FDI Spillovers and Multinational Firm Heterogeneity

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Abstract

Theoretical work implies that more investment promotion will attract less productive foreign firms. We analyze to what extent less productive foreign firms are capable of generating positive spillover effects. We find that only sufficiently productive foreign firms generate positive backward spillover effects. When we combine foreign and domestic firm heterogeneity, more productive multinationals, and especially those that are more than two standard deviations more productive than an individual domestic firm, are found to be the main source of positive backward spillover effects for the latter. More productive domestic firms benefit from larger positive effects. Supplying less productive multinationals results in negative spillover effects. Lower productivity levels of domestic and foreign firms generally lead to a more negative impact. If investment promotion aims at technology transfer to domestic firms, policy makers should be aware that attracting additional foreign investment might result in zero or negative spillover effects.

Keywords: FDI spillovers, multinationals, firm heterogeneity, technology transfer
JEL classification: F23

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1 Introduction

Many developing and developed countries have implemented investment promotion policies to attract foreign direct investment (FDI). Policy makers believe that foreign direct investment will contribute to faster economic growth and welfare through increases in capital stocks, improvements in technology, and through the creation of jobs (Harding and Javorcik, 2011; Borensztein et al., 1998). Aside from these direct effects, policy makers also expect substantial indirect positive spillover effects on domestic firms. Through a range of channels (see Crespo and Fontoura (2007) for a discussion) domestic firms may benefit from foreign presence. Expected benefits are fuelled by the idea that foreign firms must have some special advantages, such as superior technology, in order to enter new markets successfully (Markusen, 1995).

Recent trade literature that incorporates the mode of foreign market access into trade theory supports the latter idea. For horizontal investment Helpman et al. (2004) show that only the most productive firms in an industry engage in foreign activities. Of those firms that serve foreign markets, only the most productive engage in FDI. Antràs and Helpman (2004) obtain a similar finding for vertical investment. If FDI occurs (which is not necessarily the case, depending on model parameters more productive firms might only buy intermediates from independent suppliers abroad), then only the most productive firms are able to cover the costs associated with foreign investment. For a large sample of Euro-area firms, Geishecker et al. (2009) confirm that firms with affiliates abroad are more productive and contribute more to economy-wide productivity growth. The above implies that when investment promotion activities lower the costs associated with foreign investment, countries will -*ceteris paribus*- attract more firms but less productive foreign firms than those already present in the host economy.

In the empirical literature, there is also a relative consensus on the superiority of MNEs relative to their domestic counterparts in terms of productivity (Crespo and Fontoura, 2007). The latter result, however, typically builds on averages. For our Romanian data we obtain a similar result if we regress our productivity measure on a set of industry-year interaction dummies and a foreign ownership dummy. For our TFP measure obtained using the Olley-Pakes estimator (Olley and Pakes, 1996) we get a coefficient of 0.094 with a standard error of 0.003. However, when we plot the distributions of productivity levels of foreign and domestic firms for e.g. the 'Manufacture of food products and beverages' industry (NACE 2-digit code 15 revision 1.1[1]) in Figure 1, we observe that although the distribution for foreign firms is clearly to the right, the level of productivity of the most productive domestic firms certainly does not fall short of the level of productivity of the least productive foreign firms.

Interpreting the level of productivity of a foreign affiliate as a summary measure of its special characteristics, Figure 1 raises the question whether all foreign affiliates carry the same potential as a source of spillover effects. This is our main research question: do FDI spillover effects depend on the foreign firms' productivity levels? The answer to this question is important as at least part of the rationale for investment promotion activities is the expectation of positive spillover effects to domestic firms. It seems natural to expect more spillovers from more productive affiliates. At the macro-level, Findlay (1978) finds that the scope for positive spillovers increases when the distance to the technology frontier is larger. Sjöholm (1999) reaches a similar conclusion at the firm-level. The technology frontier is typically defined by the most productive foreign firm(s). However, although more productive foreign affiliates might offer a larger scope for positive spillovers, domestic firms need to be able to tap into this potential. The latter idea is not new to a literature that has often used the distance between a domestic firm's productivity level and the frontier foreign firm(s) as an indicator of absorptive capability. In this form domestic firm heterogeneity has received a considerable amount of attention (Crespo and Fontoura, 2007). Kokko (1996), for example, finds that horizontal spillovers are positive and significant only for plants with small or moderate technology gaps relative to foreign firms. Combining scope and absorptive capability arguments leads to potential non-linearities. Girma and Görg (2007) find a U-shaped relationship between productivity growth and their horizontal spillover variable interacted with the level of technology and Girma (2005) observes that horizontal spillovers increase with absorptive capability up to a threshold level, beyond which the increase is much less pronounced. We

[1]Nomenclature générale des Activités économiques dans les Communautés Européennes, i.e. the standard European classification system.

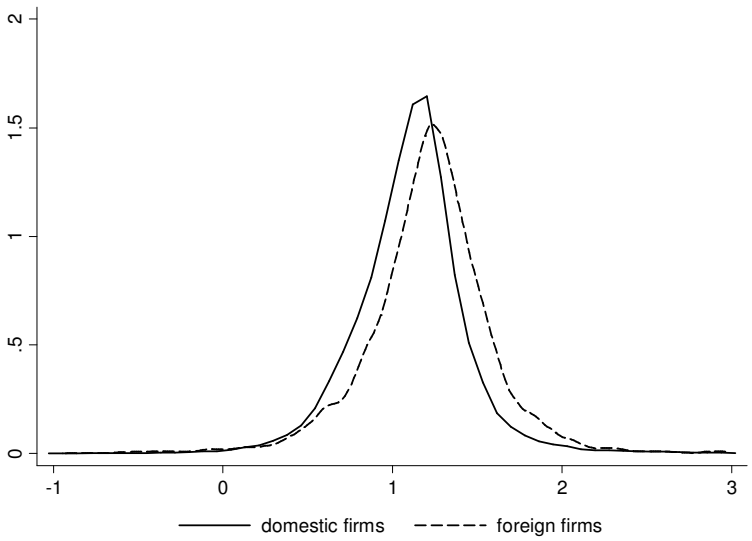


Figure 1: Density plot of Olley-Pakes (OP) TFP for domestic and foreign firms in the 'Manufacture of food products and beverages' industry (NACE 2-digit industry 15 (revision 1.1)).

therefore integrate domestic firm productivity heterogeneity into our analysis of the impact of foreign firm productivity on spillovers from foreign direct investment. In short, we try to identify *"how much whom benefits from whom"*.

To our knowledge, the heterogeneity in the productivity of foreign firms (whether or not relative to domestic firms' productivity) has not yet been analyzed as a potential determinant of FDI spillover effects. There is some related literature that looks at other forms of foreign firm heterogeneity, however. Javorcik and Spatareanu (2008) examine the relationship between a firm's ownership structure (partially versus wholly foreign-owned) and the spillovers that occur. Javorcik and Spatareanu (2011) differentiate between American and European MNEs in order to determine how spillovers are affected by the origin of foreign investors. Work by Marin and Bell (2006), Castellani and Zanfei (2007), and Marin and Sasidharan (2010) explores how differences in technology-related activities in foreign subsidiaries affect ensuing spillover effects. Nicolini and Resmini (2010) investigate whether spillovers generated by MNEs in low-tech manufacturing sectors are different from those generated by MNEs in high-tech manufacturing sectors. Bartelsman et al. (2008) examine how firms' productivity growth is affected by the distance to global and national frontiers. Their results suggest that the pull of the global frontier goes down when distance increases as opposed to the pull of the national frontier which does not change with distance.

Figure 2 illustrates the setting for our analysis. The Figure shows two stylized productivity distributions, one for foreign (F) and one for domestic (D) firms, with two domestic firms A and B and two foreign firms C and D singled out. Foreign firm D is among the most productive (foreign) firms in the market, while C is at the lower end of the foreign firms' productivity distribution. We first focus on foreign firms' ability to generate spillovers, i.e. do all foreign firms generate (equal) spillovers or do C and D differ in their ability to generate spillovers. On the one hand, only the most productive foreign firms like D could carry the potential to generate positive spillover effects, but, on the other hand, the gap between D and the domestic firms might be too wide for spillovers to manifest themselves making firm C a more likely source of spillovers in this case. The absorptive capability of domestic firms could be important as well. With A and B holding comparable positions in the domestic firms' productivity distribution as C and D in the foreign distribution, domestic firm B may not benefit from linkages with foreign firm C since B is more productive than C, but B may well benefit from the presence of foreign firm D. Firm A, on the other, hand might benefit from

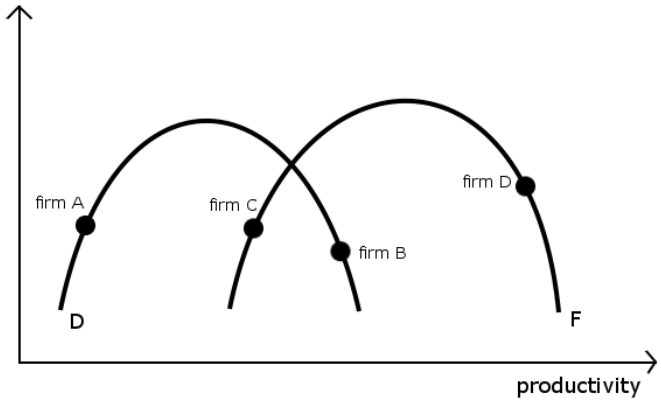


Figure 2: Stylized productivity distributions of domestic (D) and foreign (F) firms. Firms A and B are domestic, firms C and D are foreign.

