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TECHNOLOGY TRANSFER THROUGH VERTICAL LINKAGES: THE CASE OF THE SPANISH MANUFACTURING INDUSTRY

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Whether or not foreign direct investment helps to upgrade the technological capacities of firms in host countries is an important question for policy makers. Even more important is the question of what are the most effective channels of technology transfer. The econometric analysis presented here is based on a firm level database from Spain for the period 1990-2000. We associate spillovers with the effect of horizontal and vertical FDI on total factor productivity of local firms. We find that technology spillovers are limited to the case of vertical linkages. However these spillovers are affected by the technology gap between domestic firms and foreign affiliates as well as by the characteristics of foreign affiliates. Linkages with export-oriented affiliates and fully owned ones seem to have a better influence on the productivity of domestic firms.

JEL classification codes: F23
Key words: technology spillovers, vertical linkages, foreign direct investment

I. Introduction

Recently the economic literature has focused on the analysis of technology transfer, especially the technology diffused through foreign direct investment (FDI). The interest in technology transfer finds its origin in the new theory of economic growth (Romer 1990). This theory suggests that technological progress is the main contributor to economic growth. Developing countries aim to attain high levels of economic growth and to fill the development gap with developed countries. However, these countries lack the capacity to undertake research and

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development activities and to generate technological innovations; therefore, they rely on the imitation of foreign innovations in their growth process.

The econometric literature presents pessimistic results concerning the capacity of foreign affiliates to internationally diffuse technology. Despite some studies analyzing developed countries that present significant evidence on spillovers (Haskel et al. 2002), a major share of this literature is concerned with developing countries and finds negative or non-significant correlation between foreign presence and the productivity of local firms.

The absence of technological spillovers is generally explained by the lack of absorptive capacity of the local firms. However, all these studies have focused on technology transfers between foreign affiliates and local enterprises belonging to the same sector, i.e., technology spillovers resulting from the proximity to foreign affiliates commonly known as horizontal transfers.

One plausible explanation for the absence of this kind of technology transfer is that the diffusion of their technology and know-how to their local competitors is not in the strategic interest of foreign affiliates, especially when the technological superiority of the foreign affiliates is the main element of their competitive advantage in the host market.

Considering this and the fact that foreign affiliates can be interested in the technological upgrading of their suppliers, backward linkages between foreign affiliates and domestic suppliers may be a more effective channel through which FDI may transfer technology to the host economy.

Forward linkages, between local final-good producers and foreign suppliers, may also help the diffusion of the foreign technology through the local economy. The productivity of local firms may be improved if they use modern, technologically advanced and good quality inputs produced by foreign affiliates in upstream industries.

The literature on technology transfer through vertical linkages is relatively rare but we can cite the studies of Javorcik (2004) on Lithuania and Garrick and Gertler (2003) on Indonesia. These studies confirm the absence of spillovers at the intra-sector level. However, they provide strong evidence on the presence of vertical spillovers between foreign affiliates and local ones.

This paper proposes an analysis of the case of the Spanish manufacturing industry. It aims to verify the existence of technological spillovers through vertical linkages. It also examines what kind of foreign firms are most favorable for the

establishment of vertical linkages with local firms and for the transfer of technology to them. More precisely, we distinguish between foreign affiliates serving essentially the local market and those using the local market as an export platform. We also distinguish between fully-owned foreign affiliates and those with some local participation. These distinctions are important for policy makers aiming to upgrade the technological capacities of their domestic enterprises by attracting foreign multinationals.

We estimate total factor productivity using the semi-parametric estimation method proposed by Olley and Pakes (1996). This method accounts for the endogeneity of input demand, thus improving the quality of the estimation. We estimate the effect of backward and forward linkages with foreign affiliates on the total factor productivity (TFP) of domestic firms and find positive and significant correlation. We also find negative and significant correlation between foreign presence and productivity of domestic firms in the same sectors.

The rest of the paper is structured as follows. In the second section, we shall present the analytical framework of the paper. In the third section we shall present the data and methodology. In the fourth section we shall measure the effect of foreign presence and the effect of vertical linkages with foreign affiliates on the productivity of domestically-owned firms. Section five concludes the paper.

II. Analytical framework

Foreign direct investment has many implications on host economies. The entry of multinational firms affects, among others, the labor market, the size of the market, the balance of payments, as well as industrial development. These implications can be positive or negative and the net effect of FDI on the host economy is in general hard to determine.

In this paper we are particularly interested in the effect of FDI on industrial development through the creation of backward and forward linkages with the host economy. The economic literature presents two main analyses of the relation between vertical linkages, FDI and industrial development.

