Which International Technology Transfer Channels Are Effective in Raising Firm Productivity?

Research Paper

Richard Kneller,
(GEP, University of Nottingham)

Smaranda Pantea[1]
(GEP, University of Nottingham)

Richard Upward
(GEP, University of Nottingham)
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Abstract

Recognition that the creation of new technology is concentrated in just a handful of countries has motivated the study of foreign sources of technology for domestic productivity growth (Keller, 2004). In this paper, we study the relative importance of foreign ownership, FDI intraindustry spillovers, FDI spillovers through backward linkages, exporting, importing, and acquiring licensing agreements as channels of international technology transfer. In contrast to the existing evidence on this topic, we recognise that access to foreign sources of technology will differ across firms within an industry and, therefore, we use firm-specific measures of global engagement. The data used comes from the Business Environment and Enterprise Performance Survey, which provides detailed plant level information for a stratified random sample of plants in 26 transition economies in Central and Eastern Europe. Our results suggest that foreign ownership, supplying MNEs, exporting and importing are associated with higher firm productivity. We find no evidence that intraindustry FDI spillovers or acquiring licensing agreements are associated with higher firm productivity.

Keywords: foreign direct investment, technology transfer, productivity spillovers

JEL classification: F23, O33, O12

[1] lexsp8@nottingham.ac.uk

1 Introduction

Firms that want to upgrade their technology can either develop new technology themselves or acquire it from other firms. However, most of the creation of new technology is concentrated in a few industrialised economies (Keller, 2004). For instance in 2004, the seven largest industrialised countries accounted for more than 86% of all patents granted by USPTO (USPTO, 2008). Thus, in many countries, but especially in developing and transition countries, the adoption of new technology is determined in large part by international technology diffusion.

The theoretical literature on international technology transfer has identified two major channels through which technology developed in one country is transferred across borders: foreign direct investment (FDI) and international trade.

Foreign direct investment implies a direct transfer of technology from parent Multinational Enterprises (MNEs) to their foreign affiliates and has long been considered one of the major channels of international technology transfer. Most of the literature on multinationals suggests that MNEs must possess some firm specific advantages in order to compete successfully with domestic firms which have better knowledge of their local environment (Dunning, 1993). These advantages consist of firm-specific, knowledge-intensive assets. When an MNE undertakes foreign production it exports services of these firm specific assets to its foreign affiliates (Markusen, 2002). In turn, this means that foreign affiliates of MNEs should benefit from this knowledge transfer from their parent MNEs.

FDI affects not only the foreign affiliates that receive technology from their parent MNEs, but also other domestic firms in the host country. The establishment of foreign affiliates in a host country may affect domestic firms in the same industry through several mechanisms: demonstration/imitation effects, increased competition and labour turnover. Exposure to MNEs products and practices helps local firms learn about new technology, new products or new marketing techniques (Wang and Blomström, 1992). Local firms may hire workers who were previously employed and trained by MNEs and thus have knowledge and experience with technology and business practises used by MNEs (Fosfuri, Motta and Ronde, 2001). Increased competition from foreign owned firms may induce the local firms to reduce their inefficiencies and allocate more resources for learning from foreign affiliates and adopting new technology (Wang and Blomström, 1992). Foreign affiliates may also have a negative impact on local firms. By paying higher wages MNEs may limit labour turnover and even attract the best workers away from domestic firms. In addition, the entry of MNEs may result in the loss of local firms' market share, which will force them to operate on a less efficient scale and thus increases their average costs (Aitken and Harrison, 1999). These effects are generally called "horizontal spillover" effects, and are usually measured by estimating the relationship between individual firms' productivity and the share of foreign owned plants in the same sector or region.

MNEs may also affect domestic firms through the linkages established by MNEs with local suppliers (backward linkages) and local customers (forward linkages). MNEs may benefit from transferring technology or business practices, such as quality control or inventory management techniques, to their suppliers to enable them to produce

higher quality intermediated inputs, improve their on-time delivery, and lower prices (Pack and Saggi, 2001; Javorcik, 2008). In addition, in the presence of economies of scale, increased demand for their output will generate productivity gains for MNEs suppliers (Markusen and Venables, 1999). MNEs may also improve the performance of suppliers without transferring technology to them is by imposing tougher requirements regarding product quality, on time delivery and costs (Javorcik, 2008). These effects are generally called “vertical spillover effects, and are usually measured by combining the share of foreign-owned firms in a sector with input-output tables to identify potential links between firms in the upstream and downstream foreign firms.

The second major channel of international technology transfer is international trade. Theoretical models by Ethier (1982), Markusen (1989) and Grossman and Helpman (1991) show that firms that import intermediate inputs can enjoy productivity gains due to access to a greater number of varieties or access to higher quality inputs. International technology transfer can take place also through learning by exporting. Interactions with foreign competitors and customers provide information on new products and technology that allows exporters to reduce costs and to improve quality (Greenaway and Kneller, 2007). Foreign customers might offer technical assistance to exporting firms to adapt their products and technology to the requirements of international markets (Pack and Saggi, 2001). This is particularly true in the case of developing countries. Exporting may also lead firms to increase their production and, in the presence of economies of scale, their productivity will increase. Finally, exposure to intense competition in international market may force firms to become more efficient by reducing X inefficiency (Greenaway and Kneller, 2007).

Firms can also acquire technology from abroad through licensing agreements. Licensing typically involves the purchase of production and distribution rights for a product and the underlying knowledge technical information and know how necessary to for its production. However, many technologies are not available through licensing. An important reason why firms exploit their technology assets through FDI rather than licensing is to overcome difficulties related to writing and enforcing licensing contracts (Dunning, 1993; Markusen, 1995).

There is a large literature that examines empirically these potential channels of technology transfer. General surveys on international technology transfer are provided by Keller (2004) and Saggi (2002), and for technology transfer through FDI by Görg and Strobl (2001) and Görg and Greenaway (2004) and for learning by exporting by Greenaway and Kneller (2007) and Wagner (2007).

There is considerable evidence that suggest that foreign owned firms are more productive than domestic owned firms. However, there is also evidence that these differences might be due to foreign investors buying the most productive domestic firms, or due to foreign firms operating in the most productive industries, being larger or using more resources per worker. The empirical evidence for intra-industry FDI spillovers is mixed and in developing and transition countries most studies have found that intra industry FDI spillovers are insignificant or even negative (Görg and Greenaway, 2004). There is more consistent evidence consistent with productivity spillovers through backward linkages in transition and developing countries (Javorcik, 2004; Blalock and Gertler, 2008; Javorcik and Spatareanu, 2008).

There is also considerable evidence of technology transfer through intermediate inputs as conduits for technology transfer at country level (Coe and Helpman, 1995; Coe, Helpman and Hoffmaister, 1997) and at firm level (Amiti and Konings, 2005; Kasahara and Rodrigue, 2008, Altomonte and Bekes, 2009, Muul and Pisu, 2007; Andersson et al. 2008). Finally, two studies focused on Slovenia found evidence of learning by exporting (Damijan et al., 2007; De Loecker (2007).

Several studies examined technology transfer through licensing. Mansfield and Romeo (1980) study the age of the technologies transferred by US companies to their foreign affiliates and the age of technologies transferred to their joint ventures and unaffiliated firms through licensing. They find that technologies transferred by US firms though licensing or joint ventures were older than those transferred to foreign affiliates. Mansfield (1994) provides survey evidence that US MNEs are less likely to transfer advanced technologies through licensing to unaffiliated companies compared to foreign owned affiliates, especially in countries with weak intellectual protection rights.

We contribute to the literature in several ways. First, this study improves on the existing literature by using firm specific measure of linkages with MNEs. Most of the previous studies on FDI productivity spillovers through backward linkages (Javorcik, 2004; Blalock and Gertler, 2008; Javorcik and Spatareanu, 2008) rely on an industry level measure of foreign presence in downstream industries calculated using input–output tables. This methodology does not identify MNEs suppliers and thus, it assumes that all firms in an upstream industry have access and benefit from the technology MNEs transfer to their local producers. The dataset used here allows one

to identify the MNEs' local suppliers and to use a firm-specific measure of linkages with MNEs, which reflects their access to MNEs' technology.