C, but not from D, or it may even lack the absorptive capacity to benefit at all.

We use a panel of Romanian manufacturing firms to analyze how foreign firms' productivity affects their ability to generate spillover effects and how this interacts with domestic firms' productivity as an indicator of their ability to capture them. First, we focus on foreign firms' productivity. We decompose the traditional spillover variables into subcomponents according to foreign firms' productivity levels. More specifically, we classify foreign firms in four productivity quartiles and calculate horizontal and vertical spillover variables for every quartile separately. We find that positive backward spillovers predominantly emerge from the most productive foreign firms in each industry. Next, we introduce domestic firm heterogeneity. We first test whether domestic firms are affected differently by more and less productive foreign firms. In order to do so, we split the traditional 'overall' spillover variables into a component that refers to 'more productive' and one that refers to 'less productive' foreign firms relative to each domestic firm's productivity level. Backward linkages with more productive foreign clients are found to result in positive spillovers, whereas the opposite holds for linkages with less productive foreign firms. A further refinement reveals that especially linkages with foreign firms with a productivity level more than two standard deviations larger than the domestic firm boost the latter's productivity. Domestic firm heterogeneity matters as well. More productive domestic firms benefit more from the backward spillover effects, whereas negative spillovers weigh more heavily on the least productive domestic companies.

The remainder of the paper is structured as follows. In Section 2, spillovers from foreign direct investment are introduced in the standard empirical framework. Section 2 also introduces our data. Section 3 introduces foreign firm heterogeneity in the standard empirical framework and presents results. Section 4 presents results for the interaction of foreign and domestic firm heterogeneity. Section 5 presents some robustness tests and, finally, Section 6 summarizes the key points of the article.

2 Spillover measurement, empirical framework and data

2.1 Spillovers from foreign direct investment in the standard empirical framework

The literature on linkages and technology transfer between multinationals and local firms is extensive. Commonly, indirect or spillover effects from FDI are analyzed by including variables capturing spillover potential as additional inputs explaining total factor productivity

(TFP) in a production function framework. Spillovers are categorized into horizontal (intra-industry) and vertical (inter-industry) effects. Horizontal spillover effects occur between firms in competitive relationships in similar stages of the supply chain. Vertical spillover effects arise between firms in supplier-client relationships. In this case, the literature identifies backward spillover effects that originate from linkages between MNEs and their local suppliers and forward spillover effects that originate from linkages between MNEs and their local clients. Following Caves (1974), the first studies on the indirect effects of FDI focused exclusively on horizontal spillovers. Although the idea of vertical spillovers dates back to McAleese and McDonald (1978) and Lall (1980), these vertical effects did not receive a lot of attention until theoretical work by Rodriguez-Clare (1996) and Markusen and Venables (1999) and empirical work by Javorcik (2004) revived the interest. Since then vertical and especially backward spillovers are regarded as a more likely channel for (positive) productivity spillovers. Although literature surveys by Görg and Greenaway (2004), Crespo and Fontoura (2007), Meyer and Sinani (2009) and Havranek and Irsova (2011, 2013) suggest that empirical evidence on overall FDI spillovers is ambiguous[2], positive backward spillover effects seem robust throughout the literature. Havranek and Irsova (2011) confirm this by means of a meta-analysis. They conclude that the average backward spillover effect of foreign firms on their suppliers is both statistically and economically significant. Havranek and Irsova (2011) further indicate that the best practice estimate of forward spillovers is insignificant. Given these findings and in line with other recent work such as Damijan et al. (2013), we focus on backward spillover effects in this study.[3]

To define variables that capture spillover potential the literature typically draws on work by Caves (1974) and Javorcik (2004). Following Caves (1974) the horizontal or intra-industry spillover variable is commonly calculated as follows:

$$Horizontal_{jt} = \frac{\sum_{i \in j} F_{it} * Y_{it}}{\sum_{i \in j} Y_{it}} \tag{1}$$

where Y_{it} is the output produced by firm i in industry j at time t and F_{it} is the share of foreign participation in firm i at time t. A firm is classified as foreign when there is at least a single foreign investor who owns at least 10% of the shares. $Horizontal_{jt}$ captures the degree of foreign presence in industry j at time t by the share of industry j's output produced by foreign firms.

The backward spillover variable for industry j measures the foreign presence in industries c supplied by industry j at time t and is commonly calculated as follows:

$$Backward_{jt} = \sum_{c} \gamma_{jct} * Horizontal_{ct} \tag{2}$$

$Backward_{jt}$ is a weighted average of $Horizontal$ in the sourcing industries c. The weights are technical coefficients: γ_{jct} represents the share of industry j's total intermediate supply that is supplied to each industry c. The technical coefficients are derived from input-output tables for intermediate consumption. Following Lenaerts and Merlevede (2012), we do include within-industry intermediate supply in $Backward_{jt}$ because within-industry intermediate supply does refer to supplier-client relationships (i.e. the rationale for backward spillover effects).[4] In our view $Backward$ serves as a proxy for linkages between MNEs and their local suppliers, which does include within-industry intermediate supply.

As indicated above FDI spillover variables are introduced as additional inputs explaining total factor productivity in a production function framework. In this paper, we rely on the

[2]A potential explanation for these results is that MNEs fear technology leakage and therefore do not bring their most advanced technologies with them but only technologies that are sufficiently advanced to allow them to have an incremental advantage over domestic firms (Glass and Saggi, 1998).

[3]Furthermore, Damijan et al. (2013) indicate that foreign affiliates in Eastern Europe -we consider Romania- are mainly engaged in end-user consumer goods.

[4]In most studies, inputs supplied or sourced within the same industry are excluded from the backward spillovers because these inputs are included in the horizontal spillover (hence $c \neq j$ would be introduced as additional condition in (2); see Javorcik (2004)). We present results using this definition as a robustness check.

standard 'best practice' framework (see Havranek and Irsova, 2011) and specify equation (3) as our basic model where we relate the productivity level of firm i in industry j at time t to a set of FDI spillover variables, FDI_j, and a set of control variables, Z_{ij}.

$$TFP_{ijt} = \alpha_i + \psi_1 FDI_{jt-1} + \psi_2 Z_{ijt-1} + \xi_{ijt} \tag{3}$$

Our set of control variables includes firm age, firm size, a Herfindahl index of industry concentration, import competition and export intensity at the industry-level[5], the share of intermediates in total industry output, and an index of demand in downstream industries[6]. Equation (3) is first-differenced and time (α_t), industry (α_j), and region (α_r) dummies are added to obtain equation (5) which is estimated by OLS. Following Moulton (1990), we cluster standard errors at the industry-year level because the estimation is performed at the firm-year level whereas some of the explanatory variables are defined at the industry-year level.

$$\Delta TFP_{ijt} = \psi_1' \Delta FDI_{jt-1} + \psi_2' \Delta Z_{ijt-1} + \alpha_t + \alpha_j + \alpha_r + \epsilon_{ijt} \tag{5}$$

Because the input choices of a firm are likely to be based on its productivity, the estimation of total factor productivity (TFP) will be biased if the endogeneity of inputs is not addressed (Griliches and Mairesse, 1995). A number of alternative estimation procedures have been suggested in order to tackle this issue. The most popular alternatives are the semi-parametric approaches developed by Olley and Pakes (1996) (OP) and Levinsohn and Petrin (2003) (LP). In the semi-parametric approaches, a proxy is introduced to handle the endogeneity bias. Olley and Pakes (1996) use investment as a proxy. Levinsohn and Petrin (2003) argue that investment is lumpy and does not respond smoothly to productivity shocks and propose to use material inputs as a proxy instead. In a more recent contribution, Ackerberg et al. (2008) (ACF) present an alternative semi-parametric procedure that deals with potential collinearity issues in Olley and Pakes (1996) and Levinsohn and Petrin (2003).[7] We present results for OP and ACF TFP.[8] Note that TFP estimates are obtained from production functions estimated by NACE 2-digit manufacturing industry, while (5) pools domestic firms from all manufacturing industries.

2.2 Data

We use a large panel of Romanian manufacturing firms extracted from the Amadeus database by Bureau Van Dijk Electronic Publishing. The Amadeus database consists of financial and ownership information on public and private companies across Europe (Bureau Van Dijk, 2011). From this large database, we constructed a sample covering the period 1996-2005.[9] Other work that makes use of the Amadeus database has pointed out the excellent coverage of the subset of Romanian firms (see e.g. Altomonte and Colantone (2008) and Merlevede et al. (2014)). Foreign direct investment started to enter Romania only in the late 1990s after the implementation of several privatization and market access reforms (UNCTAD, 2003). Combined with an excellent coverage, the timing of the start of FDI inflows makes our sample an ideal setting to study FDI spillover effects. In our data set, we observe firm entry and exit and find that whereas only 16% of the total number of firms was foreign in 1996, the number

[5]Unfortunately, this information is not available at the firm-level.

[6]Downstream foreign entry could increase demand for intermediate products which may result in scale economies. To separate this effect, the regression includes demand for intermediates. Following Javorcik (2004) this is calculated as:

$$demand_{jt} = \sum_k a_{jk} * Y_{kt} \tag{4}$$

where α_{jk} is the IO-matrix coefficient which indicates that in order to produce one unit of good k, α_{jk} units of good j are needed. Y_{kt} is the output of industry k deflated by an industry-specific deflator.

