Technological Trajectories and FDI: Top Bananas and Underdogs

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Abstract: Previous empirical evidence searching for externalities from Foreign Direct investment in Portugal showed mixed results. Using a new database containing 5,045 Portuguese manufacturing firms grouped by technological trajectories, we investigate the occurrence and magnitude of externalities from FDI in 1995-2007. We find both positive and negative externalities in scale-intensive and supplier-dominated industries. The magnitude of externalities is higher in the current period than in lagged periods. Because positive externalities outweigh the negative externalities, on the whole a 1% increase in foreign presence (measured by turnover) increases the Total Factor Productivity of domestic firms by 0.42 percentage points. Thus, the Investment Promoting Agency should attract foreign projects in those technological groups.

Key words- Technological Trajectories, Multinational Corporations, Productivity

1. INTRODUCTION

The issue on whether FDI contributes to the increase of the Total Factor Productivity (TFP) in the manufacturing sector is of particular importance, since Portugal is a small open economy facing restrictions arising from the economic crisis that slowed down the productivity growth.[1]

We investigate the occurrence of externalities from FDI in the Portuguese manufacturing sector with data panel at firm-level. Data coming from the AMADEUS™ includes firms of all sizes to ensure that firms with different levels of (TFP) are evenly distributed in the sample.[2] Our time span is from 1995 to 2007 (13 years), allowing for the study of dynamic effects, which is crucial since, according to empirical literature, externalities from FDI need 2 years to occur.[3, 4]

In empirical grounds, the validity of results depends on the robustness of the estimation method for the TFP. OLS estimation of firm-level production functions introduces a simultaneity or endogeneity problem because productivity and input choices are likely to be correlated; while GMM and fixed effects estimators behave poorly. Thus, semi-parametric estimators (Olley and Pakes, 1996 or Wooldridge-Levinsohn and Petrin, 2009) are preferred. While the Olley and Pakes (1996) approach employs investment as a proxy for unobserved productivity; the Wooldridge-Levinsohn and Petrin (2009) procedure employs intermediate inputs. We chose this method to estimate the TFP as a residual of a growth-accounting equation, because intermediate inputs are always positive in our sample, and thus, it has the advantage of retaining a higher number of observations than the Olley and Pakes (1996) approach. In the second stage of our empirical strategy, we to evaluate the impact of FDI on the growth of TFP, estimated in the previous stage, using the system GMM estimator (Arellano and Bover, 1995; Blundel and Bond, 1998).

We contribute to the related literature in a number of ways. First, we estimate horizontal and vertical externalities for the two-digit NACE (revision 2) industries to ascertain in which industries externalities might occur. Second, we list the industries by technological trajectories, according to the adaptation of O'Mahony e Van Ark (2003) and Bogliacino and Pianta (2011) of Pavitt's taxonomy. Third, we employ lags of the measures of foreign presence on a large panel of manufacturing firms to assess the dynamic effects of FDI.

The paper is organized as follows. Section 2 reviews the empirical studies for the Portuguese manufacturing sector; Section 3 presents data sources and the variables, as well as methodology; Section 4 reports and discusses the results; and Section 5 concludes.

[1] Although the innovative density of services in Portugal is higher than that of manufacturing, in most countries it is below that of manufacturing firms (Tamura et al, 2005). Therefore, for the sake of comparing results with other international studies, we investigate the existence of externalities from FDI in the manufacturing sector.

[2] Amador (2011) in his analysis of the Portuguese manufacturing finds a high probability of larger firms (with higher turnover) being more productive.

[3] Dynamic effects are analysed through the inclusion of the *lagged dependent variables* on the *right* hand *side* of estimating equations.

[4] Haskel et al. (2007) and Sembenelli and Siotis (2005) report a period of around two years for FDI to be fully reflected in the productivity of domestic firms in the UK and Spain, respectively. Arnold and Javorcik (2005) and Keller and Yeaple (2009) find shorter lags of one year or less.

2. EVIDENCE FOR PORTUGAL

Panel studies, at firm level, include Farinha and Mata (1996), Proença et al. (2002) and Crespo et al. (2009, 2012). Farinha and Mata (1996) analyzed the 1986-1992 period while Proenca et al. (2002) focused their analysis between 1996 and 1998 and Crespo et al. (2009, 2012) analyzed the period 1996-2001. With the exception of Farinha and Mata (1996), that use a random effects model, all authors use the system GMM to estimate an equation where the dependent variable is the labour productivity, which depends on variables of foreign presence in level (whose proxy is the employment in foreign firms, except Proença et al. that use the capital stock). Data sources are Dun & Bradstreet and Quadros de Pessoal, except Farinha and Mata (1996) that use data from Banco de Portugal.[5]

The present study is the most comprehensive for Portugal, regarding time (1995-2007) and sample size (65,585 observations). In addition, until now, only Crespo et al. (2009, 2012) have investigated the existence of vertical spillovers for Portugal. Moreover, there are no studies for 2001-2007 and the results for 1996-2000 are controversial. Regarding horizontal externalities, while Crespo et al. (2012) find negative results for 1996-2001; Proença et al. (2002, 2006) find no significant results for 1996-1998; and Crespo et al. (2009) find negative results for 1996-2000. Finally, Crespo et al. (2012) find evidence of positive vertical externalities (via backward linkages) for 1996-2001, but only at regional level. One possible cause for these controversial results may be the underestimation of the externality effects due to econometric problems associated with traditional panel data estimation methods, as highlighted by Proença et al. (2006).[6]

Given the lack of consensus of these studies, analyse the existence of horizontal and vertical externalities from FDI for manufacturing firms in 1995-2007. The results will enable policymakers to identify the industries that benefit most from attracting foreign capital and to implement the relevant policies in order to leverage positive externality effects.

3. DATA AND EMPIRICAL APPROACH

Our data for the Portuguese manufacturing firms come from the AMADEUS database and covers the period 1995-2007. We list firms by technological groups. Firms in scale-intensive industries (NACE rev. 2 codes 10, 11, 12, 19, 22, 23, 24, 25, 29 and 30) are large and their main source of technology relies on production engineering of their suppliers and R&D; Firms in science based industries (NACE rev. 2 codes 20, 21, 26 and 27) are characterized by relative large size and produce roughly the same share of process and product innovations. The sources of process innovations are internal and external (from suppliers); In supplier-dominated industries (NACE rev. 2 codes 13, 14, 15, 16, 17, 18 and 31) firms are characterized by a relative small size, limited resources regarding engineering and internal R&D and rely on suppliers to innovate; finally, in specialized suppliers industries (NACE rev. 2 codes 28, 32 and 33), firms are relatively small and the consumers are sensitive to their performance.

The balanced panel data set includes 5,045 manufacturing firms of all sizes (4,685 domestic and 360 foreign) for the 13 years in a total of 65,585 observations. Our

[5] The Portuguese Central Bank.

[6] Proença et al. (2006) use system GMM with variables in first differences.

regression analysis, however, includes only 51,535 observations since the rest had to be dropped due to collinearity. Firms with foreign capital (of which 12 Greenfield projects in 9 industries) represent 7% of our sample with a mean share of foreign capital of 58%. The TFP growth is assumed to depend on three sets of variables; variables that measure the foreign presence; interaction terms; and control variables, that are described in Table 1.

