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FDI spillovers and time since foreign entry

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Abstract

This study measures the effect of foreign direct investment (FDI) on the productivity of local firms. Unlike earlier studies, our empirical approach does not require that FDI manifests immediate or permanent effects. We find that foreign entry initially affects productivity of local competitors negatively, but is more than offset by a permanent positive effect on local competitors once majority-foreign-owned firms have been present for a while. The effect on the productivity of local suppliers, in contrast, is transient. The entry of majority-foreign-owned firms boosts productivity of local suppliers after a short adaption period, but then fades. The positive impact of minority-foreign-owned firms on local suppliers is immediate, but smaller and transient.

Keywords: FDI, spillovers, dynamics, timing
JEL Classification: F2

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1 Introduction

When a firm invests in a foreign country, it often brings with it proprietary technology to compete successfully with indigenous firms (Markusen, 1995). Believing their domestic firms will adopt transferred technology, host country policymakers often implement policies to attract foreign direct investment (FDI). The literature surveys of Görg and Greenaway (2004) and Crespo and Fontoura (2007) conclude there is no clear evidence of aggregate positive FDI spillovers, suggesting such FDI strategies are futile. More recently, Havranek and Irsova (2011) use a meta-analysis of 3,626 estimates of backward spillovers to demonstrate that the average spillover to suppliers is both positive and economically significant.

FDI spillovers are commonly analyzed in a production function framework, wherein FDI spillover variables are introduced as additional input variables to explain the productivity of domestic firms. The size and significance of the resulting coefficients are then treated as evidence of FDI spillovers. The literature distinguishes between horizontal spillovers to firms in the same industries and vertical spillovers to firms in other industries linked to the foreign firm through the supply chain. Following new theoretical insights on the importance of firm-level heterogeneity in participation of firms in international markets (e.g. Melitz, 2003 and Helpman *et al.*, 2004), the spillover literature has begun to consider firm- or industry-specific characteristics that could mediate spillover effects. The relevant characteristics include such measures as the absorptive capability of the domestic firms (e.g. Merlevede and Schoors, 2007), as well as the characteristics of foreign affiliates such as technological capability, embeddedness, and autonomy (e.g. Giroud *et al.*, 2012 and Marin and Bell, 2006).

Rather than implicitly assuming technological spillovers from foreign entry are immediate and permanent, we here allow FDI spillovers to vary with the number of years a multinational enterprise (MNE) has been present in the domestic economy. Although recent literature acknowledges the intuition that foreign entry might not necessarily affect local firm productivity immediately or permanently, the issue is usually addressed with lagged values of spillover variables. We find this approach unsatisfactory. The literature captures the spillover effect on domestic firms of all foreign presence in a given year (both recent foreign presence and mature foreign presence) by a single variable (usually the share of foreign firms in total industry output or investment). Lagging the spillover vari-

ables fails to adequately address the time-since-entry dynamics of spillovers, i.e. lagged variables retain the property of lumping together the effect of all previous foreign investment into one variable.

Thus, the aggregate approach implicitly assumes that the contemporaneous spillover effect of a foreign firm that entered the domestic economy in a given year *t* is identical to that of a foreign firm that entered in some other year -*t*. This defies our established understanding of the transmission channels of spillover effects. Teece (1977), for example, suggests that technology imitation and worker mobility could be important channels for horizontal spillovers. Neither the mobility of workers trained by foreign firms nor technology imitation are, however, likely to materialize immediately after foreign entry. Workers need to receive training and absorb technologies before they can move to a domestic firm to boost its productivity. Moreover, increased foreign competition may hurt domestic companies before it makes them better (e.g. through successful imitation).

Similarly, vertical spillovers driven by access to better inputs produced by foreign firms or by supplying inputs to multinational companies do not necessarily occur instantaneously or permanently. The presence of better foreign inputs probably requires an adjustment effort before domestic firms can reap the full benefits. Equivalent dynamic effects may arise in the spillovers to local suppliers. While foreign affiliates may provide immediate assistance to their local suppliers, it may result in transient effects rather than permanently higher productivity growth. On the other hand, if foreign affiliates tend to increase their local sourcing over time, backward spillovers would not reach their full effect immediately.

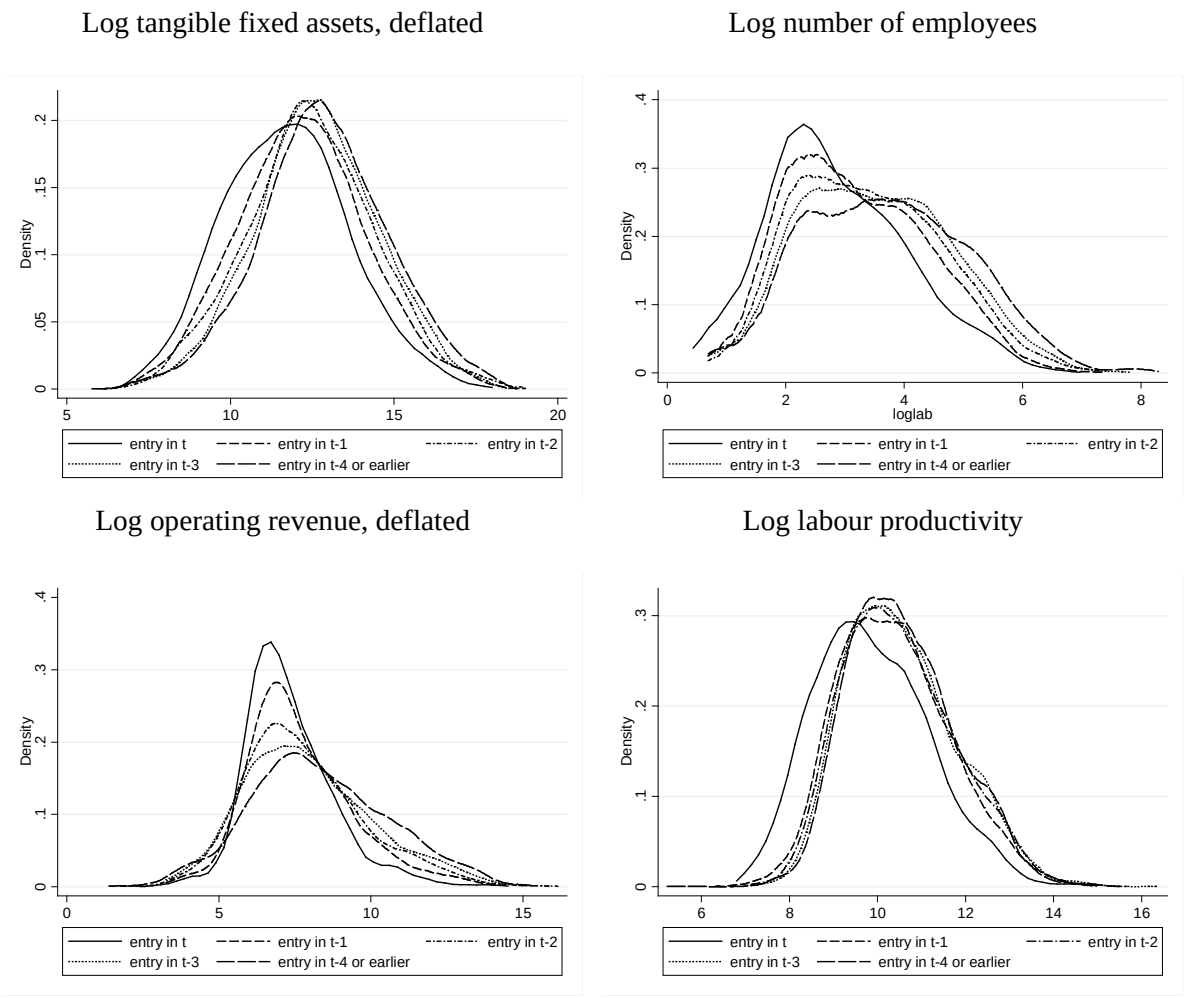
Moreover, there is circumstantial evidence that timing may be important for spillover effects. For a long panel (1982–1995) of firms in the Irish electronics sector, Görg and Ruane (2001) find that foreign firms start off with a relatively low extent of local linkages, but as they acclimatize to the local market, they develop local input linkages. For a cross-section of 19 African countries, Amendolagine et al. (2013) find a non-linear, hump-shaped relationship between the experience of the foreign firm and its demand for local inputs. Giroud (2007) confirms this by comparing the impacts of foreign firms on local suppliers in Malaysia and Vietnam. Local suppliers benefit significantly less from foreign presence in Vietnam than in Malaysia, where multinationals have been present for a longer period. Based on their AB Volvo case study, Ivarsson and Alvstam (2005) conclude that technology transfer to suppliers is more efficient in Volvo's older plants. Even *within* mul-

tinationals, technology is not necessarily transferred easily or rapidly (e.g. Urata and Kawai, 2000). This may give rise to specific time patterns in the transfer of technology to foreign affiliates and the ensuing spillovers.

Furthermore, the time-since-entry effect is in line with improvements in foreign firms. Arnold and Javorcik (2009) show for Indonesia that acquired firms have higher sales, fixed assets, employment and productivity immediately after acquisition. The improvements appear in the acquisition year and continue in following years. We observe a comparable pattern in our panel of Romanian firms (*cf. infra* for full details on the data). Figure 1 shows the evolution of the distribution of four characteristics of foreign acquired firms in the time-since-entry dimension. Time since entry coincides with increasing investments in tangible fixed assets. More mature foreign firms hire additional employees and have higher operating revenues; labor productivity also increases with time since entry.

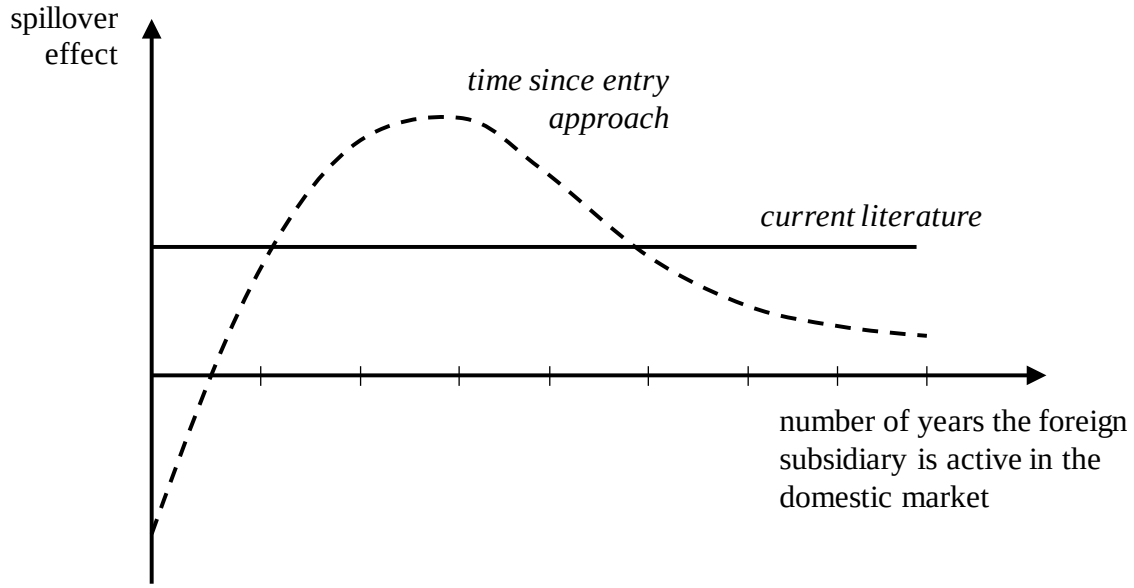
These arguments all suggest the current static empirical approach to identifying spillover effects is inadequate. Our dynamic approach, illustrated below in Figure 2, looks at spillover effects at a specific point in time generated by MNEs that differ in the number of years they have been active in a domestic market. The bold line represents the entry-time-invariant spillover effect that dominates the current literature. Introducing spillover variables with a time lag shifts the bold line to the right, but fails to capture dynamic spillover effects. The dashed line[i], in contrast, shows a hypothetical pattern where MNEs first generate a negative spillover effect, for example driven by an adjustment cost of the local firm to the foreign entrant, which then turns into a positive spillover effect, and eventually wanes[ii].

Figure 1 Evolution of characteristics of foreign firms in time since MNE entry



"entry in t" groups all observations of the variables for the first year the foreign firm enters the domestic economy, irrespective of calendar time; "entry in t-1" groups firms in their second year in the domestic economy, …; "entry in t-4 or earlier" groups all firms which have been present for at least five years.

Figure 2 Spillover effect to productivity of domestic firms for a given year as a function of time since foreign entry in the domestic market: current literature versus time-since-entry approach.