[7]Other recent efforts include TFP estimation based on firm-level quantity data (TFPQ) rather than deflated revenue data (TFPR). Unfortunately, data on quantities are not available to us. Results should therefore be interpreted with this caveat in mind.

[8]We apply the procedure from Amiti and Konings (2007) to compute investment from our data.

[9]We use multiple issues (published on DVDs) of the database because a single issue is only a snapshot of the ownership information and firms that exit are dropped from the next issue released. In order to get a full overview of ownership and financials through time, multiple issues are required. See Merlevede et al. (2014).

Table 1: Summary statistics (period 1996-2005).

	All firms		Domestic firms		Foreign firms	
	mean	sd	mean	sd	mean	sd
employment	85.82	409.92	65.15	263.27	137.79	500.64
log real output	13.52	2.03	13.32	1.95	14.25	2.12
log real capital	12.02	2.35	11.75	2.27	12.96	2.35
log real materials	12.67	2.21	12.67	2.21	13.25	2.53
log TFP OP	1.97	0.94	1.93	0.91	2.09	1.01
log TFP ACF	5.74	1.52	5.69	1.52	5.95	1.47

	obs	mean	sd	min	max
horizontal	464	0.271	0.191	0.000	0.872
backward	464	0.081	0.075	0.000	0.738

had increased to 22% by 2005. Most of these investors are European.

We focus on firms with at least five employees on average. Our sample is further trimmed for outliers by removing the top and bottom percentiles of the annual growth rates of real operating revenues, real material inputs, real capital and labour.[10] Nominal data are deflated with industry price-level data at the NACE 2-digit level. Price-level data are taken from the Statistical Yearbook of the Romanian Statistical Institute (RSO, 2005) and the Industrial Database for Eastern Europe from the Vienna Institute for International Economic Studies (WIIW, 2007). Labour (L) is the number of employees. Real output (Y) is constructed by deflating operating revenues with industry-level producer price indices. Real capital (K) is calculated as tangible fixed assets deflated by the average of the following industry deflators: machinery and equipment (NACE 2-digit 29), office machinery and computing (30), electrical machinery and apparatus (31), motor vehicles, trailers and semi-trailers (34) and other transport equipment (35). Real material inputs are obtained by deflating material inputs with a weighted intermediate input deflator. The weights are taken from input-output tables that were obtained from the Romanian Statistical Office. These input-output tables are provided in a Romanian industry code classification that maps into the NACE 3-digit classification. We have a time-series of input-output tables which allows us to calculate time-varying technical coefficients.

Table 1 displays summary statistics of firm-level variables for all firms and for domestic and foreign firms separately. Foreign firms realize more output, have higher capital stocks and employ more workers. On average, they are also more productive than their local counterparts. Foreign firms produce on average 27.1 per cent of industry output (based on 464 industry-year observations). This number varies between 0 and 87.2 per cent. On average 8.1 per cent of output in client industries is produced by foreign firms. Note that we only consider vertical linkages with manufacturing industries here, whereas technical coefficients are calculated on the basis of IO-tables containing all industries. We do so because we do not want to use the productivity estimators discussed above to obtain TFP measures for services sectors.[11] Additionally, FDI has been concentrated in manufacturing industries in our sample period (Pauwels and Ionita, 2008).

3 Foreign firm heterogeneity

We first investigate whether the productivity level of foreign firms is important for their capacity to generate spillover effects to domestic firms. In order to study the impact of foreign firm heterogeneity on FDI spillover effects, we split the spillover variables defined

[10] If the 'outlier' is due to the first or last observation for a specific firm and other data points are normal, the other firm-year data are kept. If this is not the case, all observations for the firm are dropped from the data.

[11] Backward spillover variables for services industries are included as a control variable.

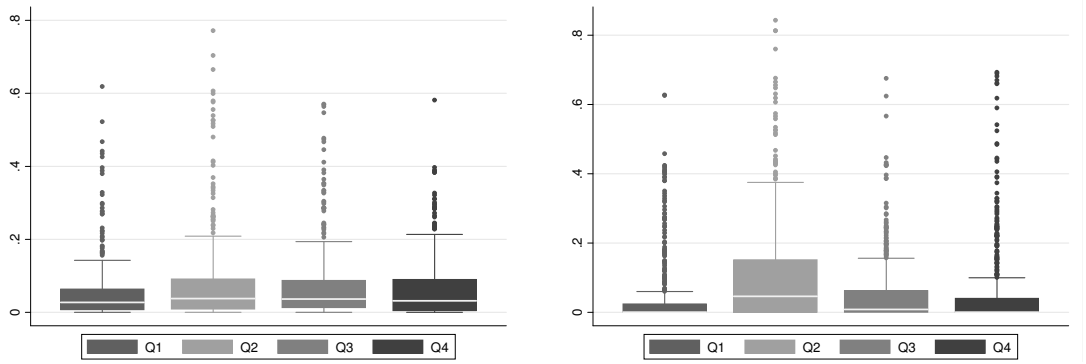
in (1) and (2) above in different subcomponents. The decomposition of the horizontal and backward variables is based on the categorization of MNEs in different productivity classes. A firm is classified on the basis of its 'initial' productivity, i.e. the average productivity over the first three years we observe the firm.[12] The decomposition is operationalized by defining four different dummy variables, Qx^{TFP} that indicate to which productivity quartile x a foreign firm belongs. For example, $Q1^{\text{TFP}}$ is set to one if the firm belongs to the first (lowest) quartile of the productivity distribution and zero otherwise. As shown in equation (6), these dummies are then introduced in (1) such that the four subcomponents sum to the original horizontal spillover variable. Rather than restricting the subcomponents' impact to be equal, each HR_{jt}^{Qx} will enter (3) as a separate explanatory variable, i.e. we relax the implicit assumption that all foreign firms are equal in generating spillover effects, notwithstanding substantial productivity differences. Using (2) and (6), the backward spillover variable is decomposed accordingly as shown in equation (7).

$$\begin{aligned} Horizontal_{jt} &= \frac{\sum_{i\in j} F_{it} * Y_{it}}{\sum_{i\in j} Y_{it}} \\ &= \frac{\sum_{i\in j} (Q1^{TFP} + Q2^{TFP} + Q3^{TFP} + Q4^{TFP}) * F_{it} * Y_{it}}{\sum_{i\in j} Y_{it}} \\ &= \frac{\sum_{i\in j} Q1^{TFP} * F_{it} * Y_{it}}{\sum_{i\in j} Y_{it}} + ... + \frac{\sum_{i\in j} Q4^{TFP} * F_{it} * Y_{it}}{\sum_{i\in j} Y_{it}} \\ &= HR_{jt}^{Q1} + HR_{jt}^{Q2} + HR_{jt}^{Q3} + HR_{jt}^{Q4} \end{aligned} \tag{6}$$

$$\begin{aligned} Backward_{jt} &= \sum_{c} \gamma_{jct} * Horizontal_{ct} \\ &= \sum_{c} \gamma_{jct} \left(HR_{ct}^{Q1} + HR_{ct}^{Q2} + HR_{ct}^{Q3} + HR_{ct}^{Q4}\right) \\ &= BK_{jt}^{Q1} + BK_{jt}^{Q2} + BK_{jt}^{Q3} + BK_{jt}^{Q4} \end{aligned} \tag{7}$$

We consider three alternatives to classify firms in initial productivity quartiles. First, we determine percentile cut-offs on the basis of the within-industry distribution of initial productivity. In this case potential differences in productivity across industries are not taken into account. Second, we use percentile cut-offs that are based on the distribution of initial productivity across all industries. This allows foreign firms in a specific industry to cluster in the same quartile (and therefore spillover variable). Intuitively this difference boils down to the issue whether domestic firms learn differently from the most productive foreign firms within each (downstream) industry or whether domestic firms learn differently from the most productive foreign firms altogether (irrespective of whether the latter belong to the same or different industries). Clearly, both decompositions will be different only to the extent that the variation within industries is small relative to the variation across industries. Table 2 shows a cross-tabulation of both sets of productivity quartiles with table entries expressed as a percentage of the total number of foreign firms. The diagonal accounts for about 34% of observations, so two thirds of foreign firms are classified in a different quartile depending on whether one uses the within- or across-industry distribution of initial productivity. As a third alternative, we consider a combination of the previous approaches and split the horizontal spillover variable on the basis of the within-industry distribution of initial productivity and the backward spillover variable on the basis of the productivity distribution across all industries. Figure 3a shows a boxplot of the decomposition of the horizontal spillover variable in four quartiles defined according to the initial productivity level within each industry of foreign firms. The 25 per cent least productive foreign firms seem to produce a smaller share

[12] Classifying firms based on average productivity does not qualitatively affect results. These results are available on request.



(a) Decomposition of the horizontal spillover variable based on the within-industry distribution of initial productivity.

(b) Decomposition of the horizontal spillover variable based on the across-industry distribution of initial productivity.

Figure 3: Comparison of the two decompositions of the horizontal spillover variable.

Table 2: Cross-tabulation of within-industry and across-industry productivity quartiles.

			across industries			
			Q1	Q2	Q3	Q4
within	industries	Q1	10.8	7.5	5.8	1.3
		Q2	7.6	5.8	8.1	3.7
		Q3	5.4	5.7	6.0	8.2
		Q4	0.8	6.2	5.5	11.5

than the foreign firms in the other quartiles, which do not seem to differ very much in terms of their share in industry output. Figure 3b presents a boxplot of the decomposition of the horizontal spillover variable in four quartiles defined according to the initial productivity level across manufacturing industries. In this case foreign firms in the second quartile seem more likely to be producing larger shares of industry output.

