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Abstract

This paper aims to identify genuine technological spillovers from multinational firms (MNEs). To this end, we use data on R&D from MNEs to measure spillovers, while most of the existing literature uses output to measure the foreign presence in an industry (what we call output-based spillovers). In line with the existing literature, we distinguish between horizontal spillovers (i.e., intra-industry linkages) and vertical spillovers (i.e., backward –or downstream– and forward –or upstream– inter-industry linkages). Our results show that the three types of technological spillovers from MNEs are positive, with the horizontal spillovers the larger ones, followed by backward spillovers. The effect of forward spillovers is much smaller in magnitude. Moreover, we find that not controlling for industry size (i.e., technological spillovers from all firms in an industry) leads to underestimating both horizontal and backward spillovers from MNEs, and to overestimating forward spillovers from MNEs. Finally, we find that the distinction between technological and output-based spillovers is of great relevance. The size of backward technological spillovers is approximately 44% of the size of output-based backward spillovers, while for horizontal spillovers both types of spillovers are quite similar. Importantly, output-based forward spillovers are negative while technological forward spillovers are positive.

Keywords: technological spillovers; multinational firms; productivity; R&D

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1 Introduction

Since the pioneering work by Caves (1974), a large body of empirical literature in international economics has focused on analyzing productivity spillovers from foreign affiliates to domestic firms. Early studies focused on horizontal spillovers (i.e., intra-industry linkages), while more recent studies also analyze vertical spillovers (i.e., inter-industry spillover linkages from buyers to suppliers and from suppliers to buyers). However, in this large and still growing literature, the empirical evidence is not conclusive. Overall, the strongest evidence is related to the positive spillovers from multinational customers to domestic suppliers (the so-called backward spillovers) (Havranek and Irsova, 2011).

The lack of robust evidence for spillovers from multinational firms may be explained by differences in the way linkages between foreign affiliates and domestic firms are measured. In this sense, the correct measure of this type of spillover is still debated in the literature. Related to this debate, the main body of literature measures the foreign presence in an industry in terms of the proportion of the total output produced by foreign affiliates. Some leading examples of this literature are Javorcik (2004), Blalock and Gertler (2008) and Haskel et al. (2007), while Görg and Greenaway (2001), Smeets (2008) Havranek and Irsova (2012) and Rojec and Knell (2018) present reviews of this literature. From now on, we identify these spillovers as *output-based spillovers*. At the same time, this literature identifies technological (or knowledge) externalities as one of the most important factors in explaining productivity spillovers from foreign presence to domestic firms. In fact, most studies that use data on output to measure spillovers identify them, explicitly or implicitly, as technological spillovers. However, although output produced by multinational firms is a reasonably good measure of foreign presence in an industry, its interpretation as genuine technological spillovers is not straightforward.

To overcome this limitation, a group of recent studies uses technology-related variables to measure spillovers from multinationals. Therefore, this type of spillover can be correctly identified as a technological spillover. This paper aims to contribute to this literature. In particular, we use data on R&D expenditures to measure productivity spillovers from foreign presence to domestic firms. In this sense, as pointed out by Rojec and Knell (2018), R&D expenditures are more closely related to the issue of technology transfer than to output. As a comparison exercise, we also present the results using output to measure spillovers.

We also contribute to the literature by distinguishing between technological spillovers from foreign affiliates and technological spillovers from all firms in the industry. The distinction between these two types of measures is important because it allows us to distinguish between two types of effects: the effect of multinational presence and the effect of industry size, as MNEs are usually in larger industries. The literature is interested in the first effect, linked to R&D international spillovers, which might occur because of the existence of a firm's unique and superior technology or other intangible assets and incentives to use these assets abroad in foreign affiliates. Thus, the international transfer of technology to their subsidiaries is an important consequence of MNE activities. Nevertheless, since the transferred knowledge has a certain public goods component, it may spread through non-market mechanisms over the host country economy, thus affecting productivity levels of domestic firms). The second effect just reflects the role played by industry size and should not be confused with the effect of multinationals.

The paper is structured as follows. A brief literature review is given in Section 2. Section 3 describes the data used in our analysis. The empirical model is presented in Section 4. Section 5 discusses the results and robustness checks. Finally, Section 6 presents the main conclusions.

2 Literature Review

There is substantial evidence that technological spillovers exist (see Hall et al., 2010, and Mohnen, 2019, for reviews of this literature). Generally speaking, these technological spillovers arise when knowledge flows to the firm from other firms. In practice, the technological spillover pool is mainly measured as the R&D stock accumulated outside of the firm. One particular area of interest has been whether the presence of multinationals in an industry increases the pool of knowledge that spills over to local firms. The aim of this section is to review the literature that uses technology-related variables to measure technological spillovers from foreign affiliates to domestic firms. Therefore, we restrict our attention to one channel of international technological spillovers: the spillover effect of inward FDI. [1]

A first classification distinguishes between the type of data used for the measurement of technological spillovers: industry- or firm-level data. The first contributions estimate technological spillovers from multinationals to local firms using industry-level data and focus only on horizontal spillovers. This strand of literature includes the works of Driffield (2001), McVicar (2002), Frantzen (2002) and Añón Higón (2007). Results regarding the existence of positive horizontal technological spillovers are mixed and inconclusive. McVicar (2002) shows evidence of international horizontal R&D spillovers for a sample of OECD countries. However, Driffield (2001), McVicar (2002) and Añón-Higón (2007), using data from British manufacturing industries, do not find any evidence of horizontal R&D spillovers from foreign-owned R&D. According to Driffield (2001), this result may be related to the existence of a "crowding out effect" from foreign R&D to domestic R&D.