Our results indicate that spillover effects of foreign investment on domestic firm productivity are dynamic. The productivity of domestic firms seems to benefit from the presence of majority-foreign-owned firms in their industry, although the majority-foreign-owned firms need to be present for a longer period in the host country before domestic firms see a positive contribution to their productivity. Indeed, the impact of majority-foreign-owned firms that entered the domestic economy only recently is negative, possibly pointing to a short-run negative competition effect. The impact of entry of minority-foreign-owned firms on the productivity of their local competitors is, on the other hand, quite modest. Nevertheless, minority-foreign-owned firms do generate transient positive backward spillover effects to their local suppliers. Within the first two years after foreign entry, domestic suppliers enjoy a considerable augmentation to productivity growth from supplying the minority-foreign-owned entrant. As time goes by, however, the positive backward spillover effect fades. Backward spillovers from majority-foreign-owned firms are also positive, but less immediate. Although the post-entry effect lasts longer than for minority-foreign-owned firms, it also fades. We find no evidence of forward spillovers, a finding in line with most of the literature (e.g. Javorcik, 2004, and Javorcik and Spatareanu, 2008). The notable exception here is the case of China, where positive forward spillovers have been found for

domestic firms that purchase high-quality intermediate goods or equipment from foreign firms (Xu and Sheng, 2011).

Our overall results suggest a strong positive productivity spillover from foreign investment to local competitors that have been around for a while. Backward productivity spillovers to local suppliers are more pronounced in the immediate aftermath of foreign investment, but fade after the foreign firms have been present for a longer time. Thus, the mixed results in the literature about the direction and magnitude of horizontal spillovers to local competitors could to some extent reflect a failure to take spillover dynamics into account.

This paper continues as follows. In section 2, we provide a description of FDI spillovers and how our MNE entry time approach fits with the literature. Section 3 lays out the data and estimation strategy. Results and interpretation are provided in section 4. Section 5 concludes.

2 Spillovers and time since MNE entry

Horizontal spillovers run from a foreign firm to a host country firm in the same industry. Teece (1977) suggests two main channels for horizontal spillovers: technology imitation (the demonstration effect) and mobility of workers trained by foreign firms (see also Fosfuri *et al.*, 2001, and Görg and Strobl, 2005). Marin and Bell (2006) confirm the latter by showing that training activities by foreign subsidiaries are related to stronger horizontal spillovers in Argentina. Foreign entry may also fuel competition in the domestic market. Fiercer competition urges host-country firms to use existing technologies and resources more efficiently or adopt new technologies and organizational practices, which provides another important channel of horizontal spillovers (see Aitken and Harrison, 1999, and Glass and Saggi, 2002). None of these effects is necessarily positive.

Labor market dynamics may entail negative spillovers such as a brain drain of local talent to foreign firms to the detriment of local firm productivity (Blalock and Gertler, 2004) or an overall increase in wages irrespective of productivity improvements caused by foreign firms paying higher wages (Aitken *et al.*, 1996). Where foreign technology is easily copied, the foreign investor may choose to avoid leakage costs on state-of-the-art technology by transferring technology that is only marginally superior to technology found in the host country (Glass and Saggi, 1998). Such policies obviously limit the scope for hori-

zontal spillovers via demonstration effects. The higher productivity of foreign affiliates may also lead to lower prices or less demand for the products of domestic competitors. If domestic firms fail to raise productivity in response to the increased competition, they will be pushed up their average-cost curves. Ultimately, domestic producers may not merely fall behind, but fall by the wayside as they are driven out of business by the shock of foreign entry.[iii] These partial effects are hard to disentangle empirically and a general measure for horizontal spillovers will identify the net effect of all these channels.

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

A forward spillover goes from a foreign firm to its downstream local buyer of inputs. Inputs due to foreign investment may enhance the productivity of local firms that use these inputs, but inputs produced locally by foreign firms may also be more expensive and less adapted to local firm requirements, so they dent local firm productivity.

The current empirical literature applies a definition for the variable intended to capture horizontal spillovers that at least dates back to Caves (1974). Typically, the horizontal spillover variable HR_{jt} captures the degree of foreign presence in industry j at time t and is measured as:

$$HR_{jt} = \frac{\sum_{i \in j} F_{it} * Y_{it}}{\sum_{i \in j} Y_{it}} \quad (1)$$

where Y_{it} is the output produced by firm i in year t. HR_{jt} is industry j's share of output produced by foreign firms. Foreign firms are identified by F_{it}. In the literature, F_{it} is usually the exact share of foreign participation in firm i in year t. Alternatively, F_{it} is sometimes a

dummy variable that takes the value 1 if firm *i* is foreign in year *t*, and 0 otherwise. To be classified as *foreign*, foreign participation by at least one investor at the 10% level is required.[iv] HR_{jt} is then combined with technical coefficients obtained from input-output tables to calculate vertical spillover variables. For the measurement of the backward spillover variable BK_{jt}, the literature employs:

$$BK_{jt} = \sum_{k \; if \; k \neq j} \gamma_{jkt} * HR_{kt} \tag{2}$$

where γ_{jkt} is the proportion of industry *j*'s output supplied to sourcing industry *k* at time *t*. The γs are calculated from (possibly time-varying) IO tables for intermediate consumption. Inputs sold within the firm's industry are excluded ($k \neq j$) as this is captured by HR_{jt}. Since firms cannot easily or quickly switch industries to buy inputs, this approach avoids the problem of endogeneity by using the share of industry output sold to downstream domestic markets *k* with some level of foreign presence HR_{kt}. Employing the share of *firm* output sold to foreign firms in different industries causes endogeneity problems if the latter prefer to buy inputs from more productive domestic firms. In the same spirit, the forward spillover variable FW_{jt} is defined as:

$$FW_{jt} = \sum_{l \; if \; l \neq j} \delta_{jlt} * HR_{lt} \tag{3}$$

where the IO tables reveal the proportion δ_{jlt} of industry *j*'s inputs purchased from upstream industries *l*. Inputs purchased within the industry ($l \neq j$) are again excluded, since this is already captured by *HR*. HR_{jt}, BK_{jt}, and FW_{jt} are then related to the productivity of domestic firms to infer the direction, magnitude, and significance of spillovers.

Employing the above measures in a regression analysis implicitly assumes spillover intensity (i.e. the coefficients of the spillover variables in the regression) to be constant in time since MNE entry.[v] However, as discussed in the introduction, there are a number of reasons why spillover effects may differ in the time-since-entry dimension. Moreover, to our knowledge there is no theoretical guidance on a uniform effect in time since entry. Therefore, we define as a variable indicating foreign ownership status *and* time since entry *x*. equals the percentage of shares owned by foreign investors in firm *i*

at time *t* if at least 10% of shares were owned by at least one foreign investor in year *t-x* and this was not the case in *t-x-1*. thus indicates that foreign firm *i* observed in year *t* became foreign owned in *t-x*. Technically, for firm *i* observed in year *t*, is set to the percentage of shares owned by foreign investors in firm *i* at time *t* when

$$\widehat{F}_{it}^{x} = \%_t \text{ if } \left(\sum_{v=0}^{x-1} F_{i,\,t-v} = x\right) \;\wedge\; \left(\sum_{v=x}^{\infty} F_{i,\,t-v} = 0\right) \tag{4}$$

and zero otherwise. This definition can now be used to decompose the traditional horizontal spillover variable (horizontal) as follows:

$$HR_{jt} = \frac{\sum_{i\in j}\widehat{F}_{it}^{0}Y_{it}}{\sum_{i\in j}Y_{it}} + \frac{\sum_{i\in j}\widehat{F}_{it}^{1}Y_{it}}{\sum_{i\in j}Y_{it}} + \ldots + \frac{\sum_{i\in j}\widehat{F}_{it}^{n}Y_{it}}{\sum_{i^{2}\in j}Y_{it}} \tag{5}$$

HR_{jt} is broken down along the lines of time since MNE entry, ranging from zero to *n*. Denoting the components on the right-hand side of (5) as HR_{jt}^{0}, ..., HR_{jt}^{n}, such that HR_{jt}^{2}, for example, is industry *j*'s share of year *t* output produced by foreign firms that entered the domestic market in *t-2*.

In our empirical analysis below, we employ these time-since-entry-specific components, calculated as in (5), without restricting their coefficients to be equal. Time-since-entry definitions for BK_{jt}^{x}, and FW_{jt}^{x} then follow from (2) and (3) above:

$$HR_{jt}^{x} = \frac{\sum_{i\in j}\widehat{F}_{it}^{x}Y_{it}}{\sum_{i\in j}Y_{it}}; \qquad BK_{jt}^{x} = \sum_{k\ if\ k\neq j}\gamma_{jkt} * HR_{kt}^{x}; \qquad FW_{jt}^{x} = \sum_{l\ if\ l\neq j}\delta_{jlt} * HR_{lt}^{x} \tag{6}$$

$$HR_{jt}^{x} = \frac{\sum_{i\in j}\widehat{F}_{it}^{x}Y_{it}}{\sum_{i\in j}Y_{it}}; \qquad BK_{jt}^{x} = \sum_{k\ if\ k\neq j}\gamma_{jkt} * HR_{kt}^{x}; \qquad FW_{jt}^{x} = \sum_{l\ if\ l\neq j}\delta_{jlt} * HR_{lt}^{x}$$

$$HR_{jt}^{x} = \frac{\sum_{i\in j}\widehat{F}_{it}^{x}Y_{it}}{\sum_{i\in j}Y_{it}}; \qquad BK_{jt}^{x} = \sum_{k\ if\ k\neq j}\gamma_{jkt} * HR_{kt}^{x}; \qquad FW_{jt}^{x} = \sum_{l\ if\ l\neq j}\delta_{jlt} * HR_{lt}^{x}$$

Considering that we have ten years of data (1996–2005, *cf. infra*) and do not know the year of entry of firms that are foreign in the first year of our datatset, we opt to include HR^0_{jt} to HR^3_{jt} and create a variable HR^{4+}_{jt}. This variable aggregates all foreign firms present for at least four full years on the domestic market. The time span of our dataset is then reduced because of missing values for HR^1_{jt} to HR^{4+}_{jt} for the first years of the dataset.[vi] Table 1 illustrates how three MNEs (A, B, and C) that entered the domestic economy in 2001, 1998, and 2004, respectively, affect the value of the spillover variables in different calendar years. Firm A first contributes to HR^0 in 2001, the year of entry, then in consecutive years contributes to HR^1, HR^2, HR^3, and finally from 2005 onwards contributes to HR^{4+}. Firm B entered Romania earlier and contributes from 2002 onwards to HR^{4+}. In 2005, both A and B contribute to HR^{4+}. Note the difference with the traditional measure in the last column, where spillovers are implicitly assumed to be independent of time since entry. Late entrant C will only affect HR^0 in 2004 and HR^1 in 2005.

Table 1 Time-since-entry variables and calendar time in the dataset

		MNE - time since entry (superscript)					
		HR^0	HR^1	HR^2	HR^3	HR^{4+}	*traditional HR*
calendar	*2001*	A			B		A&B
time	*2002*		A			B	A&B
	2003			A		B	A&B
	2004	C			A	B	A&B&C
	2005		C			A&B	A&B&C

3 Empirical approach and data

3.1 Empirical approach

FDI spillovers are commonly analyzed in a production function framework. Total factor productivity (TFP) at the firm level is obtained in a first-step estimation, followed by a second step, where FDI spillover variables *HR*, *BK*, and *FW*, together with some further controls, are treated as additional inputs in explaining the productivity of domestic firms. The resulting coefficients are then taken as evidence of FDI spillover effects. The careful estimation of production functions is thus an important building block in our analysis.

The basic problem in estimating productivity is that firms react to firm-specific productivity shocks often not observed by the researcher. Griliches and Mairesse (1995) make the case that inputs should be treated as endogenous variables as they are chosen on the basis of the firm's unobservable assessment of its productivity. OLS or fixed-effects estimates of production functions, therefore, yield biased estimates of factor shares and biased estimates of productivity. The semi-parametric approaches by Olley and Pakes (1996) (OP) and its more recent modification by Levinsohn and Petrin (2003) (LP), as well as the dynamic panel data approach by Blundell and Bond (1998) (DPD) are alternative methodologies to overcome the endogeneity bias in estimating production functions. Both the OP/LP and DPD methodologies have been widely used in the recent literature on firm-level heterogeneity for derivation of total factor productivity measures. More recently, Ackerberg *et al.* (2008) (ACF) argue that, while there are some solid and intuitive identification ideas in the paper by Levinsohn and Petrin (2003), their semi-parametric techniques suffer from collinearity problems that cast doubt on the methodology. They suggest an alternative methodology that uses the ideas in these papers while avoiding the collinearity problems. As the discussion is still ongoing, we present our results using ACF-TFP as our base case and then check the robustness of our results with respect to other TFP measures.

