

## Foreign Sourcing and Productivity: Evidence at the Firm Level

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### 1. INTRODUCTION

ACCORDING to models of industry dynamics proposed by, among others, Jovanovic (1982), Hopenhayn (1992) and Ericson and Pakes (1995), the path of entry, growth and failure that characterises microdata is driven to a large extent by firm productivity differences. The empirical side of this literature, which has been nicely reviewed by Caves (1998), Bartelsman and Doms (2000) and Foster et al. (2001), shows that productivity heterogeneity at the firm level is particularly relevant to explaining various aspects of industry dynamics.

A research area that has received special attention is the relationship between opening to foreign markets and firm productivity. Melitz (2003) integrates the basic ingredients of industry dynamics models of firm heterogeneity in an open economy context, which permits us to evaluate the impact of trade. In Melitz's model, the assumption of sunk entry costs is crucial to predicting self-selection of the most productive firms in foreign markets as well as the reallocation of resources within an industry following exposure to trade (see review articles on this literature by Helpman, 2006; Greenaway and Kneller, 2004, 2007; Bernard et al., 2007). Another strand of the literature interested in the relationship between trade and firm productivity combines the intra-industry heterogeneity setting of Melitz (2003) with a property right plus an incomplete contracting approach of the Grossman and Hart (1986) type. The model

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by Antràs and Helpman (2004) is an example of this literature, which provides a set of predictions concerning the relationship between imports and firm productivity. In this framework, companies make two endogenous organisational choices: the first one concerns an integration decision and the second one a location decision. One of the key results coming out of this model is that high-productivity firms source in foreign markets and low-productivity firms do not source abroad.

This paper explores the relationship between foreign sourcing and firm productivity. We address this empirically, taking a sample of Spanish manufacturing firms as a reference, and testing the prediction of Antràs and Helpman's (2004) model that high-productivity firms engage in arm's-length trade (firms sourcing abroad) while low-productivity firms do not source abroad (firms which do not source abroad).

The paper uses the methodology proposed by Delgado et al. (2002) and Fariñas and Ruano (2005), which permits the comparison of the entire distribution of firm productivity rather than just marginal moments, typically means. In particular, we are interested in comparing the cumulative distribution function of total factor productivity for the group of firms that source abroad and the group of firms which do not source abroad. The paper implements a testing procedure based on the concept of stochastic dominance for ranking differences between productivity distributions.

Our results indicate the existence of large and significant differences in productivity between firms that source abroad and firms which do not source abroad. These differences are consistent with the predictions of Antràs and Helpman's (2004) model. Previous papers that find evidence of a link between foreign sourcing and productivity include, among others, Girma and Görg (2004), Görg and Hanley (2005), Tomiura (2007), Görg et al. (2008) and Amiti and Wei (2009).

The paper is organised as follows. Section 2 summarises the theoretical framework that we take as a reference to organise the empirical work. Section 3 describes the testing procedure that was implemented. Section 4 presents the characteristics of the dataset and the measurement of both firm productivity and foreign sourcing. Section 5 presents the main empirical results. Section 6 addresses the relationship between foreign sourcing intensity and productivity. Finally, Section 7 provides the main conclusions.

## 2. THEORETICAL FRAMEWORK

This section briefly summarises the predictions of the Antràs and Helpman (2004) model that we take as a reference to organise our empirical work. The characteristics of the model are quite specific: a world of two countries, with a

factor of production and monopolistic competition. The model integrates two elements. The first one is firm heterogeneity as in Melitz (2003): each final-good producer of a given variety draws a productivity level  $\lambda$  from a known distribution  $M(\lambda)$ . The second element comes from the incomplete contract approach literature (Grossman and Helpman, 2002), which allows for addressing the choice between outsourcing and integration. By the term outsourcing, the model means the acquisition of an intermediate input or service from an unaffiliated supplier. Integration means the production of the intermediate input or service within the boundaries of the firm. Both choices, outsourcing and integration, can be carried out either in the home country of the firm or in the foreign market.