Models like Markusen and Venables (1999) and Rodriguez-Clare (1996) treat the effect of FDI on industrial development through its effect on the intensity of vertical linkages. The basic idea behind these models is that the intensity of

backward and forward linkages within the sectors of an economy is an engine of industrial dynamism and development.

Foreign direct investment generates two opposite effects on the intensity of linkages. On one hand, the entry of foreign firms creates a new source of demand for the suppliers of intermediate goods. On the other hand, it will increase the competition faced by local firms and forces some of them to exit the market or to cut back on their output. Thus the net effect of foreign firms will depend on the linkages they generate compared to the ones that would be generated by the local firms displaced from the market.

Models like Pack and Saggi (2001) analyze the inter-sectoral transfer of technology more explicitly. The idea behind such analysis is that foreign firms are willing to transfer some of their technology and know-how to their suppliers with the purpose of guaranteeing the quality of their intermediate goods.

Case studies and interviews with managers of domestic suppliers show that foreign firms have high requirements concerning the design and the quality of the products as well as the on-time delivery. They also show that these firms often impose quality control and help the suppliers to upgrade their production process through the training and the turnover of workers, visits to the supplier's plant by the technical staff of the foreign buyer and the provision of blueprints and information on the production techniques.

Moreover, backward linkages with domestic suppliers can benefit foreign firms especially by allowing them to increase their specialization and flexibility and to adapt their production to the conditions of the local market (UNCTAD 2001). The intensity of backward linkages between foreign firms and domestic suppliers and the extent to which those linkages will generate technology transfer depends on several elements, particularly the technological capacity of domestic firms, the entry mode of foreign firms and the nature of their activity.

A. The effect of the technology gap

The extent of technology transfer may depend on the technological capacities of the domestic firms. In fact, the lack of absorptive capacity is a traditional explanation for the absence of the horizontal technology spillovers.

We assume that the technology gap may also influence spillovers through the vertical linkages. More precisely, if the technological gap between the foreign buyer and the domestic supplier is considerable, we can suppose that the foreign

firm will be reticent to purchase specialized intermediates from domestic suppliers. Even in the presence of technology transfer the suppliers will not have the capacity to absorb this technology and to develop the intermediate good. Similarly if the gap between the domestic final-good producer and the foreign supplier is significant, the former will lack the capacity to absorb and to benefit from the foreign technology incorporated in the input.

We analyze empirically the effect of the technology gap between foreign affiliates and domestic firms on the existence of technology spillovers and expect a negative correlation.

B. The effect of the mode of entry

The incentive of foreign affiliates to tie backward linkages with domestic firms may depend on their mode of entry. It is argued that foreign affiliates that enter the host country through mergers and acquisitions (M&As) or joint ventures are more likely to engage in backward linkages with domestic firms than those who enter the host country through greenfield projects (UNCTAD 2001).

In fact foreign affiliates can benefit from their local partner' knowledge concerning the conditions of the local market as well as from their established network of suppliers. However, fully-owned affiliates are more technologically advanced than partially-owned ones. In fact, we can suppose that when multinationals enter the host market through M&As or joint-ventures, they will be reticent to transfer state-of-the-art technology to their affiliates in order to prevent its leakage in the host economy (Ethier and Markusen 1996).

The effect of the entry mode on technology spillovers is not clear, fully-owned firms can have either a positive or a negative effect on spillovers; in our econometric analysis we create two measures of backward linkages, one for fully-owned affiliates and one for partially-owned ones, and try to estimate which effect overcomes the other.

Following the assumption that fully owned affiliates are more technologically advanced than partially owned ones, we consider that forward linkages with fully owned affiliates are better for technology diffusion.

C. The effect of the nature of foreign affiliates' activity

It is suggested that foreign affiliates that serve the local market are more likely

to have backward linkages with domestic suppliers than those who are export-oriented (UNCTAD 2000; Altenburg 2000). When serving the local market, foreign affiliates need to adapt their production to local conditions. Thus they tend to be more integrated into the local economy.

Export-oriented affiliates are generally part of a global sourcing and distribution network managed by the parent company. Moreover, they have higher quality requirements that can be difficult for the local suppliers to meet but at the same time offer a greater opportunity for technology transfer. We distinguish empirically between the effect of backward linkages with export-oriented affiliates and those with home market-oriented ones; however we do not have a clear expectation on the impact of foreign affiliates' activity on the extent of spillovers.

Similarly, the extent of forward linkages with exported-oriented affiliates may be limited by the nature of their activity. Moreover, the inputs produced by home market-oriented affiliates may be more adapted to local conditions and thus have a higher impact on the local final-good producers. We thus expect forward linkages with home market-oriented affiliates to be have a higher impact on the productivity of domestic firms than forward linkages with exported-oriented affiliates.