We estimate domestic industry production functions for each NACE[vii] 2-digit manufacturing industry *j* in the period 1996–2005 separately, excluding firms that are foreign at some point in time from the estimation. Capital, labor, and material input elasticities are thus industry-specific. A measure of total factor productivity tfp_{ijt} for firm *i* in industry *j* at time *t* is obtained as the difference between output and capital, labor, and material inputs, multiplied by their estimated coefficients:

$$tfp_{ijt} = Y_{ijt} - \widehat{\beta}_{lj} l_{ijt} - \widehat{\beta}_{kj} k_{ijt} - \widehat{\beta}_{mj} m_{ijt} \quad tfp_{ijt} = Y_{ijt} - \widehat{\beta}_{lj} l_{ijt} - \widehat{\beta}_{kj} k_{ijt} - \widehat{\beta}_{mj} m_{ijt} \tag{7}$$

In addition to methodological robustness checks (FE, OP[viii], DPD), we include robustness checks using a TFP measure obtained from a translog specification (TL, estimated by OLS) rather than from a Cobb-Douglas specification and using labor productivity rather than total factor productivity. Finally, we present results with a measure for total factor productivity based on an index number approach. Labor productivity and the index approach impose no specific form on the production function, thereby allowing for cross-firm differences in production technology in a NACE 2-digit manufacturing industry. For the

index, we follow the formula proposed by Good *et al.* (1996), which combines the chained Divisia approach with the representative firm index proposed by Caves *et al.* (1983), i.e.

$$tfp_{it} = \left[\left(y_{it} - y_t^* \right) + \sum_{s=2}^{t} \left(y_s^* - y_{s-1}^* \right) \right] - \left[\frac{1}{2} \sum_{j=1}^{n} \left(S_{ijt} + S_{jt}^* \right) \left(x_{ijt} - x_{jt}^* \right) + \sum_{j=1}^{n} \sum_{s=2}^{t} \frac{1}{2} \left(S_{js}^* + S_{j,\,s-1}^* \right) \left(x_{js}^* - x_{j,\,s-1}^* \right) \right] \quad (8)$$

where y_{it} denotes log value added of firm i in period t, S the share of each of the n production factors in total costs, and x_{ijt} the log of the quantity factor j used in the production of firm i in period t. Variables indicated with an asterisk refer to the representative firm (e.g. y_t^* is the log output of the representative firm in period t). Following Caves *et al.* (1983), the values of the variables for the representative firm equals the mean of that variable over all firms in a given year. The index contains a component reflecting the change in TFP of a firm relative to the productivity of the representative firm (i.e. efficiency) and a component reflecting the evolution in the productivity of the representative firm over time (technological change).

In the second step, we relate tfp_{ijt} to a firm-specific effect, a vector of spillover variables, $\mathbf{FDI_{jt}}$, a vector of control variables, and time dummies (α_t). Whereas (7) is estimated by industry, note here that (9) pools firms from all industries together in one large panel such that:

$$tfp_{ijt} = \alpha_i + \Psi_1 f\left(\mathbf{FDI}_{jt-1}\right) + \Psi_2 \mathbf{Z}_{i(j)t} + \alpha_t + \xi_{ijt} \; tfp_{ijt} = \alpha_i + \Psi_1 f\left(\mathbf{FDI}_{jt-1}\right) + \Psi_2 \mathbf{Z}_{i(j)t} + \alpha_t + \xi_{ijt} \quad (9)$$

The vector of spillover variables ($\mathbf{FDI_{jt}}$) covers the different horizontal and vertical spillover variables described in (1)−(6). $\mathbf{Z_{i(j)t}}$ is a vector of control variables. Specifically we control for within-industry competition, measured by the Herfindahl index, import competition in the industry, industry export intensity, the share of supplied intermediates in total industry output, and firm age. Specification (9) is first-differenced and estimated by OLS. After first-differencing, we include industry (α_j) and region (α_r) dummies in the specification. First-differencing does not remove the time dummies ($\Delta\alpha_t = \alpha_t$). This results in (10)

as final specification to be estimated. Note that our approach follows best practice as defined in Havranek and Irsova (2011):[ix]

$$\Delta tfp_{ijrt} = \Psi_1' \Delta f\left(\mathbf{FDI}_{jt-1}\right) + \Psi_2' \Delta \mathbf{Z}_{i(j)t} + \alpha_t + \alpha_j + \alpha_r + \varepsilon_{ijrt} \quad (10)$$

Because $\mathbf{FDI_{jt}}$ and some control variables are defined at the industry level, while estimations are performed at the firm level, standard errors need to be adjusted (Moulton, 1990). Standard errors are therefore clustered for all observations in the same industry and year (see Javorcik, 2004).

3.2 Data

We use firm-level data for a panel of Romanian manufacturing firms during 1996–2005. Because most foreign investment entered Romania after 1996, Romania makes a good candidate to study time since MNE entry as a determinant of FDI spillovers. Macroeconomic data show that Romania started attracting large FDI inflows only late in transition. The slow pace in the early 1990s of both privatization efforts and market-oriented reforms generally made Romania an unattractive place to invest relative to the other transition countries in Central and Eastern Europe. 1997 marks the first substantial wave of FDI inflows. FDI inflows took off on a large scale in 2004. As of early 2008, the most important home countries of foreign firms in Romania were Austria (21.4%), the Netherlands (16.3%), Germany (11.7%), and France (8.8%). Manufacturing accounted for about 40% of total foreign investment, with metal (7.5%) and food and tobacco (5.2%) the most important subsectors. The other sectors receiving substantial amounts of FDI were banking and insurance (23.3%), wholesale and retail (14%), and telecommunications (6.5%).

Our firm-level data are taken from the Amadeus database maintained by Bureau Van Dijk Electronic Publishing (BvDEP). Amadeus is a pan-European database of financial information on public and private companies. The Amadeus database is widely used for research and the Romanian subset of firms is known for its good quality and representativeness.[x] BvDEP updates the information every month. Unfortunately, monthly DVDs contain only the latest information on ownership and firms that go out of business are dropped from the online searchable database fairly rapidly. Furthermore, because BvDEP updates individual ownership links between legal entities rather than the full ownership

structure of a given firm, the ownership information on a specific DVD-issue often consists of a number of ownership links with different dates, referring to the last verification of a specific link. To construct our dataset with entry, exit, and time-specific foreign entry in local Romanian firms, we therefore employed a series of different issues of the database. However, since ownership information is gathered at irregular intervals, we do not have ownership information for all firm-owner-year combinations.[xi] Given these specificities of Amadeus, we first created a dataset at the firm-owner-year-level with the available information from Amadeus. We then filled out missing firm-owner-year-entries under restriction that the full ownership structure cannot exceed 100%. In case of time gaps between entries for the same owner-firm combination but with a different share-size, we assume that changes show up immediately in the database. We then fill in the gaps with the older information from the DVDs.[xii]

Data are deflated using industry price level data at NACE rev.1.1 2-digit level. These are taken from the Industrial Database for Eastern Europe from the Vienna Institute for International Economic Studies and from the Statistical Yearbook of the Romanian National Statistical Office (RNSO). Real output *Y* is measured as operating revenues deflated by producer price indices of the appropriate NACE industry; real material inputs *M* are deflated by a weighted intermediate input deflator where the industry-specific weighting scheme is drawn from the IO tables. Labor *L* is expressed as the number of employees. Real capital *K* is measured as fixed assets, deflated by the average of the deflators for five NACE industries: machinery and equipment (29); office machinery and computing (30); electrical machinery and apparatus (31); motor vehicles, trailers, and semi-trailers (34); and other transport equipment (35) (see Javorcik, 2004). IO tables for the period 1996–2005 were obtained from the RNSO. The tables are in national industry classification, but the RNSO provided a mapping into NACE rev. 1.1. The RNSO tables are fairly detailed and identify 59 manufacturing sectors. This provides us with richer detail in vertical relationships than the more common IO tables at NACE 2-digit that only have 22 manufacturing sectors. The IO tables also provide data on import competition, export intensity, and supplied intermediates control variables. These are therefore defined at the same level of industry aggregation as the spillover variables.

Table 2 Number of firms, entry, and exit by year

	All firms			*Foreign firms in sample*			
	# firms	entry	exit	# firms	entry	exit	penetration
1996	14,393			2,242			0.16
1997	15,618	1057	91	2,615	315	32	0.17
1998	16,768	996	190	3,005	328	59	0.18
1999	18,054	1200	761	3,464	373	169	0.19
2000	19,480	1845	301	3,940	472	72	0.20
2001	20,908	1374	507	4,458	445	119	0.21
2002	21,912	1224	988	4,792	332	305	0.22
2003	22,579	1336	2447	4,896	298	493	0.22
2004	21,525	1066	562	4,831	314	168	0.22
2005	20,963			4,667			0.22

Table 3 Summary statistics for firm-level and industry-level variables

	All firms n = 133154		Domestic firms n = 105854		Foreign firms n = 27300	
	mean	sd	mean	sd	mean	sd
ln(real output)	13.74	1.90	13.53	1.84	14.52	1.94
ln(employment)	3.08	1.47	2.93	1.40	3.67	1.57
ln(capital)	12.08	2.32	11.82	2.26	13.06	2.29
ln(real value added)	12.67	2.09	12.43	2.03	13.62	2.05
ln(tfp) ACF	5.74	1.52	5.69	1.52	5.95	1.47
ln(tfp) OP	2.09	0.87	2.06	0.85	2.20	0.94
ln(tfp) DPD	2.30	1.29	2.27	1.27	2.42	1.33
ln(tfp) FE	2.00	0.96	1.95	0.91	2.21	1.11
ln(tfp) TL	6.45	2.09	6.44	2.07	6.50	2.13
ln(tfp) LProd	10.65	1.36	10.60	1.33	10.86	1.47
ln(tfp) Index	−0.25	2.20	−0.28	2.18	−0.15	2.25

	Spillovers (industry-year; n = 649)					
	all foreign-owned firms		majority-foreign-owned firms		minority-foreign-owned firms	
	mean	sd	mean	sd	mean	sd
horizontal	0.28	0.14	0.22	0.19	0.02	0.04
backward	0.17	0.05	0.15	0.07	0.01	0.02
forward	0.18	0.08	0.14	0.08	0.01	0.01

We restrict the dataset to firms with at least five employees on average over the sample period. The dataset is further trimmed for outliers by removing the top and bottom percentiles of the annual growth rates of real operating revenues, real capital, labor, and real material inputs.[xiii]

Table 2 lists the annual number of firms, and the entry and exit rate of all firms and for the subsample of foreign firms. The share of foreign firms in the total number of sample firms steadily increased from 16% to 22% (10 to 15% when small firms are not excluded). The 2003 exit rate is high, but this pattern is confirmed by the pattern in the Romanian Trade Register (Romanian Trade Register data also include agriculture and services). Table 3 lists summary statistics both for domestic and foreign firms. The stylized facts commonly found in the literature are confirmed in our dataset. Foreign firms are larger in terms of employment and capital, produce more output and are more productive. The latter holds across different estimation techniques.

Figure 3 shows a breakdown by NACE 2-digit industry of the share of output produced by foreign firms for the first and last year of our sample. Leaving aside the highly concentrated tobacco industry (NACE 16), some 15% of industry output on average was produced by foreign firms in 1996. The share of foreign firms varies between 7% and 30%. In 2005 on average 39% of industry output was produced by foreign firms, while shares varied between 15% and 57% across industries.

Figure 4 gives an idea about the distribution and values of the spillover variables in the time-since-entry dimension across different spillover categories. The boxplots are based on the estimation sample collapsed to the industry level (59 manufacturing industries from the IO tables). The figure shows that the value of the spillover variables tends to increase with longer periods of foreign presence. The correlation across years and spillovers is limited, however. Majority-foreign-owned firms clearly account for the bulk of the share produced by foreign firms. In all industries besides tobacco, there are both majority- and minority-foreign-owned firms.[xiv]

Figure 3 Share of NACE 2-digit industry output produced by foreign firms in 1996 and 2005.