Table 1. Variables and Expected Signs

Variable	Source	Description	Expected Sign
hor	Constructed	Horizontal externality measure = Total turnover of foreign firms / sectoral turnover	+
back	Constructed	Measure of externality via backward linkages $back_{jt} = \sum_{k \neq j} \delta_{jk} * hor_{kt}$, where the Input-Otput (IO) coefficient δ_{jk} was calculated using the IO tables from OECD	+
for	Constructed	Measure of externality via forward linkages $for_{jt} = \sum_{k \neq j} \lambda_{kj} * hor_{kt}$, where the Input-Otput (IO) coefficient λ_{kj} was calculated using the IO tables from OECD	+
hfd	Constructed	Herfindhal index indicates market concentration $H_{it} = \sum_{g \in J} \left(\frac{X_{gt}}{\sum_{g \in J} X_{gt}} \right)^2 *100$, where g is an index for the firms (domestic or foreign) belonging to sector J to which domestic firm i belongs. X represents the output of firm g, at time t.	n.d.
rd	AMADEUS	Net Intangible assets	+
mrdf	QP	Average net Intangible assets for foreign firms by	+
s	Constructed	Measure of scale = turnover / average turnover	+
tg	Constructed	Measure of technological gap = prod/prod for sectoral	n.d.
kl	Constructed	Capital intensity =capital / labour	+

Notes- All nominal variables are deflated by the PPI index. QP denotes Quadros do Pessoal.

Expected sign of variables

Foreign presence. Following Markusen and Venables (1999) we expect a positive coefficient for variables *hor, back* and *for*.

Concentration. If the impact of the variable *hfd* on the TFP growth is positive, it means that the market power can facilitate the access to the necessary resources for domestic firms to increase their productivity. Indeed, stronger industry concentration generates larger profits that can be re-invested, for example, in new technologies or in the production of more sophisticated products; however, if the sign is negative it implies that the monopolistic inefficiencies are causing a decrease in the rate of innovation (Sjöholm, 1999) and, thus, a loss of productivity. As a result, the expected sign of this variable is not predefined.

R&D. Kinoshita (2001) considers that R&D activities increase the capacity of domestic firms to imitate new technologies and uses it as a proxy for absorptive capacity (Cohen and Levinthal, 1989; Griffith et al, 2003). Thus, we expect positive sign for the coefficient of *rd*. Liu and Buck (2007) found evidence that foreign R&D activities had positive impacts on the innovation performance of domestic firms, if domestic firms possess the absorptive capacity to learn the foreign knowledge. Because innovations are a source of TFP growth, we expect a positive sign for the coefficient of *mrdf*.

Scale. In the presence of increasing returns to scale, i.e., if there is an industry-specific optimal scale, then TFP increases with scale (Baldwin, 1996; Schoors and Van Der Tol, 2002) and we expect a positive coefficient for *s*.

Technological gap. According to the catching-up hypothesis, if the value of *tg* is close to one, the gap is too small; which means that domestic and foreign firms possess similar levels of efficiency and, thus, the domestic firms are not prone to learn much from the MNCs. However, according to the technology-accumulation hypothesis, if the value of *tg* is close to zero, the gap is too large; which means that domestic firms do not possess the necessary "absorptive capacity" to incorporate the knowledge of foreign firms (Lapan and Bardhan, 1973; Wang and Blomstrom, 1992; Perez, 1997; Kinoshita, 2001). Thus, the expected coefficient of this variable is not predefined.

Capital intensity. Capital intensity represents a firm's commitment to modernization and upgrading of its productive capacity. In the long run, capital expenditures typically have a positive impact on firms' performance (Lee & Blevins, 1990; Lee and Xiao, 2011). The higher the capital intensity is, the higher the expected TFP (Buckley et al., 2010). Hence, we expect a positive coefficient for *kl*.

After estimating the level of TFP (see details in Appendix B), the TFP growth is regressed against a set of variables that measure the foreign presence, interaction terms and other explanatory variables, within a fixed effects dynamic model**,** including a time trend, as follows.

$$d\hat{tfp}_{ijt} = \beta_0 + \beta_1 \hat{tfp}_{ij(t-1)} + \beta_2 \sum_{m=0}^{2} f_{j(t-m)} + \beta_3 (f_{jt} * hfd_{ijt}) + \beta_4 (f_{jt} * rd_{ijt}) + \beta_5 (f_{jt} * mrdf_{jt}) + \beta_6 (f_{jt} * s_{ijt}) + \beta_7 (f_{jt} * kl_{ijt}) + \beta_8 (f_{jt} * tg_{ijt}) + \beta_9 hfd_{ijt} + \beta_{10} rd_{ijt} + \beta_{11} mrdf_{jt} + \beta_{12} ds_{ijt} + \beta_{13} tg_{ijt} + \beta_{14} kl_{ijt} + \gamma_t + \mu_{it} \quad (1)$$

Where the lowercases denote variables in logarithms and *f* is the measure of foreign presence (*hor, b1* and *f1*). We have tested three measures of foreign presence: turnover, capital and value added of foreign firms (i.e., firms with, at least, 10% of foreign capital). The joint analysis through normality tests and visual inspection with the *qnorm* command in Stata, as well as the fact that empirical evidence for developed countries shows that externalities are usually positive when turnover is used, led us to choose the turnover as the preferred measure.[7]

We also include year dummies γ_t that account for possible changes in the growth of TFP due to stochastic shocks at firm or sectoral level over time and an error term μ_{it}. If it is expected that the current level of the dependent variable (DV) is heavily determined by its past level, then we use a dynamic specification that includes a lagged dependent variable ($\hat{tfp}_{ijt-1}$). The inclusion of lagged DVs is necessary to avoid unreliable results due to an omitted variable bias and reduce the occurrence of autocorrelation arising from model misspecification. We include two lags of the variables that represent the foreign presence, since empirical studies indicate a period of two years for domestic firms to absorb the foreign knowledge and externalities to materialize. For example, Merlevede et al.(2014) find evidence that "the first two years after entry, domestic firms that supply minority foreign entrants enjoy a substantial contribution to productivity growth" (*op cit.* p.22). We use the Sys-GMM to estimate equation (1), which combines the equation in first differences with the equation in levels. Hence, we place the fixed effects only in the equation in levels. In this dynamic model, the lagged dependent variable ($\hat{tfp}_{ijt-1}$) may be correlated with the error term (μ_{it}) and the endogenous variables, causing the OLS estimator to be inconsistent and biased (Hsiao, 1986). The autocorrelation problem arises from the fact that the term $\hat{tfp}_{ijt-1}$ is correlated with the term $\mu_{i,t-1}$ in $d\mu_{it} = \mu_{i,t} - \mu_{i,t-1}$.

The independent variables are endogenous (*kl, tg, f, f*hfd*); predetermined (*s*) and exogenous (*hfd*, *rd*, *mrdf, f*mrdf, f*s and f*tg)*. However, any not strictly exogenous predetermined variable becomes potentially endogenous since it can be also be correlated with the error term $\mu_{i,t-1}$ (Roodman, 2009).[8] Arellano and Bond

[7] Robustness tests for other measures indicated different results.