Table 3 presents results of the estimation of (5) with FDI spillover variables as defined in (6) and (7). Columns 1 to 3 report results for the alternative decompositions based on OP TFP. The general conclusion that emerges is that backward spillovers from the most productive foreign firms are positive and significant. In column 1, which uses the decomposition based on the within-industry distribution of TFP, there is a clear ranking in terms of point estimates with the least productive foreign firms within each industry showing the most negative, though not significant, impact on domestic firms' TFP. Only linkages with the most productive foreign firms result in a significant positive spillover effect. Switching to the "across industries"-classification affects backward spillover effects in columns 2 and 3. Now quartiles two, three and four all contribute positively to domestic firms' TFP, with coefficients of similar size. The quartile three effect is not statistically significant different from zero while the other two are. Comparing the results in column 1 with those in columns 2 and 3 suggests that especially the most productive foreign firms within each industry affect domestic firms' TFP positively as in column 2 and 3 the most productive firms from industries with lower average productive are now contained in quartile two or three (e.g. a quarter of the most productive foreign firms (Q4) within industries are classified as below median productive in Q2 (cf. Table 2)).

In column 4 we show results for spillover variables that are calculated using a zero-diagonal definition (*cf. supra*). As argued in Lenaerts and Merlevede (2012), the difference with the previous column amounts to a 'mechanical' interpretation based on within- and between-industry effects versus more intuitive supply chain, within-industry competition, and labour

Table 3: Industry-level spillovers from four quartiles of MNEs: baseline results.

	OP TFP				OP TFP manuf.		ACF TFP		ACF TFP OP class.	
	non-zero diagonal			zero diag.	non-zero diagonal		non-zero diagonal		non-zero diagonal	
	within industries	across industries	HR within BK across	HR within BK across	within industries	HR within BK across	within industries	HR within BK across	within industries	HR within BK across
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
HR Q1	0.869	0.375	0.364	0.406	0.387	0.205	3.033*	3.177**	2.244	1.212
	[0.641]	[0.389]	[0.429]	[0.423]	[0.438]	[0.353]	[1.781]	[1.614]	[1.593]	[1.168]
HR Q2	0.448	0.159	-0.097	0.181	0.247	0.226	1.605	0.065	1.482	0.069
	[0.471]	[0.241]	[0.414]	[0.383]	[0.400]	[0.376]	[1.260]	[0.989]	[1.344]	[1.154]
HR Q3	0.452	0.112	0.262	0.471**	0.345	0.306	-0.279	0.323	1.501	0.884
	[0.300]	[0.446]	[0.304]	[0.228]	[0.227]	[0.233]	[1.150]	[0.992]	[0.948]	[0.886]
HR Q4	-0.182	-0.098	0.093	0.403**	0.019	0.157	0.831	0.750	-0.474	0.388
	[0.202]	[0.412]	[0.186]	[0.187]	[0.282]	[0.269]	[0.704]	[0.581]	[0.662]	[0.611]
BK Q1	-1.977	-0.365	-0.215	-1.154	-2.216	-0.836	2.335	1.994	-3.907	-0.746
	[2.382]	[0.593]	[0.509]	[1.098]	[1.456]	[0.755]	[5.822]	[1.722]	[6.330]	[2.009]
BK Q2	-1.633	1.067*	1.105**	1.291**	-0.225	1.479*	-5.258	5.774**	-4.215	3.321**
	[1.159]	[0.565]	[0.467]	[0.629]	[0.835]	[0.780]	[4.165]	[2.409]	[3.269]	[1.601]
BK Q3	-0.337	2.237	2.093	5.373***	-0.343	-0.559	5.102*	5.624	-0.958	5.294
	[0.623]	[2.062]	[1.769]	[1.837]	[0.720]	[1.021]	[2.939]	[4.203]	[2.609]	[3.974]
BK Q4	2.416***	1.574**	1.502**	2.760*	2.841***	2.909*	2.133	2.807	7.801***	4.224**
	[0.703]	[0.696]	[0.755]	[1.411]	[0.933]	[1.494]	[2.572]	[2.013]	[2.087]	[1.695]
Obs.	96,681	96,681	96,681	96,681	96,732	96,732	73,255	73,255	73,255	73,255
R^2	0.071	0.069	0.069	0.072	0.071	0.070	0.081	0.082	0.088	0.084

Second step OLS estimates for domestic manufacturing firms with at least five employees in the period 1996-2005. Regressions include time, industry and region dummies; control variables included are downstream demand, industry concentration, firm age, firm size, import competition, export intensity, the share of intermediate supply in total industry output and services spillovers. Standard errors in brackets are clustered at the industry-year level. ***/**/* denotes significance at 1/5/10 percent.

market effects. The point estimate of the backward spillover effects is now larger, but the change in definition results in smaller values of the backward spillover variables which implies that the backward spillover effect actually decreases in size.

Horizontal spillover effects are largely absent in columns 1 to 3. Point estimates suggest that the impact of the most productive foreign firms is the smallest or even negative. Results for the zero-diagonal backward definition in column 4 show the opposite result, i.e. horizontal spillover effects from more productive foreign firms (Q3 and Q4) are now significantly positive. This is in line with Lenaerts and Merlevede (2012) who find that the impact of within-industry intermediate supply is likely to be captured as a positive horizontal spillover effects when it is not accounted for in the backward spillover variable due to the use of a zero-diagonal definition. The positive horizontal spillover effect from more productive foreign firms found in column 4 is likely to be due to within-industry intermediate supply (hence the smaller size of the backward spillover effect).

In columns 5 and 6 of Table 3 we present results on the basis of the estimation of a single production function for the manufacturing industry as a whole rather than estimations by NACE 2-digit industry. These results confirm the findings for the backward spillover effects in columns 1 and 3.

In columns 7 and 8 we repeat the analysis using ACF TFP rather than OP TFP. In column 7 the backward spillover effect is now only statistically significant for foreign firms in the third quartile of the within-industries productivity distribution, while in column 8 it is only significant for the second quartile of the across-industries productivity distribution.

Going from OP to ACF reduces the number of observations by about 25%, which might drive the observed differences in results. If we apply the classification of foreign firms obtained from the initial OP productivity distribution and estimate using ACF productivity as a dependent variable in columns 9 and 10, we do confirm the results obtained in column 3. In our further analysis (*cf. infra*) results are better aligned between OP and ACF TFP.[13]

4 Foreign and domestic firm heterogeneity

Notwithstanding the fact that foreign firms are on average more productive than their local counterparts, Figure 1 and Table 1 reveal that there is a considerable overlap between foreign and domestic firms' productivity distributions. Therefore we take the analysis a step further and allow domestic firms' productivity (and domestic firms' productivity relative to foreign firms' productivity), to bear an impact on spillover effects. In order to do so we define and calculate spillover variables at the firm-level by classifying foreign firms as either 'more productive' or 'less productive' relative to each individual domestic firm f. This is illustrated in Figure 4 where the productivity level of each individual domestic firm f, such as E, serves as a baseline for the calculation of firm-specific spillover variables. To construct the 'more productive' spillover variables for firm E, we gather the more productive foreign firms (the segment of the distribution indicated by the thick full line) and use only these foreign firms to create HR^{more} in (8) using a similar reasoning as in (1). 'Less' productive spillover variables for firm E are constructed using only those foreign firms whose productivity level falls below E's (the segment of the distribution indicated by the dotted line). This analysis is repeated for each domestic firm f and thus yields different values for domestic firms that differ in their initial level of productivity. We define firm-specific horizontal spillover variables for a given firm f in industry j at time t in (8) and (9). In (10) and (11) we show how we calculate the inter-industry BK^{more} and BK^{less} variables for a given firm f based on (2). Note that we compare the productivity level of firm f in industry j with the productivity levels of foreign firms in sourcing industries c. The spillover variables constructed in (8) and (9) and the derived backward spillover variables will enter the regressions as separate variables to allow for different effects. Equations (8)-(11) define firm-specific spillover variables. Table 4 below presents summary statistics for the spillover variables split-up according to these definitions. The share in industry output of more productive firms is on average about twice the share of less productive foreign firms in industry output.

$$HR_{fjt}^{more} = \frac{\sum_{i \in j} F_{it} * Y_{it}|_{TFP_{fj} > TFP_{ij}}}{\sum_{i \in j} Y_{it}} \tag{8}$$

$$HR_{fjt}^{less} = \frac{\sum_{i \in j} F_{it} * Y_{it}|_{TFP_{fj} \leq TFP_{ij}}}{\sum_{i \in j} Y_{it}} \tag{9}$$

$$BK_{fjt}^{more} = \sum_{c} \gamma_{jct} * \frac{\sum_{i \in c} F_{it} * Y_{it}|_{TFP_{fj} > TFP_{ic}}}{\sum_{i \in c} Y_{it}} \tag{10}$$

$$BK_{fjt}^{less} = \sum_{c} \gamma_{jct} * \frac{\sum_{i \in c} F_{it} * Y_{it}|_{TFP_{fj} \leq TFP_{ic}}}{\sum_{i \in c} Y_{it}} \tag{11}$$

[13]To rule out that these results are driven by multicollinearity, we run estimations where we enter the different subcomponents one at a time. The results of these estimations largely confirm the results in Table 3: positive backward effects are primarily driven by the best MNEs. The most noteworthy difference is that the backward spillover effect of MNEs in quartile three is now statistically significant in a higher number of cases. As a further robustness test we also ran estimations where the 'traditional' horizontal spillover variable, as defined in (1), is used and only the backward spillover variable is decomposed into four subcomponents. The results also confirm our earlier findings with regards to the backward spillovers. Horizontal spillovers are insignificant. The results of these analyses are available on request.