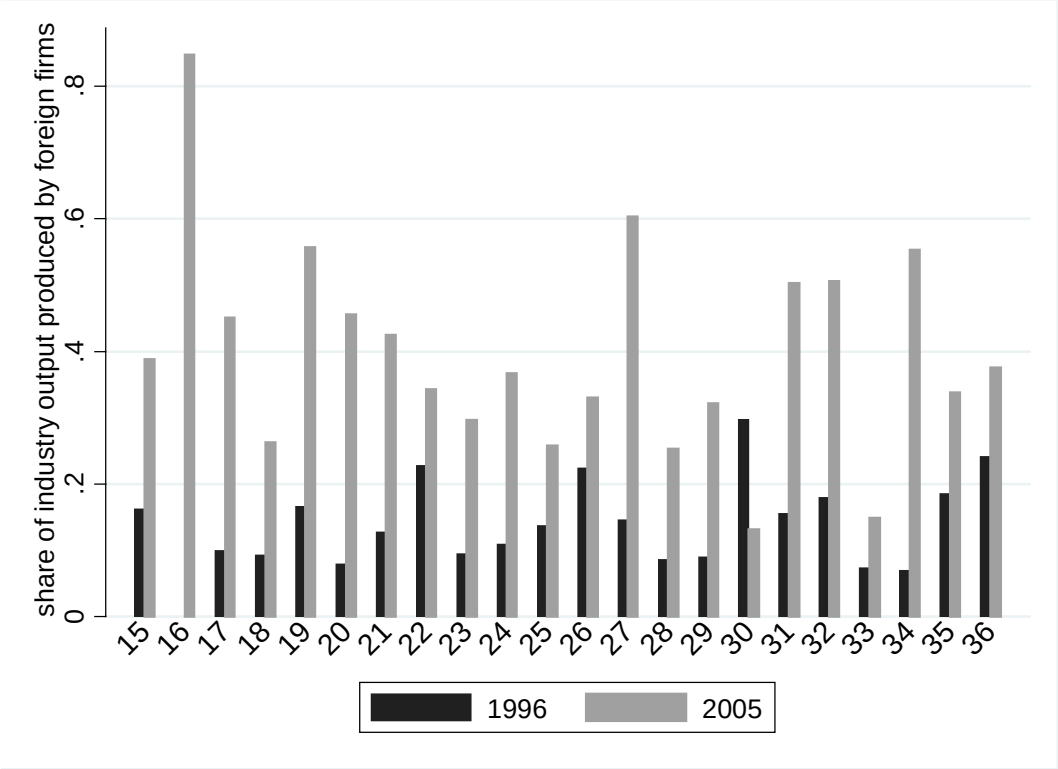
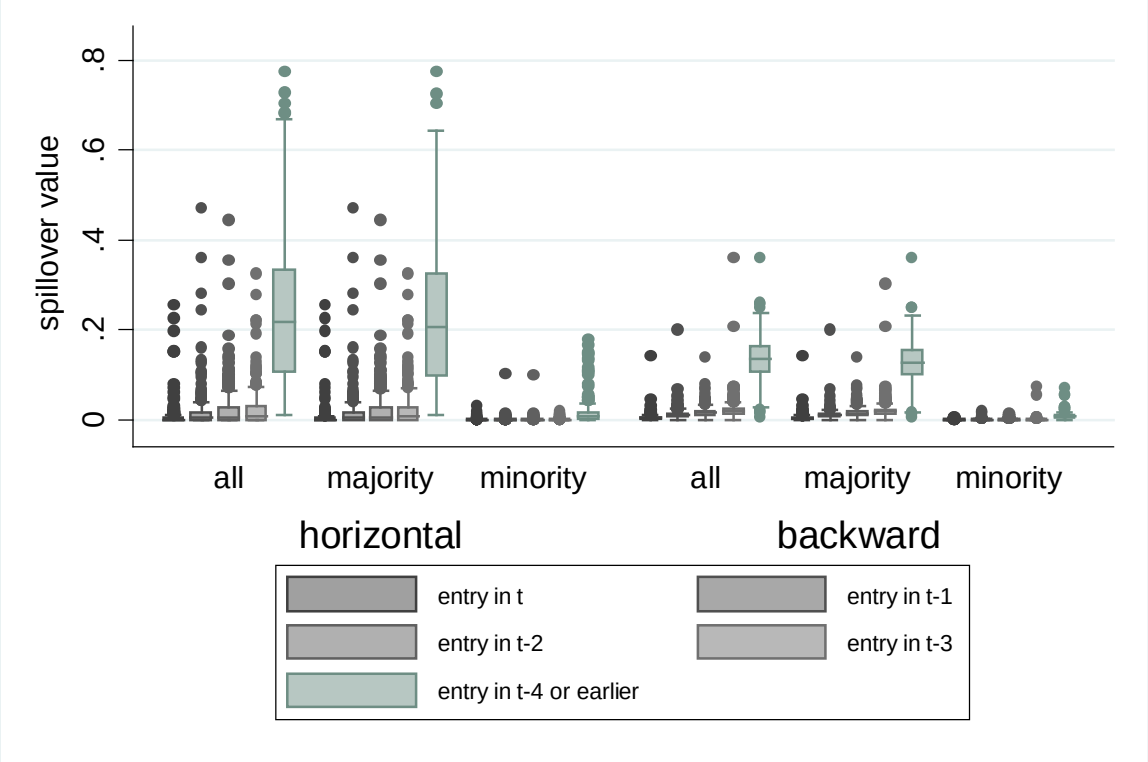


Figure 4 Boxplots of horizontal and backward spillover variables for entirely foreign-owned firms (all), majority- and minority-foreign-owned firms, at industry aggregation found in the Romanian IO tables for 2001–2005.



4 Results

This section presents results of different sets of estimations. For the sake of clarity and to keep the tables manageable, we do not report control variables. Regressions always include time, industry, and region dummies. Further control variables (always included) are age, industry competition, intermediates supplied as a share of industry output, competition from imports in the industry, and industry export intensity. Thus, changes in openness at the industry level are accounted for. We consider horizontal, backward, and forward spillovers. Forward spillovers turn out to be unimportant, so our results for forward spillovers are not presented in order to keep table size manageable (we think of them as additional control variables). This is in line with existing literature as confirmed in Havranek and Irsova (2011) who write in their meta-study on vertical spillovers: "*A similar multivariate analysis, available on request, shows that no country-specific variable matters for the degree of forward spillovers, and that the best practice estimate of forward spillovers is insignificant. These findings corroborate the view that backward linkages are more important than forward linkages.*" Basically, while there are strong incentives for foreign firms to actively promote backward spillovers, there is no such incentive for forward spillovers. In the robustness section, we show that our main results are qualitatively unaffected by dropping the forward spillover variables from the regressions altogether. The structure of Tables 4, 5, and 6 is similar and the different columns present results for alternative TFP estimation methodologies and alternative functional forms of the production function used to obtain the dependent variable. We show results for TFP measures based on Cobb-Douglas specifications, applying the ACF, OP, DPD, and FE estimators in columns 1–4. In column 5, our TFP measure is obtained from a translog specification estimated by OLS rather than from a Cobb-Douglas specification. In columns 6 and 7, we employ labor productivity and TFP based on an index approach as dependent variable.[xv]

4.1 No time since entry

As a starting point, Table 4 presents the estimation results for the standard non-dynamic specification found in the literature. Our Table 4 estimates are based on our long sample that runs from 1996 to 2005. All columns use the sample of firms with at least five employees on average and definitions (1)−(3) of the spillover variables. Except for the case of

labor productivity, our results suggest that Romanian manufacturing firms have benefited from supplying foreign firms. The backward effect is large and significant. Horizontal spillovers are also positive and significant. The presence of foreign competitors, therefore, seems to have contributed positively to the productivity growth of domestic firms.

These results are consistent throughout the other columns of Table 4. The unreported forward spillover is negatively signed, implying that firm-level productivity is lower for firms in industries that source inputs from industries with a larger foreign presence. The forward spillover loses significance when either the dummy version is used or when the time period is restricted to 2001–2005 (our sample for time-since-entry regressions, *cf. supra*).

Table 4 Spillover effects from FDI on TFP without time since entry; results from first-differenced model

	(1) ACF	(2) OP	(3) DPD	(4) FE	(5) TL	(6) LProd	(7) Index
horizontal	1.373[a]	0.380[b]	0.407[b]	0.390[b]	0.408[b]	0.530[a]	1.416[a]
	[0.466]	[0.170]	[0.171]	[0.172]	[0.173]	[0.193]	[0.494]
backward	2.148[b]	0.994[a]	1.051[a]	1.033[a]	1.007[a]	0.525	2.561[b]
	[0.972]	[0.325]	[0.312]	[0.320]	[0.327]	[0.407]	[1.001]
N	78592	105583	105635	105635	105635	109181	77342
R-squared	0.10	0.06	0.06	0.05	0.05	0.03	0.09

Second-step OLS estimates for domestic firms; regressions include industry, time, and region dummies; control variables included are industry competition, import competition, industry export intensity, importance of intermediates, and firm age. The dependent variable is first-differenced firm-level TFP based on first-step production function estimates by industry according to the indicated methodology on top of the columns. All columns are based on the sample of firms with over five employees on average. All estimations include forward spillover variables as control. Standard errors in brackets are clustered at the industry-year level. *a/b/c* denotes significance at 1%, 5%, and 10%.

4.2 The impact of time since entry

Table 5 Spillover effects from FDI on TFP with time since entry; results from first-differenced model

	(1) ACF	(2) OP	(3) DPD	(4) FE	(5) TL	(6) LProd	(7) Index
horizontal							
entry in t	0.450	0.132	0.072	0.072	0.108	0.407	0.561
	[0.851]	[0.315]	[0.302]	[0.305]	[0.316]	[0.357]	[0.925]
entry in t-1	−1.234	−0.569^{c}	−0.526^{c}	−0.539^{c}	−0.562^{c}	−0.319	−1.047
	[0.956]	[0.323]	[0.306]	[0.307]	[0.320]	[0.420]	[0.997]
entry in t-2	−1.603^{c}	−0.608^{b}	−0.596^{b}	−0.597^{b}	−0.569^{b}	−0.327	−1.442^{c}
	[0.837]	[0.271]	[0.262]	[0.259]	[0.259]	[0.292]	[0.797]
entry in t-3	0.501	0.064	0.064	0.044	0.064	0.084	0.411
	[0.599]	[0.170]	[0.165]	[0.168]	[0.166]	[0.216]	[0.565]
entry t-4 or earlier	1.976^{a}	0.359^{b}	0.361^{b}	0.364^{b}	0.361^{b}	0.577^{a}	2.052^{a}
	[0.497]	[0.149]	[0.151]	[0.148]	[0.148]	[0.192]	[0.510]
backward							
entry in t	3.902	2.223	1.949	2.301	1.368	2.663	4.541
	[5.134]	[1.705]	[1.680]	[1.684]	[1.754]	[2.354]	[4.895]
entry in t-1	8.498^{b}	3.236^{b}	3.166^{b}	3.298^{b}	2.937^{b}	3.792^{b}	8.544^{b}
	[3.626]	[1.314]	[1.320]	[1.288]	[1.319]	[1.615]	[3.530]
entry in t-2	4.331	1.840^{b}	1.750^{c}	1.838^{b}	1.767^{c}	2.168^{c}	3.801
	[2.742]	[0.914]	[0.906]	[0.886]	[0.908]	[1.235]	[2.616]
entry in t-3	6.049^{c}	2.629^{a}	2.568^{a}	2.603^{a}	2.500^{a}	1.779	5.858^{c}
	[3.282]	[0.867]	[0.875]	[0.862]	[0.867]	[1.137]	[3.174]
entry t-4 or earlier	−0.655	0.070	0.162	0.078	0.051	−0.199	−0.085
	[1.367]	[0.419]	[0.416]	[0.415]	[0.413]	[0.509]	[1.367]
N	49344	62816	62843	62843	62843	65047	48095
R-squared	0.07	0.04	0.04	0.03	0.04	0.02	0.08

Second-step OLS estimates for domestic firms; regressions include industry, time, and region dummies; control variables included are industry competition, import competition, industry export intensity, importance of intermediates, and firm age. The dependent variable is first-differenced firm-level TFP based on first-step production function estimates by industry according to the indicated methodology on top of the columns. All columns are based on the sample of firms with over five employees on average. All estimations include forward spillover variables as control. Standard errors in brackets are clustered at the industry-year level. *a/b/c* denotes significance at 1%, 5%, and 10%.

In Table 5, we allow FDI spillovers to differ according to the time since entry of the foreign firm. Column headings are the same as in Table 4. As indicated above, we created a "*4+*" variable for each spillover that brings together all foreign firms present at least four full years on the domestic market. One might characterize the coefficient of this variable as

the longer time-since-entry effect. Average values of these *4+* variables are considerably larger than the variables capturing entry in a specific more recent year. It is essential to take this into account when interpreting coefficients and the contributions of variables to firm-level productivity.

Scanning the columns in Table 5, we see the results generally suggest a positive horizontal spillover effect on the longer time-since-entry horizon. Firms that recently entered the host economy have no impact on the TFP of domestic firms, whereas firms that have been present for four years or more generate strong positive spillovers that are significant in all 7 columns of Table 5. This clearly indicates that it takes time for domestic firms to reap the benefits of foreign entry into their particular industry and that longer-established foreign firms affect domestic firm productivity in a positive fashion. Backward spillover effects on domestic firm productivity are faster than horizontal spillover, though not immediate. The strongest positive backward spillovers are found for foreign firms that entered one year earlier. There is a smaller, but still positive effect for firms entering between two and three years earlier, but the evidence is more mixed across columns. A longer time-since-entry effect is absent. This suggests that, after a short adjustment period, domestic firms supplying new foreign entrants enjoy higher productivity growth for a couple of years. With respect to the forward spillover (not shown), no significant impact remains.