III. Data description and methodology

A. Data description

This study is based on a data set taken from the ESEE survey, the annual survey conducted by the Spanish Ministry of Science and Technology and the Fundación SEPI. The survey concerns Spanish manufacturing enterprises with more than 10 employees. The survey is exhaustive for large firms, defined as firms with more than 200 employees. The sample of small and medium firms covered by the survey has been chosen randomly. The data set resulting from the survey covers approximately 40% of total employment in the manufacturing sectors included in the sample. It is an unbalanced panel that covers the period 1990-2000 with a number of firms per year varying from 2198 firms in 1990 to 3431 in 2000.

The annual survey is based on a questionnaire of approximately 100 questions. It is mainly interested in the strategies of the enterprises, especially the instruments of competition in the short and long term. It provides data on the property structure of the enterprise, output, the capital stock, the number of employees, investment,

research and development (R&D) activity and international trade activity. The variables are deflated using sectoral price indexes.

The sectoral classification of the enterprises is at the three digits level of the CNAE-93, which is a derived version of the European NACE-REV1 classification. It results in twenty manufacturing sectors.

Table 1 presents descriptive statistics of the main variables used in the study separately for domestic and foreign firms. The figures in Table 1 show that, on average, foreign affiliates are larger, more productive and more intensive in human capital than domestic firms.

Table 1. Descriptive statistics for the main variables

Variables	Obs	Mean	Std Deviation	Min	Max
Sample of domestic firms					
Output	15013	2941990	1.02e+07	1541.208	3.07e+08
Capital	15013	2080895	1.07e+07	1.11	4.04e+08
Investment	15013	144513	677773.4	0	2.81e+07
Labor	15013	169.0491	527.2269	10	14390
TFP	15013	4.710901	.3721671	1.990452	9.360614
Human capital	15013	.2754117	.1825882	0	1
Sample of foreign affiliates					
Output	4166	2.06e+07	6.37e+07	53889.87	8.42e+08
Capital	4166	1.12e+07	3.20e+07	1727.481	4.38e+08
Investment	4166	942406.2	3988534	0	1.37e+08
Labor	4166	666.9959	1506.321	10	25363
TFP	4166	5.030799	.316829	3.57686	8.348433
Human capital	4166	.3932789	.2027251	0	1

We mentioned earlier that the study of technology transfer is more interesting in the case of developing countries. The Spanish economy is not a developing one; on the contrary, it is the eighth economy in the world in terms of GDP.[1] However, the study of technology transfer through FDI in the case of Spain presents several interesting aspects.

First of all, Spain is considered as a less developed member of the European

[1] Source: the Spanish Ministry of Economy.

Union. Second, the inflows of FDI have increased significantly since Spain joined the European Union and began applying macroeconomic stability programs. For example, for the period 1995-2000, Spain is ranked sixth among the members of the European Union in terms of inward FDI and third in terms of the number of foreign affiliates.

In Spain, FDI is mostly directed to the service sector (77% of FDI inflows between 1997 and 2000); the rest (22.5%) goes to the industrial sector and more specifically to the chemical, pharmaceutical, automobile, electronics and the food and beverage sub-sectors.[2]

Table 2. Foreign presence in manufacturing at the sectoral level by mode of entry

	1990		2000	
	Fully-owned	Partially-owned	Fully-owned	Partially-owned
Production of meat	.057841	.0107357	.044375	.041706
Food and tobacco	.246296	.137941	.262483	.0199041
Beverages	.151263	.198052	.028729	.074829
Textile	.081188	.087189	.091272	.074829
Leather	0	.054314	0	.090182
Wood	.047634	.003144	.011176	.088064
Paper	.102108	.139719	.553056	.078985
Publishing and printing	.061907	.01905	.144093	.072053
Chemicals	.333441	.139719	.553056	.078985
Rubber and plastic products	.488636	.115386	.681454	.02891
Mineral (non metallic) products	.183575	.101523	.161107	.139906
Manufacture of metal	.045329	.065809	.156485	.0195687
Fabricated metal products	.07525	.075071	.238171	.052621
Machinery and equipment	.244159	.196988	.319127	.081083
Office machinery, etc	.497372	.179587	.274285	.050152
Electrical machinery	.125101	.386738	.647241	.085817
Motor vehicles	.217153	.514385	.834171	.009722
Other transport equipment	.00787	.074244	.36258	.006295
Furniture	.035206	.035206	.272698	0
Other manufacturing industries	.126264	.073656	.280111	.126022

[2] Source: the Spanish Ministry of Economy.