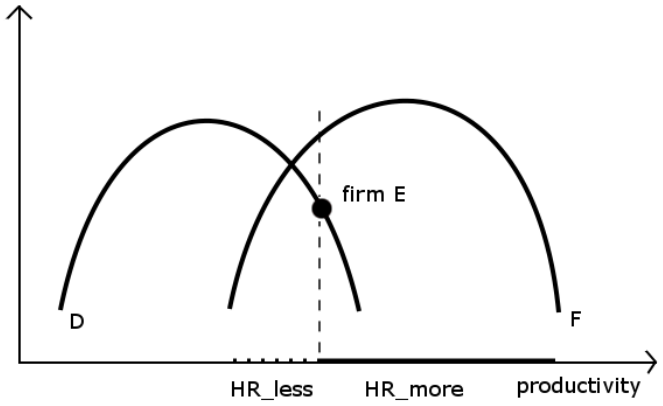


Figure 4: Stylized productivity distributions of domestic (D) and foreign (F) firms. Illustration of the calculation of firm-level spillovers for domestic firm E.

Table 4: Summary statistics of firm-level spillover variables.

	Less Productive				More Productive			
horizontal spillovers								
	$<\text{TFP}_f$	>2sd	<2sd	<1sd	<1sd	<2sd	>2sd	$>\text{TFP}_f$
mean	0.096	0.003	0.012	0.080	0.154	0.027	0.007	0.188
std. dev.	0.107	0.025	0.041	0.089	0.120	0.052	0.021	0.135
backward spillovers								
	$<\text{TFP}_f$	>2sd	<2sd	<1sd	<1sd	<2sd	>2sd	$>\text{TFP}_f$
mean	0.028	0.003	0.011	0.035	0.066	0.020	0.007	0.049
std. dev.	0.031	0.014	0.020	0.033	0.058	0.024	0.010	0.044

Table 5 contains the results for the firm-level spillover variables. The first four columns show results based OP TFP, the last four columns show results based on ACF TFP. Column 1 incorporates all spillover variables (non-zero diagonal definition, *cf. supra*) in a single estimation. Backward spillover effects are positive and significant if they originate from more productive foreign firms, and they are negative and significant if they originate from relationships with foreign firms that are less productive than domestic firm f. Columns 2 and 3 confirm these results when spillovers from more and less productive foreign firms are considered one at a time. Horizontal spillover effects are not detected when both 'more' and 'less' spillover variables are introduced in the same regression. They become significant if entered one at a time. Horizontal spillovers from more productive foreign firms are positive, whereas those from less productive foreign firms are negative. The sign of the coefficients on the horizontal spillover variables is confirmed for ACF TFP in columns 5 to 7, but the spillovers are never significant. The backward spillover effects are robust to the change in TFP-measure. Columns 4 and 8, which show results for the zero-diagonal backward definition, confirm the positive effect from more productive foreign firms. Horizontal spillover effects are significant, but, as indicated before, likely pick up within-industry intermediate supply relationships.

These findings suggest that domestic firms should be careful when entering a supplier contract with a foreign firm. Domestic firms only benefit from these linkages provided their foreign client is more productive. These results are in line with Section 3, where we found positive backward spillover effects only to originate from the most productive foreign firms within each industry. The latter will typically be more productive than most domestic firms.

We now consider a refinement of our more-less approach through a further decomposition

Table 5: Firm-level spillovers from more and less productive MNEs: baseline results.

	OP TFP				ACF TFP			
	non-zero diagonal			zero diag.	non-zero diagonal			zero diag.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
HR more	0.091	0.310***	-	0.346***	0.040	0.223	-	0.578**
	[0.126]	[0.102]	-	[0.103]	[0.363]	[0.346]	-	[0.229]
HR less	-0.197	-	-0.359***	-0.428***	-0.263	-	-0.510	-1.194***
	[0.157]	-	[0.116]	[0.112]	[0.457]	-	[0.426]	[0.275]
BK more	1.062***	1.209***	-	1.517***	2.453***	2.746***	-	3.058***
	[0.279]	[0.268]	-	[0.333]	[0.752]	[0.754]	-	[0.888]
BK less	-1.269***	-	-1.649***	-1.730***	-5.245***	-	-5.594***	-7.214***
	[0.330]	-	[0.290]	[0.355]	[1.041]	-	[1.012]	[1.259]
Obs.	96,681	96,681	96,681	96,681	73,255	73,255	73,255	73,255
R^2	0.098	0.088	0.087	0.100	0.109	0.089	0.097	0.111

Second step OLS estimates for domestic manufacturing firms with at least five employees in the period 1996-2005. Regressions include time, industry and region dummies; control variables included are downstream demand, industry concentration, firm age, firm size, import competition, export intensity, the share of intermediate supply in total industry output and services spillovers. Standard errors in brackets are clustered at the industry-year level. ***/**/* denotes significance at 1/5/10 percent.

of the 'more productive' and 'less productive' versions of the spillover variables. First, we calculate the standard deviation of the level of productivity for the sample of all domestic firms. Then, we add and subtract one and two times the standard deviation from the productivity level of each individual domestic firm f (such as firm E in Figure 4) to obtain four cut-off values. These cut-off values allow us to create three classes of MNEs on each side of the domestic firm's productivity level: i) foreign firms that are up to one standard deviation more (less) productive than the domestic firm ($< 1sd$); ii) foreign firms that are between one and two standard deviations more (less) productive ($< 2sd$); and iii) foreign firms that are more than two standard deviations more (less) productive ($> 2sd$). Foreign firms more than two standard deviations apart from the domestic firm could be considered as "significantly" more or less productive. Table 4 presents summary statistics for the spillover variables split-up according to these definitions (based on 96,681 firm-level observations). Foreign firms that fall within one standard deviation above or below the domestic firm's productivity level account for the largest part of foreign firms share in industry output. Foreign firms that have a productivity level which is more than two standard deviations larger than that of the domestic firm account on average for less than one percent of industry output, but there is substantial variation across firms.

Table 6 presents the estimation results where we allow for further heterogeneity in the spillover coefficients for different productivity classes of MNEs. Columns 1 and 4 present results for the full set of spillover variables for OP and ACF TFP respectively, while columns 2, 3, 5, and 6 introduce either the *more* or the *less* spillover variables by themselves in the estimation. Backward spillover effects are primarily driven by foreign firms that are substantially more productive ($> 2sd$). For OP TFP all more productive foreign firms generate positive backward spillover effects, while for ACF TFP only those foreign firms that are significantly, i.e. more than two standard deviations, more productive generate positive backward spillover effects. Linkages with less productive foreign firms are nearly always significantly associated with negative spillover effects. For both OP and ACF TFP point estimates switch sign from more to less productive foreign firms. The size of point estimates seems inversely related to foreign firm productivity with the most productive MNEs generating the largest positive backward spillover effects. Horizontal spillover effects are largely absent. There is some indication that significantly less productive foreign firms are associated with negative effects. Given the numbers in Table 6, this impact is fairly small, however. To rule out potential

Table 6: Firm-level spillovers from more and less productive MNEs: decomposition based on standard deviation.

	OP TFP			ACF TFP				OP TFP	ACF TFP
	(1)	(2)	(3)	(4)	(5)	(6)		(7)	(8)
HR more $_{>2sd}$	0.606	0.828	-	0.453	0.555	-	HR more $_{>2sd}$	0.160	0.337
	[0.503]	[0.505]	-	[0.720]	[0.723]	-		[0.478]	[0.626]
HR more $_{<2sd}$	-0.136	0.049	-	0.253	0.485	-	HR less $_{>2sd}$	-0.153	-3.946*
	[0.175]	[0.166]	-	[0.380]	[0.371]	-		[0.519]	[2.118]
HR more $_{<1sd}$	0.109	0.269***	-	-0.387	-0.116	-	BK more $_{>2sd}$	7.574***	8.677***
	[0.120]	[0.093]	-	[0.322]	[0.301]	-		[1.099]	[1.313]
HR less $_{<1sd}$	-0.123	-	-0.329***	-0.543	-	-0.392	BK less $_{>2sd}$	-5.848***	-16.694***
	[0.143]	-	[0.093]	[0.415]	-	[0.380]		[1.113]	[3.650]
HR less $_{<2sd}$	-0.266	-	-0.422*	-0.290	-	-0.297	Obs.	96,681	73,255
	[0.233]	-	[0.229]	[0.794]	-	[0.826]	R^2	0.110	0.136
HR less $_{>2sd}$	-0.972*	-	-1.177**	-5.130**	-	-5.248**	HR more $_{<2sd}$	-0.125	0.371
	[0.534]	-	[0.546]	[2.202]	-	[2.240]		[0.159]	[0.312]
							HR less $_{<2sd}$	-0.338	0.275
BK more $_{>2sd}$	5.754***	6.342***	-	7.638***	8.164***	-		[0.212]	[0.771]
	[1.071]	[1.089]	-	[1.406]	[1.423]	-	BK more $_{<2sd}$	2.277***	1.071
BK more $_{<2sd}$	1.875***	2.079***	-	0.359	0.909	-		[0.376]	[0.904]
	[0.359]	[0.363]	-	[0.884]	[0.886]	-	BK less $_{<2sd}$	-2.385***	-13.138***
BK more $_{<1sd}$	0.596**	0.738***	-	0.343	-0.228	-		[0.580]	[1.981]
	[0.253]	[0.236]	-	[0.688]	[0.730]	-	Obs.	96,681	73,255
BK less $_{<1sd}$	-0.278	-	-0.750***	-2.341**	-	-5.399***	R^2	0.084	0.087
	[0.297]	-	[0.254]	[1.022]	-	[1.052]	HR more $_{<1sd}$	0.254**	-0.471*
BK less $_{<2sd}$	-1.804***	-	-2.567***	-5.635***	-	-5.564***		[0.109]	[0.245]
	[0.494]	-	[0.537]	[1.786]	-	[1.861]	HR less $_{<1sd}$	-0.182	-0.737*
BK less $_{>2sd}$	-4.053***	-	-4.595***	-6.570*	-	-8.014**		[0.137]	[0.396]
	[1.149]	-	[1.175]	[3.840]	-	[4.038]	BK more $_{<1sd}$	0.369	-1.086
								[0.260]	[0.662]
Obs.	96,681	96,681	96,681	73,255	73,255	73,255	BK less $_{<1sd}$	-0.325	-5.470***
R^2	0.131	0.107	0.104	0.147	0.133	0.099		[0.344]	[1.147]
							Obs.	96,681	73,255
							R^2	0.070	0.094

