}$	
Horizontal	Proxy for horizontal spillovers $Horizontal_{jt} = \sum_{i=1}^{n_j} (\rho_i * Sales_{it}) / \sum_{i=1}^{N_j} Sales_{it}$	-
Backward	Proxy for upstream technology transfer $Backward_{jt} = \sum_{j \neq k} (\alpha_{jkt} * Horizontal_{kt})$	+
Forward	Proxy for downstream technology transfer $Forward_{jt} = \sum_{j \neq k} (\sigma_{jkt} * Horizontal_{kt})$	+/-
Horizontal_L	Proxy for labor market horizontal spillovers $Horizontal\_L_{jt} = \sum_{i=1}^{n_j} (Dummy\_FDI_i * L_{it}) \Big/ \sum_{i=1}^{N_j} L_{it}$	+
Supply_Back	Proxy for suplly-backward spillovers $Supply\_Back_{jt} = \sum_{j \neq k} (\sigma_{jkt} * Backward_{kt})$	+/-
Demand	Demand from downstream sectors $Demand_{jt} = \sum_k a_{jk} * Y_{kt}$	+
Herfindahl	Market concentration index $Herfindahl_{jt} = \sum_j (Sales_{ijt} / \sum_j Sales_{jt})^2$	-
Size	Firm size $ln(Total\_Assets_{ijt})$	+
Import	The share of imports in intermediate goods supply $Import_{jt} = Imports_{jt} / Supply\ of\ intermediate\ goods_{jt}$	-/+
Export	The share of exported output $Export_{jt} = Exports_{jt} / Sales_{jt}$	+
R&D	The share of intangible assets in total fixed assets $R\&D_{ijt} = IntgAssets_{ijt} / FixedAssets_{ijt}$	+
HumanCapital	Human capital stock $HumanCapital_{ijt} = [Cost\_L_{ijt} / \min_{jrt}(Wage_{ijt})] / L_{ijt}$	+
Gap	Technological gap $Gap_{ijt} = \max_j (TFP_{ijt}^{FDI}) / TFP_{ijt}$	+/-

Table 9. Descriptive statistics of the variables used

Variable	Mean	Std. Dev.	Min	Max	Observations
TFP	3.58	1.80	-9.11	10.3	N = 14540
Horizontal	0.45	0.21	0.00	0.94	N = 16668
Backward	0.32	0.18	0	0.64	N = 16668
Forward	0.47	0.09	0.21	0.60	N = 16668
Horizontal_L	0.35	0.18	0	0.84	N = 16677
Supply_Back	0.42	0.05	0.33	0.58	N = 16677
Herfindahl	0.09	0.10	0.01	0.87	N = 16668
Demand	12.4	1.55	7.14	15.3	N = 15746
Size	8.14	1.93	-3.41	15.6	N = 14999
Import	0.15	0.20	0	0.75	N = 16668
Export	0.14	0.20	0	0.85	N = 16668
Human Capital	3.52	4	1	29	N = 14829
R&D	0.03	0.13	0	1.92	N = 10492
Gap	1.68	2.9	-53.9	47.3	N = 14540

Table 10. Correlation matrix of the main variables

	TFP	Horizontal	Backward	Forward	Horiz_L	Supply Back	Herfin dahl	Demand	Size	Import	Export	Human Capital	R&D	Gap
TFP	1.00													
Horizontal	-0.14	1.00												
Backward	-0.25	-0.34	1.00											
Forward	0.21	-0.16	-0.40	1.00										
Horizontal_L	-0.20	0.67	-0.25	-0.08	1.00									
Supply_Back	0.05	0.52	0.05	-0.36	0.44	1.00								
Herfindahl	-0.01	0.14	0.24	-0.10	0.20	-0.07	1.00							
Demand	-0.08	-0.03	0.62	-0.43	-0.01	0.44	0.16	1.00						
Size	0.19	0.16	0.15	-0.01	0.19	0.28	0.14	0.33	1.00					
Import	-0.36	0.25	0.36	-0.12	0.39	-0.01	0.41	0.18	0.16	1.00				
Export	-0.19	0.01	0.40	0.07	0.10	-0.06	0.14	-0.11	0.07	0.44	1.00			
Human Capital	0.14	0.04	0.09	-0.02	0.08	0.09	0.03	0.13	0.50	0.05	0.09	1.00		
R&D	0.15	0.15	0.06	0.00	0.18	0.16	0.15	0.18	0.66	0.10	0.06	0.48	1.00	
Gap	-0.03	0.04	0.03	-0.02	0.05	0.02	0.01	0.04	-0.02	0.06	0.06	-0.02	-0.03	1.00