Table 3. Foreign presence in manufacturing at the sectoral level by nature of activity

	1990		2000	
	Export-oriented	Home-oriented	Export-oriented	Home-oriented
Production of meat	.003063	.0162136	.012241	.073839
Food and tobacco	.004631	.379606	.006064	.45546
Beverages	.000637	.348678	.001296	.289692
Textile	.0205	.147876	.09571	.070392
Leather	.0543114	0	.090182	0
Wood	0	.050778	.018839	.080401
Paper	.032383	.199903	.188143	.282713
Publishing and printing	0	.080957	.020803	.195343
Chemicals	.026885	.446275	.089228	.542813
Rubber and plastic products	.021818	.582204	.50143	.208928
Mineral (non metallic) products	.025815	.259283	.055969	.245044
Manufacture of metal	.046454	.064683	.07186	.280312
Fabricated metal products	.023529	.126791	.164698	.126094
Machinery and equipment	.040649	.400497	.210112	.190097
Office machinery, etc	.078249	.59871	.2435	.080937
Electrical machinery	.144939	.524409	.208648	.524409
Motor vehicles	.032747	.698791	.71775	.126114
Other transport equipment	0	.082113	.330013	.038862
Furniture	0	.070142	0	.272698
Other manufacturing industries	.041353	.158566	.189018	.217115

The sectoral distribution of FDI in our sample reflects the general trend of FDI in the Spanish industrial sectors, with 14.5% of foreign affiliates operating in food and beverages, 12.8% in automobiles, 8.3% in electronics and 8.1% in chemicals.[3]

B. Methodology

To examine whether backward linkages with foreign affiliates affect the productivity of domestic suppliers, we follow the earlier literature and estimate the following equation:

[3] Tables 2 and 3 present the foreign presence in each sector for the years 1990 and 2000 by nature of activity and by mode of entry.

$$\ln Y_{it} = \alpha + \beta_1 \ln L_{it} + \beta_2 \ln K_{it} + \beta_3 \ln M_{it} + \beta_4 intraFDI_{jt} + \beta_5 backlink_{jt} + \beta_6 fwdlink_{jt} + d_i + d_t + e_{ijt}. \quad (1)$$

Indices *i*, *j* and *t* represent respectively firms, sectors, and time. Y_{it} represents real output of firm *i* at time *t* and it is defined as the value of sales adjusted for changes in stock of final goods. L_{it} is employment and it is measured by the number of employees. K_{it} is the stock of capital, which is equal to the value of fixed assets. M_{it} stands for the use of intermediates and it is equal to the purchased value of intermediates adjusted for changes in stock. d_i and d_t are firm and time fixed effects respectively.

The variable $intraFDI_{jt}$ is sector-specific and represents foreign presence in sector *j* at time *t*, defined as foreign equity participation averaged over all firms in the sector and weighted by each firm's share in the total employment of the sector. We consider foreign affiliates as firms with 10% or more of foreign participation in their capital.[4] The variable for_{it} stands for foreign participation in the capital of firm *i* at time *t*:

$$intraFDI_{jt} = \left(\sum_{i \in j} for_{it} * L_{it} \right) / \sum_{i \in j} L_{it} \quad (2)$$

The variable $intraFDI_{jt}$ captures the effect of foreign affiliates on their local competitors. A positive coefficient on this variable reflects the existence of technology spillovers diffused through demonstration effects, labor turnover or competition.

The variable $backlink_{jt}$ is sector specific and represents the extent of backward linkages between local suppliers and foreign affiliates. A positive coefficient on this variable signifies the presence of technology transfer between foreign affiliates and their suppliers:

$$backlink_{jt} = \sum_k \alpha_{jk} * intraFDI_{kt}. \quad (3)$$

α_{jk} is equal to the proportion of sector *j* output that is supplied to sector *k*. The proportions are taken from the input-output matrix at the three digit level of the NACE. We only have input-output matrices for the period 1995-1998. Values of α_{jk}

[4] The 10% cut-off is consistent with the OECD and the IMF definitions.

for the years 1990-1994 are from the 1995 input-output matrix and those for the years 1999-2000 are from the 1998 matrix. The calculation of the α_{jk} proportion considers only the inputs supplied locally.[5]

The variable $fwdlink_{jt}$ is sector specific variable. It measures the extent of technology contained in intermediate products and transferred from suppliers to final good producers through forward linkages:

$$fwdlink_{jt} = \sum_{k} \beta_{jk} * intraFDI_{kt} \quad (4)$$

β_{jk} represents the share of the total inputs of sector *j* that is supplied by sector *k*. The β_{jk} proportions are derived from the input-output matrices. A positive coefficient on this variable is evidence on technology spillovers through forward linkages.