Second step OLS estimates for domestic manufacturing firms with at least five employees in the period 1996-2005. Regressions include time, industry and region dummies; control variables included are downstream demand, industry concentration, firm age, firm size, import competition, export intensity, the share of intermediate supply in total industry output and services spillovers. Standard errors in brackets are clustered at the industry-year level. ***/**/* denotes significance at 1/5/10 percent.

multicollinearity effects, the last two columns of Table 6 present estimation results where the different subcomponents are considered separately. Results are in line with those reported in columns 1-6. The most productive foreign firms are thus confirmed to be the main source of positive backward spillover effects.

Upon closer inspection, the definition of HR^{more} in (8) implies that -*ceteris paribus*- less productive domestic firms in a given industry will have a higher value for the *more* spillover variables. This can be seen from Figure 5 that plots for each domestic firm the initial level of OP TFP against the value of BK^{more}. The previous set of estimations therefore does not account for the potential impact of domestic firms' productivity as an indicator of absorptive capability. The literature, however, has highlighted the importance of absorptive capability of domestic firms as a determinant of spillover effects (see Crespo and Fontoura, 2007). We

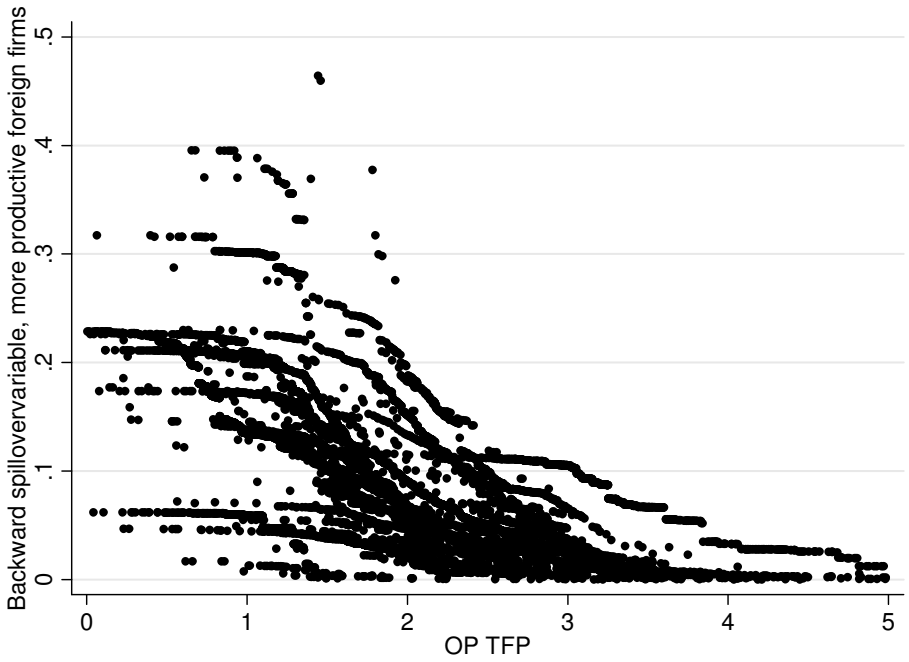


Figure 5: Backward spillover variables from more productive MNEs related to local firm OP TFP.

introduce the idea of absorptive capability by splitting domestic firms in different groups according to their initial level of productivity. As for foreign firms, we define four quartiles of initial productivity across all industries and estimate separate regressions for each quartile of domestic firms. The results are presented in Table 7. The first four columns present results for OP TFP, columns five to eight present results for ACF TFP (here quartiles for both foreign and domestic firms are defined on the basis of ACF TFP). The overall pattern is fairly stable across different productivity quartiles and it is in line with the findings in Table 6, i.e. supplying the most productive foreign firms is the main channel through which positive spillover effects are transmitted. The least productive domestic firms seem to benefit only from those MNEs in supplying industries that are considerably more productive. Domestic Q1 and Q2 firms only benefit significantly from foreign firms that are considerably more productive in the ACF TFP case, or that are at least one standard deviation more productive in the OP TFP case. Marginally more productive foreign firms do not generate positive spillover effects which is in line with the findings in Table 3 that only the most productive foreign firms generate positive backward spillover effects. The most productive domestic firms (Q3 and Q4 firms), on the other hand, seem to benefit from all foreign firms that are more productive. The more productive domestic companies also seem to benefit more: point estimates for all backward spillover variables from more productive foreign firms are positive, significant, and larger than for their less productive domestic counterparts. Supplying less productive foreign firms results in negative spillover effects. Lower levels of domestic and foreign firms' productivity generally give rise to a more negative impact.

Figures 6 and 7 show the total period-average backward spillover contribution to OP and ACF TFP respectively in function of domestic firms' initial level of TFP.[14] In the Figures each dot represents a domestic firm and the vertical lines indicate the cut-off values for domestic firm productivity quartiles. There is considerable heterogeneity across firms, but the more productive domestic firms on average clearly benefit more than their less productive counterparts. Figures 6 and 7 suggest that domestic firms need to have a sufficient absorp-

[14]The figures we obtain when we only consider the contributions of statistically significant backward spillover effects are very similar and therefore not included in this article.

Table 7: Firm-level spillovers from more and less productive MNEs: decomposition based on standard deviation and domestic firm heterogeneity.

	OP TFP				ACF TFP			
	local q1	**local q2**	**local q3**	**local q4**	**local q1**	**local q2**	**local q3**	**local q4**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
HR more $_{>2sd}$	1.254	0.019	0.140	-0.528	0.640	0.775	0.874	-1.046
	[0.782]	[0.725]	[0.631]	[0.924]	[0.695]	[0.852]	[0.879]	[1.042]
HR more $_{<2sd}$	0.232	0.247	-0.173	-0.240	0.479*	0.616	0.400	0.073
	[0.207]	[0.210]	[0.198]	[0.282]	[0.276]	[0.506]	[0.505]	[0.650]
HR more $_{<1sd}$	0.155	0.163	0.209	0.024	-0.632	0.024	0.288	-0.120
	[0.134]	[0.177]	[0.150]	[0.210]	[0.399]	[0.369]	[0.417]	[0.373]
HR less $_{<1sd}$	-0.191	-0.074	-0.045	-0.253	-0.204	-0.581	0.035	-0.287
	[0.206]	[0.202]	[0.147]	[0.251]	[0.838]	[0.542]	[0.532]	[0.420]
HR less $_{<2sd}$	-1.187*	-0.984	-0.160	-0.273	1.313	1.006	-0.729	-0.446
	[0.713]	[0.722]	[0.280]	[0.258]	[1.428]	[1.260]	[1.050]	[0.755]
HR less $_{>2sd}$	-7.028***	1.626	-0.222	-0.472	-11.014*	-2.956	-4.097*	-2.423*
	[2.253]	[2.277]	[1.162]	[0.495]	[6.360]	[2.524]	[2.384]	[1.448]
BK more $_{>2sd}$	2.709**	5.359***	8.385***	12.339***	6.315***	8.019***	9.729***	15.784***
	[1.099]	[1.505]	[1.917]	[3.450]	[1.431]	[2.092]	[2.562]	[3.279]
BK more $_{<2sd}$	1.069***	1.055**	2.048***	2.643**	-2.064***	-0.104	2.172	5.379**
	[0.309]	[0.414]	[0.670]	[1.302]	[0.713]	[1.187]	[1.365]	[2.221]
BK more $_{<1sd}$	0.126	-0.103	0.806**	1.056**	-0.826	-1.215	0.255	3.637***
	[0.152]	[0.323]	[0.391]	[0.515]	[0.919]	[0.976]	[1.077]	[1.187]
BK less $_{<1sd}$	-0.663*	-0.802**	-0.381	0.941	-5.854***	-1.744	-1.896	0.158
	[0.386]	[0.362]	[0.360]	[0.627]	[2.008]	[1.431]	[1.471]	[1.396]
BK less $_{<2sd}$	-0.181	-1.051	-1.758***	-0.607	-11.267***	-10.299***	-4.235*	-1.997
	[1.717]	[1.529]	[0.569]	[0.544]	[3.660]	[2.882]	[2.416]	[1.866]
BK less $_{>2sd}$	5.047	-12.159**	-6.310**	-3.241***	-13.340	-12.282	-21.955***	-6.828**
	[4.499]	[5.101]	[2.517]	[0.946]	[20.832]	[9.366]	[8.168]	[2.792]
Obs.	23,625	23,147	23,615	22,585	13,226	16,128	17,457	16,885
R^2	0.139	0.114	0.168	0.231	0.168	0.120	0.154	0.254