Two agents are engaged in production: final-good producers, who provide headquarter services, are located at home ( $D$ ), and component-producing firms that can be located either at home or in a foreign market ( $F$ ). Therefore, in this setting, firms make two endogenous organisational choices. The first one concerns the ownership structure of the firm, which can decide to integrate the activity within the boundaries of the firm – vertical integration ( $V$ ) – or, alternatively, to engage in some kind of outsourcing ( $O$ ). The second refers to the location decision: the production of components can be located at home or in the foreign market.

Production combines two specialised inputs: intermediate inputs and headquarter services. Sectors differ in their input intensity and firms differ in their productivity level. Fixed organisational costs of search, monitoring and communication are ranked as follows:

$$f_V^F > f_O^F > f_V^D > f_O^D,$$

which says that regardless of the ownership structure of the firms, fixed costs are higher in the foreign country. The fixed costs of integrating or outsourcing abroad,  $f_V^F, f_O^F$ , respectively, are higher than the costs of integrating or outsourcing at home,  $f_V^D, f_O^D$ , respectively. Furthermore, for a given location, fixed costs of a  $V$ -firm are higher than the fixed costs of an  $O$ -firm. With respect to this latter assumption, on one hand the integration of the production of components implies additional supervision costs, and on the other hand economies of scope may reduce the costs of integration relative to outsourcing. The model assumes that the first component is higher than the second and overall the ranking of fixed costs is as in the expression above.

The industry equilibrium predictions coming out of the model indicate that the location and integration decisions will depend on both the level of firm productivity ( $\lambda$ ) and the relative input intensity of the industry. The pattern of results can be summarised according to the following criteria:

$$\lambda_{O,V}^D < \lambda_{O,V}^F.$$

First, firms with productivity higher than  $\lambda_{O,V}^F$  engage in foreign sourcing. These firms either outsource in a foreign country or choose to integrate the production of components in a foreign country within the boundaries of the firm (intra-firm trade). Second, firms with productivity levels higher than  $\lambda_{O,V}^D$  but lower than  $\lambda_{O,V}^F$  do not engage in foreign sourcing. These firms either integrate or outsource at home.

The main prediction we want to test is whether firms that source abroad outperform firms which do not source abroad. In Antràs and Helpman's (2004) model, foreign outsourcing refers to the acquisition of intermediate inputs from a non-affiliated firm in foreign markets. When the acquisition is from an affiliated firm, the model refers to this activity as intra-firm trade. As we cannot distinguish whether the import of intermediate inputs comes from an affiliated or a non-affiliated firm, we restrict the analysis to the more general prediction that firms sourcing from abroad, including both firms that outsource and firms that insource within the boundaries of firms, dominate the productivity distribution of firms which do not source abroad. This prediction holds for both component-intensive and headquarter-intensive industries, although in the latter case foreign sourcing may also include intra-firm trade. The next section defines a procedure for testing this prediction.

### 3. TESTING PROCEDURE

The empirical implications that have to be tested can be performed comparing productivity distributions of different groups of firms. In this section, we describe a procedure for testing differences between distribution functions. The procedure is based on non-parametric techniques, which have been previously used by Delgado et al. (2002) and Fariñas and Ruano (2005). See both references for more details.

To perform the comparison between two productivity distributions, the procedure we use relies on the notion of first-order stochastic dominance. Let us define two cumulative distribution functions such that the first one corresponds to the productivity distribution of firms sourcing abroad, which we denote by  $F$ , and the second one corresponds to the group of firms which do not source abroad, denoted by  $G$ . According to the predictions of the Antràs and Helpman (2004) model, the productivity distribution of foreign sourcing firms,  $F$ , should dominate the distribution of firms which do not source abroad,  $G$ . Stochastic dominance of  $F$  relative to  $G$  requires two statistical conditions to be satisfied: first, both distributions are not identical, i.e. the null hypothesis  $H_0: F(z) - G(z) = 0$  can be rejected; second, the sign of the difference is as expected, i.e. the null