Table 11. Lagged FDI spillovers and total factor productivity

VARIABLES	Total sample (1)	Foreign (2)	Domestic (3)	Domestic (4)	Domestic (5)	Domestic (6)
Dummy_FDI	0.134***					
	(0.000)					
FDI		0.002**				
		(0.000)				
Horizontal $_{t-1}$	-0.014	0.006	-0.073	-0.039	-0.007	-0.015
	(0.150)	(0.255)	(0.179)	(0.152)	(0.171)	(0.153)
Backward $_{t-1}$	0.848***	0.741**	0.957***	0.841***	0.763***	0.748***
	(0.187)	(0.317)	(0.216)	(0.232)	(0.226)	(0.240)
Forward $_{t-1}$	-0.690**	-0.195	-1.233***	-1.502***	-1.466***	-1.434***
	(0.320)	(0.562)	(0.375)	(0.348)	(0.355)	(0.353)
Herfindahl	-0.460**	-1.050***	0.079	-0.051	0.056	0.062
	(0.229)	(0.371)	(0.275)	(0.264)	(0.214)	(0.209)
Demand	0.109***	0.159***	0.089***	0.053***	0.044***	0.043***
	(0.016)	(0.032)	(0.016)	(0.016)	(0.015)	(0.016)
Size				0.198***	0.196***	0.196***
				(0.016)	(0.016)	(0.016)
Import					-0.068***	-0.064***
					(0.021)	(0.020)
Export						0.018
						(0.026)
Constant	3.590***	1.971***	4.171***	3.963***	4.024***	4.035***
	(0.376)	(0.689)	(0.442)	(0.398)	(0.422)	(0.411)
Observations	12,148	4,735	7,413	7,413	7,413	7,413
R^2	0.82	0.83	0.83	0.84	0.84	0.84

Note: The dependant variable is ln(TFP), obtained by the Levinsohn Petrin (2003) method. Cluster robust standard errors are presented in brackets. *** p<0.01, ** p<0.05, * p<0.1. The estimation method is random effects GLS. All estimations include industry, region and time dummies.

Table 12. Robustness checks for spillover effects (domestic firms only)

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Horizontal	-0.017	-0.009	-0.055	-0.110	-0.008	0.183
	(0.150)	(0.149)	(0.151)	(0.171)	(0.154)	(0.163)
Backward	0.754***	0.789***	0.811***	0.886***	0.751***	0.391*
	(0.221)	(0.226)	(0.221)	(0.211)	(0.214)	(0.213)
Forward	-1.590***	-1.633***	-1.701***	-1.340***	-1.595***	-1.216***
	(0.359)	(0.355)	(0.362)	(0.387)	(0.358)	(0.321)
Demand	0.044***	0.045***	0.057***	0.080***	0.045***	
	(0.015)	(0.015)	(0.015)	(0.017)	(0.015)	
Herfindahl	0.071	0.069	-0.047	0.342		0.506*
	(0.273)	(0.272)	(0.266)	(0.316)		(0.288)
Size	0.206***	0.206***	0.209***		0.206***	0.214***
	(0.015)	(0.015)	(0.015)		(0.015)	(0.015)
Import	-0.071***	-0.073***		-0.115***	-0.069***	-0.104***
	(0.019)	(0.019)		(0.019)	(0.019)	(0.020)
Export	-0.024		-0.029	0.008	-0.024	-0.035**
	(0.018)		(0.018)	(0.019)	(0.018)	(0.018)
Constant	3.332***	3.309***	3.159***	4.065***	3.332***	3.738***
	(0.407)	(0.412)	(0.404)	(0.423)	(0.401)	(0.330)
Observations	8,213	8,213	8,213	8,213	8,213	8,213
R^2	0.86	0.86	0.86	0.83	0.86	0.86

Note: The dependant variable is ln(TFP), obtained by the Levinsohn Petrin (2003) method. Cluster robust standard errors are presented in brackets. *** p<0.01, ** p<0.05, * p<0.1. The estimation method is random effects GLS. All estimations include industry, region and time dummies.