Second step OLS estimates for domestic manufacturing firms with at least five employees in the period 1996-2005. Regressions include time, industry and region dummies; control variables included are downstream demand, industry concentration, firm age, firm size, import competition, export intensity, the share of intermediate supply in total industry output and services spillovers. Standard errors in brackets are clustered at the industry-year level. ***/**/* denotes significance at 1/5/10 percent.

tive capability in order to benefit from positive spillover effects. Overall, positive backward spillover effects are the largest for more productive domestic firms whereas spillover effects turn negative for less productive firms. Horizontal spillovers are absent. These findings are in line with Gorodnichenko et al. (2007) and Damijan et al. (2013). Gorodnichenko et al. (2007) find positive backward spillover effects that decrease with domestic firms' distance to frontier. Damijan et al. (2013) report that less productive firms are more likely to be faced with negative vertical spillovers than more productive firms, which are more likely to benefit from positive effects. While we confirm these previous findings, we more importantly show that they are not solely related to absorptive capability, but also crucially depend on foreign firms' level of productivity as an indicator of their capability to generate spillover effects.

Since not all foreign firms are a source of positive productivity spillover effects, policy makers have to take this issue into account in the design and implementation of investment

1). This will shift the relative productivity levels of foreign and domestic firms in favour of the latter which is associated with smaller spillover effects. If foreign firms' productivity levels are too low, they are even likely to generate negative backward spillover effects. Measures aimed at increasing domestic firms productivity are a good idea because they increase competitiveness and absorptive capability. In terms of spillover effects, increases in domestic firm productivity require accompanying increases in foreign firm productivity for positive backward spillover effects. Clearly, our analysis is partial and in addition to the indirect effects of FDI, direct effects should also be considered. Although less productive foreign firms may not give rise to positive spillovers, these firms do bring capital and jobs.[15] But as far as technology transfer is the aim of policy makers, they should be aware that attracting foreign firms with lower productivity levels might result in zero or negative spillover effects.

5 Robustness

In this Section, we verify the robustness of the estimation results presented in Table 7. We focus on Table 7 because this Table integrates the different layers of foreign and domestic firm heterogeneity.

As a first robustness test, we start from a similar set-up as in Table 7 and perform two estimations, one in which the *more* spillover variables are entered separately and one in which only the *less* spillover variables are entered. Results are presented in the top and bottom panel of Table 8. In the top panel, results confirm that positive backward spillover effects predominantly originate from foreign firms whose productivity level exceeds the domestic firm's productivity level by more than two standard deviations. The more productive domestic firms are able to absorb positive backward spillover effects from all more productive foreign firms. Less productive domestic firms only benefit from linkages with foreign firms that are more than two standard deviations more productive in the ACF TFP case and at least one standard deviation more productive for OP TFP. The estimated impact of linkages with the other foreign firms is mixed. There also is limited evidence of positive horizontal spillovers. In the bottom panel of Table 8, the pattern of backward spillover effects is similar to the pattern in Table 7, and again all statistically significant effects are negative. Overall, the results in Table 8 confirm our previous findings.

One may wonder whether our results are driven by specific exit and entry patterns. Therefore we present in Table 9 the results of repeating Table 7 for a balanced subsample of domestic firms that are present in the sample in years 1998-2005. A comparison of Tables 7 and 9 reveals that the obtained coefficient patterns are highly similar in both tables. Specific entry or exit patterns are therefore not driving our results. Classifying domestic firms in productivity quartiles within rather than across industries neither alters our conclusions as one can infer from Table 10. Although the additional benefits accruing to more productive domestic firms seem somewhat smaller in Table 10 than in Table 7, more productive foreign firms are once more confirmed to generate larger positive backward spillover effects and more productive domestic firms are able to benefit more. Figure 8 shows results for ACF TFP where we consider ten deciles of domestic firm productivity rather than four quartiles. The drawback of this approach is that this decreases the degrees of freedom and the number of represented industries in the decile subsamples, thus reducing the source of variation for identification. Bearing this caveat in mind, moving from quartiles to deciles in Figure 8 shows fairly similar results to Figure 7.

Could it be that results are driven by a limited number of extremely (un)productive 'outlier' foreign firms that dominate the spillover variables that are more than two standard deviations larger (smaller) than the productivity level of all domestic firms? A calculation of the average number and the share of foreign firms that are more or less productive reveals that in 2005 on average between 12 (7) per cent and 93 (88) per cent of foreign firms are classified as more (less) productive. The average percentages of more productive foreign firms are the smallest in various sub-industries of the 'Manufacture of food products and bever-

[15] In our sample, a comparison of average capital and employment levels of foreign firms does not suggest clear differences between the different quartiles.

Table 8: Firm-level spillovers from more and less productive MNEs: decomposition based on standard deviation and domestic firm heterogeneity - more and less spillover variables separated.

	OP TFP				ACF TFP			
	local q1	**local q2**	**local q3**	**local q4**	**local q1**	**local q2**	**local q3**	**local q4**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
HR more $_{>2sd}$	1.438*	0.019	0.228	-0.617	0.720	0.729	0.896	-1.001
	[0.780]	[0.728]	[0.655]	[0.937]	[0.721]	[0.839]	[0.872]	[1.025]
HR more $_{<2sd}$	0.423**	0.362*	-0.093	0.096	0.668**	0.827*	0.451	0.122
	[0.193]	[0.206]	[0.190]	[0.352]	[0.289]	[0.487]	[0.467]	[0.639]
HR more $_{<1sd}$	0.402***	0.315**	0.243**	0.308**	-0.323	0.222	0.461	-0.012
	[0.113]	[0.137]	[0.119]	[0.151]	[0.410]	[0.357]	[0.377]	[0.351]
BK more $_{>2sd}$	3.091***	6.634***	9.360***	13.698***	6.715***	9.286***	11.085***	16.419***
	[1.110]	[1.520]	[1.998]	[3.463]	[1.490]	[2.096]	[2.555]	[3.138]
BK more $_{<2sd}$	1.218***	1.732***	2.775***	2.684*	-1.343*	0.681	3.435***	6.201***
	[0.325]	[0.463]	[0.690]	[1.434]	[0.789]	[1.196]	[1.295]	[2.046]
BK more $_{<1sd}$	0.157	0.181	1.627***	1.332**	-2.403**	-1.881*	0.258	4.166***
	[0.162]	[0.296]	[0.393]	[0.536]	[1.022]	[1.033]	[1.152]	[1.144]
Obs.	23,625	23,147	23,615	22,585	13,226	16,128	17,457	16,885
R^2	0.113	0.082	0.139	0.215	0.150	0.103	0.139	0.248
HR less $_{<1sd}$	-0.383**	-0.309**	-0.351***	-0.471***	-0.447	-0.692	-0.213	-0.417
	[0.167]	[0.130]	[0.107]	[0.179]	[0.853]	[0.510]	[0.434]	[0.385]
HR less $_{<2sd}$	-1.381**	-1.308*	-0.419	-0.267	0.256	0.948	-1.007	-0.349
	[0.678]	[0.675]	[0.288]	[0.232]	[1.412]	[1.290]	[1.115]	[0.762]
HR less $_{>2sd}$	-6.909***	1.319	-0.504	-0.525	-6.326	-3.164	-4.470*	-2.550*
	[2.088]	[2.279]	[1.194]	[0.502]	[6.996]	[2.606]	[2.465]	[1.430]
BK less $_{<1sd}$	-1.108***	-0.915***	-0.820**	0.431	-10.179***	-4.588***	-4.674***	-2.449*
	[0.404]	[0.308]	[0.337]	[0.567]	[2.162]	[1.515]	[1.364]	[1.306]
BK less $_{<2sd}$	-0.839	-1.331	-2.569***	-1.932***	-5.793	-9.635***	-4.266	-4.273**
	[1.639]	[1.474]	[0.651]	[0.590]	[3.631]	[2.736]	[2.632]	[1.859]
BK less $_{>2sd}$	4.102	-12.517**	-7.161***	-4.321***	-31.224	-14.405	-25.393***	-9.429***
	[4.315]	[5.110]	[2.564]	[0.982]	[21.705]	[9.638]	[8.236]	[2.932]
Obs.	23,625	23,147	23,615	22,585	13,226	16,128	17,457	16,885
R^2	0.106	0.097	0.140	0.209	0.098	0.080	0.117	0.222

Second step OLS estimates for domestic manufacturing firms with at least five employees in the period 1996-2005. Regressions include time, industry and region dummies; control variables included are downstream demand, industry concentration, firm age, firm size, import competition, export intensity, the share of intermediate supply in total industry output and services spillovers. Standard errors in brackets are clustered at the industry-year level. ***/**/* denotes significance at 1/5/10 percent.

ages' (NACE 2-digit industry 15) and the 'Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials' (20). On the other hand, the average percentages are the highest in various sub-industries of 'Manufacture of refined petroleum products' (23); 'Manufacture of machinery and equipment n.e.c.' (29); 'Manufacture of office machinery and computers' (30); and 'Manufacture of radio, television and communication equipment and apparatus' (32). Furthermore, in 2005, averaged over domestic firms, up to 51 per cent of foreign firms over all industries are more than two standard deviations more productive (mean is 10 per cent), between 1 and 37 per cent of foreign firms fall between one and two standard deviations (mean is 19) and between 10 and 41 per cent of foreign firms are up to one standard deviation more productive (mean is 30). On average up to 22 per cent of foreign firms are more than two standard deviations less productive (mean

Table 9: Firm-level spillovers from more and less productive MNEs: decomposition based on standard deviation and domestic firm heterogeneity - balanced panel of local firms.