Second, we analyse the impact of all the main channels of international technology transfer simultaneously and assess their relative importance. There is a large empirical literature on each of these channels of international technology diffusion. However, Keller (2004) notes that the evidence is usually partial. There is little evidence on the relative importance of these different channels, and where this evidence exists, it is usually confined to results from aggregate data (Keller, 2004). In practice, firms rarely confine themselves to a single form of international activity, and therefore, it is important to consider the impact of different channels of international technology simultaneously.

Our paper is closest to Gorodnichenko, Svejnar and Terrell (2007) (henceforth GST) who study similar questions using the same data source. We depart from their study in a number of dimensions. First, GST's method is to relate changes in sales revenues to a combination of changes and levels of measures of internalisation. We use a simpler measure which relates levels of productivity to contemporaneous levels of the explanatory variables, as is standard. Second, we extend the sample to include 26 countries rather than the 17 countries used by GST. Third, we conduct a number of robustness checks: we consider whether the intensity of global engagement matters; we allow for the possibility that global engagement changes the parameters of the production function; and we relax the assumption that the production function is Cobb-Douglass.

Our results suggest that foreign ownership, supplying MNEs, exports are associated with higher firm productivity, which is consistent with our hypotheses of technology transfer through these channels. We find no evidence that intraindustry FDI spillovers, importing or acquiring licensing agreements are associated with higher firm productivity. With regard to the relative importance of different channels of international technology transfer, we cannot reject the hypothesis that foreign ownership, supplying MNEs and exporting are equally important.

The paper is organised as follows. Section 2 describes the data used in this paper and provides preliminary evidence of the relationship between firm performance and participation in international activities. Section 3 explains the methodology used to study the effect of engaging in international activities on productivity and productivity growth. Section 4 presents and discusses the results. Section 5 concludes.

2 Data Description

2.1 Business Environment and Enterprise Performance Survey

The data used in this paper comes from Business Environment and Enterprise Performance Survey (BEEPS) 2005 and 2002 dataset conducted by the World Bank and European Bank of Reconstruction and Development (EBRD). The implementation of the survey is described in detail in Synovate (2002, 2005). It provides detailed plant level data for a sample of firms in 27 economies in transition for the years 2001 and 2004. The countries included in this study are Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Estonia, Georgia Hungary, Kazakhstan, Kyrgyzstan, Latvia, Lithuania,

FYROM, Moldova, Poland, Romania, Russia, Serbia and Montenegro, Slovakia, Slovenia Tajikistan, Ukraine and Uzbekistan. Turkmenistan was not included due to lack of data.

This survey uses standardised questionnaires and uniform sampling methods to generate internationally comparable data. Information about the plants' characteristics is gathered through interviews with the general manager of the plant and other members of the staff, for instance, accountants or human resources managers. Plants surveyed were selected from the population of registered plants in each country. To ensure that the dataset is representative of the whole economy in each country, the survey was stratified by sector, size category and in the case of larger economies also by region. In the case of smaller economies only the main industrial areas were surveyed. The share of plants in industrial sectors and in service sectors is determined by their contribution to the GDP in each country. The survey does not include plants that operate in health, education, welfare, public administration, agriculture, electricity, gas, water and water waste and financial intermediation sectors. In addition, the survey aimed at including at least 10% of foreign firms, 10% of state owned and at least 10% exporters[2]. However, in smaller or less developed economies these quotas and the quota for large firms could not be met mainly due to the small number of such firms. In these cases, the quotas were eased or completely removed (Synovate, 2002, 2005).

The dataset consists of a total of 9098 plants for the 2005 wave and 6153 for the 2002 wave. However, a large number of plants do not report data on sales, capital, material

[2] Firms were considered to be foreign if at least 50% of their capital was foreign owned, state-owned if at least 50% of their capital was state owned, and exporters if they exported at least 20% of their output.

inputs or energy, imports, exports and share of output sold to MNEs[3]. The sample used in the empirical analysis excludes observations with missing values for these variables. Observations with negative value added and observations in the lowest and highest percentile of the distribution of capital per worker were also excluded. After excluding these observations the sample is reduced to 3690 observations for 2004 wave, and to 2864 observations for 2001.

In Table 12 and Table 13 we summarise the distribution of the sample across countries and across industries. The sample selection process does not have a great affect on the sectoral composition of the sample, but it does reduce the sample size considerably in particular countries (Azerbaijan, Belarus, Kazakhstan, Russian and Uzbekistan). In these countries, a large share of firms did not provide the information on sales, capital and material inputs.

2.2 Participation in International Activities

We use six key measures of exposure to foreign technology, summarised in Table 1. *Foreign-ownership* is measured by a dummy variable indicating whether more than 10% of the plant's capital is owned by foreign investors. *Foreign presence in the sector* within each country is calculated as the share of employment accounted for by foreign plants in total employment in the sector *j* and country *c* to which the plant belongs. *Backward linkages* are measured by a dummy indicating whether the plant sells any of its output to MNEs located in the same country. The definition of *exporting* and *importing* we use includes firms that import and export directly and

[3] The main reason for this appears to be that firms were reluctant to provide this information despite reassurances of confidentiality (see Synovate (2002, 2005)).

indirectly, through intermediates[4]. Finally, *licensing* is measured by a dummy variable indicating whether the firm acquired licensing contracts for new products over the previous three years.

Table 1 Six measures of exposure to foreign technology

	2001		*2004*	
	Mean	*Std. Dev.*	*Mean*	*Std. Dev.*
Foreign owned	0.16	0.36	0.11	0.31
Foreign presence in the sector	0.23	0.37	0.23	0.21
Backward linkages (supplies MNEs)	0.16	0.24	0.17	0.37
Exporter	0.29	0.46	0.29	0.45
Importer	0.59	0.49	0.55	0.50
Licensing	0.22	0.41	0.13	0.34

The proportion of foreign owned plants in the selected sample falls from 16% in 2001 to 11% in 2004, which possibly reflects the larger sample size in 2004. However, the proportion of employment accounted for by foreign plants remains very stable at 23%. Around 16% of plants supply MNEs, 29% export some of their output and over half use imported inputs. Finally, there appears to have been an increase in the use of licensing agreements between 2001 and 2004.

To compare these patterns with the stylized facts regarding participation in international trade documented in previous studies we calculate the share of firms that export and import directly in manufacturing sectors. In 2004, 37.8% of the manufacturing firms exported directly. For comparison, previous studies found that the percentage of manufacturing firms that exports directly was 27% for US (Bernard *et al.*, 2005), 36% for Sweden (Andersson *et al*.), 41.2% for Belgium (Muuls and

[4] This is in contrast to previous studies on exporting and importing effects, which typically consider only direct imports and exports. For the purpose of this study, both direct and indirect exports and imports are relevant. Both direct and indirect imports embody technology developed abroad, while both direct and indirect exports imply that firms are exposed to competition in export markets and have access to information about new products and or quality requirements, either directly or through the intermediary company.

Pisu, 2007) and 37.9% for Hungary (Altomonte and Bekes, 2008). The percentage of manufacturing plants that imported material inputs directly is 36.8%. For comparison, Bernard et al. (2005) report that 14% of the US firms were importers, Andersson et al. (2008) found that 27% of firms import in Sweden, Pisu and Muuls (2007) found that 43.2% of Belgian firms import and Altomonte and Bekes (2008) found the 29.9% of Hungarian firms import. In conclusion, the share of firms that export or import directly is large, but is comparable to the shares found in other small and open European countries.

As well as binary indicators of participation in international activities, we also consider the intensity of participation. For foreign owned firms, intensity is defined as the ratio of foreign owned capital to total capital. For backward linkages, intensity is defined as the ratio of sales to MNEs to total sales. Export intensity is the ratio of exports to total sales. Import intensity is the ratio of imports of intermediate inputs in total costs with material inputs. The dataset provides information only on whether a firm acquired or not any licensing agreements, so we cannot compute any intensity measure for this variable. Figure 1 and Figure 2 show the distribution of the intensity of foreign ownership, supplying MNEs, exporting and importing among the firms that engage in these activities in 2001 and 2004.