[8] These are the variables in our final models for the three types of externalities, after performing robustness tests. The selection of the instruments was based on the relevance of the model and statistical significance of the variables so that it can support the Hansen test.

(1991) and Bond (2002) suggest the use of instrumental variables in equation (1) to deal with the autocorrelation and endogeneity issues. Considering equation (1), we use lags of the dependent variable in levels, lagged two or more periods, as valid instruments for periods t=3,…, T, as in Arellano and Bond (1991) and Bond (2002).

Regarding the explanatory variables, it is assumed that increases in capital intensity, technological sophistication, foreign presence, and the joint impact of foreign presence and market concentration are correlated with contemporaneous shocks in the TFP. On the other hand, it is likely that contemporaneous innovations may have an impact in future increases in the scale. Finally, increases in concentration, domestic and foreign R&D expenses, and the joint impacts of foreign presence and foreign R&D expenses, scale and technological gap are not correlated with contemporaneous innovations. Thus, to overcome the autocorrelation and endogeneity issues, the endogenous variables (*kl, tg*, *f, f*hfd*) are dealt with in a similar way as the dependent variable ($\hat{tfp}_{ijt}$); the predetermined variable (*s*) use its lagged values for two or more periods for t=1,…(T-2) as instruments; and exogenous variables (*hfd*, *rd*, *mrdf, f*mrdf, f*s and f*tg)* are used as their own valid instruments. Blundell and Bond (1998) proposed the use of the system-GMM estimator that combines a system of equations in differences and in levels as the best estimator to deal with endogeneity of the explanatory variables (including the lagged dependent variable) and firms' unobserved fixed effects. We prefer the system-GMM to the difference-GMM for two reasons. First, system-GMM generally produces more efficient and precise estimates by improving precision and reducing the finite sample bias (Baltagi, 2008); second, differencing variables within groups will remove any variable that is constant; which mean the loss of a number of observations.[9] All explanatory variables are instrumented with their lags, as discussed in Arellano and Bond (1988, 1991). We use the command *xtabond2* in software STATA 13.0 to implement the System GMM two-step estimator with the Windmeijer (2005) correction.[10] Industries of tobacco and petroleum (with codes 12 and 19 according to classification Nace Revision 2) were dropped due to insufficient number of observations.

Takii and Narkojo (2012) assume scale as predetermined and Karpaty and Lundberg (2004) assume R&D as exogenous, while Griffith et. al (2006) take firm level variables as endogenous and industry level variables as exogenous.

[9] Indeed, a potential problem of the difference-GMM estimator is that, under certain conditions, the variance of the estimates may increase asymptotically and create considerable bias if: (i) the dependent variable follows a random walk, which makes the first lag a poor instrument for its difference, (ii) the explanatory variables are persistent over time, which makes the lagged levels weak instruments for their differences, (iii) the time dimension of the sample is small (Alonso-Borrego and Arellano, 1996 and Blundell and Bond, 1998).

[10] The calculation of the efficient two-step GMM estimator uses a weight matrix based on initial consistent parameter estimates. In small samples, this may cause a severe downward bias in the estimated asymptotic standard errors. Indeed, when the moment conditions used are linear in the parameters, there is a difference between the finite sample and the usual asymptotic variance of the estimator. Applying Monte Carlo technique to the data panel approach, Windmeijer (2005) estimates this difference and obtains a corrected variance estimate that is approximate to the finite sample variance.

4. RESULTS

We test the presence of second-order autocorrelation in the error term and report the results of Hansen's J test of over-identifying restrictions.[11] Following Roodman (2009), we also report the number of instruments. We examined the sensitivity of system-GMM regression results to the number of lagged instruments and to alternative number of independent variables. However, in theses alternative specifications, Arellano-Bond [AR (2)] and Hansen tests rejected the null hypothesis and/or the coefficient of variables become non-significant**.** Tables 2 to 13 in Appendix A show that the results for AR (2) and Hansen's J test support the validity of the chosen model specification. In this analysis, we report only the significant results (p-values are listed in parenthesis, next to the coefficient values).

Externalities. In scale-intensive industries, in the current period, we find positive externalities in the TFP growth of domestic firms in downstream industries (0.00871, $p<0.001$) of the other transport equipment industry. However, the effect of FDI is negative in the TFP growth of domestic firms in the upstream industries (-0.0567, $p<0.001$) of the motor vehicles industry. With one lag period, we find positive externalities in the TFP growth of domestic firms in the same industry (0.000789, $p<0.05$) in rubber and plastics; and in downstream industries (0.000942, $p<0.01$) of other non-metallic minerals industry. However, we find negative externalities in the TFP growth of domestic firms in the upstream industries (-0.189, $p<0.001$) of the beverages industry. In supplier-dominated industries, we find negative horizontal externalities (-0.00285, $p<0.05$) with one-period lag in textiles; and positive horizontal externalities (0.00264, $p<0.05$) with a two-period lag in wearing apparel. We also find positive externalities (0.00824, $p<0.001$) via backward linkages in the wood industry, in the current period.
The sum of total externality effects for scale intensive industries (i.e., including horizontal and vertical externalities for the 3 time periods) is negative (-0.2353), which implies that 1% raise in foreign presence decreases the TFP of domestic firms by nearly 0.24 percentage points (p.p.). Because the combined externality effect is positive but small for supplier-dominated industries (0.00803); the overall effect is negative (-0.227229), that is to say that 1% raise in foreign presence decreases the TFP of domestic firms by nearly 0.23 p.p.

Influence of concentration on the impact of FDI on the TFP growth. In scale-intensive industries, concentration has a negative effect on the impact of FDI on the TFP growth of domestic firms in the same industry (-0.0121, $p <0.001$) of rubber and plastics industry. In specialized suppliers industries, concentration has a positive effect on the impact of FDI on the TFP growth of domestic firms in the same industry (2.240, 0.00847 and 0.00665, $p <0.001$) in machinery and equipment, other manufacturing and repair and installation of machinery and equipment; it has a positive impact (0.00843, $p<0.001$) in domestic firms in upstream industries of repair and installation of machinery and equipment industry; and a negative impact (-0.00825, $p<0.001$) in domestic firms in downstream industries of other

[11] In addition, the difference-in-Hansen test of exogeneity of instruments do not reject the null hypothesis that the instrument subset for level equations are orthogonal to the error (p-values 0.150, 0.426 and 0.253, respectively for horizontal externalities and externalities via backward and forward linkages). As a result, we cannot detect invalid instruments based on this test statistic.

manufacturing industry. In science-based industries, concentration has a negative effect on the impact of FDI on the TFP growth of domestic firms in the same industry (-0.00729, $p<0.001$) in chemicals; and a positive effect (0.00973, $p<0.001$) in pharmaceuticals. Concentration has a negative effect on the impact of FDI on the TFP growth of domestic firms in the upstream sectors (-0.00841 and -0.00889, $p<0.001$) of pharmaceuticals and computer and electronics industries, and a positive effect (0.00973, $p<0.001$) in domestic firms in the upstream industries of electrical equipment; we also find a negative effect (-0.00841, $p<0.001$) in domestic firms in downstream industries of the pharmaceuticals industry. In supplier dominated industries, the concentration has a positive effect (0.0120 and 0.00978, $p<0.001$) on the impact of FDI on the TFP growth of domestic firms in the same industry in leather and paper industries; and negative (-0.00809, $p<0.001$) in the printing industry. The concentration has a negative effect (-0.00867, $p<0.001$) on the impact of FDI on the TFP growth of domestic firms in the upstream industries of the printing industry. The concentration has a positive effect (0.0126, $p<0.001$) on the impact of FDI on the TFP growth of domestic firms in the downstream industries of the leather industry.