4.3 Time since entry and ownership structure

The literature on FDI spillovers acknowledges that the level of local participation can play an important role in determining spillover effects. On the one hand, local participation in a foreign investment project gives the local firm the opportunity to become familiar with the proprietary technology of foreign firm, thereby facilitating spillovers (Blomström and Sjöholm, 1999). On the other hand, the fear of technology leakage on the part of the foreign firm could induce foreign firms to bring in less advanced technology or shy away from shared ownership when bringing in sophisticated technologies. Desai *et al.* (2004), for example, find evidence that majority subsidiaries receive more intangible property from their parent companies than minority subsidiaries. Furthermore, while advanced technologies offer a larger scope for spillovers, they may impede knowledge diffusion to local

firms operating in the same sector if the local firms lack sufficient absorptive capacity. In any case, acquiring real benefits via these channels takes time for domestic firms.

With respect to backward spillovers, Javorcik and Spatareanu (2008) find positive effects mainly for spillovers from joint ventures. Majority-foreign-owned firms, they argue, may, due to their greater technological sophistication, require more complex inputs that may be more difficult for local firms to provide. Therefore, they may be less likely to engage in local sourcing than affiliates with shared ownership. Giroud *et al.* (2012) give a fairly complete description of the ways in which the extent of the backward linkage and the intensity of the backward linkage may be related. In our view, most, if not all, of these channels leading from the extent of the backward linkage (minority versus majority in our case) to the intensity of the backward linkage may be subject to entry-timing issues. Indeed, the impact on productivity of domestic firms from supplying majority-foreign-owned firms may take time to show up (either because majority-foreign-owned firms initially do not source locally or because domestic suppliers need to get acquainted with the requirements of the majority-foreign-owned firms).

Accordingly, we allow the timing-of-entry effects to be different for majority- and minority-foreign-owned firms in Table 6. This is done by considering two versions of (6), where our single foreign-ownership variable is broken in two versions and . In (11), is the share of majority foreign participation (50% or more) taken *x* years ago in firm *i* in year *t*, and is set to zero if foreign participation is smaller than 50%. Likewise, in (12) is the share of minority-foreign participation (less than 50%, but more than 10%) taken *x* years ago in firm *i* in year *t*, and is set to zero if foreign participation exceeds 50% or is smaller than 10%. The horizontal versions in (11) and (12) are then used to generate both majority- and minority-foreign-owned versions of all our previously defined vertical spillover variables along the lines of (2) and (3). Note that both minority- and majority-foreign-owned firms are present in all industries besides tobacco, i.e.:

$$Horizontal_{jt}^{xM} = \frac{\sum_{i \in j} \widehat{F}_{i,t}^{xM} * Y_{it}}{\sum_{i \in j} Y_{it}} \tag{11}$$

$$Horizontal_{jt}^{xm} = \frac{\sum_{i \in j} \widehat{F}_{i,t}^{xm} * Y_{it}}{\sum_{i \in j} Y_{it}} \tag{12}$$

Table 6 Spillover effects from FDI on TFP with time since entry and ownership structure; results from first-differenced model

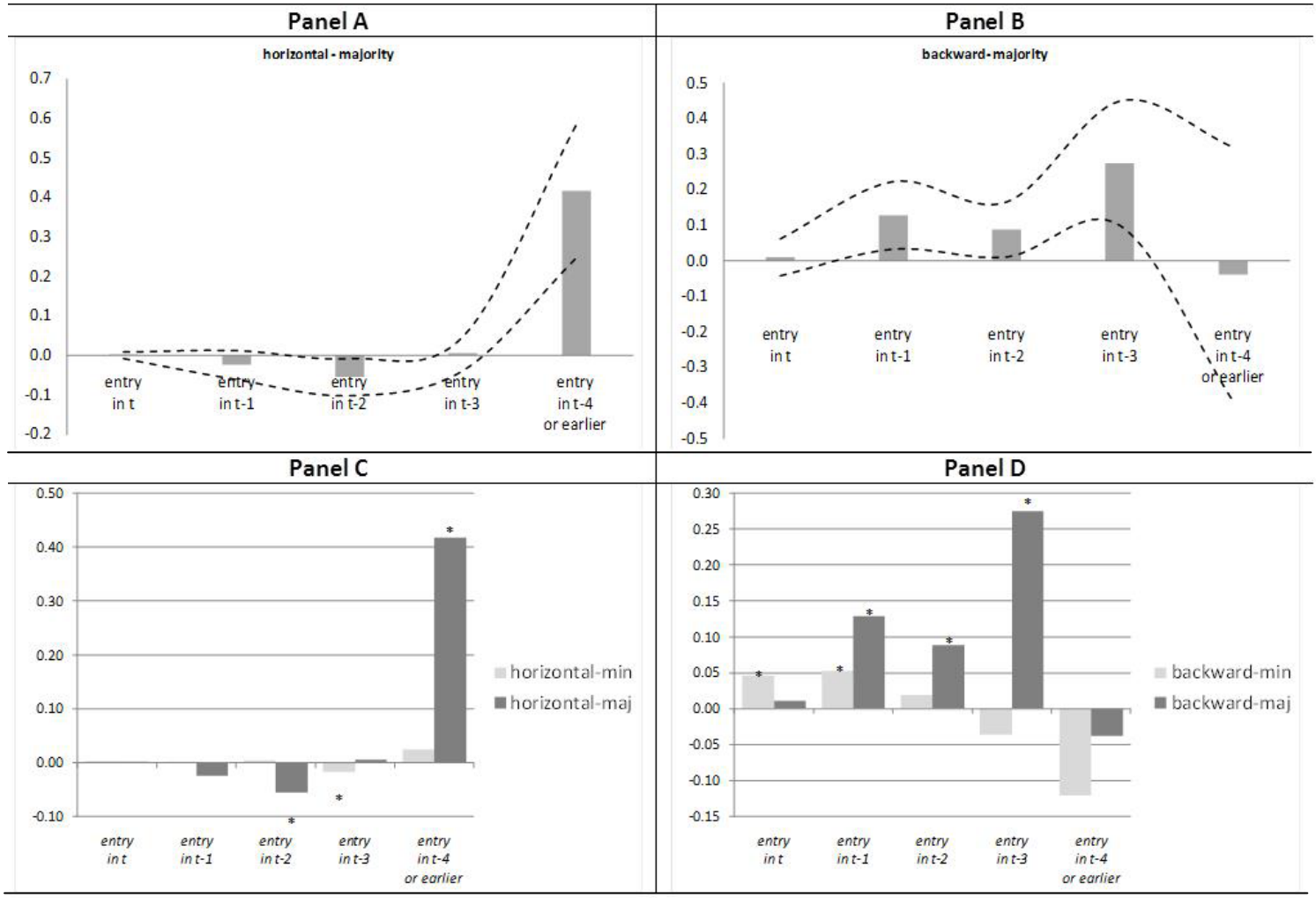
	(1) ACF	(2) OP	(3) DPD	(4) FE	(5) TL	(6) LProd	(7) Index
horizontal-majority							
entry in t	0.165	0.066	−0.021	−0.004	−0.005	0.242	0.238
	[0.833]	[0.330]	[0.324]	[0.324]	[0.321]	[0.393]	[0.847]
entry in t-1	−1.375	−0.641	−0.626	−0.622	−0.625	−0.290	−1.315
	[1.113]	[0.403]	[0.379]	[0.384]	[0.390]	[0.462]	[1.147]
entry in t-2	−2.001^{b}	−0.706^{b}	−0.709^{b}	−0.691^{b}	−0.683^{b}	−0.384	−1.937^{b}
	[0.912]	[0.293]	[0.280]	[0.280]	[0.276]	[0.299]	[0.932]
entry in t-3	0.180	0.046	0.040	0.029	0.021	0.059	0.277
	[0.721]	[0.205]	[0.199]	[0.202]	[0.199]	[0.242]	[0.734]
entry t-4 or earlier	1.805^{a}	0.372^{a}	0.372^{a}	0.377^{a}	0.374^{a}	0.564^{a}	1.792^{a}
	[0.431]	[0.136]	[0.135]	[0.135]	[0.136]	[0.201]	[0.436]
horizontal-minority							
entry in t	7.113	2.333	2.053	1.863	3.047	6.147	7.877
	[8.530]	[2.859]	[2.776]	[2.772]	[2.855]	[3.845]	[8.306]
entry in t-1	4.472	2.677	2.478	2.551	2.857	4.545	4.526
	[7.848]	[2.337]	[2.222]	[2.259]	[2.402]	[3.552]	[7.545]
entry in t-2	6.099	0.304	0.084	0.112	0.234	2.304	3.892
	[10.653]	[2.957]	[2.914]	[2.915]	[2.967]	[4.063]	[10.682]
entry in t-3	−11.070^{b}	−5.011^{a}	−5.414^{a}	−5.043^{a}	−5.121^{a}	−5.170^{b}	−10.905^{b}
	[5.594]	[1.614]	[1.616]	[1.600]	[1.637]	[2.200]	[5.593]
entry t-4 or earlier	2.060	−0.247	−0.412	−0.334	−0.278	0.611	1.917
	[1.875]	[0.611]	[0.585]	[0.595]	[0.608]	[0.845]	[1.863]
backward-majority							
entry in t	3.081	1.708	1.614	2.230	1.174	1.436	3.260
	[7.940]	[2.617]	[2.568]	[2.594]	[2.614]	[3.141]	[8.354]
entry in t-1	11.593^{b}	5.099^{a}	4.968^{a}	5.280^{a}	4.765^{a}	3.891^{c}	11.171^{b}
	[4.915]	[1.678]	[1.669]	[1.647]	[1.674]	[2.160]	[5.112]
entry in t-2	5.353^{c}	3.018^{a}	2.980^{a}	2.964^{a}	2.917^{a}	3.164^{b}	4.407
	[2.908]	[1.047]	[1.048]	[1.029]	[1.053]	[1.460]	[2.966]
entry in t-3	14.069^{a}	5.332^{a}	5.277^{a}	5.324^{a}	5.303^{a}	4.686^{b}	13.131^{a}
	[4.807]	[1.397]	[1.375]	[1.371]	[1.391]	[1.869]	[4.903]
entry t-4 or earlier	−0.350	0.342	0.443	0.377	0.336	−0.483	−0.373
	[1.554]	[0.524]	[0.514]	[0.512]	[0.516]	[0.612]	[1.629]

cont. >>

	(1) ACF	(2) OP	(3) DPD	(4) FE	(5) TL	(6) LProd	(7) Index
backward-minority							
entry in t	132.687b	46.674b	39.592b	42.162b	39.398b	42.274b	130.280b
	[56.291]	[18.839]	[18.375]	[18.513]	[19.115]	[19.895]	[56.255]
entry in t-1	115.141a	19.767	18.184	18.047	19.870	35.744b	106.791a
	[36.365]	[12.864]	[12.457]	[12.691]	[12.505]	[16.679]	[37.165]
entry in t-2	40.716	−3.452	−5.603	−4.215	−4.275	0.902	38.814
	[44.369]	[14.813]	[15.142]	[14.863]	[14.846]	[19.862]	[45.739]
entry in t-3	−43.644	−13.369	−13.612	−14.376	−14.779c	−19.541c	−39.821
	[28.890]	[8.978]	[8.898]	[8.783]	[8.942]	[11.466]	[29.345]
entry t-4 or earlier	−14.872	−3.990	−4.305	−5.119	−4.194	−0.940	−13.543
	[16.059]	[5.338]	[5.332]	[5.322]	[5.299]	[5.985]	[16.813]
N	47609	60766	60793	60793	60793	62927	46360
R-squared	0.09	0.05	0.04	0.04	0.05	0.03	0.09

Second-step OLS estimates for domestic firms; regressions include industry, time, and region dummies; control variables included are industry competition, import competition, industry export intensity, importance of intermediates, and firm age. The dependent variable is first-differenced firm-level TFP based on first-step production function estimates by industry according to the indicated methodology on top of the columns. All columns are based on the sample of firms with over five employees on average. All estimations include forward spillover variables as control. Standard errors in brackets are clustered at the industry-year level. *a/b/c* denotes significance at 1%, 5%, and 10%.