Figure 1 Intensity of global engagement (2001)

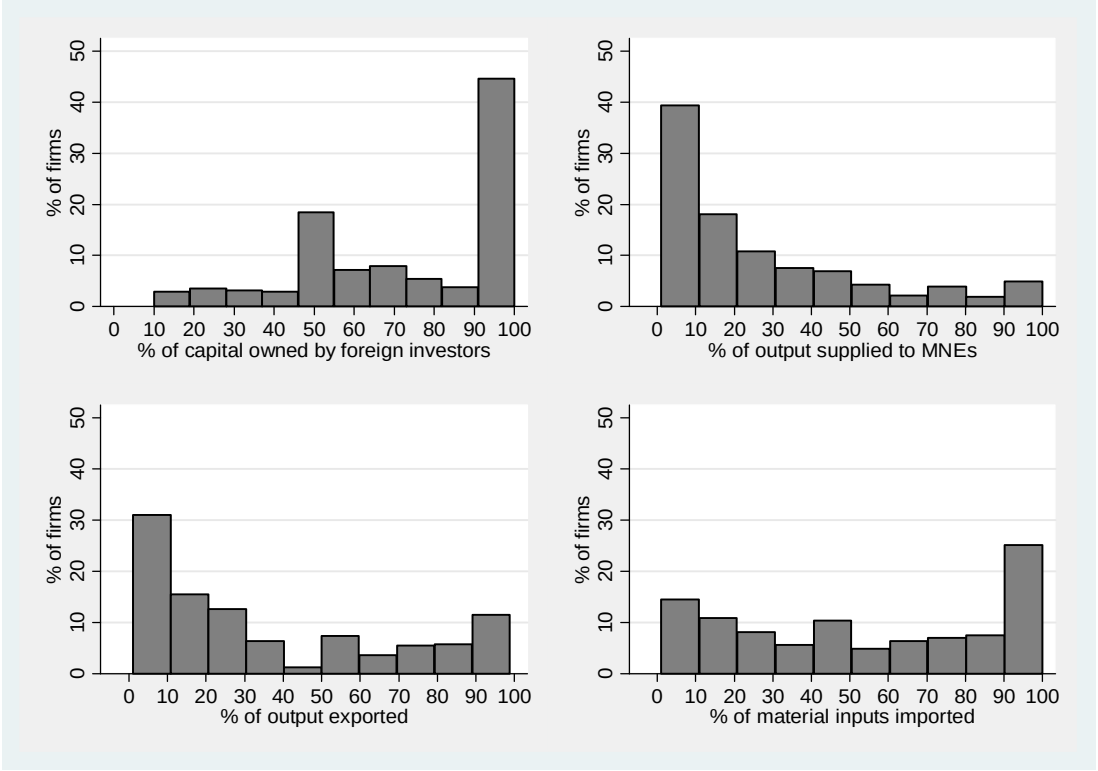
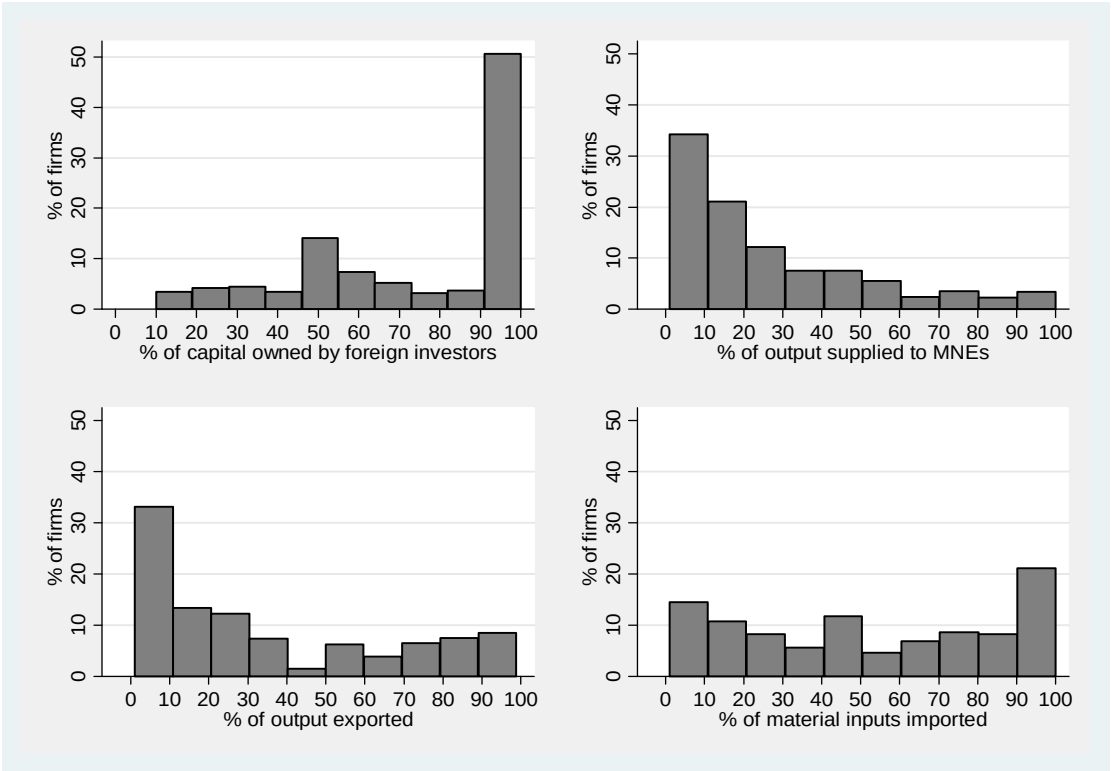


Figure 2 Intensity of global engagement (2004)



Patterns of intensity are very similar in 2001 and 2004. Most foreign owned firms are either majority foreign owned or wholly foreign owned. Most exporters export only a small share of their output; although a significant minority sell more than half of their output abroad (average export intensity is 35%). Similarly, most of the MNEs suppliers sell only a small part of their output to MNEs, but 25% of MNEs suppliers sell more than half of their output to MNEs (average share of output sold to MNEs is 30%). The distribution of the share of imported inputs in total material inputs for importers suggests a very different pattern. Most importers purchase a large share of their inputs from abroad. 60% of the importers import more than 50% of their material inputs (average import intensity is 56%).

An important aspect of plants' participation in international activities considered is whether firms engage in several international activities simultaneously. Table 2 summarises the relationship between participation in international activities.

Table 2 Participation in different international activities

	All	Foreign-owned	Supplies MNEs	Exporter	Importer	Licensing agreements
2001						
Foreign owned	0.16	1.00	0.29	0.29	0.21	0.18
Supplies MNEs	0.16	0.30	1.00	0.30	0.21	0.19
Exporter	0.29	0.54	0.54	1.00	0.39	0.29
Importer	0.59	0.81	0.75	0.79	1.00	0.61
Licensing agreements	0.22	0.25	0.26	0.21	0.22	1.00
2004						
Foreign owned	0.11	1.00	0.20	0.22	0.16	0.17
Supply MNEs	0.17	0.30	1.00	0.28	0.23	0.22
Exporter	0.29	0.59	0.49	1.00	0.41	0.35
Importer	0.55	0.80	0.76	0.78	1.00	0.64
Licensing agreements	0.13	0.20	0.18	0.16	0.15	1.00

Table 2 shows that most of the plants which are globally engaged tend to participate in several international activities simultaneously. For instance, the foreign firms are

more likely to export, supply other MNEs, and import part of their intermediate inputs and to acquire licensing agreement compared than domestic firms. Similarly, plants with supply linkages with MNEs, importers and exporters are more likely to be engaged in other international activities compared with the average plant. This suggests that there might be complementarities between different international activities. Therefore, it is important to account for all channels of international technology transfer when estimating the impact of participation in these activities on firm productivity.