The sum of total externality effects via concentration is negative (-0.0121) for scale intensive industries; positive for specialized suppliers (2.2553); negative for science-based industries (-0.0051); and positive (0.01762) for supplier-dominated industries. This implies that the benefits from resource effects in specialized suppliers and supplier-dominated industries overweight the monopoly inefficiencies in scale-intensive e science-based industries. The overall effect is positive (2.26), that is to say that 1% raise in foreign presence increases the TFP of domestic firms by nearly 2.26 p.p.

Influence of the technological gap on the impact of FDI on the TFP growth. In scale-intensive industries, the technological gap has a negative effect on the impact of FDI on the TFP growth of domestic firms in the same industry in non-metallic minerals, basic metals, metal products and motor vehicles industries (-0.00842, -0.00845,-0.00691 and -0.00900, $p<0.001$). It also has a negative effect on domestic firms in upstream industries of the food, basic metals and metal products industries (respectively, -0.00860,-0.00819 and -0.00846, $p<0.001$); and a negative effect on domestic firms in downstream industries of food, basic metals and other transport equipment industries (-0.00861,-0.00819 and -0.00878, $p<0.001$). However, the technological gap has a positive effect on the impact of FDI on the TFP growth of domestic firms in upstream (0.187, $p<0.001$) and downstream industries (0.331, $p<0.001$) of beverage industries. In specialized suppliers industries, the technological gap has a negative effect on the impact of FDI on the TFP growth of domestic firms in the same industry (-0.0393, -0.00855 and -0.00846, $p<0.001$) in machinery and equipment, other manufacturing and repair and installation of machinery and equipment. In science-based industries, the technological gap has a negative effect on the impact of FDI the TFP growth of domestic firms in pharmaceuticals and computer and electronics (-0.00935 and -0.00923, $p<0.001$). In supplier dominated industries, the technological gap has a negative effect on the impact of FDI on the TFP growth of domestic firms in the same industry of firms producing wearing apparel, leather and paper (-0.0103, -0.0121 and -0.00972, $p<0.001$).

The sum of total externality effects via technological gap is positive (0.45163) for scale intensive industries; negative for specialized suppliers (-0.0563); negative for science-based industries (-0.0186); and negative (-0.0321) for supplier-dominated industries. The overall effect is positive (0.34), that is to say that 1% raise in foreign presence increases the TFP of domestic firms by nearly 0.34 p.p. This confirms technology-accumulation hypothesis, according to which the technological gap must not be too low, or domestic firms will not possess the necessary "absorptive capacity" to incorporate the knowledge of foreign firms.

Influence of scale on the impact of FDI on the TFP growth. In scale-intensive industries, the scale exerts a positive effect on the impact of FDI on the TFP growth of domestic firms in the same industry (0.0111, 0.0121, 0.00846 and 0.00906, $p<0.01$) of beverages, rubber and plastics, basic metals and motor vehicles industries; in upstream industries (0.00850, 0.00690, 0.00820, 0.00847and 0.0562, $p<0.001$) of food, beverages, basic metals, metal products and motor vehicles industries; as well as in downstream industries (0.00853, 0.00690, 0.00820 and 0.0562, $p<0.001$) of food, beverages, basic metals and motor vehicles industries. In specialized suppliers industries, scale influences positively the impact of FDI on the TFP growth of domestic firms in the same industry (0.0420 and 0.00184, $p<0.01$) of machinery and equipment and repair and installation of machinery and equipment; and in downstream industries (0.00816 and 0.00786, $p<0.001$) of the other manufacturing and repair and installation of machinery and equipment industries. In science-based industries, the scale has a positive effect on the impact of FDI the TFP growth of domestic firms in the same industry of chemicals and computer and electronics (0.00729 and 0.00924, $p<0.001$); and also in upstream (0.00841 and 0.00109 $p<0.001$) and downstream industries (0.00631 and 0.00887, $p<0.001$) of pharmaceuticals and computer and electronics industries. In supplier dominated industries, the scale has a positive effect (0.0105 and 0.00796, $p<0.001$) on the impact of FDI on the TFP growth of domestic firms in the same industry in wearing apparel and printing. The scale has a positive effect (0.0126 and 0.00867, $p<0.001$) on the impact of FDI on the TFP growth of domestic firms in the upstream industries of leather and printing industries.

The sum of total externality effects via scale is positive (0.14659) for scale intensive industries; positive for specialized suppliers (0.05986); positive for science-based industries (0.04121); and positive (0.03973) for supplier-dominated industries. The overall effect is positive (0.29), that is to say that 1% raise in foreign presence increases the TFP of domestic firms by nearly 0.29 p.p.

Influence of R&D activities of foreign firms (average stock of foreign knowledge) on the impact of FDI on the TFP growth. In scale-intensive industries, the stock of foreign knowledge has a positive effect on the impact of FDI on the TFP of domestic firms in the same industry (0.00689, $p<0.001$) of metal products. In specialized suppliers industries, the stock of foreign knowledge has a negative effect on the impact of FDI on the TFP growth of domestic firms in the same industry of machinery and equipment (-2.243, $p<0.001$).

The sum of total externality effects via stock of foreign knowledge is positive (0.00689) for scale intensive industries and negative for specialized suppliers (-2.243). This may point for an incapacity of entrepreneurs in specialized suppliers industries to absorb the foreign knowledge and thus the stock of foreign knowledge causes an overall decrease in the TFP of domestic firms by nearly 2.24 p.p.

5. CONCLUSION

We investigate the occurrence and magnitude of externalities from FDI in the Portuguese Manufacturing Firms, by technological groups, for 1995-2007. Our results show significant positive vertical externalities in scale-intensive (other transport equipment) and specialized supplier industries (wood products). With one period lag we find significant positive horizontal and vertical externalities in scale-intensive industries (rubber and plastics and non-mineral metals, respectively); and with two-period lag we find significant positive horizontal externalities in supplier-dominated industries (wearing apparel). However, we also find negative externalities in firms producing beverages, motor-vehicles and textiles. The magnitude of externalities is stronger in the current period, followed by externalities with one-period lag. Summing-up the (direct and indirect) externality effects, the foreign presence can contribute to the increase of the TFP in the manufacturing sector in nearly 0.42 percentage points. Although it's the magnitude of these externalities is low, the results suggest that the Portuguese *Investment Promotion Agency* (AICEP) should endeavour to promote FDI especially in scale intensive and supplier-dominated industries. This could be achieved, in the case of horizontal externalities, by providing incentives for R&D cooperation and supporting private sector training programmes. On the other hand, the government can contribute to the occurrence of vertical externalities from FDI by supporting partnerships with foreign firms. This can be attained by several ways: providing linkage information in seminars, exhibitions and missions; sponsoring fairs and conferences; organising meetings and visits to plants; promoting supplier associations; and providing advice on subcontracting deals. It has been shown in this study that industries are affected by foreign presence in different ways. Indeed, the technological groups more positively affected by foreign presence are scale intensive and supplier-dominated industries. Thus, an important contribution has been made by providing a more complete picture of the effects of FDI in Portugal. By-and-large, the fact that externalities from FDI are unevenly distributed across and within industries makes possible to understand the conflicting results of previous studies for Portugal.