We include in the vertical linkages variable the linkages within a sector, e.g., the case where *k=j*. In fact, because of the level of aggregation of the data an important proportion of the products is supplied within sectors. Thus, if we exclude inputs supplied within a sector the effect of the intra-sectoral linkages will be captured by the *intraFDI* variable and the coefficient on this variable will be biased.

A positive effect of vertical linkages on TFP may drive from the exchange of technology and know-how between final-good producers and their suppliers but can also reflect the industrial dynamism generated by these linkages. If the latter hypothesis holds the positive coefficient on the vertical linkage variables will be related to the amount of linkages and not to the relation with foreign affiliates.

To verify if vertical linkages are a channel of technology transfer we introduce the total backward linkages of a sector as an explanatory variable, *totallink*, which measures the global amount of backward linkages of a sector with both kinds of firms (domestic and foreign) in upstream sectors. Thus $totallink_{jt} = \sum_{k} \alpha_{jk} * Y_{kt}$, where Y_{kt} stands for output of industry *k* at time *t*. If the positive effect of backward and forward linkages reflects industrial dynamism, we expect this to be captured by *totallink*.

To examine the effect of the technology gap on technology transfer we have

[5] Imported intermediate inputs are excluded.

defined a technology gap variable for each firm as the difference between its total factor productivity and that of the average foreign firm in the same sector:

$$tgap_{ijt} = AverageTFP^{f}_{jt} - TFP^{d}_{ijt} \quad . \tag{5}$$

TFP^{d}_{ijt} is the total factor productivity of firm i in sector j at time t and $AverageTFP^{f}_{jt}$ is the mean of total factor productivity of foreign affiliates in sector j at time t.

Since the $tgap_{ijt}$ variable is calculated using the total factor productivity variable it may suffer from an endogeneity problem. We tested the endogeneity of this variable using an instrumental variables methodology, also known as two stage least squares. As instruments for $tgap_{ijt}$ we used the difference in capital intensity and human capital intensity between each firm and the average foreign firm in the same sector of activity. The Hansen-Sargan test of overidentifying restrictions confirmed the validity of the instruments and the "difference-in-Sargan" test of the orthogonality conditions confirms the exogeneity of the instruments. Finally the Durbin-Wu-Hausman test for endogeneity validated the exogeneity of the $tgap_{ijt}$ variable.

We defined a positive gap dummy that take the value one when $tgap_{ijt}$ is positive and zero otherwise. This dummy allows the isolation of domestic firms with low absorptive capacity. We interact the positive gap dummy with the measures of intra-sector and inter-sector technology transfer and expect it to have a negative effect.

To verify if the ownership structure of foreign affiliates affects their relation with their local firms, we have created two measures of foreign presence. The first one, for foreign affiliates with 100% foreign participation in their capital, and the second, for the remaining foreign affiliates. For each of the vertical linkages variables we created two measures, one for the linkages toward fully-owned affiliates, *full*, and the one for linkages toward partially-owned ones, *partial*. For the former, we replaced the measure of *intraFDI* in equations (3) and (4) by the measure of fully-owned affiliates' presence in sector j at time t and for the latter we replace it with a measure of the presence of partially-owned affiliates.

To explore the effect of the activity of foreign affiliates we have created a measure of vertical linkages with export-oriented affiliates, *export*, and a measure

of linkages with home market-oriented affiliates, *home*. These measures are calculated analogously to the backward and forward linkages variables. For the former we replaced the variable *intraFDI* with a measure of the presence of export-oriented affiliates in sector *j* at time *t*. For the latter we replaced it with a measure of the presence of home market-oriented affiliates. We have followed Javorcik (2004) and defined export-oriented affiliates as the ones that export more than half of their output.

C. The semi-parametric estimation

When estimating productivity, we face a simultaneity problem. This problem arises because productivity shocks are unobservable for the econometrician but are known to the firms when they choose their inputs (Marschak and Andrews 1944). The firms' knowledge of their productivity makes it more appropriate to consider inputs as endogenous variables (Griliches and Mairesse 1995).

The estimation of productivity by ordinary least squares (OLS) considers labor, capital and other inputs as exogenous variables and may lead to a biased estimation of the coefficients. The semiparametric estimation, suggested by Olley and Pakes (1996), is based on a dynamic model of firm behavior which allows avoiding the simultaneity problem. More precisely, the model assumes that investment is strictly increasing in productivity shocks and thus uses investment as a proxy for these shocks (Pakes 1994).

The model assumes that some inputs, like labor and intermediates, will adjust immediately to the productivity shocks while others, especially capital, will need a certain lag of time to adjust. Markets are supposed to be perfectly competitive.