2.3 Characteristics of Globally Engaged Firms

How do the characteristics of plants engaged in international activities differ from plants which are not involved in those activities? Previous studies have shown that exporters are larger, more productive, pay higher wages, and use more inputs per worker than non exporters (Bernard and Wagner (1997) for Germany, Bernard and Jensen (1999) for US, among others). Similarly, studies have shown that foreign firms have a superior performance regarding these characteristics compared with domestic firms (Globerman, Ries and Vertinksy (1994) for Canada, Doms and Jensen (1998) for US, Djankov and Hoekman (2000) for Czech Republic). More recently, similar evidence has been found for importers as compared with non importers (Bernard, *et al.* (2005) for US, Muûls and Pisu (2007) for Belgium). In this section, we examine whether foreign affiliates, exporter and importers in our sample display similar characteristics. In addition, we study whether suppliers of MNEs and firms that acquired licensing agreements have similar characteristics. Table 3 reports summary statistics for various plant characteristics across the different types of international activity.

Table 3 Characteristics of internationally engaged firms

	All	*Foreign owned*	*Supplies MNEs*	*Exporter*	*Importer*	*Licensing*
2001						
Sales	2178.91	4432.18	4789.09	4125.64	2724.77	1748.44
Labour	138.6	172.6	221.23	243.52	170.95	152.09
Sales/employee	19.89	27.9	28.98	26.11	22.47	19.44
Capital	952.95	2292.78	2414.02	1924.12	1209.99	635.36
Capital per employee	8.87	13.21	14.07	11.59	9.75	7.34
Human capital (secondary education)	84.03%	86.23%	82.88%	81.58%	84.69%	87.96%
Human capital (tertiary education)	24.90%	34.07%	32.71%	27.77%	26.54%	27.60%
R&D	38.27%	49.77%	51.19%	53.82%	44.17%	46.52%
2004						
Sales	3573.02	8314.48	6183.90	7246.75	5061.55	5423.89
Value Added	1679.08	3702.17	2937.28	3362.7	2363.59	2679.76
Labour	86.37	147.92	107	152.69	110.07	142.92
Sales/employee	40.14	56.03	54.21	49.87	45.58	37.35
VA/employee	18.83	25.44	25.11	23.63	20.85	17.91
Average wage	5.35	5.91	6.38	6.63	5.7	4.88
Capital						
Capital /employee	18.63	22.86	23.28	22.67	20.11	16.84
Material inputs/ employee	19.25	28.1	26.37	23.6	22.54	17.42
Human capital (secondary education)	62.40%	69.63%	68.11%	62.64%	64.25%	65.48%
Human capital (tertiary education)	24.23%	34.13%	28.28%	26.93%	26.40%	29.53%
R&D	15.66%	28.04%	24.67%	29.48%	26.40%	29.53%

All the monetary values are in current $US.

Table 3 shows that foreign firms, suppliers of MNEs, exporters and importers are larger both in terms of sales and number of employees, generate more value added, are more productive, pay higher wages, use more capital and material inputs per worker, have a better educated workforce, especially when measured as the share of employees with tertiary education, and are more likely to invest in R&D. In contrast, while firms that acquired licensing agreements are typically larger (at least in the 2004 data), do not seem to enjoy the same superiority relative to other firms in terms of productivity and wages.

Participation in international activities varies considerably across countries and sectors. In addition, as shown above, most globally integrated firms tend to engage in several international activities simultaneously. Therefore, to examine the characteristics of globally engaged firms we estimate a regression of the firm level characteristics in logarithmic form on dummies controlling for participation in international activities and sector and country fixed effects. Similar methods have been used to study premia related to exporting (Bernard and Jensen, 1995, 1999), foreign ownership (Doms and Jensen, 1998), importing (Muûls and Pisu, 2007).

Table 4 reports the results of these regressions. There are large size premia associated with all the measures of the measures of international engagement in terms of both sales and employment. The largest plants are those which export; the smallest premia are associated with plants which have licensing agreements. Exporters are also largest in terms of capital stock, but the most capital intensive plants are those that are foreign owned. In terms of sales or value added per worker, foreign-owned plants and plants that supply MNEs have the largest productivity premia, followed by importers and exporters. As noted in Table 3, there is no productivity premia associated with licensing agreements. There are also significant wages premia associated with all types of international activity apart from licensing agreements. Workers in plants which engage internationally also tend to be significantly more skilled, with a higher proportion having tertiary education. Finally, international activity is also associated with conducting R&D activities.

Table 4 Premia associated with global integration

Dependent variable	*Foreign affiliates*	*Backward Linkages*	*Exporter*	*Importer*	*Licensing*	*Obs.*	R^2
2001							
Total sales	0.472***	0.463***	0.938***	0.433***	0.234**	2864	0.339
	(0.090)	(0.089)	(0.079)	(0.068)	(0.077)		
Total employment	0.245**	0.210**	0.822***	0.323***	0.210**	2864	0.243
	(0.081)	(0.080)	(0.071)	(0.061)	(0.069)		
Sales per worker	0.227***	0.253***	0.116**	0.110**	0.025	2864	0.530
	(0.046)	(0.046)	(0.041)	(0.035)	(0.040)		
Capital	0.486***	0.527***	0.936***	0.381***	0.181*	2864	0.355
	(0.102)	(0.101)	(0.090)	(0.077)	(0.088)		
Capital per worker	0.241**	0.317***	0.114	0.058	-0.028	2864	0.367
	(0.078)	(0.078)	(0.069)	(0.059)	(0.067)		
Human capital	0.020	0.002	0.005	0.026**	0.006	2833	0.320
(secondary education)	(0.012)	(0.012)	(0.011)	(0.009)	(0.010)		
Human capital	0.074***	0.071***	0.051***	0.033**	0.001	2833	0.277
(tertiary education)	(0.013)	(0.013)	(0.012)	(0.010)	(0.011)		
R&D	0.037	0.094***	0.118***	0.094***	0.082**	2864	0.147
	(0.025)	(0.025)	(0.023)	(0.017)	(0.025)		
2004							
Total sales	0.844***	0.336***	1.054***	0.435***	0.254***	3690	0.324
	(0.084)	(0.071)	(0.063)	(0.056)	(0.077)		
Total employment	0.642***	0.149*	0.941***	0.285***	0.202**	3690	0.271
	(0.077)	(0.065)	(0.058)	(0.052)	(0.070)		
Sales per worker	0.202***	0.187***	0.112***	0.150***	0.051	3690	0.616
	(0.034)	(0.029)	(0.026)	(0.023)	(0.031)		
VA per worker	0.206***	0.174***	0.122***	0.136***	0.035	3690	0.603
	(0.034)	(0.029)	(0.025)	(0.023)	(0.031)		
Average wage	0.094***	0.106***	0.050**	0.065***	0.011	3677	0.746
	(0.023)	(0.019)	(0.017)	(0.015)	(0.021)		
Capital	0.774***	0.192**	0.909***	0.423***	0.213**	3690	0.322
	(0.088)	(0.074)	(0.065)	(0.059)	(0.080)		
Capital per worker	0.132*	0.043	-0.032	0.138***	0.011	3690	0.360
	(0.061)	(0.052)	(0.046)	(0.041)	(0.056)		
Material inputs per worker	0.209***	0.227***	0.122***	0.178***	0.061	3690	0.580
	(0.044)	(0.038)	(0.033)	(0.030)	(0.040)		
Human capital	0.052**	0.066***	0.002	0.032**	0.022	3648	0.164
(secondary education)	(0.017)	(0.014)	(0.012)	(0.011)	(0.015)		
Human capital	0.067***	0.041***	0.050***	0.033***	0.023	3648	0.256
(tertiary education)	(0.013)	(0.011)	(0.010)	(0.009)	(0.012)		
R&D	0.056*	0.046*	0.121***	0.061***	0.118***	3690	0.158
	(0.023)	(0.018)	(0.019)	(0.013)	(0.022)		

*p<0.05, ** p<0.01, *** p<0.001.