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APPENDIX A

Table 2- Horizontal Externalities by Technological groups (scale intensive industries)

Industry	Food	Beverages	Rubber and Plastics	Non-metallic Minerals	Basic Metals	Metal Products	Motor Vehicles	Other Transport Equipment
tfp_{t-1}	-0.910*	-0.721***	-0.325*	-0.0218	-0.00186	0.0799	-0.0650	-0.0368
	(-2.05)	(-2.39)	(-2.51)	(-0.48)	(-0.05)	(0.18)	(-1.39)	(-0.07)
hor_t					-0.00000687			
					(-0.12)			
hor_{t-1}	-0.00068		0.000789*	-0.0000132	-0.00000344	-0.00236	0.0000351	0.000011
	(-0.82)		(2.03)	(-0.28)	(-0.04)	(-0.37)	(-0.15)	(-0.02)
hor_{t-2}	-0.000806		0.000351	-0.00000361	-0.00000292	-0.00198	-0.000259	-0.000439
	(-1.03)		(0.65)	(-0.09)	(-0.04)	(-0.67)	(-1.15)	(-0.68)
hor*hfd			-0.0121***	0.00700				-0.0114
			(-6.53)	(0.18)				(-1.92)
hor*tg	-0.0000568			-0.00842***	-0.00845***	-0.00691***	-0.00900***	
	(-0.24)			(-3.84)	(-9.31)	(-4.92)	(-10.90)	
hor*s		0.0111***	0.0121***	0.00143	0.00846***		0.00906***	0.0115
		(-2.92)	(-6.54)	(-0.04)	(8.86)		(-11.26)	(1.90)
hor*mrdf	0.000105	-0.0000304	-0.0000368	-0.0000119	-0.000000246	0.00689***	-0.0000545	
	(-0.42)	(-0.22)	(-0.75)	(-0.28)	(-0.05)	(-4.91)	(-1.24)	
tg	0.00326	-0.00831**	-0.0100***				0.000175	-0.0100
	(-0.46)	(-3.87)	(-6.45)				(-0.67)	(-0.45)
Year effects	yes	yes	yes	yes	yes	yes	yes	yes
cons	-0.0289***	0.444***	0.323***	-0.000773	0.00714	-0.0358	-0.270***	0.375***
	(-4.23)	(2.43)	(4.78)	(-0.82)	(-1.58)	(0.59)	(-4.70)	(-5.97)
N	3 470	1 050	300	1 690	2 080	520	1 630	780
AR(2)	0.333	0.291	0.835	0.699	0.962	0.329	0.125	0.953
Hansen	0.290	0.512	0.142	0.310	0.629	0.739	0.490	0.251
instruments	28	25	28	27	28	28	28	28
Wald	1.12e+09	6.64e+07	8.34e+08	1.91e+06	2.73e+08	3.15e+09	1.67e+09	3.77e+07

Notes- hor is the measure of horizontal externalities and b1 and f1 are measures of vertical externalities; hfd is concentration, mrdf is the R&D expenses of foreign firms; s is scale, kl is capital intensity and tg is the technological gap, cons is the constant. Lower cases denote variables in logs; t-1 refers to one-period lag, and t-2 refers to two-period lag. Missing values were omitted due to collinearity. Omitted industries failed to satisfy AR(2) and/or Hansen tests; z statistics in parentheses * p<0.05, ** p<0.01, *** p<0.001. Source: own calculations in Stata 13.0.

Table 3- Externalities via Backward Linkages by Technological groups (scale intensive industries)

Industry	Food	Beverages	Rubber and Plastics	Non-metallic Minerals	Basic Metals	Metal Products	Motor Vehicles	Other Transport Equipment
tfp_{t-1}	0.0251	-0.0157	0.306	-0.0337	-0.0463	-0.00499*	-2.005	-0.0754
	(-0.88)	(-1.13)	(-0.64)	(-0.17)	(-0.50)	(-2.24)	(-0.07)	(-0.28)
$b1_t$				-0.00171			-0.0567***	
				(-0.01)			(-4.62)	
$b1_{t-1}$	0.0000533	-0.189***	0.000885	0.000939	-0.0000293	-0.0000103	0.00594	-0.000662
	(-1.68)	(-5.08)	(-0.03)	(-0.51)	(-0.52)	(-0.70)	(-0.87)	(-0.59)
$b1_{t-2}$	0.0000657		-0.00146	-0.0000232	-0.0000455	-0.000000309	-0.00116	-0.000405
	(-1.27)		(-0.04)	(-0.09)	(-0.40)	(-0.05)	(-0.29)	(-0.41)
b1t*hfd	0.0000822		0.0101					
	(-0.76)		(-0.62)					
b1t*tg	-0.00860***	0.187***	-0.00967		-0.00819***	-0.00846***		
	(-8.41)	(6.84)	(-0.71)		(-6.47)	(-5.20)		
b1t*s	0.00850***	0.00690***		-0.00140	0.00820***	0.00847***	0.0562***	-0.114
	(-4.65)	(-8.9)		(-0.67)	(-6.73)	(-8.21)	(-4.69)	(-0.13)
b1t*mrdf	0.0000197			0.00313	-0.00000908	-0.0000108		0.113
	(-0.97)			(-0.01)	(-0.17)	(-0.74)		(-0.98)
tg		-0.193***		-0.00850***			-0.0565***	-0.00878***
		(-5.83)		(-4.19)			(-4.59)	(-7.59)
Year effects	yes	yes	yes	yes	yes	yes	yes	yes
cons	-0.607***	-0.170***	-0.303	0.271**	-0.00838***	0.000280***	-0.0339	-0.265*
	(-3.65)	(-61.0)	(-0.24)	(3.02)	(-8.69)	(-8.18)	(-0.04)	(-1.98)
N	3 470	1 050	300	1 690	2 080	520	1 630	780
AR(2)	0.150	0.485	0.125	0.359	0.164	0.290	0.625	0.843
Hansen	0.360	0.950	0.956	0.547	0.292	0.166	0.184	0.925
instruments	26	23	26	25	25	26	26	26
Wald	1.40e+10	6.84e+07	1.76e+09	2.58e+08	400912.46	1.72e+08	4.11e+07	2.94e+08

Table 4- Externalities via Forward Linkages by Technological groups (scale intensive industries)