Considering the incipient stream of studies that estimate technological spillovers from foreign affiliates to local firms using firm-level data, evidence is not very clear, because the literature that analyzes this issue is also scarce and heterogeneous regarding the methodologies used, the type of country analyzed or the spillover variables defined. Then, for the review of this stream of the literature, we first distinguish those contributions that estimate just horizontal spillover from those that also analyze vertical spillover. A second classification takes into account whether studies disentangle MNE technological spillovers from local technological spillovers (or alternatively, control

[1] The literature has identified at least three other channels through which international knowledge spillovers take place: outward FDI, intermediate goods imports and a disembodied direct channel (see Lee, 2006).

for industry size).

Most of the literature only considers the estimation of intrasectoral (or horizontal) R&D spillovers from foreign affiliates to local firms. This is the case of Todo (2006), Marin and Sasidharan (2010), Todo et al. (2011), Añón-Higón and Manjón-Antolín (2014) and Añón-Higón and Manjón-Antolín (2016). In all of the cases, horizontal R&D spillovers from MNE to local firms are positive.

Only two very recent studies estimate vertical and horizontal R&D spillovers from foreign affiliates to local firms. This is the case of Liang (2017) and Ben Hassine et al. (2017), who use data from Chinese and French firms, respectively. In this case, results are mixed. Liang (2017) finds that foreign presence only positively affects local productivity in upstream sectors (forward spillovers), whereas Ben Hassine et al. (2017) also obtain positive horizontal and backward R&D spillovers effects.

Finally, the distinction between MNE R&D spillovers and R&D spillovers from local firms has rarely been discussed in the empirical literature using firm-level data. This distinction is highly relevant in the sense that it allows us to disentangle MNEs technological spillover effects from technological spillovers from all firms in the industry. Only the studies of Todo (2006) and Todo et al. (2011) have also considered R&D spillovers from domestic firms to the rest of the firms. These authors define stocks of both foreign and domestic R&D activities at the industry level, considering that stock variables better represent the amount of foreign (domestic) knowledge that spills over to domestic (foreign) firms, in relation to the more standardized spillover variables based on the industry share of foreign firms in terms of production or employment (e.g., Javorcik, 2004). They find in both studies that the effect of industry R&D stock of foreign firms on domestic firms' TFP is substantially larger than the effect of industry R&D stock of domestic firms, using data on Japanese and Chinese firms, respectively.

3 Data description

3.1 Data source and sample

Our data comes from the Panel de Innovación Tecnológica (PITEC), a firm-level panel data base for innovative activities of Spanish firms based on the Community Innovation Survey (CIS).[2] This survey is carried out by the INE (The National Statistics Institute) and it is available to researchers.[3] Regarding its composition, PITEC consists of several subsamples, the most important of which are a sample of firms with 200 or more employees and a sample of firms with R&D expenditures.

Our final sample covers a total of 7,286 firms in manufacturing and services for the period

[2] CIS data has been widely used to analyze a variety of topics related to innovation (see Mairesse and Mohnen, 2010, for a detailed review of econometric studies using CIS data).

[3] For more information, see the FECYT web site https://icono.fecyt.es/pitec

2005-2013. Table A1 in the Appendix shows the composition in terms of time observations of the unbalanced panel sample used. The final sample is the result of the application of selection and filtering criteria. First, given the sample design of PITEC, we restrict our analysis to firms with R&D expenditures. Second, the estimation method we use (see below) implies that only observations with positive investment can be used. Therefore, we drop observations with zero investment. Third, we drop from our sample those firms that report a number of contingencies (including mergers and acquisitions). Fourth, we also drop observations with missing values in variables used in the estimation. Finally, all continuous variables are winsorized at the 1st and 99th percentiles to reduce the influence of extreme observations.

3.2 Variables and descriptive statistics

The key variables of interest are measures of technological spillovers from multinationals to domestic firms. First, we focus on the definition and construction of these key variables. Later, we define the remaining variables used in our production function framework.

Our measures of spillovers are based on widely adopted proxies for spillovers from FDI in the literature (see, among others, Javorcik 2004; Blalock and Gertler 2008). However, we depart from this literature in two important ways. First, as explained in the introduction, the literature identifies technological (or knowledge) externalities as one of the most important factors in explaining productivity spillovers from foreign presence to domestic firms. However, most studies use data on output to measure spillovers, and, explicitly or implicitly, identify them as technological spillovers. A few exceptions are the works previously mentioned in Section 2. Instead of this, we use data on R&D expenditures to measure productivity spillovers from multinationals.[4] In this sense, as pointed out by Rojec and Knell (2018), R&D expenditures are more closely related to the issue of technology transfer than variables such as sales and employment.[5] Second, most of the existing literature uses ratio variables to measure linkages between foreign affiliates and local firms (for example, the share of the total output of an industry that is produced by foreign firms). Rather than this, we distinguish between technological spillovers from foreign affiliates and technological spillovers from all firms in the industry. The distinction between the two types of measures is important because it allows us to distinguish between two types of effects. The first is the effect of foreign presence within an industry (horizontal spillovers from MNE), or in supplier or customer industries (forward and backward spillovers from MNE, respectively). The second is the effect of industry size (a firm's industry, supplier industries and customer industries), where industry size is measured by the different indicators used to define spillovers (R&D expenditures, sales, internal R&D expenditures and innovation expenditures).

Following the main literature, we distinguish between horizontal technological spillovers (i.e.,

[4] We use data on R&D expenditures (both internal and external) in our main specification. As robustness checks, we also present the results using internal R&D and innovation expenditures to measure our variables of technological spillovers.

[5] As a comparison exercise, we also present the results using output-based spillovers.

intra-industry technological spillovers), backward technological spillovers (i.e., downstream inter-industry technological spillovers), and forward technological spillovers (i.e., upstream inter-industry technological spillovers), where the latter two identify vertical linkages. As we said before, for each type of spillover, we further distinguish between those generated by foreign presence in the industry and those generated by all firms in the industry. Moreover, we define all spillover variables in logarithmic form.