These patterns are in line with those documented by the previous literature for exporters as compared to non exporters, for foreign owned as compared to domestic firms, importer and non importers. The findings for MNEs suppliers show that they share many of the characteristics of the firms engaged in international trade and foreign affiliates. They are significantly larger, more productive; pay higher wages, use more material inputs, have a better educated labour force and are more likely to invest in R&D. Firms that acquired licensing agreements are significantly larger and invest more in R&D than firms without licensing agreements. However, they do not differ significantly from firms without licensing agreements with regard to their productivity, average wages, factor intensity or the education of their workforce.

In the next section, we test more formally whether engaging in these international activities is associated with higher total factor productivity, by controlling for other characteristics which themselves are correlated with productivity.

3 Empirical Strategy

The central hypothesis is that having access to technology developed abroad has a positive impact on a firm's total factor productivity *ceteris paribus*. Define Z_i as the vector of our measures of access to this foreign technology, specifically:

Z_i=(Foreign-owned, Foreign presence in the sector, Supplies MNEs, Exporter, Importer, Licensing Agreements).

Each of these variables varies at the level of plant, *i*, with the exception of foreign presence in the sector, which varies at the level of industry-country level.

To isolate the effect of Z_i on TFP, we also control for a number of other firm characteristics that may affect firm productivity, denoted X_i. We assume that the productivity of firms depends also on internal sources of knowledge as well as access to foreign technology, so we also control for firms' human capital, R&D activities and age. X_i also includes controls for product market competition. Given the possible effects of FDI on productivity through its impact on market structure (Wang and Blomström, 1992; Aitken and Harrison, 1999) discussed above, many studies on FDI spillovers control for competition in product market to isolate the effect of FDI on productivity through technology transfer (among other, Javorcik, 2004; Haskel, Pereira and Slaugher, 2002; Blalock and Gertler, 2008). We control for product market competition using dummy variables for low elasticity of demand, medium elasticity of demand and high elasticity of demand. The definitions of all variables are reported in Table 11. Most studies on FDI spillovers and on other channels of international technology transfer control include region fixed effects to control for characteristics of the region, for instance infrastructure, which might affect firm productivity. This dataset does not include information on the region where the firms are located within the country, but it does contain information on whether the firm is located in the capital city and on the size of the city or town in which the firm is located. I will use dummies for capital city and city size to control for the effects of regional characteristics. The equation also includes industry fixed effects and country fixed effects which control for industry specific and country specific effects on the total factor productivity of the firms.

Then, assuming that the production function is Cobb-Douglass, we have

$$ln(Y_i)=\beta_0+\beta_K ln(K_i)+\beta_L ln(L_i)+\beta_M ln(M_i)+\beta_E ln(E_i)+\beta_Z Z_i+\beta_X X_i+\alpha_j+\alpha_c+\alpha_r+ui \quad (1)$$

Yi is total sales of plant *i*. K_i is the capital of plant *i* and it is measured as the replacement value of the physical production assets owned and used by the firm (land, buildings and equipment). L_i is measured as the number of full time employees. M_i is measured as the cost of material inputs and purchased components and services. E_i is measured as the energy and fuel costs. The sales, capital and the costs with material inputs and energy are expressed in current USD.

All the regressions are estimated using clustered standard errors for the plants in the same industry and country. Moulton (1990) showed that in the case of regressions performed on micro units, like firms, but including aggregate variables, if there is a correlation in the disturbance terms of individual units that share a common aggregate variable, the standard errors from OLS estimation can be biased downwards. Therefore, the standard errors in the regressions estimated are clustered for all observations that belong to the same country and industry.

A similar approach is used by most studies on the effects of FDI and FDI spillovers on firm productivity (Aitken and Harrison, 1999; Javorcik, 2004; Blalock and Gertler, 2008 among others) and in the studies on the impact of imports on intermediate inputs on productivity (Kasahara and Rodrigue, 2008), and studies on performance of exporters (Bernand and Jensen, 1999, among others).

The key issue with Equation 1 is whether it identifies the causal impact of international activities on TFP. If, as seems likely, elements of Z_i are correlated with u_i then the estimates of β_Z will partly reflect these correlations. For example, firms

which supply MNEs might have higher TFP ex ante, and the estimated effect will be larger than the causal impact. In principle, the panel element of BEEPS could be used to estimate a first differenced version of (1) which would mitigate this problem if selection into Z was caused by fixed differences between firms. However, the panel element of the survey is extremely limited and various key variables are not available for both years.

4 Estimation results

4.1 Baseline Results

Table 5 shows the results of estimating Equation (1). Columns (1) and (2) report estimates for all plants while columns (3) and (4) report estimates for domestically-owned plants only. Columns (2) and (4) include a vector of control X_i for the firm's age, R&D expenditure, human capital and product market competition.

Table 5 The impact of international technology channels on TFP

	All firms		*Domestic firms*	
	(1)	(2)	(3)	(4)
Foreign owned	0.044**	0.040*		
	(0.016)	(0.016)		
Foreign presence in sector	0.015	0.020	0.021	0.024
	(0.042)	(0.040)	(0.046)	(0.045)
MNEs supplier	0.030*	0.025*	0.028*	0.021
	(0.012)	(0.012)	(0.014)	(0.014)
Importer	0.021*	0.019	0.021	0.019
	(0.010)	(0.011)	(0.011)	(0.011)
Exporter	0.028*	0.028*	0.034**	0.034**
	(0.012)	(0.012)	(0.012)	(0.012)
Licensing	0.008	0.004	0.007	0.002
	(0.015)	(0.015)	(0.017)	(0.017)
Capital	0.024***	0.025***	0.023***	0.024***
	(0.005)	(0.005)	(0.005)	(0.005)
Labour	0.256***	0.252***	0.262***	0.258***
	(0.015)	(0.015)	(0.017)	(0.017)
Material Inputs	0.614***	0.616***	0.605***	0.608***
	(0.023)	(0.023)	(0.025)	(0.025)
Energy	0.120***	0.119***	0.123***	0.122***
	(0.013)	(0.013)	(0.014)	(0.014)
Industry fixed-effects	yes	yes	yes	yes
Country fixed-effects	yes	yes	yes	yes
Other controls	no	yes	no	yes
Observations	3690	3630	3287	3239
R^2	0.977	0.977	0.975	0.976

* p<0.05, ** p<0.01, *** p<0.001

Foreign owned plants have a significant TFP advantage of around 4%. These results are rather larger than existing results from Djankov and Hoekman (2000) for the Czech Republic who found that foreign owned firms are 1.7% more productive than domestic firms and Javorcik (2004) who found that foreign owned firms are 2.5% more productive than domestic firms. Other studies on countries in transition have found different results for different countries (Konings, 2001; Damijan *et al.* 2003). Comparing with studies from other countries than transition countries the results are similar to those obtained by Doms and Jensen (1998) who found that foreign firms are 3.7% more productive than domestic firms in the US and the results of Girma,

Greenaway and Wakelin (2001) who found that foreign firms are 5.2% more productive than domestic firms.

Our measure of horizontal spillovers, (the proportion of employment in foreign-owend plants in the sector) is smaller and never significant. In the specifications which include additional controls, the effect is almost exactly zero.

In contrast, our measure of vertical spillovers suggests that firms which supply MNEs are between 2 and 3% more productive than firms that do not. As mentioned before, most of previous studies on productivity spillovers through backward linkages used industry level variables. They found that increasing the share of foreign owned firms in downstream sectors from 0 to 1 increases productivity of firms in the upstream sectors by 4% in Lithuania (Javorcik, 2004) and by 9% in Indonesia Blalock and Gertler (2008).

Exporting firms have significantly higher TFP than non-exporting firms of about 3% in all specifications, while importing effect is slightly smaller. We find no significant relationship between licensing agreement and TFP.