Figure 5 Contribution of 2001–2005 mean horizontal and backward spillovers to 2001–2005 mean log ACF-TFP of domestic firms as implied by specification (1) in Table 6 (dotted lines in panels A and B show a 95%-confidence interval; asterisks in lower panels mark statistically significant coefficients; average log ACF-TFP of domestic firms is 5.69)



In Table 6, we jointly consider the ownership structure and time-since-entry effects. Reassuringly, the patterns found are fairly stable across the various TFP measures. To better visualize the economic significance of our findings, Figure 4 plots the actual contribution of minority- and majority-foreign-owned firms to the productivity of their local competitors and suppliers implied by column (1) of Table 6. The dynamic time-since-entry spillover effects illustrated in Figure 5 are obtained as the estimated coefficient times the mean of the respective spillover variables. This allows for a better comparison of effects (comparing the relative size of the coefficients is pointless bearing in mind the large differences in the values of the spillover variables in Figure 4). The upper panels show the time-since-

entry pattern for horizontal and backward effects from majority-foreign-owned firms and 95% confidence intervals around them. The lower panels show a comparison for both spillovers with their minority-foreign-owned counterparts. An asterisk indicates that the estimated coefficient is significant at least at the 10% level.

Panel A and C show that the positive time-invariant horizontal spillover effect from Table 4 is mainly driven by a positive spillover effect from majority-foreign-owned firms that entered the domestic economy four or more years earlier. The horizontal spillover from majority-foreign-owned firms (horizontal majority spillover) seems to initially become more negative with time since entry for recent entrants (significantly for entry in *t-2*). This is reversed with longer time since entry, where the spillover turns strongly positive.

The finding is consistent with the thesis that the advanced technology of majority-foreign-owned firms drives positive spillovers and that it takes time to absorb advanced technology. It is also consistent with the labor market theory of spillovers. Majority-foreign-owned entrants may initially push up local wages and poach the top talent, creating a negative spillover. After a few years, however, local employees that have received on the job training from the majority-foreign-owned firm can quit and join domestic firms, reversing the effect.

Panel C also shows that the productivity spillovers from minority-foreign-owned firms are much smaller (recalling, of course, that they account for a substantially smaller share of industry output). The initial impact is insignificant, but the spillover turns negative for firms that entered in *t-3*. Taking into account average values of the variables concerned (Figure 4), we may conclude that the spillovers from minority-foreign-owned firms are fairly small relative to those from majority-foreign-owned firms.

Panel D, however, indicates that minority-foreign-owned firms generate immediate positive backward spillover effects. During the first two years after foreign entry, domestic firms enjoy a substantial productivity boost. This positive backward spillover from minority-foreign-owned firms is short-lived, however. The effect actually turns negative, albeit insignificant, for minority-foreign-owned firms that entered longer ago.

Panels B & D indicate how backward spillovers from majority-foreign-owned firms also boost productivity. The effect seems less immediate but longer lived than for minority-foreign-owned firms. Majority-foreign-owned firms need to be present for at least a full year for domestic firms to grasp meaningful positive backward spillover effects.

These positive effects are also conferred by firms that entered two and three years earlier. The coefficients for longer periods since entry are insignificant.

Table 7 Selection of tests for equality of coefficients constituting the time-since-entry patterns

Figure 5	(1) ACF	(2) OP	(3) DPD	(4) FE	(5) TL	(6) LProd	(7) Index
horizontal-majority							
$e_t = e_{t-1} = e_{t-2} = e_{t-3} = e_{t-4+}$	5.01[a]	3.74[a]	4.08[a]	4.03[a]	4.01[a]	2.63[b]	4.69[a]
$e_{t-3} = e_{t-4+}$	4.86[b]	2.87[c]	3.08[c]	3.33[c]	3.45[c]	4.33[b]	4.24[a]
$e_{t-2} = e_{t-3} = e_{t-4+}$	8.84[a]	7.17[a]	7.75[a]	7.68[a]	7.53[a]	4.92[a]	5.89[a]
horizontal-minority							
$e_t = e_{t-1} = e_{t-2} = e_{t-3} = e_{t-4+}$	1.96[c]	3.08[b]	3.33[b]	3.07[b]	3.20[b]	2.78[b]	1.48
backward-majority							
$e_t = e_{t-1} = e_{t-2} = e_{t-3} = e_{t-4+}$	2.84[b]	4.54[a]	4.26[a]	4.66[a]	4.33[a]	3.03[b]	2.32[c]
$e_{t-1} = e_{t-2} = e_{t-3}$	1.84	1.44	1.42	1.62	1.49	0.34	1.8
$e_{t-1} = e_{t-2} = e_{t-3} = e_{t-4+}$	3.76[a]	5.87[a]	5.52[a]	6.11[a]	5.55[a]	4.05[a]	3.08[b]
$e_t = e_{t-1} = e_{t-2} = e_{t-3}$	1.25	1.26	1.25	1.28	1.34	0.38	1.21
$e_t = e_{t-1} = e_{t-2}$	1.06	1.37	1.33	1.38	1.38	0.37	0.99
$e_t = e_{t-1}$	1.22	2.02	2.01	1.66	2.28	0.73	0.92
backward-minority							
$e_t = e_{t-1} = e_{t-2} = e_{t-3} = e_{t-4+}$	4.47[a]	2.05[c]	1.77	1.92[c]	1.92[c]	2.35[c]	3.94[a]
$e_t = e_{t-1}$	0.07	1.58	1.06	1.31	0.83	0.08	0.12
$e_t = e_{t-1} = e_{t-2}$	1.22	2.24[c]	1.86	1.93	1.81	1.53	0.99
$e_t = e_{t-1} = e_{t-2} = e_{t-3}$	5.51[a]	2.73[b]	2.35[c]	2.56[c]	2.56[c]	3.07[b]	4.89[a]

a/b/c denotes rejection of the null hypothesis of equality of the coefficients (indicated on the left) at 1%, 5%, and 10%. e.g. e_{t-1} refers to the coefficient on the '*entry in t-1*'-variable.

We apply several tests for the equality of coefficients in Table 7 to confirm that time since entry matters. For almost all TFP measures, we can reject for all types of spillovers that all coefficients in time since entry are equal. We also perform additional tests with respect to the patterns identified. The coefficient for horizontal spillovers from majority-foreign-owned firms that entered at *t-4* or earlier is significantly different from the effect of entrants in *t-3* or *t-2*. Spillovers from backward majority-foreign-owned firms that entered recently are significantly different from those from firms entering in *t-4* or earlier. The coefficient for the most recent entrants is estimated relatively imprecisely and it cannot be rejected to be equal to the coefficients for entrants in *t-1*, *t-2*, and *t-3*. Note that, in terms of the actual contribution to productivity (as shown in Figure 5), recent entrants contribute

very little to the TFP of domestic firms. This suggests that the backward spillovers from majority-foreign-owned firms are less immediate than those from minority-foreign-owned firms. Backward spillovers from minority-foreign-owned firms are confirmed to be immediate upon entry and to differ between recent and more mature entrants.

Our results are consistent with the thesis that domestic firms receive immediate, well-tailored assistance from the minority-foreign-owned entrant they supply. Given a domestic majority, minority-foreign-owned firms are probably better aware of possible constraints on their domestic suppliers and more willing initially to provide straightforward assistance. The foreign minority shareholder may, on the other hand, be unwilling to bring in its most advanced technologies, implying a limited scope for spillovers. Hence an immediate, but rather short-lived positive effect. For domestic firms supplying majority-foreign-owned firms, it may take longer to benefit from the relationship as they need to get acquainted with the demands and technologies of their majority-foreign-owned clients. On the other hand, the accruing benefits are large and positive once they arrive. While they are still transient, they also tend to last longer.

4.4 Robustness checks

In this section, we present further robustness checks in Tables 8 and 9. The robustness checks deal with the sensitivity of the results to the introduction of a set of industry-year dummies, the sample constellation, and the construction of spillover variables. For the ease of comparison, column 1 of each of the tables repeats our basic specification, i.e. the results for the sample of firms with at least five employees on average, ACF-TFP as a dependent variable, and the share version of the spillover variables. All robustness checks use ACF-TFP as a dependent variable.

Table 8 Spillover effects from FDI on TFP with time since entry and ownership structure; ro bustness tests (sample constellation)

	(1) Basic	(2) all firms	(3) balanced sample	(4) reduced sample 1	(5) reduced sample 2	(6) industry-year dummies
horizontal-majority						
entry in t	0.165	0.578	0.066	0.775	−1.175	−1.088
	[0.833]	[0.812]	[0.808]	[1.030]	[0.947]	[0.715]
entry in t-1	−1.375	−1.156	−1.105	−0.376	−2.512[a]	−0.935
	[1.113]	[1.186]	[1.063]	[1.106]	[0.863]	[0.897]
entry in t-2	−2.001[b]	−1.964[b]	−1.934[b]	−3.191[a]	−1.785[a]	−0.908
	[0.912]	[0.869]	[0.936]	[1.224]	[0.540]	[0.749]
entry in t-3	0.180	−0.228	0.024	0.187	−0.032	−0.178
	[0.721]	[0.732]	[0.747]	[0.735]	[0.470]	[0.626]
entry t-4 or earlier	1.805[a]	1.704[a]	1.666[a]	0.983[b]	2.141[a]	0.948[b]
	[0.431]	[0.520]	[0.440]	[0.490]	[0.366]	[0.469]
horizontal-minority						
entry in t	7.113	16.281[b]	4.494	14.901	−3.947	6.356
	[8.530]	[7.392]	[8.419]	[12.308]	[9.908]	[6.904]
entry in t-1	4.472	6.905	2.630	8.479	−12.547[c]	4.893
	[7.848]	[6.651]	[7.884]	[9.211]	[6.396]	[4.935]
entry in t-2	6.099	8.005	3.580	−6.774	−14.295	12.474
	[10.653]	[10.662]	[11.227]	[21.327]	[10.654]	[10.071]
entry in t-3	−11.070[b]	−15.295[a]	−10.585[c]	−15.650[b]	−18.299[a]	−14.425
	[5.594]	[5.687]	[5.656]	[6.890]	[5.871]	[8.821]
entry t-4 or earlier	2.060	−0.925	1.791	3.517[c]	3.903[b]	2.630
	[1.875]	[1.986]	[1.864]	[1.959]	[1.673]	[1.909]
backward-majority						
entry in t	3.081	−5.605	2.463	11.076	1.192	1.934
	[7.940]	[8.545]	[7.800]	[10.258]	[7.039]	[6.289]
entry in t-1	11.593[b]	12.610[b]	13.677[a]	13.237[b]	15.146[b]	2.230
	[4.915]	[5.365]	[4.637]	[5.340]	[6.265]	[3.663]
entry in t-2	5.353[c]	5.191	4.724[c]	1.895	5.204[c]	6.314[a]
	[2.908]	[3.150]	[2.848]	[3.482]	[2.999]	[3.650]
entry in t-3	14.069[a]	17.706[a]	13.907[a]	20.022[a]	13.443[a]	11.534[a]
	[4.807]	[4.565]	[4.931]	[4.370]	[4.329]	[3.311]
entry t-4 or earlier	−0.350	0.887	−0.641	−3.335[b]	1.879	0.459
	[1.554]	[1.509]	[1.510]	[1.580]	[1.564]	[1.271]
backward-minority						
entry in t	132.687[b]	125.039[b]	120.273[b]	40.274	127.605[b]	78.377[b]
	[56.291]	[55.008]	[51.834]	[77.102]	[49.351]	[37.691]
entry in t-1	115.141[a]	87.925[a]	94.393[a]	31.000	143.578[a]	74.943[a]
	[36.365]	[23.865]	[34.255]	[44.155]	[38.686]	[21.365]
entry in t-2	40.716	20.342	29.654	179.710[a]	18.083	64.438
	[44.369]	[35.212]	[44.179]	[65.120]	[35.717]	[54.644]
entry in t-3	−43.644	−74.172[b]	−47.535	57.140[c]	−70.608[a]	−65.740[b]
	[28.890]	[30.663]	[29.124]	[32.000]	[26.703]	[31.276]
entry t-4 or earlier	−14.872	−11.391	−12.976	24.453[c]	−20.961	6.902
	[16.059]	[14.262]	[16.264]	[13.921]	[14.416]	[14.008]
N	47609	78070	35130	38844	37786	47609
R-squared	0.09	0.07	0.09	0.10	0.12	0.13

Second-step OLS estimates for domestic firms; regressions include industry, time, and region dummies; control variables included are industry competition, import competition, industry export intensity, importance of intermediates, and firm age. The dependent variable is the first-differenced ACF TFP. Results in all columns are based on the sample of firms with over five employees on average, except those in column 2 that are based on the sample of all firms. Column 3 uses a balanced sample; column 4 restricts the sample such that for the first year of sample observations the *t-4 or earlier* variable contains the first large inflow of FDI in 1997; column 5 reduces the sample such that the FDI surges in 2004 and 2005 do not show up in any of the spillover variables. Column 6 introduces industry-year dummies. All columns use the share version of the spillover variables. All estimations include forward spillover variables as control. Standard errors in brackets are clustered at the industry-year level. *a/b/c* denotes significance at 1%, 5%, and 10%.