First, horizontal technological spillovers from multinationals to domestic firms are defined as the R&D expenditures of foreign firms in the industry. For each firm, this spillover variable is defined so as not to include the firm's own R&D expenditures. With respect to industry breakdown, we group firms into 30 manufacturing and service industries (15 manufacturing industries and 15 service industries). The number of different industries available is the result of matching information from PITEC and two input-output tables.[6] Hence, for the ith firm operating in the sth industry, our measure of horizontal technological spillovers from MNEs (HS_{it}^{mne}) is defined as follows (as we said before, this variable excludes firm i's R&D expenditures):

$$HS_{it}^{mne} = \ln\left[\sum_{j\in s\ if\ j\neq i} Foreignshare_{jt} * R\&D_{jt}\right] \tag{1}$$

where $R\&D_{jt}$ are R&D expenditures of firm j belonging to industry s at time t, and $Foreignshare_{jt}$ is a proxy of the share of the firm's equity owned by foreign firms. Unfortunately, we do not have an exact figure for the share of the firm's equity owned by foreign firms. Instead of this, in the survey, questions on foreign ownership use predefined response categories. In particular, in our main specification, our variable $Foreignshare_{jt}$ takes a value of 0 for firms with 0 percent of foreign ownership; a value of 0.05 for firms with a foreign ownership greater than 0 percent and lower than 10 percent; a value of 0.35 for firms with a foreign ownership greater than or equal to 10 percent and lower than 50 percent; and a value of 0.75 for firms with a foreign ownership greater than or equal to 50 percent.[7]

For the ith firm operating in the sth industry, horizontal technological spillovers from all firms in the industry are defined as the total R&D expenditures in the industry (excluding firm i's R&D

[6] PITEC classifies firms into 31 manufacturing industries and 21 service industries, the 2005 input-output table classifies firms into 29 manufacturing industries and 31 service industries, and the 2010 input-output table classifies firms into 21 manufacturing industries and 32 service industries. To merge PITEC with input-output tables, all industry codes are matched to the NACE Rev. 1 codes. Table A2 in Appendix shows the industry breakdown considered to define our spillover variables and the corresponding NACE Rev. 1 codes.

[7] As a robustness check, we also present the results using an alternative definition of this variable. In this case, the variable $Foreignshare_{it}$ takes a value of 0 for firms with 0 percent of foreign ownership; a value of 0.1 for firms with a foreign ownership greater than 0 percent and lower than 10 percent; a value of 0.3 for firms with a foreign ownership greater than or equal to 10 percent and lower than 50 percent; and a value of 1 for firms with a foreign ownership greater than or equal to 50 percent.

expenditures):

$$HS_{it}^{allfirms} = \ln \left[\sum_{j \in s \ if \ j \neq i} R\&D_{jt} \right] \tag{2}$$

Before explaining the details of the definition of the other spillover variables, it is important to notice that, although these two variables of horizontal spillovers are firm-specific, they are constructed using the total R&D expeditures carried out in an industry (except the firm's own R&D expenditures).

The second type of spillovers (i.e., backward technological spillovers) occurs through backward linkages (i.e., from buyers to suppliers). Backward technological spillovers from multinationals to domestic firms measure the foreign R&D expenditures in the industries supplied by industry s at time t. In this case, this measure of backward technological spillovers from MNEs (BS_{st}^{mne}) varies by industry (s) and time (t). Therefore, for all the firms operating in the sth industry, this variable is defined as follows:

$$BS_{st}^{mne} = \ln \left[\sum_{k \ if \ k \neq s} \alpha_{sk} * \left(\sum_{j \in k} Foreignshare_{jt} * R\&D_{jt} \right) \right] \tag{3}$$

where α_{sk} is the share of industry s's production that is sold to industry k taken from the input-output tables. In practice, we use information from two different input-output tables. Values of α_{sk} from 2005 to 2009 are from the 2005 input-output table, while values of α_{sk} from 2010 to 2013 are from the 2010 input-output table. The use of different input-output tables is scarce in the literature (two exceptions are Blalock and Gertler, 2008, and Lenaerts and Merlevede, 2015), but it allows us to control for possible changes in the relationship between sectors over time.

Similarly, backward technological spillovers at the industry level are a function of total R&D expenditures in the industries supplied by industry s at time t:

$$BS_{st}^{allfirms} = \ln \left[\sum_{k \ if \ k} \alpha_{sk} * \left(\sum_{j \in k} R\&D_{jt} \right) \right] \tag{4}$$

Finally, the third type of spillovers (i.e., forward technological spillovers) occurs through forward linkages (i.e., from suppliers to buyers). Forward technological spillovers from multinationals to domestic firms measure the foreign R&D expenditures in the upstream (or supplying) industries of industry s at time t. Again, this measure of forward technological spillovers from MNEs (FS_{st}^{mne}) varies by industry (s) and time (t). Now, for all the firms operating in the sth industry, this variable is defined as follows:

$$FS_{st}^{mne} = \ln \left[\sum_{m\ if\ m \neq s} \sigma_{sm} * \left(\sum_{j \in m} Foreignshare_{jt} * R\&D_{jt} \right) \right] \tag{5}$$

where σ_{sm} is the share of industry s's inputs that is purchased from industry m taken from the input-output tables. Again, we use information from the 2005 and 2010 input-output tables.

Forward technological spillovers at the industry level are a function of total R&D expenditures in the upstream (or supplying) industries of industry s at time t.

$$FS_{st}^{allfirms} = \ln \left[\sum_{m\ if\ m \neq s} \sigma_{sm} * \left(\sum_{j \in m} R\&D_{jt} \right) \right] \tag{6}$$

Regarding the remaining variables we use, the PITEC provides information on firms' economic data necessary in the estimation of a production function. In particular, it provides information on sales, number of employees and investment in physical capital.[8], along with data on R&D expenditures. All nominal variables are deflated to express values in real terms. The deflators are based on the industrial price index and the service sector price index provided by the INE. We use the GDP deflator when industry-level prices are not available. Physical capital and R&D capital are constructed for each firm using a perpetual inventory by accumulating physical investments and R&D expenditures, respectively.