The estimation procedure is in two stages.[6] In the first stage, we estimate the coefficient on the variable inputs (labor and materials) and in the second stage we estimate the coefficient on fixed factors (capital) conditional on the prior period's shock.

Given a production function of the following form:

[6] The original Olley and Pakes methodology consists of three stages. In the second stage they estimate a survival probability in order to correct the sample selection bias. In our data we can not determine if a firm exits the sample because it has exited the market or because it has not responded to the survey. For this reason we eliminate the second stage of the estimation.

$$\ln Y_{it} = \alpha + \beta_L \ln L_{it} + \beta_K \ln K_{it} + \beta_M \ln M_{it} + \omega_{it} + \eta_{it}, \quad (6)$$

where ω_{it} represents productivity and η_{it} is either a measurement error or a shock to productivity. Labor and materials represent variable factors and their amounts are affected by the current level of productivity. Capital is a fixed factor and it is only affected by the distribution of productivity, conditional on information at time *t-1* and past values of ω.

Following Pakes (1994) and assuming that investment is strictly increasing in ω for each *K*:

$$\ln I_t = I_t(\omega_t, \ln K_t) \quad (7)$$

We can invert equation (7) and use investment as a proxy for productivity shocks:

$$\omega_t = h_t(\ln I_t, \ln K_t) \quad (8)$$

By substituting (8) in (6) we obtain:

$$\ln Y_{it} = \alpha + \beta_L \ln L_{it} + \beta_M \ln M_{it} + \phi_t(\ln K_{it}, \ln I_{it}) + \eta_{it}, \quad (9)$$

$$\phi_t(\ln K_{it}, \ln I_{it}) = \alpha + \beta_K \ln K_{it} + h_t(\ln I_t, \ln K_t a_t). \quad (10)$$

To estimate the partially linear model in (9), we regress output on labor, materials and a third order polynomial P_t, with a full set of interactions in capital, investment and the age of each firm represented by the variable *a*.[7] Since the error term η_{it} is not correlated with the variable inputs, the estimation of equation (9) gives unbiased coefficient for labor and materials.

To obtain an estimation of the coefficient on capital we consider the expectation of $\ln Y_{it+1} - \beta_L \ln L_{it+1} - \beta_M \ln M_{it+1}$, conditional on capital:

$$\mathrm{E}\,[\ln Y_{it+1} - \beta_L \ln L_{it+1} - \beta_M \ln M_{it+1} | \ln K_{it+1}] = \alpha + \beta_K \ln K_{it+1} + \mathrm{E}\,[\omega_{it+1} | \omega_{it}]. \quad (11)$$

[7] We included in our estimation time and industry fixed effects.

We assume that ω_{it+1} is serially correlated and thus we rewrite ω_{it+1} as a function of ω_{it} and we consider ξ_{t+1} as the innovation in ω_{it+1}; we thus can rewrite (11) as a function of capital and investment:

$$\ln Y_{it+1} - \beta_L \ln L_{it+1} - \beta_M \ln M_{it+1} = \beta_K \ln K_{it+1} + g(\phi_t - \beta_K \ln K_{it}) + \xi_{t+1} + \eta_{it+1}, \quad (12)$$

where g is a third order polynomial in P_t, and $(\phi_t - \beta_K K_{it})$. Since capital at time $t+1$ responds only to the lagged productivity shock ω_{it}, the error terms in equation (12) are mean independent of $\ln K_{it+1}$. Thus the estimation of equation (12), using non-linear least squares, will provide unbiased coefficient on capital.

After the estimation of TFP by the Olley and Pakes methodology we estimated the impact of the different measure of the vertical and horizontal presence of foreign affiliates on the productivity of domestic firms using a fixed effect panel model.

IV. Evidence on technology spillovers

A. Horizontal and vertical technology spillovers

Table 4 reports the results of the estimation of equation (1). All the results are from the subsample of domestic firms. As control variables we added the scale of the firm measured by the number of employees. We also added the Herfindhal index at the industry level as a proxy for the intensity of competition faced by each firm.

Table 4 shows that small firms seem to be more productive than large ones. The coefficient on the scale variable is negative and significant at the 1% level in all regressions. The concentration of activity at the industrial level has a positive but very small impact on the productivity of firms. The theoretical literature does not present a clear conclusion on the impact of competition on the productivity of firms. However, competition generally has a negative impact on the profitability of firms. Since in our estimation of the TFP we use the value of output and not the volume, the estimated TFP can also measure the markup of the firm.

Moreover the results show an absence of technology spillovers through horizontal channels such as demonstration effects and worker turnover. The

coefficient on the *intraFDI* variables is non significant except in the second and third regression when we include the vertical linkages variables.