Table 8 presents our tests for alternative sample constellations. In column 2, small firms with less than five employees on average are included in the sample as well. The main results are unaffected. Column 3, containing the results for a balanced sample and therefore limiting our results to the impact on firms existing throughout the estimation period 2001–2005, confirms our main findings.

Columns 4 and 5 relate to the macroeconomic pattern of FDI inflows in Romania. Romania experienced two major shifts of the level of FDI inflows in 1997 and 2004–2005. To rule out that our results for *entry t-4 or earlier* spillover variables are driven by the first shift in 1997, we drop the first years of the estimation sample in column 4. We find robust patterns for the horizontal and backward spillovers from majority-foreign-owned firms, confirming our main results. The negative longer term backward spillover from majority-foreign-owned firms turns marginally significant. The pattern of the backward spillover form minority-foreign-owned firms changes slightly. Column 5 drops the last years from the sample. This allows us to test whether the impact of the surge of macroeconomic FDI inflows at the end of the sample drives our results on the *entry in t* and *t-1* spillover variables. The time-since-entry patterns we obtain are again fairly similar to our basic result, especially with respect to our main findings. This suggests a basis for our claim of positive horizontal spillovers from majority-foreign-owned firms for longer times since entry and positive backward spillovers from majority-foreign-owned firms for medium time since entry. To verify the robustness of these findings, we extend the time-since-entry dimension by one additional period, i.e. for each spillover we introduce an additional variable that brings together all foreign firms that have entered in *t-5 or earlier* rather than *t-4 or earlier*. The coefficients (clustered standard errors in square brackets) from this regression confirm that the positive horizontal effect is present in the longer run, while the positive backward effect is shorter-lived:

$$\underset{[1.08]}{-0.41}\,HR^{t,\,Maj}\ \underset{[1.27]}{-1.79}\,HR^{t-1,\,Maj}\ \underset{[1.09]}{-3.56^{a}}\,HR^{t-2,\,Maj}\ \underset{[0.69]}{-0.53}\,HR^{t-3,\,Maj}\ \underset{[0.71]}{-0.41}\,HR^{t-4,\,Maj}\ \underset{[0.45]}{+1.43^{a}}\,HR^{t-5\,\&\,earlier,\,Maj}$$

$$\underset{[9.57]}{+15.58}\,BK^{t,\,Maj}\ \underset{[5.57]}{+15.39^{a}}\,BK^{t-1,\,Maj}\ \underset{[4.14]}{+5.21}\,BK^{t-2,\,Maj}\ \underset{[5.25]}{+16.57^{a}}\,BK^{t-3,\,Maj}\ \underset{[3.70]}{-1.51}\,BK^{t-4,\,Maj}\ \underset{[1.47]}{-2.07}\,BK^{t-5\,\&\,earlier,\,Maj}$$

Our results further suggest important immediate, but short-lived, backward minority spillovers. The latter finding is, however, somewhat less stable across the various robustness checks.

Finally, in column 6 of Table 8 we replace separate industry and year dummies by a full set of industry-year interaction dummies. Although we already controlled for competition, import competition and export intensity at the IO table industry level, our spillover variables may still capture other unobserved industry-year effects when defined at the industry-year level.

We cannot control for a full set of industry-year fixed effects, however, since their dimension would perfectly overlap with our spillover variables. We can, however, introduce industry-year effects at a slightly higher level of industry aggregation. Since the Romanian industry classification maps into a combination of NACE 2- and 3-digit levels, we include NACE subsection-year fixed effects in the estimation.[xvi] This is a tough test, but the main results are quite robust. We find i) a positive horizontal effect from majority-foreign-owned firms that have been in the domestic economy for four years or more; ii) an immediate positive backward spillover from minority-foreign-owned firms that dies out fairly rapidly; and iii) a positive backward spillover from majority-foreign-owned firms that takes more time to manifest itself and is transient.

Finally, in Table 9 we introduce some robustness checks that go into the construction of the spillover variables. Column 2 uses a dummy rather than share version of the spillover variables (*cf. supra*). Horizontal and backward majority spillover results are again confirmed, while backward minority spillovers more or less disappear.

Driffield (2006) argues that one should consider the share in physical capital rather than the share in production, because it is the incoming physical capital and technology that drives the spillover effect. Firuge 1 indeed shows that physical capital increases in the time since entry dimension, which is consistent with this argument. Therefore column 3 replaces output Y with tangible fixed assets in our spillover definitions. Our main findings are confirmed once more.

Table 9 Spillover effects from FDI on TFP with time since entry and ownership structure; robustness tests (calculation of spillover variables)

	(1) basic	(2) dummy	(3) tang fixed assets	(4) hor Y BK mat	(5) hor L BK mat	(6) hor Y BK mat 2005 IO
horizontal-majority						
entry in t	0.165	−0.177	0.221	−0.179	2.177	0.302
	[0.833]	[0.849]	[1.266]	[0.768]	[1.551]	[0.815]
entry in t-1	−1.375	−1.134	−0.990	−1.686	0.714	−1.258
	[1.113]	[1.025]	[0.837]	[1.062]	[1.365]	[0.947]
entry in t-2	−2.001^{b}	−1.652^{c}	−1.096	−1.983^{b}	0.080	−2.154^{b}
	[0.912]	[0.838]	[0.691]	[0.851]	[1.013]	[0.961]
entry in t-3	0.180	0.010	−0.049	−0.005	0.067	0.386
	[0.721]	[0.705]	[0.603]	[0.656]	[1.239]	[0.669]
entry t-4 or earlier	1.805^{a}	1.563^{a}	1.061^{a}	1.519^{a}	2.199^{b}	1.605^{a}
	[0.431]	[0.435]	[0.397]	[0.414]	[0.855]	[0.403]
horizontal-minority						
entry in t	7.113	0.031	10.474	10.320	−3.875	8.374
	[8.530]	[2.306]	[15.483]	[7.700]	[7.043]	[9.345]
entry in t-1	4.472	−0.772	42.538^{a}	3.555	−2.311	1.549
	[7.848]	[1.490]	[14.070]	[6.798]	[23.553]	[7.055]
entry in t-2	6.099	−1.227	−8.468	8.031	−2.709	−3.767
	[10.653]	[2.497]	[6.022]	[9.109]	[18.437]	[10.226]
entry in t-3	−11.070^{b}	−1.237	−0.968	−9.628	−13.238	−13.874^{a}
	[5.594]	[1.786]	[3.132]	[6.298]	[10.359]	[7.679]
entry t-4 or earlier	2.060	0.340	0.492	2.332	4.458^{a}	3.970^{a}
	[1.875]	[0.547]	[1.407]	[1.909]	[2.414]	[2.202]
backward-majority						
entry in t	3.081	2.545	5.523	−5.861	−5.931	9.105
	[7.940]	[7.578]	[8.840]	[5.886]	[5.746]	[5.914]
entry in t-1	11.593^{b}	12.907^{a}	7.024^{b}	6.207^{a}	1.884	5.522
	[4.915]	[4.778]	[3.277]	[3.291]	[2.647]	[3.540]
entry in t-2	5.353^{c}	1.855	5.491^{b}	7.074^{a}	4.326	8.378^{a}
	[2.908]	[2.921]	[2.143]	[2.287]	[2.798]	[2.817]
entry in t-3	14.069^{a}	7.258^{c}	4.178^{a}	7.253^{a}	6.283^{a}	5.767^{b}
	[4.807]	[3.901]	[2.523]	[2.388]	[2.174]	[2.765]
entry t-4 or earlier	−0.350	−0.285	0.994	−0.083	−0.121	−3.569^{b}
	[1.554]	[1.411]	[1.625]	[1.059]	[1.209]	[1.683]
backward-minority						
entry in t	132.687^{b}	7.192	60.549^{b}	78.635^{b}	86.943^{b}	27.740
	[56.291]	[6.008]	[27.497]	[39.027]	[41.904]	[23.099]
entry in t-1	115.141^{a}	10.885	28.996	136.617^{a}	133.779^{a}	84.514^{a}
	[36.365]	[9.520]	[21.885]	[34.269]	[36.562]	[30.720]
entry in t-2	40.716	14.929^{c}	154.164^{a}	36.793	40.758	−28.379
	[44.369]	[8.234]	[40.249]	[35.455]	[38.627]	[35.468]
entry in t-3	−43.644	0.686	−24.17	−19.438	−50.874^{a}	−9.894
	[28.890]	[7.980]	[32.443]	[23.667]	[26.071]	[34.713]
entry t-4 or earlier	−14.872	−2.174	−9.868	−2.085	−8.547	−0.380
	[16.059]	[4.631]	[12.159]	[14.716]	[16.108]	[21.598]
N	47609	47609	47609	47609	47609	47609
R-squared	0.09	0.08	0.10	0.09	0.08	0.09

Second-step OLS estimates for domestic firms; regressions include industry, time, and region dummies. Control variables included are industry competition, import competition, industry export intensity, importance of intermediates, and firm age. The dependent variable is the first-differenced ACF-TFP. Column 2 uses a dummy rather than a share-version of the spillover variables; column 3 uses tangible fixed assets to calculate (share-version) spillover variables; columns 4 to 6 use MNE share of material inputs to calculate the backward spillover variables; column 4 (5) uses output (employment) to calculate the horizontal spillover variables; column 6 is similar to column 4 but uses only the technical coefficients from the 2005 IO-tables rather than from the annual time-varying IO-tables. All columns are based on a sample of firms with more than five employees on average. All estimations include forward spillover variables as control. Standard errors in brackets are clustered at the industry-year level. *a/b/c* denotes significance at 1%, 5%, and 10%.

Barrios *et al.* (2010) presents an interesting discussion of the correct measurement of the backward spillover variable. Although we cannot accommodate all their suggestions due to lack of data, we show the robustness of our results for some of their points. In columns 4 and 5, we follow their suggestion of using share in material cost rather than share in output to calculate the backward spillover. We recalculate our backward spillovers accordingly. Column 4 uses output for the horizontal variables, whereas column 5 uses employment as a basis for the horizontal variables. Our results are fairly robust to this alternative specification and the time-since-entry pattern with respect to backward spillovers remains in place: immediate backward minority, medium time since entry for the backward majority. In column 5, where the horizontal spillover is based on the share in employment, we observe that the negative medium-term horizontal spillover falls away, while the positive long-term horizontal spillover is strongly confirmed. This may be an indication that the medium-term negative horizontal spillover found in most specifications is probably mainly driven by the competition effect and that labor market spillovers are essentially positive. Barrios *et al.* (2010) additionally suggest using the input-output tables from the home countries to measure backward spillover variables, because the new incoming technology will resemble the technology of the home country rather than that of the host country. While data limitations prevent us from implementing this suggestion directly, we accommodate this view by using the technical coefficients of the 2005 IO table for the calculation of the spillover variables in all years. By 2005, the foreign involvement in most of the industries was already considerable (see Figure 3), so the industrial structure found in the 2005 IO table already well reflects modern production technologies. Our results in column 6 thus take into account the suggestion of using material costs for the calculation of backward spillovers and to use 'modern' technical coefficients to calculate vertical spillovers. Again, the main time-since- entry patterns in our results are robust to these spillover variable refinements.

4.5 Firm-level heterogeneity

Finally, in line with Békés *et al.* (2009) who show that firm size and productivity are potential drivers of the intensity of spillover effects, as well as other recent literature that stresses the importance of firm level heterogeneity in analyzing firms (e.g. Melitz, 2003, and Helpman *et al.*, 2004), we allow the time-since-entry pattern to differ according to absorptive capacity and firm size. Following Damijan *et al.* (2008), we define the following

firm size classes: micro firms ($5 \leq L \leq 10$), small firms ($10 < L \leq 50$), medium firms ($50 < L \leq 250$), and large firms ($L > 250$).

The FDI spillover literature stresses absorptive capacity (see e.g. the survey by Crespo and Fontoura, 2007). Absorptive capacity refers to the ability of firms to assimilate outside knowledge and technology. Blomström (1986) finds that foreign firms are more likely to eliminate the local competition when the initial level of technology is low and human capital is poor (i.e. low absorptive capacity). Kokko *et al.* (1996) find that horizontal spillovers are positive and significant only for plants with small or moderate technology gaps relative to foreign firms. Findlay (1978), on the other hand, constructs a model of technology transfer through FDI from developed to developing countries. His model is based on a scope argument that suggests spillovers are a negative function of the level of technology, while the absorptive capacity interpretation suggests a positive relation.

Here, our measure of absorptive capacity is defined as the ratio of the mean productivity of domestic firm *i* over the sample period and the mean productivity of all foreign firms in the same industry. We estimate separate regressions for four quartiles of our measure of absorptive capacity. Table 10 presents the results. Columns 1 to 4 present the results for different size classes, and columns 5 to 8 present the mean absorptive capability results for four quartiles.