A set of variables is also included as other controls. We define a foreign ownership dummy indicating whether the firm's equity owned by foreign investors is equal to at least 50 percent (variable MNE). We also have information on the firm's age,[9] and define industry and regional dummies. Regarding industry dummies, we group firms into six different categories according to technological intensity: high-tech manufacturing firms; medium-high tech manufacturing firms; medium-low tech manufacturing firms; low-tech manufacturing firms; knowledge-intensive services; and non-knowledge-intensive services (see Table A3 in the Appendix). Finally, we consider four Spanish regions: Madrid, Cataluña, Andalucía, and the rest of Spain. Table 1 gives descriptive statistics on the dependent variable, inputs factors and other independent variables and controls, while Table 2 gives descriptive statistics on the spillover variables.

[8] Unfortunately, PITEC does not have data on materials. As pointed out by Jaumandreu (2009), when this is the case, a solution is to assume the materials/sales ratio to be constant (and absorbed by the constant). Therefore, the elasticities should be interpreted as value added elasticities.

[9] Following Huergo and Jaumandreu (2004), when age is older than 40 years, we change it to a unique category of 40 or more years.

Table 1: Descriptive statistics

	Mean	St. dev
Dependent variable		
Sales (y_{it})	15.990	1.947
Factor inputs		
Labor (l_{it})	4.206	1.526
Capital (k_{it})	14.622	2.290
R&D stock (r_{it})	13.469	1.877
Other variables and controls		
Age	21.920	10.766
MNE	0.128	
High-tech manufacturing	0.074	
Medium-high tech manufacturing	0.229	
Medium-low tech manufacturing	0.180	
Low-tech manufacturing	0.161	
Knowledge-intensive services	0.256	
Non-knowledge-intensive services	0.100	
Madrid	0.153	
Cataluña	0.263	
Andalucía	0.054	
Rest of Spain	0.530	
2005	0.127	
2006	0.126	
2007	0.124	
2008	0.121	
2009	0.113	
2010	0.107	
2011	0.099	
2012	0.093	
2013	0.090	

Table 2. Variable descriptive statistics: Spillover variables

	Technological spillovers from R&D		*Output-based spillovers*		*Technological spillovers from internal R&D*		*Technological spillovers from innovation expenditures*	
	Mean	St. dev	Mean	St. dev	Mean	St. dev	Mean	St. dev
HS from MNE (HS_{it}^{mne})	17.334	1.925	22.234	1.489	17.039	1.938	17.737	1.870
BS from MNE (BS_{st}^{mne})	17.028	2.171	21.741	2.563	16.715	2.141	17.438	2.223
FS from MNE (FS_{st}^{mne})	17.171	2.244	21.332	2.631	16.877	2.213	17.527	2.293
HS from all firms ($HS_{it}^{allfirms}$)	19.229	1.367	23.691	1.048	18.975	1.365	19.587	1.248
BS from all firms ($BS_{st}^{allfirms}$)	18.305	2.270	22.938	2.685	18.000	2.238	18.698	2.318
FS from all firms ($FS_{st}^{allfirms}$)	18.562	2.337	22.541	2.758	18.288	2.301	18.876	2.372

Spillover variables are calculated using the main proxy of the firm's equity owned by foreign firms ($Foreignshare_{jt}$)

4 Empirical Model

Our approach follows the model of technological change introduced by Griliches (1979), where the production function is augmented with a measure of the firm's own R&D capital and measures of the external knowledge stock available to the firm in a firm-level production function framework. Regarding external knowledge sources, we are especially interested in the effect of foreign multinational firms' (MNEs) technological spillovers on local firms' productivity.

4.1 Specification of the production function

Our starting point is a conventional Cobb-Douglas production function augmented with a firm's own knowledge capital term:

$$Y_{it} = A_{it} L_{it}^{\alpha_l} K_{it}^{\alpha_k} R_{it}^{\alpha_r} \tag{7}$$

where Y_{it} is the output of firm i in year t, A_{it} is a productivity shifter, L_{it} is labor, K_{it} is the physical capital stock, and R_{it} is the firm's own R&D capital stock.

We model the firm-specific productivity term as composed of the technological spillovers variables and the set of control variables (z_{it}) described earlier. In particular, we parameterize the productivity shifter as:

$$\begin{aligned} \ln A_{it} \;=\; & \beta_0 + \beta_1 HS_{it}^{mne} + \beta_2 BS_{st}^{mne} + \beta_3 FS_{st}^{mne} \\ & + \beta_4 HS_{it}^{allfirms} + \beta_5 BS_{st}^{allfirms} + \beta_6 FS_{st}^{allfirms} \\ & + \delta' z_{it} + t_t + \omega_{it} + u_{it} \end{aligned} \tag{8}$$

Eq. (8) also includes a constant to measure the mean efficiency level across firms (β_0), year dummies to control for common macro effects (t_t), an unobserved productivity term (ω_{it}), and a serially uncorrelated additional productivity shock (u_{it}).