Several studies found that FDI spillovers affect differently domestic firms and other foreign firms. For instance, Aitken and Harrison (1999) found that FDI spillovers have a positive impact on other foreign firms, but a negative impact on domestic firms in Venezuela. Similarly, Javorcik and Spatareanu (2008) found that horizontal FDI spillovers have a negative impact on domestic firms, but an insignificant effect on foreign firms in Romania. Similar results were found by Konings (2001) for firms in

Bulgaria and Romania and by Djankov and Hoekman (2000) for firms in Czech Republic. In addition Javorcik and Spatareanu (2008) found that foreign firms do not benefit from supply linkages with other foreign firms. Their explanation for these findings is that foreign firms already have technology comparable to the technologies used by the foreign firms they supply. The results in columns (3) and (4) show that the coefficients of exports and supplying multinationals remain positive and statistically significant and have similar magnitude in both specifications. The coefficient of horizontal spillovers remains statistically insignificant.

Our baseline results suggest that foreign ownership is associated with highest productivity, followed by exporting and supplying MENs. However we cannot reject the hypothesis that these channels are equally important in any of the specifications.

4.2 Extensions and Robustness Tests

We now test the robustness of our findings by relaxing equation (1) in several ways. First, we examine the intensity of global engagement on firm productivity, rather than just using dummy variables for each activity. Second, we examine the possibility that participation in international activities affects differently the productivity of the production inputs. Third, we estimate a more flexible translog specification instead of the Cobb Douglas.

4.2.1 The Intensity of Global Engagement

Several studies have suggested that intensity of participation in these activities also matter. For instance, Javorcik (2004b) argues and presents evidence that MNEs tend to transfer to more advanced technologies to their majority owned foreign affiliates than to minority owned foreign affiliates because of fear of technology leakage.

Djankov and Hoekman (2000) also found evidence that majority owned foreign affiliates are more productive than minority owned affiliates.

Castellani (2003), Kraay (1999), Girma et al. (2004) found evidence that exporters which export a larger share of their output and therefore are more exposed to foreign markets benefit more from learning by exporting. They interpret export intensity as experience in foreign markets. If export intensity reflects experience in export markets than evidence that that firms benefit from increased experience in foreign markets can be interpret as evidence of learning by exporting. Similar arguments apply for suppliers of MNEs.

In view of these arguments, and in the light of Figures 1 and 2, we sub-divide plants into a series of bands which represent the intensity of their involvement in international activities.

Table 6 Do spillover effects vary with the intensity of global engagement?

	All firms		*Domestic firms*	
Foreig owned < 50 %	0.068	0.069		
	(0.039)	(0.039)		
Foreign owned 50-90 %	0.058**	0.053*		
	(0.021)	(0.021)		
Foreign owned > 90 %	0.026	0.020		
	(0.019)	(0.019)		
Supplies MNEs < 10%	-0.014	-0.032	-0.021	-0.043
	(0.032)	(0.029)	(0.036)	(0.031)
Supplies MNEs 10 - 50%	0.036*	0.033*	0.031	0.027
	(0.014)	(0.014)	(0.016)	(0.016)
Supplies MNEs > 50%	0.042*	0.042*	0.051*	0.050*
	(0.020)	(0.021)	(0.023)	(0.024)
Importer < 10%	0.016	0.016	0.024	0.024
	(0.025)	(0.025)	(0.027)	(0.026)
Importer 10 - 50%	0.014	0.011	0.013	0.011
	(0.012)	(0.013)	(0.012)	(0.013)
Importer > 50%	0.028*	0.025*	0.027*	0.025
	(0.012)	(0.013)	(0.013)	(0.013)
Exporter < 10%	0.019	0.020	0.020	0.019
	(0.018)	(0.018)	(0.020)	(0.021)
Exporter 10 - 50%	0.038**	0.037**	0.047**	0.046**
	(0.014)	(0.014)	(0.014)	(0.014)
Exporter > 50%	0.011	0.013	0.012	0.014
	(0.016)	(0.016)	(0.019)	(0.019)
Industry fixed-effects	yes	yes	yes	yes
Country fixed-effects	yes	yes	yes	yes
Other controls	no	yes	no	yes
Observations	3690	3630	3287	2890
R^2	0.977	0.977	0.975	0.975

* p<0.05, ** p<0.01, *** p<0.001

The coefficient of firms with a foreign share of the capital between 50% and 90% is positive and significant. Firms with a foreign share of capital larger than 90% are not significantly different from domestic owned firms. The coefficient of the minority foreign owned affiliates are positive, but statistically insignificant. These coefficients are poorly determined due to the small number of firms that are minority owned.

The results suggest that coefficient for MNEs suppliers that sell more than 50% to MNEs is positive and significant in all specifications. The coefficient for the MNEs suppliers that sell between 10% and 50% of their output to MNEs is positive and statistically significant for the sample of all firms, but it is not always statistically significant for the sample of domestic firms. The MNEs suppliers that sell less than 10% to MNEs are not significantly different from firms that do not supply MNEs. Taken together, these results, suggest that firms that supply a larger share of their output to MNEs benefit more from these linkages.

The firms that import more than 50% of their material inputs are more productive than firms that do not import any material inputs, although the coefficient for the sample of domestic firms is only significant at a 10%. The firms that import less than 50% of their output are not significantly different from the firms that do not import any material inputs.

The results suggest that the firms that export more than 50% of their output and those that export less that 10% of their output are not significantly different than non exporters. Firms that export between 10% and 50% of their output are significantly more productive than non exporters and firms that export more than 50% of their output and those that export less than 10% of their output.

In conclusion, the results suggest that intensity of global engagement matters. Firms that supply a larger share of their output to MNEs benefit more from these linkages. For exporters, it appears that firms that export a very large share of their output are not more productive than domestic firms. Regarding the differences between majority

and minority foreign owned firms, it is difficult to draw a conclusion because the coefficients are poorly determined.

4.2.2 Allowing for Interactions with Input Coefficients

So far we have assumed that access to technology developed abroad affects firm productivity only though its impact on total factor productivity. It is possible that technology transfer might also have an impact on the production inputs. For instance, imported material inputs and capital may be more productive than those purchased domestically. To examine whether global engagement affects firms through production inputs, we allow the coefficients of capital, labour and material inputs and energy to differ if firms are foreign owned, supply MNEs, import, export or acquired licensing agreements. We interacted capital, labour, material inputs and energy variables with dummies for foreign ownership, supplying MNEs, exporting, importing and licensing and test whether the interactions terms are significantly different from zero.

Most of the interaction terms are individually insignificant. Only the interaction term of imports with material intermediate inputs is statistically significant. The tests for joint significance of the terms are presented in table below.

Table 7 Test for joint significance of the interaction terms between input coefficients and channels of international technology transfer

	p- value
F test of joint sig. of interaction terms of foreign ownership with production inputs	0.899
F test of joint sig. of interaction terms of supplying MNEs with production inputs	0.096
F test of joint sig. of interaction terms of exporter with production inputs	0.065
F test of joint sig. of interaction terms of importer with production inputs	0.284
F test of joint sig. of interaction terms of licensing with production inputs	0.966

The results of the tests show that the interaction terms between participation in international activities and production inputs are also jointly insignificant at 5%.

4.2.3 Translog Production Function

The translog production function is less restrictive than the Cobb Douglass specification because it relaxes the assumption of constant returns to scale, which is rejected by the data and it allows the elasticity of substitution between inputs to vary. The translog production function estimated is a version of equation (1) which includes a set of quadratic terms in the inputs K_i, L_i, M_i and E_i as well as a full set of interaction terms between them. Table 8 compares the estimates of β_Z from the translog with the baseline estimates reported in Table 5.

Table 8 Estimation results of the translog production function

	Cobb Douglass	*Translog*
Foreign owned	0.040*	0.030*
	(0.016)	(0.015)
Foreign presence in sector	0.020	0.033
	(0.040)	(0.033)
MNEs supplier	0.025*	0.024*
	(0.012)	(0.012)
Importer	0.019	0.023*
	(0.011)	(0.009)
Exporter	0.028*	0.029**
	(0.012)	(0.011)
Licensing	0.004	-0.001
	(0.015)	(0.013)
Industry fixed-effects	yes	yes
Country fixed-effects	yes	yes
Other controls	yes	yes
Observations	3630	3630
R^2	0.977	0.982

* p<0.05, ** p<0.01, *** p<0.001

The results for the main variables of interest show that the coefficients of foreign ownership, supplying MNEs and exporting remain positive and significant. In terms of magnitude, the coefficients are similar to the ones obtained from the estimation of

equation (1). The main difference between this and the previous specifications is that the imports have a positive and significant coefficient, suggesting that imports of intermediate inputs are a channel of international technology transfer. The coefficients of horizontal spillovers from FDI and of licensing agreements are statistically insignificant as in the previous specifications. The results for the other variables are very similar to the results obtained from the Cobb Douglass production function.