Industry	Food	Beverages	Rubber and Plastics	Non-metallic Minerals	Basic Metals	Metal Products	Motor Vehicles	Other Transport Equipment
tfp_{t-1}	0.0289	-0.0157	0.258	-0.0341	-0.0463	-0.00498*	-2.015	-0.0773
	(-0.92)	(-1.13)	(-0.05)	(-0.19)	(-0.50)	(-2.24)	(-0.61)	(-0.17)
$f1_t$				-0.00202			0.0226	0.00871***
				(-0.01)			(0.01)	(4.01)
$f1_{t-1}$	0.0000578		0.000677	0.000942**	-0.0000293	-0.0000103	0.00591	-0.000673
	(-1.36)		(-0.04)	(-2.85)	(-0.52)	(-1.17)	(-0.99)	(-1.06)
$f1_{t-2}$	0.0000667		-0.00126	-0.0000239	-0.0000455	-0.000000307	-0.00114	-0.000412
	(-1.28)		(-0.03)	(-0.15)	(-0.40)	(-0.05)	(-0.45)	(-1.12)
f1t*hfd	0.0000699		0.07					
	(-0.64)		(-0.15)					
f1t*tg	-0.00861***	0.331***	-0.0695		-0.00819***			-0.00878***
	(-8.78)	(2.55)	(-0.15)		(-6.47)			(-2.29)
f1t*s	0.00853***	0.00690***		0.00204	0.00820***	0.000000534	0.0562***	
	(-6.07)	(-8.00)		(-0.01)	(-6.73)	(-0.78)	(-3.43)	
f1t*mrdf	0.0000189	0.000116		-0.0000281	-0.00000908	-0.00000101	-0.0794	0.0000429
	(-0.85)	(-1.71)		(-0.68)	(-0.17)	(-0.90)	(-0.05)	(-0.23)
kl	-0.0000588	-0.000307***	0.000211	-0.000640	-0.000119	-0.000146***	0.00240	-0.000108*
	(-0.55)	(-3.41)	(-0.06)	(-1.58)	(-1.40)	(17.86)	(0.82)	(-2.14)
tg	-0.337***	0.0599	-0.00850***		-0.00846***	-0.0564**		-0.337***
	(-4.99)	(-0.13)	(-7.38)		(-5.23)	(-3.20)		(-4.99)
Year effects	yes	yes	yes	yes	yes	yes	yes	yes
cons	-0.0199***	-0.194***	1.158	0.270**	-0.00838***	0.00253***	-0.330***	0.478***
	(-12.59)	(-7.03)	(1.72)	(-3.25)	(-8.64)	(9.39)	(-6.68)	(-9.85)
N	3 470	1 050	300	1 690	2 080	520	1 630	780
AR(2)	0.500	0.450	0.964	0.161	0.674	0.558	0.213	0.621
Hansen	0.350	0.320	0.292	0.456	0.476	0.985	0.967	0.390
instruments	26	23	26	25	25	26	26	26
Wald	1.44e+10	6.84e+07	7.23e+08	9.68e+08	400906.34	1.71e+08	3.75e+07	1.05e+09

Table 5-Horizontal Externalities by Technological groups (Specialized Suppliers industries)

Industry	Machinery&Equip.	O.Manufacturing	Repair & Install.
tfp_{t-1}	-0.291	-0.00925	0.0166
	(-1.72)	(-1.85)	(1.83)
hor_{t-1}	0.00203	-0.000139	-0.0000360
	(0.69)	(-1.23)	(-0.49)
hor_{t-2}	0.00170	-0.000139	0.0000840
	(0.75)	(-0.36)	(0.75)
hor*hfd	2.240***	0.00847***	0.00665***
	(9.04)	(8.28)	(3.99)
hor*tg	-0.0393***	-0.00855***	-0.00846***
	(-11.63)	(-6.12)	(-12.74)
hor*s	0.0420***		0.00184***
	(13.02)		(9.94)
hor*mrdf	-2.243***	0.0000768	-0.0000201
	(-9.05)	(1.23)	(-0.62)
Year effects	yes	yes	yes
cons	-0.272	0.0149***	-0.000183
	(-0.99)	(6.90)	(-0.50)
N	1630	1160	8360
AR(2)	0.937	0.476	0.147
Hansen	0.130	0.294	0.300
Instrum	28	28	27
Wald Chi2	4.76e+08	9.45e+08	5.26e+07

Table 6-Externalities via Backward Linkages, by Technological groups (Specialized Suppliers industries)

Industry	Machinery&Equip.	O.Manufacturing	Repair&Install.
tfp_{t-1}	0.136	-0.0198	-0.00298
	(0.04)	(-0.36)	(-1.07)
$b1_{t-1}$	0.0000216	-0.000199	-0.0000805
	(0.01)	(-0.71)	(-0.93)
$b1_{t-2}$	-0.000158	-0.000603	-0.000264
	(-0.01)	(-1.26)	(-0.69)
b1t*hfd	0.0550	-0.000531	0.00843***
	(0.07)	(-0.00)	(12.61)
b1t*s		0.000443	
		(0.08)	
b1t*mrdf	-0.0479	0.0000790	0.0000370
	(-0.06)	(1.43)	(0.82)
tg		-0.00951***	
		(-5.29)	
Year effects	yes	yes	yes
cons	1.980***	0.0546	-0.420***
	(11.93)	(0.33)	(-5.02)
N	1090	2890	1160
AR(2)	0.922	0.540	0.800
Hansen	0.238	0.153	0.391
Instrum	26	25	26
Wald Chi2	7.36e+08	4.06e+08	7.77e+08

Table 7- Externalities via Forward Linkages by Technological groups (Specialized Suppliers industries)

Industry	Machinery&Equip.	O.Manufacturing	Repair&Install.
tfp_{t-1}	0.137	-0.0197	-0.00293
	(0.02)	(-0.36)	(-0.96)
$f1_t$	-0.240		
	(-0.05)		
$f1_{t-1}$	0.0000209	-0.000200	-0.0000756
	(0.01)	(-0.71)	(-0.91)
$f1_{t-2}$	-0.000162	-0.000603	-0.000243
	(-0.08)	(-1.28)	(-0.66)
f1t*hfd	0.246	-0.00825***	0.000568
	(0.05)	(-10.99)	(0.56)
f1t*s		0.00816***	0.00786***
		(10.74)	(7.39)
f1t*mrdf	0.0000380	0.0000790	0.0000382
	(0.03)	(1.43)	(0.85)
kl	-0.000641	0.00131	-0.000137***
	(-0.01)	(1.01)	(-8.66)
tg		-0.00632***	
		(-5.25)	
Year effects	yes	yes	yes
cons	-4.003	0.829***	0.348***
	(-1.91)	(8.75)	(6.08)
N	1090	2890	1160
AR(2)	0.585	0.620	0.123
Hansen	0.621	0.165	0.385
Instrum	26	25	26
Wald Chi2	3.17e+07	4.05e+08	1.47e+09

Table 8-Horizontal Externalities by Technological groups (science based industries)