Using lowercase letters (y, l, k, and r) to denote natural logarithms, we obtain our empirical model:

$$\begin{aligned} y_{it} \;=\; & \beta_0 + \alpha_l l_{it} + \alpha_k k_{it} + \alpha_r r_{it} \\ & + \beta_1 HS_{it}^{mne} + \beta_2 BS_{st}^{mne} + \beta_3 FS_{st}^{mne} \\ & + \beta_4 HS_{it}^{allfirms} + \beta_5 BS_{st}^{allfirms} + \beta_6 FS_{st}^{allfirms} \\ & + \delta' z_{it} + t_t + \omega_{it} + u_{it} \end{aligned} \tag{9}$$

4.2 Estimation method

We estimate our empirical model using the Olley and Pakes (1996) approach.[10] In particular, we follow Griffith et al. (2006) to include R&D capital stock in the OP model. In our specification, labor is the only freely variable input, while physical capital stock and R&D stock are quasi-fixed. At the beginning of period t, firm i observes its productivity state (ω_{it}) and capital stocks (i.e., capital stocks are state variables). As originally proposed by Olley and Pakes (1996), we include the age of the firm as an additional state variable. It is important to notice the difference between the two unobservable (to the econometrician) terms. The productivity state (ω_{it}) refers to factors observed by the firm, and therefore affects investment decisions, while u_{it} is an i.i.d. term which is also unobservable to the firm, and hence does not affect the investment decisions.

Following Griffith et al. (2006), the spillover terms are assumed to be exogenous and they are included as additional exogenous variables in the production function. The underlying hypothesis to justify this assumption is that the productivity state (ω_{it}) is uncorrelated with all industry-level variables. As mentioned before, our variables of horizontal spillovers are firm-specific but defined through an aggregate measure at the industry level, while our backward and forward spillover variables are industry-specific.[11] We calculate the standard errors through a bootstrapping procedure with 100 replications. Finally, we compare OP results to simple OLS estimates.

5 Results

5.1 Main Results

Table 2 shows our main results. Columns (1)-(3) use R&D to build the technological spillovers measure while columns (4)-(6) use deflated sales to build output-based spillovers. Columns (1) and (4) provide OLS estimates. The rest of the columns provide OP estimates. In columns (3) and (6), we do not include any covariate proxying for spillovers from all firms in the industry (industry size according to the indicator, R&D or sales, used to measure spillovers), while in the rest of the columns, the size of each industry is included so that the effect of multinational presence can be distinguished from the effect of industry size. It should be noted that the larger industries show a greater presence of multinationals, so the omission of this relevant confounding factor has the important consequence that the spillovers coefficients in columns (3) and (6) confound the effect of multinationals and the effect of industry size [12].

[10]We perform the estimation using the *prodest* command of Stata, developed by Rovigatti and Mollisi (2018).

[11]As a robustness check, we present the main results lagging the spillover variables by one period to mitigate possible endogeneity problems.

[12]When the usual ratio of multinational presence is used, the absence of industry size as an additional covariate is actually equivalent to a restricted regression where the effects of the numerator and the denominator on the dependent variable cannot be distinguished from each other.

Before discussing the main results, we briefly comment on estimated input coefficients. Our results are in line with those from previous studies. The elasticity of labor is around 0.8, the elasticity of capital is 0.175 and the elasticity of R&D capital is 0.07. We also find that older firms and multinationals are more productive. Turning to our main results, OLS and OP estimates from columns (1) and (2) actually show very similar results. Interestingly, and different from previous literature, we find that the three types of technological spillovers from MNEs are positive, with the horizontal spillovers the larger ones (a 1% increase of R&D by multinationals in the same industry is related to a 0.22% increase in focal firm productivity in the OP specification), followed by backward spillovers (a 1% increase of R&D by multinationals in downstream industries is related to a 0.15% increase in focal firm productivity). The effect of forward spillovers is much smaller in magnitude and statistically significant only in the OP estimates (a 1% increase of R&D by multinationals among provider industries is related to a 0.013% increase in productivity of the focal firm).

The importance of taking account of industry size is revealed by comparing these results against those from column (3). Horizontal spillovers decrease by around 67% when industry size is not controlled for, backward spillovers become negative and forward spillovers, on the contrary, are positive. The reason is that, on the one hand, there is a positive relationship between multinational presence and industry size and, on the other, the effect of industry size in horizontal/client industries is different than in provider industries, as shown by the last three rows of the table. While being located in a large industry reduces productivity like selling to a large industry does, buying from a small industry increases productivity. In other words, the importance of disentangling the effect of multinationals from the effect of industry size is crucial.

While columns (1)-(3) actually measure technological spillovers, columns (4)-(6) provide the results using deflated sales as the indicator for multinational presence, what we call ouput-based spillovers. OLS and OP estimates from columns (4) and (5) again show very similar results. The backward spillovers are the larger ones (a 1% increase of sales by multinationals in downstream industries is related to a 0.33% increase in focal firm productivity in the OP specification), followed by horizontal spillovers (a 1% increase of sales by multinationals in the same industry is related to a 0.25% increase in the productivity of the focal firm). Finally, forward spillovers are found to be negative (a 1% increase in sales by multinationals among provider industries is related to a 0.18% decrease in the productivity of the focal firm).

A comparison between columns (2) and (5) allows us to delve into the nature of spillovers. While the size of horizontal technological spillovers is 90% the size of output-based spillovers, suggesting that other channels of spillovers almost cancel each other, this is far from being the case for vertical spillovers. The size of backward technological spillovers is approximately 44% of the size of output-based backward spillovers, suggesting that at least half of the spillovers from multinational clients to local providers are received from channels different from technology. Finally, output-based forward spillovers are negative while technological forward spillovers are small but positive. That is, the negative effect of multinational providers on the productivity of the focal firm is driven by reasons different from technology.

The importance of controlling for the size of the industry is still important when deflated sales is used as an indicator. The comparison of results from columns (5) and (6) shows that, although the difference between controlling and not controlling for industry size is not very relevant for the estimation of output-based horizontal spillovers, the effect of backward spillovers is greatly underestimated and the effect of forward spillovers is greatly overestimated when the industry size of providers is not controlled for, as happened with technological spillovers.