Our main findings are confirmed with respect to firm size. The medium-run positive backward spillover from majority-foreign-owned firms and the short-lived positive backward spillover from minority-foreign-owned firms are present and comparable in all size classes. Additionally, both medium and large firms seem to experience negative productivity effects when supplying minority-foreign-owned firms that entered before *t-3*. The longer term positive horizontal spillover effect from majority-foreign-owned firms is present in all size classes. Medium-sized firms seem, however, to be hit significantly harder by the presence of majority-foreign-owned firms that entered between *t* and *t-2* in their industry, while large firms do not experience any medium-term negative impact. The patterns for medium and large firms with respect to the horizontal productivity impact of minority-foreign-owned firms show that they immediately benefit from the presence of minority-foreign-owned firms. The negative impact for minority-foreign-owned firms entering in *t-3* is present for all firms except for the small firms. It is noteworthy that the pattern for micro firms shows relatively large negative, but insignificant, coefficients.

Table 10 Spillover effects from FDI on TFP with time since entry and ownership structure; firm-level heterogeneity and timing-of-entry patterns

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	mean firm size classes				mean absorptive capability quartiles			
	micro	small	medium	large	Q1	Q2	Q3	Q4
horizontal-majority								
entry in t	0.388	0.151	−1.090	−1.319	−2.624^{c}	−0.101	0.330	0.972
	[0.960]	[0.698]	[0.854]	[1.001]	[1.388]	[0.903]	[0.589]	[0.598]
entry in t-1	−1.062	−1.507	−2.729^{a}	−0.107	−3.770^{b}	−1.899^{c}	−0.565	−0.309
	[1.230]	[1.129]	[0.926]	[0.691]	[1.706]	[1.091]	[0.823]	[0.917]
entry in t-2	−2.375^{b}	−2.081^{b}	−1.380^{c}	−1.075	−3.302^{b}	−2.966^{a}	−1.196	−1.252^{b}
	[1.001]	[0.913]	[0.764]	[0.863]	[1.393]	[1.074]	[0.784]	[0.543]
entry in t-3	0.116	0.094	0.483	−0.481	0.098	0.171	0.106	−0.065
	[0.699]	[0.662]	[0.555]	[0.724]	[1.053]	[0.802]	[0.570]	[0.393]
entry t-4 or earlier	1.970^{a}	1.849^{a}	1.699^{a}	1.022^{a}	2.421^{a}	1.948^{a}	1.328^{a}	1.460^{a}
	[0.442]	[0.396]	[0.407]	[0.381]	[0.583]	[0.378]	[0.378]	[0.333]
horizontal-minority								
entry in t	−9.184	9.734	22.876^{c}	23.009^{b}	9.289	9.572	1.185	8.322
	[9.711]	[9.065]	[13.474]	[10.515]	[14.952]	[9.794]	[7.636]	[8.311]
entry in t-1	−9.746	4.775	25.163^{a}	17.763^{b}	9.967	3.482	1.034	0.262
	[6.406]	[6.960]	[9.057]	[7.452]	[12.657]	[6.976]	[5.589]	[5.308]
entry in t-2	−16.917	11.571	31.717^{a}	12.210	1.321	6.761	6.492	2.133
	[11.431]	[9.468]	[9.116]	[9.095]	[16.803]	[10.370]	[8.320]	[7.660]
entry in t-3	−15.387^{b}	−8.405	−8.670^{c}	−8.533^{c}	−19.999^{b}	−12.930^{b}	−9.735^{c}	−8.002^{c}
	[6.060]	[5.342]	[4.886]	[5.165]	[7.758]	[5.503]	[5.007]	[4.469]
entry t-4 or earlier	2.195	2.467	0.198	0.773	3.881^{c}	2.575	1.059	−0.946
	[1.992]	[1.752]	[1.830]	[1.825]	[2.227]	[1.774]	[1.601]	[1.883]
backward-majority								
entry in t	−1.049	8.104	4.372	−5.494	13.579	3.989	0.454	−6.412
	[9.221]	[6.952]	[6.668]	[3.938]	[10.903]	[6.957]	[7.285]	[5.604]
entry in t-1	11.887^{b}	12.762^{a}	9.486^{b}	7.382^{b}	15.787^{a}	12.400^{a}	12.075^{b}	7.069^{c}
	[5.775]	[4.358]	[4.068]	[2.920]	[6.024]	[4.452]	[4.820]	[4.011]
entry in t-2	4.522	4.942^{b}	6.610^{a}	4.386	3.960	8.587^{a}	3.429	4.950^{b}
	[3.051]	[2.437]	[2.219]	[2.901]	[3.453]	[2.518]	[2.415]	[2.407]
entry in t-3	15.955^{a}	12.607^{a}	12.052^{a}	14.896^{a}	16.465^{a}	14.424^{a}	14.767^{a}	11.371^{a}
	[5.307]	[4.596]	[4.063]	[4.041]	[5.795]	[4.900]	[4.396]	[3.486]
entry t-4 or earlier	−2.053	0.353	1.176	−0.975	−0.816	0.052	−0.081	0.027
	[1.750]	[1.540]	[1.363]	[1.276]	[1.975]	[1.626]	[1.242]	[1.258]
backward-minority								
entry in t	132.575^{b}	110.612^{b}	157.255^{a}	161.825^{b}	126.480	153.855^{a}	115.121^{a}	98.106^{a}
	[62.615]	[50.452]	[44.134]	[67.705]	[83.335]	[58.650]	[42.772]	[37.370]
entry in t-1	130.414^{a}	115.300^{a}	65.113^{b}	100.282^{a}	111.385^{b}	119.109^{a}	108.072^{a}	118.184^{a}
	[42.806]	[36.525]	[27.985]	[33.474]	[55.088]	[35.617]	[34.576]	[28.520]
entry in t-2	16.415	54.534	39.251	41.174	63.042	26.655	42.210	25.849
	[42.229]	[37.644]	[31.065]	[39.965]	[62.424]	[39.536]	[34.932]	[27.464]
entry in t-3	−54.845	−31.984	−57.487^{b}	−44.343	−45.712	−26.781	−51.716^{b}	−52.006^{b}
	[33.718]	[27.449]	[26.091]	[29.531]	[45.127]	[31.915]	[24.724]	[20.478]
entry t-4 or earlier	−13.774	−13.485	−19.079	−29.403^{b}	−24.173	−15.853	−14.682	−5.009
	[17.301]	[14.512]	[14.408]	[14.659]	[21.532]	[16.495]	[13.448]	[11.718]
N	16991	22189	5745	2684	9624	13031	13383	11571
R-squared	0.09	0.10	0.13	0.15	0.09	0.12	0.10	0.11

Second-step OLS estimates for domestic firms; regressions include industry, time, and region dummies; control variables included are industry competition, import competition, industry export intensity, importance of intermediates, and firm age. The dependent variable is the first-differenced firm-level ACF-TFP estimated by industry. Columns 2 to 5 present estimates for different firm size, while columns 6 to 9 present estimates for different quartiles of the TFP gap between the domestic firm and the within the industry average TFP for foreign firms. All columns are based on the sample of firms with over five employees on average and use the share version of the spillover variables. All estimations include forward spillover variables as control. Standard errors in brackets are clustered at the industry-year level. *a/b/c* denotes significance at 1%, 5%, and 10%.

The mean absorptive capacity results for four quartiles largely confirm our main findings for different absorptive capacity quartiles. For all four quartiles, we find strong positive permanent horizontal-majority, strong transient backward-majority, and immediate transient backward-minority spillovers. There are a number of deviations from the general pattern, however. Firms with the lowest absorptive capacity experience immediate negative productivity effects from majority-foreign-owned firms in their industry. Firms in the second quartile experience a similar strong negative impact, but to a lesser extent. Firms with higher absorptive capacity (Q3 and Q4) are more resistant. Q3 and Q4 firms experience negative productivity effects when supplying minority-foreign-owned firms that entered in *t-3* (as do Q1 and Q2 firms, but not significantly). Further, firms with the highest absorptive capability (Q4) seem to benefit less and later both from minority- and majority-backward spillovers. This may be explained by a scope effect, whereby they benefit less from easy-to-implement improvements that immediately affect productivity. Additionally, these firms are likely to supply the toughest foreign firms in terms of input requirements.

5 Conclusion

This study analyzed horizontal and vertical productivity spillovers of foreign direct investment on domestic Romanian manufacturing companies from 1996 to 2005. Rather than implicitly assuming that productivity spillovers from foreign entry are immediate and permanent as is common in the literature, we apply an empirical approach that allows the effect of a foreign entrant on local firm productivity to depend on how long that foreign entrant has been present in the domestic market. Moreover, where the empirical literature has addressed this problem, it has done so merely by introducing lagged values of spillover variables in the specification. This approach is clearly unsatisfactory. Spillover variables are typically based on foreign firms' share in total industry output, implying that the spillover effects of all accumulated foreign investment, new and old, are lumped together in a single spillover variable. Lagging the spillover variable is therefore unhelpful in assessing the longevity of the impact of foreign entrants on local firm productivity.

To overcome this, we identify the longevity of spillovers by allowing them to vary with the time since foreign entry. Our findings are economically intuitive and consistent with theory. The spillover effects of majority-foreign-owned firms are economically larger than for minority-foreign-owned firms. Although we find that the entry of majority-

foreign-owned firms initially impairs the productivity of their domestic competitors, we find that the productivity of the local competitor is permanently boosted once the majority-foreign-owned firm has been present in the domestic economy for a while. This is consistent with the thesis that it takes time and effort for domestic firms to absorb foreign technology. It is also in line with the labor market channel theory of horizontal spillovers. In contrast, the effect of majority-foreign-owned investment on the productivity growth of local suppliers (backward spillovers), is economically large, but transient. Although the entry of majority-foreign-owned firms boosts productivity growth of local suppliers considerably, the effect fades after the foreign firm is present more than three years.

The spillover effects of minority-foreign-owned firms, which account for a smaller share of industry output than majority-foreign-owned firms in Romania's case, are considerably smaller, less robust, and transient. More specifically, minority-foreign-owned firms have an economically tiny, short-lived effect on the productivity of their local competitors and a somewhat larger, but equally short-lived, effect on the productivity of their local suppliers.

We conclude that attracting foreign direct investment has in the longer run strongly boosted the productivity of local competitors in Romania. It seems that the economic significance of the horizontal spillover has been severely underestimated as the dynamic nature of productivity spillovers was not considered. Further research will show whether these conclusions hold for other countries and whether the contradictory findings in the literature with respect to the direction and magnitude of horizontal spillovers may be due to the failure to correctly identify their dynamic nature.

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Endnotes

i This pattern serves as an illustration, any other pattern in the time-since-entry dimension is possible.

ii The literature does not provide clear guidance on what to expect with respect to the effect of MNEs present for longer periods. For example, spillovers from labor mobility conceivably do not fade over time.

iii Aitken and Harrison (1999) discuss the market-stealing effect.

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

v Altomonte and Pennings (2009) is a related study that investigates threshold effects generated by incremental entry and cumulative presence of the number foreign investors. They restrict their attention to horizontal spillovers only.

vi We only observe the exact date of foreign entry (ownership changes) within our sample. For firms that are foreign from the start of the sample, we do not know their exact date of entry.

vii *Nomenclature générale des activités économiques dans les Communautés européennes*, i.e. the EU's classification system .

viii We apply the procedure from Amiti and Konings (2007) to calculate investment from our data.

ix Specifying a dynamic model (estimated by GMM) by including the lagged level or first difference of TFP as an explanatory variable does not alter results, neither does the re-inclusion of fixed effects in the first difference model.

x E.g. Altomonte and Colantone (2008), Altomonte and Pennings (2009), Damijan et al. (2008)**,** Javorcik and Spatareanu (2008), and Konings (2001) also have used the Romanian subset of firms. Altomonte and Colantone (2008) provide a detailed discussion about the representativeness of the firms covered.

xi Identifying the same owner in different issues is not always straightforward; an ID is only listed if the owner is a firm listed in Amadeus itself. For all other owners, matching is done on the basis of name. Differences in spacing, plurals, addition to the name of a company-type, the use of characters specific to Romanian versus standard Roman characters, etc. are corrected for to the extent possible.

xii For example,

	Amadeus	immediate
2000	40	40
2001	.	40
2002	50	50

xiii If the "outlier" is the first or last observation for a specific firm and other datapoints are normal, the other firm-year data are retained. If not, all observations for this firm are dropped from the dataset.

xiv Including or excluding the tobacco industry does not affect our results.

xv OLS and LP results are similar and available on request.

xvi Section D is manufacturing, subsections refer to one or more NACE 2-digit industries. They are labeled DA, DB,..., DN. We obtain 14 NACE 2 subsections that on average contain slightly over four industries as defined using the Romanian classification.

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