Industry	Chemicals	Pharmaceuticals	Computer and Electronics	Electrical Equipment
tfp_{t-1}	0.0806	0.149	-0.280	-0.560
	(1.33)	(0.55)	(-1.49)	(-0.49)
hor_{t-1}	-0.0000563	0.00132	-0.000282	-0.00101
	(-0.61)	(0.37)	(-0.42)	(-0.04)
hor_{t-2}	-0.000192	-0.00123	-0.0000774	0.000457
	(-1.61)	(-0.83)	(-0.33)	(0.06)
hor*hfd	-0.00729***	0.00973***		
	(-9.05)	(5.94)		
hor*tg		-0.00935***	-0.00923***	-0.215
		(-7.49)	(-10.28)	(-0.42)
hor*s	0.00729***		0.00924***	0.215
	(9.14)		(10.27)	(0.42)
hor*mrdf	-0.00000389	-0.0000423	-0.00000494	-0.0000403
	(-0.17)	(-0.35)	(-0.24)	(-0.04)
tg	-0.00708***		0.0000463	0.209
	(-7.94)		(0.13)	(0.41)
Year effects	yes	yes	yes	yes
cons	0.0251***	-0.265***	-0.0347	0.217
	(10.62)	(-4.16)	(-0.21)	(1.27)
N	750	300	600	1090
AR(2)	0.345	0.503	0.890	0.862
Hansen	0.510	0.521	0.093	0.672
instruments	27	28	28	28
Wald	1.99e+09	2.01e+09	3.04e+09	4.00e+09

Table 9-Externalities via Backward Linkages by Technological groups (science based industries)

Industry	Pharmaceuticals	Computer and Electronics	Electrical Equipment
tfp_{t-1}	-0.0285	0.0139	-0.215***
	(-1.67)	(0.11)	(-6.46)
$b1_{t-1}$	-0.0000816	-0.00174	0.0000516
	(-1.23)	(-0.78)	(0.06)
$b1_{t-2}$	-0.0000975	-0.00146	0.000160
	(-1.56)	(-1.46)	(0.27)
b1t*hfd	-0.00841***	-0.00889***	0.00973***
	(-12.18)	(-7.32)	(3.83)
b1t*s	0.00631***	0.00109***	
	(12.43)	(7.36)	
b1t*mrdf	-0.00000770	-0.00000884	-0.00000948
	(-0.87)	(-0.51)	(-0.43)
tg	-0.00844***	-0.00874***	
	(-9.38)	(-6.03)	
Year effects	yes	yes	yes
cons	0.193***	0.0116	-0.0943***
	(4.72)	(0.09)	(-5.57)
N	750	600	1090
AR(2)	0.149	0.070	0.775
Hansen	0.560	0.597	0.810
instruments	25	26	26
Wald	2.23e+09	3.34e+09	2.76e+09

Table 10-Externalities via Forward Linkages by Technological groups (science based industries)

Industry	Pharmaceuticals	Computer and Electronics	Electrical Equipment
tfp_{t-1}	-0.0285	0.0143	-0.182
	(-1.50)	(0.18)	(-0.01)
$f1_{t-1}$	-0.0000816	-0.00178	0.0000708
	(-1.09)	(-0.65)	(0.01)
$f1_{t-2}$	-0.0000975	-0.00150	0.000166
	(-1.41)	(-0.69)	(0.03)
df1*hfd	-0.00841***	-0.000146	0.00971
	(-7.99)	(-0.13)	(0.15)
df1*s	0.00841***	0.00887***	
	(10.18)	(7.00)	
df1*mrdf	-0.00000770	-0.00000905	-0.00000895
	(-0.90)	(-0.52)	(-0.02)
kl	-0.000141**	-0.000122	-0.000121
	(-3.10)	(-0.42)	(-0.00)
tg	-0.00844***		
	(-5.35)		
Year effects	yes	yes	yes
_cons	0.0458***	0.0464	-0.123
	(5.45)	(0.45)	(-0.01)
N	300	600	1090
AR(2)	0.079	0.561	0.987
Hansen	0.966	0.497	0.170
instruments	25	26	26
Wald	2.16e+09	3.60e+09	5.25e+07

Table 11-Horizontal Externalities by Technological groups (Supplier Dominated industries)

Industry	Textiles	Wearing Apparel	Leather	Wood	Paper	Printing
tfp_{t-1}	-0.143	-0.596***	-0.460		-0.184*	-0.00597
	(-0.30)	(-7.79)	(-1.54)		(-2.35)	(-0.07)
hor_t						
hor_{t-1}	-0.00285*	0.00128	-0.000361	0.0000752	-0.000316	-0.00133
	(-1.97)	(1.61)	(-0.31)	(0.03)	(-0.22)	(-1.08)
hor_{t-2}	-0.00336	0.00264*	0.000301	0.00000312	0.000247	-0.00120
	(-1.58)	(2.23)	(0.56)	(0.00)	(0.19)	(-1.68)
hor*hfd	0.00554	-0.000201	0.0120***	-0.00885	0.00978***	-0.00809***
	(1.74)	(-0.22)	(3.81)	(-0.55)	(8.48)	(-8.45)
hor*tg	-0.00368	-0.0103***	-0.0121***		-0.00972***	
	(-0.26)	(-7.30)	(-3.73)		(-8.28)	
hor*s	-0.00181	0.0105***		0.00883		0.00796***
	(-0.13)	(5.43)		(0.55)		(8.44)
hor*mrdf	-0.0000208	0.0000508	0.0000722	0.00000734	-0.0000187	0.000123
	(-0.23)	(1.52)	(0.49)	(0.06)	(-0.65)	(1.06)
tg				-0.00881		-0.00977***
				(-0.53)		(-4.98)
Year effects	yes	yes	yes	yes	yes	yes
cons	-0.886*	-0.269***	0.0134**	-0.0823	-0.000807	-0.0867
	(-2.05)	(-5.76)	(3.06)	(-0.82)	(-1.05)	(-1.44)
N	2010	3810	2730	560	2160	2890
AR(2)	0.475	0.211	0.339	0.935	0.111	0.138
Hansen	0.325	0.402	0.705	0.410	0.355	0.592
instruments	28	28	28	28	28	27
Wald	3.11e+08	4.04e+09	1.23e+09	7.52e+08	3.30e+09	2.48e+08

Table 12-Externalities via Backward Linkages by Technological groups (Supplier Dominated industries)

Industry	Textiles	Wearing Apparel	Leather	Wood	Paper	Printing
tfp_{t-1}	-0.518*	-0.576***	-0.278		-0.107	0.207
	(-2.14)	(-6.13)	(-1.14)		(-0.53)	(0.39)
$b1_t$				0.00824***		
				(3.92)		
$b1_{t-1}$	-0.00136	0.000766	-0.000341	0.0000619	-0.000175	-0.000599
	(-1.58)	(0.11)	(-1.69)	(0.88)	(-0.08)	(-1.04)
$b1_{t-2}$	-0.00242	0.00196	0.0000424	0.0000310	0.000995	-0.000857
	(-1.40)	(0.45)	(0.06)	(0.71)	(0.48)	(-1.29)
b1t*hfd	-0.00953	0.0103			-0.0734	-0.00867***
	(-1.73)	(1.44)			(-0.16)	(-3.87)
b1t*s	0.00949		0.0126***			0.00867***
	(1.73)		(6.20)			(3.86)
b1t*mrdf	0.00000461	0.0000346	0.0000667	0.00000524	0.0734	0.0000298
	(0.07)	(0.28)	(1.11)	(1.15)	(0.16)	(0.96)
tg	-0.0131*				-0.00919***	-0.00865***
	(-2.30)				(-10.66)	(-7.12)
Year effects	yes	yes	yes	yes	yes	yes
cons	-0.538*	-0.228***	0.0111	0.285***	0.0250	0.410
	(-2.41)	(-3.71)	(1.33)	(6.55)	(0.23)	(1.34)
N	2010	3810	2730	560	2160	2890
AR(2)	0.150	0.604	0.677	0.154	0.650	0.504
Hansen	0.780	0.192	0.458	0.755	0.389	0.875
instruments	26	25	26	26	26	26
Wald	5.37e+08	1.18e+09	2.57e+09	2.26e+09	2.41e+09	6.79e+07