Table 2: Main results

	Technological spillovers from R&D			Output-based spillovers		
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OP	OP	OLS	OP	OP
Age	0.009***	0.036***	0.026***	0.009***	0.026***	0.030***
	(0.000)	(0.006)	(0.004)	(0.000)	(0.008)	(0.004)
Labor	0.833***	0.798***	0.808***	0.835***	0.800***	0.799***
	(0.005)	(0.010)	(0.011)	(0.005)	(0.010)	(0.010)
Capital	0.158***	0.175***	0.183***	0.162***	0.159***	0.176***
	(0.003)	(0.008)	(0.003)	(0.003)	(0.010)	(0.003)
R&D stock	0.069***	0.071***	0.067***	0.061***	0.075***	0.079***
	(0.003)	(0.006)	(0.003)	(0.003)	(0.006)	(0.003)
MNE	0.323***	0.337***	0.354***	0.311***	0.329***	0.334***
	(0.011)	(0.004)	(0.003)	(0.011)	(0.004)	(0.003)
HS from MNE	0.208***	0.224***	0.074***	0.234***	0.250***	0.223***
	(0.007)	(0.005)	(0.003)	(0.012)	(0.009)	(0.003)
BS from MNE	0.142***	0.145***	-0.111***	0.319***	0.329***	-0.005
	(0.035)	(0.010)	(0.005)	(0.083)	(0.004)	(0.004)
FS from MNE	0.008	0.013***	0.142***	-0.181*	-0.183***	0.005*
	(0.036)	(0.005)	(0.003)	(0.095)	(0.003)	(0.003)
HS from all firms	-0.311***	-0.285***		-0.030*	-0.014	
	(0.010)	(0.008)		(0.018)	(0.012)	
BS from all firms	-0.322***	-0.326***		-0.315***	-0.324***	
	(0.036)	(0.010)		(0.083)	(0.004)	
FS from all firms	0.191***	0.195***		0.178*	0.183***	
	(0.037)	(0.004)		(0.095)	(0.002)	
Observations	45,032	45,032	45,032	45,032	45,032	45,032

Bootstrap standard errors in parentheses (100 reps)

Time dummies, industry dummies and regional dummies included in all specifications

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

5.2 Robustness Checks

In this section we provide different robustness checks on previous results. More precisely, we check how different methodological choices affect the results. First, we allow for the possibility of one lag between spillovers and productivity. Second, we analyze the effect of using a different indicator to define the multinational property of the firms and, third, we consider how technological spillovers vary if we proxy technology in a different way (using only internal R&D or using all innovation expenditures, including design or marketing for new products, among others).

5.2.1 Results lagging spillovers by one period

Table 3 shows the results when one lag is allowed between spillovers and productivity. The structure of this table is similar to that of Table 2: columns (1)-(3) use R&D to build the technological spillovers measure while columns (4)-(6) use deflated sales to build output-based spillovers. In columns (3) and (6), we do not include any covariate which proxies for industry size, while in the rest of the columns, we do.

Results are very similar to those from Table 2. Horizontal technological spillovers are those of greater magnitude (0.218 with the lag, 0.224 with the contemporaneous relationship in the OP specification), followed by backward spillovers (0.159 with the lag, 0.145 with the contemporaneous relationship) and forward spillovers, which are close to zero (in this case with a small negative coefficient). Regarding the importance of controlling for industry size, we find exactly the same pattern as before. Column (3), where industry size is not controlled for, underestimates the effect of horizontal and backward spillovers and overestimates the effect of forward spillovers. Finally, the relationship between output-based and technological spillovers is also similar. While output-based and technological horizontal spillovers are of similar size, backward output-based spillovers are considerably higher than backward technological spillovers, suggesting that there are other channels through which these spillovers take place. In turn, forward output-based spillovers are considerably lower, suggesting that the negative effect of multinational providers on productivity is not channeled through technology.

5.2.2 Results using an alternative proxy of foreign ownership

Table 4 shows the results using a different definition for multinational. The main findings hold under this different definition: (i) technological horizontal and backward spillovers are positive and large in magnitude while technological forward spillovers are close to zero; (ii) not controlling for industry size leads to underestimating technological horizontal and backward spillovers and to overestimating forward spillovers; and (iii) while most horizontal spillovers are actually technological, less than half of backward spillovers are technological. For its part, the negative effect of forward spillovers is not due to technology.

Table 3: Results lagging spillovers by one period

	Technological spillovers from R&D			Output-based spillovers		
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OP	OP	OLS	OP	OP
Age	0.008***	0.030***	0.026***	0.007***	0.025***	0.030***
	(0.000)	(0.006)	(0.007)	(0.000)	(0.008)	(0.003)
Labor	0.811***	0.781***	0.791***	0.813***	0.783***	0.782***
	(0.006)	(0.011)	(0.012)	(0.005)	(0.011)	(0.011)
Capital	0.184***	0.207***	0.208***	0.187***	0.207***	0.202***
	(0.004)	(0.006)	(0.005)	(0.004)	(0.008)	(0.003)
R&D stock	0.068***	0.080***	0.067***	0.060***	0.073***	0.076***
	(0.003)	(0.004)	(0.003)	(0.003)	(0.005)	(0.003)
MNE	0.310***	0.322***	0.341***	0.299***	0.313***	0.316***
	(0.012)	(0.004)	(0.010)	(0.012)	(0.004)	(0.003)
HS from MNE	0.206***	0.218***	0.078***	0.228***	0.248***	0.225***
	(0.008)	(0.004)	(0.004)	(0.014)	(0.009)	(0.003)
BS from MNE	0.144***	0.159***	-0.104***	0.263***	0.272***	0.005
	(0.039)	(0.005)	(0.007)	(0.099)	(0.004)	(0.005)
FS from MNE	-0.014	-0.014***	0.139***	-0.137	-0.132***	-0.002
	(0.041)	(0.004)	(0.005)	(0.113)	(0.003)	(0.003)
HS from all firms	-0.300***	-0.271***		-0.017	0.002	
	(0.012)	(0.006)		(0.021)	(0.011)	
BS from all firms	-0.322***	-0.324***		-0.247**	-0.255***	
	(0.041)	(0.005)		(0.099)	(0.005)	
FS from all firms	0.208***	0.209***		0.121	0.125***	
	(0.042)	(0.003)		(0.113)	(0.004)	
Observations	33,657	33,657	33,657	33,657	33,657	33,657