As we expected, foreign presence in upstream and downstream sectors has a positive and significant impact on the productivity of domestic firms. This positive impact may drive from the diffusion of technology through backward and forward linkages and/or through the industrial dynamism and demand creation generated by foreign entry. To dissociate these two effects we include, in regression 4, a demand variable defined as the natural logarithm of the total backward linkages of a sector: *demand* = ln *totallink*.

The results in regression 4 indicate the absence of technology spillovers through vertical linkages. The positive coefficients on the backward and forward linkages variables seem to result from demand creation and not from vertical technology transfer. In fact, after the inclusion of the demand variable, the coefficients on these variables become non significant.

B. The importance of absorptive capacity

The absence of technology transfer from foreign affiliates to domestic firms is generally related to the technology gap between domestic firms and foreign ones. We assume that a certain level of absorptive capacity is needed for the domestic firms to assimilate the technology brought in by the foreign affiliates.

In regression 5 of Table 4 we interacted a dummy, *gap*, with our variables of interest to verify the impact of the technology gap on the extent of technology spillovers. The *gap* dummy takes the value one if the technology gap variable, defined in Section III, is positive, and zero otherwise.

The figures in regression 5 confirm the importance of the absorptive capacity of firms. After the control for the technology gap, and even in the presence of the demand variable, the coefficients on the backward and forward linkages variables become positive and significant. However, there is no significant evidence on the presence of horizontal technology spillovers. In other words, regression 5 indicates that the technology brought in by the foreign affiliates do diffuse through, and only through, backward and forward linkages, but only highly productive domestic firms benefit from this diffusion.

Table 4. Horizontal and vertical technology spillovers

TFP	(1)	(2)	(3)	(4)	(5)
Intercept	4.96 ***	4.92 ***	4.90 ***	3.45 ***	2.80 ***
	(0.03)	(0.04)	(0.04)	(0.28)	(0.26)
intraFDI	0.00	- 0.07 *	-0.09 *	- 0.04	0.05
	(0.04)	(0.04)	(0.04)	(0.04)	(0.05)
scale	- 0.09 ***	- 0.09 ***	- 0.09 ***	- 0.09 ***	- 0.07 ***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Herfindhal index	0.00 ***	0.00 ***	0.00 ***	0.00 ***	0.00 ***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
backlink		0.19 ***	0.16 ***	0.02	0.29 ***
		(0.06)	(0.07)	(0.07)	(0.07)
fwdlink			0.08 *	0.07	0.25 ***
			(0.05)	(0.05)	(0.05)
demand				0.07 ***	0.11 ***
				(0.01)	(0.01)
*gap*intraFDI*					- 0.32 ***
					(0.03)
*gap*backlink*					- 0.51 ***
					(0.03)
*gap*fwdlink*					- 0.29 ***
					(0.03)
Year dummies	Yes	Yes	Yes	Yes	Yes
N	15013	15013	15013	15013	15013
R^2	0.048	0.048	0.048	0.051	0.197

Note: *, ** and *** indicate coefficients significant at the 10%, 5% and 1% level.

C. The effectiveness of linkages with fully-owned affiliates

The results in Table 5 show that backward linkages with partially-owned affiliates have a negative and significant effect on the productivity of domestic firms, whereas backward linkages with fully-owned affiliates have a positive effect. This result does not mean that fully-owned affiliates have more linkages with domestic suppliers than partially-owned ones. In our estimation, we do not verify the effect of the

activity of foreign affiliates on the intensity of backward linkages; rather, we consider the effect on productivity of backward linkages while taking account of the presence of foreign affiliates. This result means that established linkages with fully-owned affiliates offer higher opportunities for technology transfer.

The negative effect of backward linkages with partially-owned affiliates may reflect that these firms benefit from their knowledge of the market to diversify their supply network and thus to impose low price on their suppliers.

Moreover, forward linkages with both fully and partially owned affiliates have a positive impact on the productivity of domestic firms.

D. The difference between export-oriented and home-oriented affiliates

Table 5 also presents the results of the analysis of the impact of the nature of activity of the foreign affiliates.

We find positive and significant coefficients on export-oriented backward linkages and insignificant coefficients on home-oriented ones. This result does not reject the hypothesis that home market-oriented affiliates are more likely to establish backward linkages with local suppliers. It means that established backward linkages with export oriented affiliates have a greater effect on the productivity of domestic firms than those established with home market-oriented affiliates.

This result confirms our hypothesis that export-oriented affiliates may have higher quality requirements than affiliates that serve the local market and thus will transmit newer technologies and know-how to their suppliers. This result is consistent with the conclusion of the UNCTAD report on "Enhancing the competitiveness of SMEs through linkages" that "investors focused on export-oriented industries created relatively few linkages, but those linkages were more competitive and sustainable".