Table 13-Externalities via Forkward Linkages by Technological groups (Supplier Dominated industries)

Industry	Textiles	Wearing Apparel	Leather	Wood	Paper	Printing	Furniture
tfp_{t-1}	-0.487*	-0.577***	-0.287		-0.120	0.214	-0.487*
	(-2.03)	(-6.15)	(-1.08)		(-0.13)	(0.03)	(-2.03)
fl_t				-0.00233			
				(-0.33)			
fl_{t-1}	-0.00134	0.000780	-0.000350	0.0000571	-0.000136	-0.000594	-0.00134
	(-1.59)	(0.11)	(-1.73)	(0.82)	(-0.02)	(-0.03)	(-1.59)
fl_{t-2}	-0.00236	0.00197	0.0000274	0.0000140	0.000989	-0.000854	-0.00236
	(-1.40)	(0.45)	(0.03)	(0.27)	(0.11)	(-0.05)	(-1.40)
dfl*hfd	-0.00953	0.0103	0.0126***		0.339	-0.00868	-0.00953
	(-1.75)	(1.44)	(5.79)		(0.35)	(-0.31)	(-1.75)
dfl*s	0.00949			0.0105		0.00868	0.00949
	(1.75)			(0.90)		(0.32)	(1.75)
dfl*mrdf	0.00000373	0.0000344	0.0000665	-0.000118	-0.330	0.0000304	0.00000373
	(0.06)	(0.28)	(1.11)	(-0.01)	(-0.34)	(0.05)	(0.06)
kl	0.00403	-0.000410	0.000582**	-0.000288**	-0.00105	-0.000327	0.00403
	(1.83)	(-0.17)	(2.87)	(-3.10)	(-1.12)	(-0.04)	(1.83)
tg	-0.0132*					-0.00864	-0.0102*
	(-2.34)					(-0.88)	(-2.01)
Year effects	yes	yes	yes	yes	yes	yes	yes
cons	0.867**	0.492***	-0.117	-0.224***	-0.428	0.114	0.867**
	(2.91)	(3.95)	(-0.93)	(-9.26)	(-1.66)	(0.05)	(2.91)
N	2010	3810	2730	560	2160	2890	2010
AR(2)	0.380	0.882	0.874	0.467	0.269	0.885	0.380
Hansen	0.155	0.606	0.703	0.710	0.207	0.425	0.155
Instrum	26	25	26	26	26	26	26
Wald Chi2	5.41e+08	1.19e+09	2.61e+09	2.76e+09	4.03e+09	5.72e+07	5.41e+08

APPENDIX B

We estimate the level of TFP from the following equation

$$Y_{ijt} = A_{ijt} K_{ijt}^{\beta k} L_{ijt}^{\beta l} M_{ijt}^{\beta m} \qquad \text{(B1)}$$

where Y_{ijt} represents physical output of firm i in sector j and period t, K_{ijt}, L_{ijt} and M_{ijt} are the inputs of capital, labour and materials, respectively. A_{ijt} is the Hicksian neutral efficiency level (our concept of total factor productivity – TFP) of firm i in period t. For a given level of A, higher output levels demand higher inputs (K, L and M) levels.

We assume that $L = L^P + L^{NP}$, where where L^P stands for production worker (unskilled) labour and L^{NP} stands for non-production worker (skilled) labour. We proxy L^{NP} by the sectoral average of years of schooling since we do not possess information for individual firms.

Although we can observe Y_{ijt}, K_{ijt}, L_{ijt} and M_{ijt}, A_{ijt} is not observable and hence, needs to be estimated. The estimation of A_{ijt}, depends on several different components such as skills, knowledge and firm-level capabilities, including managerial and organisational competences. We assume that A_{ijt} or TFP in logs is given by:

$$\ln (A_{ijt}) = \beta_0 + \varepsilon_{ijt} \qquad \text{(B2)}$$

where β_0 measures the mean efficiency level across firms over time; ε_{ijt} is the time- and producer-specific deviation from that mean. Taking natural logs of (1) and inserting equation (2) we obtain a linear production function

$$y_{ijt} = \beta_0 + \beta_k k_{ijt} + \beta_{lP} l^P_{ijt} + \beta_{lNP} l^{NP}_{ijt} + \beta_m m_{ijt} + \varepsilon_{ijt} \qquad \text{(B3)}$$

where lower-cases refer to natural logarithms. The error term ε_{ijt} can be further decomposed into an observable (or at least predictable); and an unobservable i.i.d. component, representing unexpected deviations from the mean due to measurement error, unexpected delays or other external circumstances, i.e., $\varepsilon_{ijt} = v_{ij} + u^q_{ijt}$. Hence, equation (3) becomes

$$y_{ijt} = \beta_0 + \beta_k k_{ijt} + \beta_{lP} l^P_{ijt} + \beta_{lNP} l^{NP}_{ijt} + \beta_m m_{ijt} + v_{ijt} + u^q_{ijt} \qquad \text{(B4)}$$

Since the firm-level productivity is $tfp_{ijt} = \beta_0 + v_{ijt}$; and rearranging the terms of (2) we obtain[1]

$$tfp_{ijt} = y_{ijt} - (\beta_k k_{ijt} + \beta_{lP} l^P_{ijt} + \beta_{lNP} l^{NP}_{ijt} + \beta_m m_{ijt}) - u^q_{ijt} \qquad \text{(B5)}$$

And the estimated productivity is

$$\hat{tfp} = tfp_{ijt} + u^q_{ijt} \qquad \text{(B6)}$$

This empirical model allows us to address the simultaneity bias in traditional OLS regression techniques to estimate the TFP when unobserved productivity or TFP shocks, *i, j* and *t*, are correlated to the choice of inputs. Since the Olley-Pakes (1996) and Levinsohn-Petrin (LP) (2003) techniques, while controlling for the simultaneity bias, suffer from collinearity problems (Ackerberg et al., 2007), and later, Wooldridge (2009) suggested modifications to the original LP

[1] The productivity term is identified assuming that tfp_{ijt} is a state variable in the firm's decision problem (i.e. it is a determinant of both firm selection and input demand decisions), although u^q_{ijt} is either the measurement error or a non-predictable productivity shock (Olley and Pakes, 1996).

approach aiming to correct the collinearity issue. Defining the value added as $va_{ijt}=y_{ijt}-\beta_m m_{ijt}$, then it can be estimated through equation (4) as a residual

$$\hat{tfp}_{ijt} = va_{ijt} - (\hat{\varepsilon}^{v}_{jP}\ l^{P}_{ijt} + \hat{\varepsilon}^{v}_{jNP}\ l^{NP}_{ijt} + \hat{\varepsilon}^{v}_{jK}\ k_{ijt}) \qquad \text{(B7)}$$