Standard errors in parentheses

Time dummies, industry dummies and regional dummies included in all specifications

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4: Results using an alternative proxy of foreign ownership

	Technological spillovers from R&D			Output-based spillovers		
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OP	OP	OLS	OP	OP
Age	0.009***	0.029***	0.027***	0.009***	0.026***	0.020***
	(0.000)	(0.007)	(0.004)	(0.000)	(0.007)	(0.004)
Labor	0.833***	0.798***	0.808***	0.835***	0.800***	0.799***
	(0.005)	(0.010)	(0.011)	(0.005)	(0.010)	(0.010)
Capital	0.158***	0.163***	0.186***	0.161***	0.159***	0.177***
	(0.003)	(0.009)	(0.003)	(0.003)	(0.010)	(0.003)
R&D stock	0.070***	0.096***	0.067***	0.061***	0.076***	0.078***
	(0.003)	(0.005)	(0.003)	(0.003)	(0.005)	(0.003)
MNE	0.323***	0.335***	0.348***	0.312***	0.330***	0.329***
	(0.011)	(0.005)	(0.003)	(0.011)	(0.004)	(0.003)
HS from MNE	0.213***	0.232***	0.072***	0.240***	0.271***	0.221***
	(0.007)	(0.005)	(0.003)	(0.013)	(0.010)	(0.003)
BS from MNE	0.142***	0.150***	-0.112***	0.418***	0.428***	-0.003
	(0.035)	(0.012)	(0.006)	(0.086)	(0.003)	(0.004)
FS from MNE	0.005	0.011**	0.141***	-0.315***	-0.316***	0.002
	(0.037)	(0.005)	(0.004)	(0.098)	(0.003)	(0.003)
HS from all firms	-0.315***	-0.291***		-0.038**	-0.022*	
	(0.010)	(0.008)		(0.018)	(0.012)	
BS from all firms	-0.324***	-0.332***		-0.419***	-0.427***	
	(0.036)	(0.012)		(0.086)	(0.003)	
FS from all firms	0.193***	0.198***		0.313***	0.319***	
	(0.038)	(0.004)		(0.098)	(0.002)	
Observations	45,032	45,032	45,032	45,032	45,032	45,032

Standard errors in parentheses

Time dummies, industry dummies and regional dummies included in all specifications

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

5.2.3 Results using internal R&D and innovation expenditures to define technological spillovers

Table 5 shows the results using different indicators of technology. Columns (1)-(3) use only internal R&D while columns (4)-(6) use all innovation expenditures. The general pattern is again observed:(i) technological horizontal and backward spillovers are positive and large in magnitude while technological forward spillovers are close to zero; (ii) not controlling for industry size leads to the underestimation of technological horizontal and backward spillovers and to the overestimation of forward spillovers.

Table 5: Results using different measures for technological spillovers

	Technological spillovers from internal R&D			Technological spillovers from innovation expenditures		
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OP	OP	OLS	OP	OP
Age	0.009***	0.032***	0.029***	0.009***	0.036***	0.031***
	(0.000)	(0.005)	(0.006)	(0.000)	(0.005)	(0.004)
Labor	0.832***	0.797***	0.808***	0.835***	0.800***	0.807***
	(0.005)	(0.010)	(0.011)	(0.005)	(0.011)	(0.011)
Capital	0.156***	0.173***	0.186***	0.161***	0.184***	0.181***
	(0.003)	(0.006)	(0.004)	(0.003)	(0.007)	(0.003)
R&D stock	0.072***	0.077***	0.074***	0.066***	0.079***	0.068***
	(0.003)	(0.006)	(0.004)	(0.003)	(0.005)	(0.003)
MNE	0.324***	0.332***	0.358***	0.320***	0.329***	0.342***
	(0.011)	(0.004)	(0.004)	(0.011)	(0.004)	(0.003)
HS from MNE	0.188***	0.203***	0.053***	0.208***	0.226***	0.089***
	(0.006)	(0.004)	(0.004)	(0.007)	(0.006)	(0.003)
BS from MNE	0.123***	0.130***	-0.114***	0.129***	0.142***	-0.107***
	(0.030)	(0.011)	(0.007)	(0.043)	(0.011)	(0.004)
FS from MNE	-0.018	-0.013**	0.143***	-0.015	-0.014***	0.136***
	(0.033)	(0.005)	(0.005)	(0.043)	(0.004)	(0.003)
HS from all firms	-0.323***	-0.304***		-0.290***	-0.261***	
	(0.010)	(0.007)		(0.011)	(0.006)	
BS from all firms	-0.313***	-0.329***		-0.298***	-0.302***	
	(0.031)	(0.011)		(0.045)	(0.010)	
FS from all firms	0.221***	0.234***		0.199***	0.199***	
	(0.033)	(0.006)		(0.045)	(0.004)	
Observations	45,032	45,032	45,032	45,032	45,032	45,032

Standard errors in parentheses.

Time dummies, industry dummies and regional dummies included in all specifications

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

6 Conclusions

The amount of literature on spillovers by multinational firms has increased in the last twenty years. However, despite the considerable attention this subject has received, the contradictory results on the sign and magnitude of the different types of spillovers have prevented the development of stylized facts. We highlight two important issues from previous research. First, although the specific findings from each study have usually been interpreted in terms of technological spillovers, the great majority of studies have used output of multinationals rather than an indicator of their technological activity. Second, previous studies have not usually controlled for technological spillovers from all firms in the industry, meaning that the coefficient can potentially confuse the effect of spillovers from multinationals with the technological spillovers from all firms if multinationals are likely to locate in industries of larger size. In this analysis we address these two issues. On the one hand, we distinguish technological and non-technological spillovers by comparing the results when using an indicator of technology (R&D or innovation expenditures) against those using deflated sales of multinationals. On the other hand, we distinguish between spillovers from multinationals and spillovers from all firms in the industry.