Contrary to backward linkages, forward linkages with home-oriented affiliates are more effective for technology spillovers. Given the nature of their activity, export-oriented affiliates have a small probability of tieing forward linkages with domestic firms and to produce inputs tailored to the needs of the domestic economy.

We performed two robustness checks of our results. First, we estimated equation (1) with a fixed effect panel model and the results of all our regressions were robust. Second, we replaced our intra-FDI variable by a measure of the share of

foreign affiliates in output, and replaced this measure in the calculation of the backward and forward linkages variables, with results similar to those presented in the paper.

Table 5. Estimation of the effect mode and the nature of activity

TFP	(1)	(2)	(3)	(4)	(5)	(6)
Intercept	3.73 ***	3.47 ***	3.82 ***	3.80 ***	3.47 ***	4.09 ***
	(0.27)	(0.26)	(0.28)	(0.27)	(0.26)	(0.27)
intraFDI	-0.06	-0.07 *	-0.09 **	-0.03	-0.06	-0.08 *
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
scale	-0.09 ***	-0.09 ***	-0.09 ***	-0.09 ***	-0.09 ***	-0.09 ***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Herfindhal index	0.00 ***	0.00 ***	0.00 ***	0.00 ***	0.00 ***	0.00 ***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
demand	0.06 ***	0.07 ***	0.06 ***	0.06 ***	0.07 ***	0.04 ***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
backlink full	0.18 ***		0.16 **			
	(0.07)		(0.01)			
backlink partial	-0.11 **		-0.22 **			
	(0.06)		(0.06)			
fwdlink full		0.18 ***	0.06			
		(0.07)	(0.06)			
fwdlink partial		0.11 ***	0.22 ***			
		(0.04)	(0.05)			
backlink home				-0.07		-0.17 ***
				(0.05)		(0.06)
backlink export				0.26 ***		0.40 ***
				(0.07)		(0.07)
fwdlink home					0.15 ***	0.21 ***
					(0.03)	(0.04)
fwdlink export					0.10	-0.35 ***
					(0.07)	(0.08)
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
N	15013	15013	15013	15013	15013	15013
R^2	0.052	0.052	0.054	0.054	0.052	0.059

Note: *,** and *** indicate coefficients significant at the 10%, 5% and 1% level.

V. Conclusion

Whether or not foreign direct investment helps to upgrade the technological capacities of firms in host countries is an important question for policy makers. And even more important is: What are the most effective channels of technology transfer?

Our attempt to answer these questions has used a panel of Spanish manufacturing firms between 1990 and 2000. We have distinguished two mechanisms of diffusion of the technology brought in by foreign affiliates: a horizontal one, between foreign affiliates and domestic firms within the same sector, and a vertical one, between final good producers and their suppliers.

As a proxy for the horizontal presence of foreign affiliates we use the share of employment controlled by foreign affiliates, and for the backward and forward linkages with foreign affiliates we use the input-output matrix and associate the backward (forward) linkages between two sectors with the foreign presence in the downstream (upstream) sector.

We find that potential technology transfer between foreign affiliates and their local competitors is more than offset by the competition induced by the entry of foreign affiliates. Thus the net effect of the horizontal presence of foreign affiliates on the productivity of domestic firms is negative. An important finding of this study is that backward linkages with foreign affiliates sharply increase the productivity of domestic suppliers. However this result is affected by the extent of the technology gap between foreign affiliates and domestic firms.

The existence of technology transfer through backward linkages is also affected by the quality of those linkages. In fact, while home market-oriented affiliates and partially-owned affiliates may have more intense backward linkages with local suppliers, the established linkages with export-oriented affiliates and with fully-owned ones offer greater opportunities for technology transfer to the suppliers. Thus, host countries that aim to promote technology transfer to their domestic firms need to encourage the establishment of backward linkages between foreign investors and domestic suppliers, especially in the case of export-oriented affiliates and fully-owned ones.

We also find that forward linkages with foreign affiliates induce the productivity of the local final-good producers. There is no difference between fully-owned affiliates and partially-owned ones in regard to technology transfer through forward

linkages. However spillovers are limited to forward linkages with home-oriented affiliates.

Further research is necessary to provide a better understanding of the elements that affect the establishment of backward linkages with foreign affiliates and those that affect vertical technology transfers, and to draw policy lessons. For example, if host countries can enhance technology transfer through backward linkages by creating a network of competitive suppliers, if this can be achieved by subsidizing R&D activity and the formation of human capital, and if this can lead to a decrease in the technology gap and to an increase of the confidence of foreign investors in the capacities of domestic suppliers.

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