	OP TFP				ACF TFP			
	local q1	**local q2**	**local q3**	**local q4**	**local q1**	**local q2**	**local q3**	**local q4**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
HR more $_{>2sd}$	2.099*	-0.773	-0.421	-0.647	0.414	0.837	0.102	-0.789
	[1.117]	[0.736]	[0.872]	[0.822]	[0.675]	[1.006]	[0.838]	[0.863]
HR more $_{<2sd}$	0.258	0.029	-0.186	-0.194	-0.656	-0.036	0.241	0.208
	[0.260]	[0.228]	[0.263]	[0.314]	[0.434]	[0.694]	[0.657]	[0.438]
HR more $_{<1sd}$	0.175	0.075	0.317*	-0.191	-1.167*	-0.553	-0.090	-0.211
	[0.172]	[0.161]	[0.177]	[0.220]	[0.626]	[0.554]	[0.430]	[0.332]
HR less $_{<1sd}$	-0.114	-0.003	0.018	0.111	-0.450	-0.474	-0.471	-0.489
	[0.262]	[0.236]	[0.176]	[0.277]	[0.891]	[0.921]	[0.625]	[0.349]
HR less $_{<2sd}$	-1.201	0.527	0.176	-0.325	1.588	4.423	-0.394	0.477
	[0.870]	[0.826]	[0.367]	[0.301]	[3.160]	[3.034]	[1.216]	[0.716]
HR less $_{>2sd}$	-8.984**	-2.227	-0.178	-0.620	-16.787***	-5.755*	-16.284**	-6.998***
	[3.790]	[2.594]	[1.949]	[0.552]	[5.889]	[3.310]	[7.724]	[2.195]
BK more $_{>2sd}$	2.937**	5.049***	9.115***	11.653***	6.635***	8.664***	9.630***	12.131***
	[1.145]	[1.557]	[1.999]	[3.826]	[1.470]	[2.881]	[2.361]	[2.761]
BK more $_{<2sd}$	1.188***	2.188***	2.766***	2.581*	0.084	1.819	3.978**	3.990***
	[0.322]	[0.528]	[0.884]	[1.346]	[0.967]	[1.803]	[1.987]	[1.473]
BK more $_{<1sd}$	0.240	0.364	0.445	1.726***	0.496	-0.169	-0.364	2.103**
	[0.181]	[0.321]	[0.539]	[0.579]	[1.281]	[1.312]	[1.261]	[0.922]
BK less $_{<1sd}$	-0.868*	-0.888**	-0.421	-0.386	-3.813*	-3.899	-2.398	-0.692
	[0.473]	[0.395]	[0.458]	[0.637]	[1.960]	[2.414]	[1.799]	[0.920]
BK less $_{<2sd}$	-0.315	-4.918***	-1.936**	-1.492**	-16.039**	-17.002***	-6.223**	-5.829***
	[2.308]	[1.827]	[0.767]	[0.657]	[7.546]	[6.483]	[2.954]	[1.787]
BK less $_{>2sd}$	8.379	-5.625	-5.523	-3.977***	30.715	-11.886	20.580*	-3.843
	[6.594]	[6.597]	[4.074]	[1.130]	[22.909]	[18.811]	[11.672]	[3.269]
Obs.	17,791	17,842	17,984	17,530	10,909	13,893	14,473	14,231
R^2	0.183	0.142	0.186	0.207	0.199	0.178	0.191	0.168

Second step OLS estimates for a balanced panel domestic manufacturing firms with at least five employees in the period 1998-2005. Regressions include time, industry and region dummies; control variables included are downstream demand, industry concentration, firm age, firm size, import competition, export intensity, the share of intermediate supply in total industry output and services spillovers. Standard errors in brackets are clustered at the industry-year level. ***/**/* denotes significance at 1/5/10 percent.

is 5), between 1 and 32 per cent of foreign firms fall between one and two standard deviations (mean is 12) and between 5 and 39 per cent of foreign firms are up to one standard deviation less productive (mean is 24). A detailed inspection of the data further revealed that for the average domestic firm, firms of almost all industries are part of each of the six subclasses. We therefore conclude that the values of the $> 2sd$ spillover variables are not driven by 'outlier' firms.

Our results clearly indicate that there is substantial heterogeneity among foreign firms in terms of productivity levels. This heterogeneity implies that not all firms carry an equal spillover potential. One might argue that the level of productivity is merely conveying other characteristics that drive spillover potential. Javorcik and Spatareanu (2008) examined the relationship between a foreign firm's ownership structure and ensuing spillover effects. Foreign

Table 10: Firm-level spillovers from more and less productive MNEs: decomposition based on standard deviation and domestic firm heterogeneity - alternative decomposition of local firms.

	OP TFP				ACF TFP			
	local q1	**local q2**	**local q3**	**local q4**	**local q1**	**local q2**	**local q3**	**local q4**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
HR more $_{>2sd}$	0.513	0.564	0.680	0.409	0.157	0.060	0.660	-0.121
	[0.414]	[0.673]	[0.876]	[0.915]	[0.611]	[0.818]	[0.957]	[1.121]
HR more $_{<2sd}$	-0.098	-0.482**	-0.139	0.132	0.020	0.233	0.248	0.554
	[0.134]	[0.198]	[0.256]	[0.253]	[0.377]	[0.488]	[0.517]	[0.558]
HR more $_{<1sd}$	-0.043	0.069	0.259*	0.212	-0.936**	-0.239	-0.205	0.172
	[0.096]	[0.136]	[0.152]	[0.164]	[0.380]	[0.360]	[0.428]	[0.459]
HR less $_{<1sd}$	-0.447***	-0.197	0.136	0.066	-0.756	-0.571	-0.197	-0.179
	[0.159]	[0.177]	[0.189]	[0.178]	[0.851]	[0.539]	[0.473]	[0.456]
HR less $_{<2sd}$	-1.405***	-0.243	-0.109	0.153	-1.445	-0.805	0.266	0.022
	[0.415]	[0.322]	[0.323]	[0.274]	[1.373]	[1.016]	[1.029]	[0.722]
HR less $_{>2sd}$	-3.310***	-2.227**	-0.066	-0.022	-11.549**	-4.976**	-12.306***	-2.371
	[1.088]	[1.086]	[1.372]	[0.647]	[5.690]	[2.527]	[4.636]	[1.474]
BK more $_{>2sd}$	4.748***	6.767***	5.595***	8.085***	7.473***	8.995***	8.818***	11.394***
	[0.820]	[1.659]	[1.743]	[1.845]	[1.281]	[1.806]	[2.175]	[2.652]
BK more $_{<2sd}$	1.219***	2.353***	2.284***	2.032***	-1.161	1.074	1.786	1.113
	[0.259]	[0.462]	[0.454]	[0.529]	[0.901]	[1.270]	[1.372]	[1.410]
BK more $_{<1sd}$	0.294	0.692***	0.694**	1.000***	0.035	-0.093	0.813	1.371
	[0.217]	[0.266]	[0.307]	[0.324]	[0.900]	[0.930]	[1.034]	[1.162]
BK less $_{<1sd}$	-0.339	-0.298	-0.575	0.200	-4.460**	-1.551	-1.772	-1.641
	[0.371]	[0.388]	[0.392]	[0.328]	[1.986]	[1.475]	[1.287]	[1.162]
BK less $_{<2sd}$	-1.730**	-2.237***	-2.095***	-1.263**	-4.756	-8.380***	-8.383***	-3.613**
	[0.670]	[0.718]	[0.728]	[0.549]	[3.677]	[2.759]	[2.796]	[1.672]
BK less $_{>2sd}$	-2.141	-0.251	-6.919***	-4.607***	-23.373	-4.427	-5.282	-6.812*
	[2.238]	[1.962]	[2.502]	[1.451]	[17.061]	[5.914]	[5.143]	[3.878]
Obs.	22,483	23,911	24,003	22,575	13,865	16,879	17,172	15,780
R^2	0.128	0.134	0.156	0.141	0.153	0.147	0.162	0.164

Second step OLS estimates for domestic manufacturing firms with at least five employees in the period 1996-2005. Regressions include time, industry and region dummies; control variables included are downstream demand, industry concentration, firm age, firm size, import competition, export intensity, the share of intermediate supply in total industry output and services spillovers. Standard errors in brackets are clustered at the industry-year level. ***/**/* denotes significance at 1/5/10 percent.

productivity does not appear to be driven by the ownership structure of foreign firms. Figure A.1 shows the productivity distributions of majority- and minority-owned MNEs. It is clear that the distributions for both types of ownership are very close to one another. Foreign productivity is also not driven by the country of origin of a foreign firm. For a sample of foreign firms locating in Romania, Javorcik and Spatareanu (2011) find no relationship between the country of origin of an MNE and its level of productivity. Finally, foreign firm characteristics such as R&D efforts are potentially correlated with productivity levels. However, we prefer to think of productivity as an outcome variable that not only reflects R&D efforts itself but also the efficiency and usability of R&D efforts.