In conclusion, the results from the translog specification show that the results for technology transfer through foreign ownership, supplying MNEs and exporting are robust to the use of a more flexible functional form. However, it shows that the impact of imports on productivity might not be adequately captured in the Cobb Douglas production function.

4.2.4 Estimations Results for 2001 Wave

All the results thus far have relied on a single cross section of data from 2004. In this section we investigate whether similar results are obtained from the 2001 data and the pooled sample. Unfortunately, there are some significant differences in the questionnaires used in the BEEPS across two waves. In particular, we have no data on material inputs or energy use for the earlier wave. To take into account these data limitations, we estimate a restricted form of Equation (1) without these measures. The results of these estimations are presented in Table 9. For comparison, we also report the results from the baseline estimation for the 2004 data as well as the restricted model for that year.

Table 9 Estimation results for 2001 and 2004 waves

	2001	*2004*	*2004 (base model)*
Foreign owned	0.150**	0.128**	0.040*
	(0.054)	(0.039)	(0.016)
Foreign presence in sector	0.085	-0.002	0.020
	(0.088)	(0.068)	(0.040)
MNEs supplier	0.162***	0.151***	0.025*
	(0.042)	(0.033)	(0.012)
Importer	0.082**	0.105***	0.019
	(0.030)	(0.025)	(0.011)
Exporter	0.104**	0.096***	0.028*
	(0.040)	(0.027)	(0.012)
Licensing	0.008	0.045	0.004
	(0.040)	(0.031)	(0.015)
Capital	0.180***	0.164***	0.025***
	(0.015)	(0.012)	(0.005)
Labour	0.806***	0.878***	0.252***
	0.014	(0.013)	(0.015)
Material Inputs			0.616***
			(0.023)
Energy			0.119***
			(0.013)
Industry fixed-effects	yes	yes	yes
Country fixed-effects	yes	yes	yes
Other controls	yes	yes	yes
Observations	2830	3630	3630
R^2	0.842	0.897	0.977

* p<0.05, ** p<0.01, *** p<0.001

The results for the year 2001 show that the coefficients of foreign ownership, supplying MNEs, importing and exporting are all positive and statistically significant. The coefficient of foreign presence in the industry of the firm is insignificant. Similarly, having acquired a licensing agreement in the last 3 years has an insignificant impact on the productivity of the firm.

These results are very similar to the results obtained from the estimation of the restricted model on the 2004 data reported in column (2), both qualitatively and quantitatively. Comparing the results of the restricted model to the base model

(equation 1) reported in column 3, it can be noticed that qualitatively the results are similar. However, the magnitude of the coefficients obtained from the restricted models is larger than of the coefficients obtained from the estimation of the base model. Also the results of the estimation of the restricted model suggest that the coefficient of the variable that controls for importing part of the material inputs is positive and statistically significant.

We can conclude that the results for the 2001 data confirm the previous findings for foreign ownership, supplying MNEs and exporting.

4.2.5 Comparison with Gorodnichenko et al (2007)

The study by Gorodnichenko et al (2007) is very much related to this study. They examine similar questions using the same data source. However, there are several differences between our study and Gorodnichenko et al (2007). The most important difference is that they focus on the impact of global engagement on productivity growth, while this study focuses on productivity levels. One important advantage of focusing on productivity levels instead of productivity growth rates is that productivity levels reflect long term performance, while growth rates may reflect transitory changes (Hall and Jones, 1999).

They estimate the equation:

$$\Delta lnY_i = \alpha_k \Delta k_i + \alpha_l \Delta l_i + \alpha_m \Delta m_i + \delta_1 HorizontalSpillovers_j + \delta_2 BackwardLinkages_j + \delta_3 ForwardLinkages_j + \delta_4 BackwardLinkages_i + \delta_5 Exports_i + \delta_6 Imports_i + \delta_i X_i + \alpha_j + \alpha_c + u_i$$

In this equation, the firm level measure of backward linkages, exports and imports are dummy variables that control for the fact that the firm supplies MNEs, exports part of its output or imports part of its intermediate inputs. Their specification also includes

an industry level measure of backward and forward linkages, which are calculated based on input output tables. The coefficients δ_1 to δ_5 measure how much faster grew the productivity of firms that were supplied MNEs, exported or imported relative to firms not engaged in these activities and controlling for other firm characteristics. The survey does not include information on the changes in foreign ownership, sales to MNEs and imports from 2001 to 2004. Gorodnichenko, Svejnar and Terrell (2007) use levels of these variables in 2004 and assume that they remained constant between 2001 and 2004. The foreign presence in the sector is measured as the share of the output in the sector and country accounted for by foreign firms. Backward and forward linkages industry level variables are calculated using output input tables. With regard to the firm characteristics included, our study differs in two ways. First, due to data limitations we are not able to include industry level measures of backward and forward FDI spillovers. Secondly, we consider a larger number of characteristics of the firm that might contribute to upgrading technology including human capital and R&D efforts of the firm. Our results suggest that R&D is an important determinant of productivity.

In terms of the data used, our study differs in two ways from Gorodnichenko et al. (2007). Our study covers 25 countries while Gorodnichenko et al. (2007) covers only 17. In addition, they focus only the sample of domestic firms and therefore they do not study the direct technology transfer from the parent MNEs to their foreign affiliates.

We estimated the main specification from Gorodnichencko et al (2007) study excluding the backward and forward linkages variables at industry level, on which we

do not have data. All the regressions presented below include country and industry fixed effects and standard errors are clustered for all observations that belong to the same industry and country. Other control variables included are variables that control for competition in product market. The results of the estimation are presented in Table 10. The results of Gorodnichenko et al (2007) are reported in column (2).

Table 10 Estimates of the impact of international technology channels on TFP growth

	(1)	(2)
Foreign presence in the sector	-0.017	0.020
	(0.019)	(0.016)
Supplies MNEs	0.094***	0.047***
	(0.023)	(0.014)
Importer	0.000	-0.009
	(0.012)	(0.008)
Exporter	0.063***	0.056***
	(0.018)	(0.014)
Industry fixed-effects	yes	yes
Country fixed-effects	yes	yes
Other controls	yes	yes
Observations	3712	4981
R^2	0.615	0.600

* p<0.05, ** p<0.01, *** p<0.001

The results are very similar to the results obtained by Gorodnichenko, Svejnar and Terrell (2007), reported in column (2). The coefficients of the variables that control for supplying MNEs and exporting are positive and statistically significant, suggesting that supplying MNEs located in the same country and exporting are associated with higher productivity growth. However, there is no evidence of horizontal spillovers from foreign owned firms to firms in the same industry in terms of firm productivity growth. Also, we there is no evidence of imports having a significant effect on productivity growth.

In addition, the results are consistent with the results obtained for the productivity levels. Gorodnichenko, Svenjar and Terrell (2007) do not interpret their result for the

impact of exporting and backward linkages on productivity as long term equilibrium, but rather as changes in firms' productivity in a period of rapid change. In view of this interpretation, and of the fact that the timing of the period considered by them (2001 to 2004), our results for productivity levels in 2004 may reflect the productivity of firms after the adjustment took place.

5 Conclusions

In this paper we study the relative importance of foreign ownership, intraindustry productivity spillovers from FDI, FDI spillovers through backward linkages, exporting, importing, and acquiring licensing agreements as channels of international technology transfer in 26 transition economies in Central and Eastern Europe using data from Business Environment and Enterprise Performance Survey. In contrast to the existing evidence on this topic, we recognise that access to these sources of technology will differ across firms within an industry, and therefore, we use firm-specific measures of global engagement.