Our results show that the three types of technological spillovers are positive; the horizontal ones are the largest, followed by backward spillovers. Forward spillovers are of a lower magnitude. The importance of addressing the two issues is revealed. On the one hand, we find that the size of backward technological spillovers is only around 44% the size of output-based backward spillovers. Moreover, forward output-based spillovers are negative but forward technological spillovers are practically zero. For horizontal spillovers, the size of technological spillovers is around 90% the size of output-based spillovers. On the other hand, we find that the estimate of technological horizontal spillovers from multinationals decreases by 67% when we control for technology spillovers for all firms in the industry. In addition, the estimate of backward technological spillovers would be negative if technology spillovers for all firms were not accounted for and forward technological spillovers would become positive in that case. The reason is that, on the one hand, there is a positive relationship between multinational presence and industry size and, on the other, the effect of industry size is different in horizontal/downstream and in upstream industries. Being located in a large industry reduces productivity as does selling to a large industry. However, buying from a large industry increases it.

The aforementioned set of results is robust to the consideration of different estimation methodologies, to the assumption of different lags between multinational presence and firms' productivity and to different indicators for multinational presence or technology.

This work shows some limitations. First, we do not address the issue of heterogeneity of spillovers. That is, we do not analyze whether the size of spillovers to the focal firm is contingent on some firm characteristics (e.g., size, age) or strategic decisions (e.g., building absorptive capacity, exporting). Second, because of the database employed, we have to rely on a discrete indicator of the foreign share of a firm instead of a continuous one. These limitations also constitute opportunities for future research.

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9 Appendix

Table A1. Firms by number of observations

No. of observations	No. of firms	Observations
1	335	335
2	464	928
3	563	1,689
4	655	2,620
5	748	3,740
6	758	4,548
7	838	5,866
8	1,019	8,152
9	1,906	17,154
Total	7,286	45,032

Table A2. Industry breakdown to define spillover variables

Manufacturing	
Industry	NACE Rev.1
Food products and beverages. Tobacco products	15, 16
Textiles. Wearing apparel; dressing and dyeing of fur. Leather and footwear	17, 18, 19
Wood and of products of wood and cork	20
Pulp, paper and paper products	21
Publishing, printing and reproduction	22
Coke, refined petroleum products. Chemicals and chemical products. Pharmaceuticals	23, 24
Rubber and plastic products	25
Ceramic tiles and flags. Other non-metallic mineral products	26
Basic ferrous metals. Basic precious and non-ferrous metals	27
Fabricated metal products	28
Machinery and equipment. Electrical machinery and apparatus. Manufacture of office machinery and computers. Electronic components. Radio, television and communication equipment. Medical, precision and optical instruments	29, 30, 31, 32, 33
Motor vehicles	34
Manufacture of aircraft and spacecraft. Building and repairing of ships and boats. Other transport equipment	35
Furniture. Games and toys. Manufacturing n.e.c.	36
Recycling	37

Services	
Industry	NACE Rev.1
Sale, maintenance and repair of motor vehicles	50
Wholesale trade	51
Retail trade	52
Hotels and restaurants	55
Transport	60, 61, 62
Auxiliary transport activities; travel agencies	63
Post and courier activities. Telecommunications	64
Financial intermediation	65, 66, 67
Real estate activities	70
Renting of machinery and equipment	71
Software consultancy and supply. Computer and related activities	72
Research and development	73
Architectural and engineering activities. Technical testing and analysis. Other business activities	74
Education	80 (except 803)
Motion picture and video activities. Radio and television activities. Other services	85, 90, 91, 92, 93

Table A3. Industry breakdown to define technological intensity dummies

Manufacturing		Services	
	NACE Rev.1		NACE Rev.1
High-tech manufacturing		*Knowledge-intensive services*	
Pharmaceuticals	244	Transport	60, 61, 62
Manufacture of office machinery and computers	30	Post and courier activities	641
Electronic components	321	Telecommunications	642
Radio, television and communication equipment	32 (except 321)	Financial intermediation	65, 66, 67
Medical, precision and optical instruments	33	Real estate activities	70
Manufacture of aircraft and spacecraft	353	Renting of machinery and equipment	71
Medium-high tech manufacturing		Software consultancy and supply	722
Chemicals and chemical products	24 (except 244)	Computer and related activities	72 (except 722)
Machinery and equipment	29	Research and development	73
Electrical machinery and apparatus	31	Architectural and engineering activities	742
Motor vehicles	34	Technical testing and analysis	743
Other transport equipment	35 (except 351, 353)	Other business activities	74 (except 742, 743)
Medium-low tech manufacturing		Education	80 (except 803)
Coke, refined petroleum products	23	Motion picture and video activities	921
Rubber and plastic products	25	Radio and television activities	922
Ceramic tiles and flags	263	*Non-knowledge-intensive services*	
Other non-metallic mineral products	26 (except 263)	Sale, maintenance and repair of motor vehicles	50
Basic ferrous metals	27 (except 274)	Wholesale trade	51
Basic precious and non-ferrous metals	274	Retail trade	52
Fabricated metal products	28	Hotels and restaurants	55
Building and repairing of ships and boats	351	Auxiliary transport activities and travel agencies	63
Low-tech manufacturing		Other services	85, 90, 91 92 (except 921, 922), 93
Food products and beverages	15		
Tobacco products	16		
Textiles	17		
Wearing apparel; dressing and dyeing of fur	18		
Leather and footwear	19		
Wood and products of wood and cork	20		
Pulp, paper and paper products	21		
Publishing, printing and reproduction	22		
Furniture	361		
Games and toys	365		
Manufacturing n.e.c.	36 (except 361, 365)		
Recycling	37		