To study whether there is evidence of technology transfer through international activities, we test whether engaging in these international activities is associated with higher total factor productivity. Following other empirical studies on this topic, we begin our analysis by estimating a Cobb Douglass production function augmented with variables that control for the ownership of the firm, participation in importing, exporting, licensing agreements, supply linkages with MNEs, the foreign presence in the industry of the firm and country, industry and regional fixed effects. The results suggest that foreign ownership, supplying MNEs, exports and are associated with higher firm productivity. With regard to the relative importance of different channels

of international technology transfer, we cannot reject the hypothesis that these channels are equally important. We find no evidence that intraindustry FDI spillovers, importing or acquiring licensing agreements are associated with higher firm productivity.

In conclusion, our results are consistent with the hypotheses of technology transfer through foreign ownership and relationships with foreign customers (either MNEs located in the same countries or foreign firms located abroad) and we cannot reject the hypothesis that these channels are equally important.

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A Additional tables

Table 11 Variable Definitions

Variable Name	*Definition*
Foreign owned	A dummy variable that takes the value 1 if more than 10% of the firm's capital is owned by foreign investors and 0 otherwise
Majority foreign owned	A dummy variable that takes the value 1 if more than 50% of the firm's capital is owned by foreign investors and 0 otherwise
Minority foreign owned	A dummy variable that takes the value 1 if more than 10%, but less than 50% of the firm's capital is owned by foreign companies and 0 otherwise
Backward linkages	A dummy variable that takes the value 1 if the firm sells part of its output to MNEs located in the same country and 0 otherwise
Exporter	A dummy variable that takes the value 1 if the firm exports part of its output (directly or indirectly) and 0 otherwise
Importer	A dummy variable that takes the value 1 if the firm imports part of its material inputs (directly and indirectly) and 0 otherwise
Licensing	A dummy variable that takes the value 1 if the firm acquired licensing contracts for new products over the previous three years and 0 otherwise
Foreign presence in the sector	The share of employment accounted for by foreign plants in total employment in the sector and country to which the plant belongs
Output	Total sales
Capital	Replacement value of the physical production assets like land, buildings and equipment
Labour	Number of full time employees
Material inputs	Cost of material inputs and purchased components and services
Energy	Energy and fuel costs
Human capital	Share of the number of employees with at least secondary education or the share of employees with at least tertiary education
R&D	A dummy variable that takes the value 1 if the firm had positive expenditure on R&D and 0 otherwise
Age	The year of the survey minus the year when the firm was established
Inelastic demand	A dummy variable that takes the value 1 if the firm indicated that if it increased the price of its main product by 10% its customers would continue to buy the same quantities and 0 otherwise.
Low elasticity of demand	A dummy variable that takes the value 1 if the firm indicated that if it increased the price of its main product by 10% and the firm's competitors maintained their current prices its customers would decrease slightly the quantities they buy from the firm and 0 otherwise
Medium elasticity of demand	A dummy variable that takes the value 1 if the firm indicated that if it increased the price of its main product by 10% and the firm's competitors maintained their current prices its customers would buy much lower quantities they buy from the firm and 0 otherwise
High elasticity of	A dummy variable that takes the value 1 if the firm indicated that if it increased the price

demand	of its main product by 10% and the firm's competitors maintained their current prices, its customers buy from the firms' competitors instead and 0 otherwise

Table 12 Sample composition by country

	2004				*2001*			
	All plants		*Sample used*		*All plants*		*Sample used*	
	Plants	%	Plants	%	Plants	%	Plants	%
Albania	204	2.24	100	2.71	170	2.76	98	3.42
Armenia	351	3.86	200	5.42	171	2.78	63	2.2
Azerbaijan	350	3.85	-	-	170	2.76	36	1.26
Belarus	325	3.57	67	1.82	250	4.06	179	6.25
Bosnia and Herzegovina	200	2.20	73	1.98	182	2.96	82	2.86
Bulgaria	300	3.30	135	3.66	250	4.06	102	3.56
Croatia	236	2.59	134	3.63	187	3.04	71	2.48
Czech Rep.	343	3.77	243	6.59	268	4.36	107	3.74
Estonia	219	2.41	114	3.09	170	2.76	90	3.14
Georgia	200	2.20	81	2.20	174	2.83	67	2.34
Hungary	610	6.70	369	10.00	250	4.06	158	5.52
Kazakhstan	585	6.43	106	2.87	250	4.06	119	4.16
Kyrgyzstan	202	2.22	90	2.44	173	2.81	60	2.09
Latvia	205	2.25	94	2.55	176	2.86	93	3.25
Lithuania	205	2.25	124	3.36	200	3.25	139	4.85
Macedonia, FYR	200	2.20	87	2.36	170	2.76	43	1.5
Moldova	350	3.85	65	1.76	174	2.83	94	3.28
Poland	975	10.72	622	16.86	500	8.13	184	6.42
Romania	600	6.59	244	6.61	255	4.14	131	4.57
Russia	601	6.61	111	3.01	506	8.22	178	6.22
Serbia and Montenegro	300	3.30	117	3.17	250	4.06	51	1.78
Slovakia	220	2.42	95	2.57	170	2.76	78	2.72
Slovenia	223	2.45	111	3.01	188	3.06	112	3.91
Tajikistan	200	2.20	47	1.27	176	2.86	118	4.12
Ukraine	594	6.53	212	5.75	463	7.52	309	10.79
Uzbekistan	300	3.30	49	1.33	260	4.23	102	3.56
CEE countries	5040	55.40	2662	72.14	3386	55.03	1539	53.74
CIS countries	4058	44.60	1028	27.86	2767	44.97	1325	46.26

Total	9098	100.00	3690	100.00	6153	100.00	2864	100.00

Table 13 Sector definition and composition of the sample

		2004				*2001*			
		All plants		*Sample used*		*All plants*		*Sample used*	
Sector	**NACE 1.1 codes**	Plants	%	Plants	%	Plants	%	Plants	%
Mining and quarrying	10, 11, 12, 13, 14	93	1.02	47	1.27	70	1.14	38	1.33
Food, beverages and tobacco	15, 16	889	9.77	401	10.87	775	12.60	439	15.33
Textiles, apparel and footwear	17, 18, 19	1,068	11.74	456	12.36	381	6.19	196	6.84
Wood and furniture	20, 36	679	7.46	277	7.51	205	3.33	86	3.00
Paper	21	245	2.69	105	2.85	181	2.94	89	3.11
Publishing and printing	22	24	0.26	15	0.41	23	0.37	14	0.49
Chemicals and chemical products	23, 24	156	1.71	64	1.73	107	1.74	57	1.99
Rubber and plastics	25	102	1.12	38	1.03	78	1.27	40	1.40
Non metallic mineral products	26	74	0.81	31	0.84	45	0.73	23	0.80
Basic metals and metal products	27, 28	113	1.24	49	1.33	99	1.61	53	1.85
Machinery and equipment	29	630	6.92	338	9.16	151	2.45	95	3.32
Electrical apparatus	31	359	3.95	156	4.23	120	1.95	58	2.03
Electronics	30, 32	51	0.56	28	0.76	65	1.06	35	1.22
Precision instruments	33	23	0.25	14	0.38	17	0.28	6	0.21
Motor vehicles and other transport vehicles	34, 35	33	0.36	16	0.43	18	0.29	6	0.21
Construction	45	43	0.47	14	0.38	44	0.72	19	0.66
Wholesale and retail trade	50, 51, 52	2,184	24.01	855	23.17	1862	30.26	851	29.71
Hotels and restaurants	55	467	5.13	190	5.15	384	6.24	159	5.55
Transport, storage and communications	60,61, 62, 63, 64	599	6.58	195	5.28	496	8.06	190	6.63
Real estate, renting and business activities	70, 71, 72, 73, 74	801	8.80	245	6.64	641	10.42	262	9.15
Other community, social and personal service	92, 93	465	5.11	156	4.23	391	6.35	148	5.17
Industry		4582	50.36	2049	55.53	2379	38.66	1254	43.78
Services		4516	49.64	1641	44.47	3774	61.34	1610	56.22
Total		9098	100.00	3650	100.00	6153	100.00	2864	100.00