hypothesis  $H_0: F(z) - G(z) \leq 0$  cannot be rejected. These two-sided and one-sided tests can be performed respectively by the following Kolmogorov–Smirnov test statistics:

$$\delta_N = \sqrt{\frac{n.m}{n+m}} \sup_{z \in Z} |F_n(z) - G_m(z)|$$

$$\eta_N = \sqrt{\frac{n.m}{n+m}} \sup_{z \in Z} (F_n(z) - G_m(z)),$$

where  $n$  and  $m$  are, respectively, the size of the sample of firms corresponding to the distribution  $F$ , the group of firms that source abroad, and  $m$  is the size of the sample drawn from the distribution  $G$ . The limiting distributions of both test statistics are known under independence between the sample of firms drawn from distributions  $F$  and  $G$  (see Delgado et al., 2002).

To further illustrate the comparisons between different groups of firms, we have graphed the estimates of the distribution functions for these groups. In particular, we have computed the smooth, or perturbed, sample distribution function rather than the sample distribution function itself, which provides nice smooth distribution estimates. Since the purpose here is to produce graphical representations of the differences between two groups of firms, we represent these distributions for the whole population of firms. See the Appendix for details.

#### 4. DATA AND DESCRIPTIVE EVIDENCE ON FOREIGN SOURCING

The dataset we employ is a longitudinal survey of Spanish manufacturing firms that comes from the Encuesta sobre Estrategias Empresariales (ESEE). This is sponsored and collected by the Spanish Ministry of Industry. This database contains a longitudinal sample of firms from 1990 to 2002. The panel of firms contains 19,007 observations that correspond to an average number of 1,462 firms per year. A characteristic of the dataset is that firms participating in the survey were chosen according to a selective sampling scheme. The sample of firms includes almost all Spanish manufacturing firms with more than 200 employees (large firms) in 1990. In fact, the rate of participation of firms in this size category was 67.6 per cent of the population of large firms in 1990. Firms employing between 10 and 200 employees (small firms) were chosen according to a stratified random sampling procedure. A total of 3.9 per cent of the population of firms within this size category was randomly sampled in 1990. Given the procedure used to select firms participating in the survey, both samples of small and large firms can be considered samples that permit us to

estimate the distribution of any of the characteristics of the population of Spanish manufacturing firms with available information in the dataset.

The first variable of interest is firm productivity. This is defined by an index of total factor productivity for each firm over the period 1990–2002. The index follows the framework developed by Aw et al. (2001) and it is an extension of the multilateral total factor productivity index proposed by Caves et al. (1982). The index takes a hypothetical firm as a reference and measures productivity in each year relative to this reference firm. In particular, the index uses the average firm of the industry and the size group the firm belongs to as the reference point, and then chain-links the average firm for both size groups to preserve transitivity between firms of different size groups within the same industry. Reference firms are defined in terms of the industry and size group the firm belongs to in order to take advantage of the characteristics of the dataset.

Let each firm  $i$  produce a single output  $y$  using the set of inputs  $x$ ; then the expression of total factor productivity for firm  $i$ , at time  $t$ , in a given industry is:

$$\begin{aligned} \ln \lambda_{it} = & \ln y_{it} - \overline{\ln y}_\tau - \frac{1}{2} \sum_{r=1}^R (\overline{\varpi}_{it}^r + \overline{\varpi}_\tau^r) (\ln x_{it}^r - \overline{\ln x}_\tau^r) \\ & + \overline{\ln y}_\tau - \overline{\ln y} - \frac{1}{2} \sum_{r=1}^R (\overline{\varpi}_\tau^r + \overline{\varpi}^r) (\overline{\ln x}_\tau^r - \overline{\ln x}^r), \end{aligned} \quad (1)$$

where  $x_{it}^r$  is the quantity of input  $r$ , and  $\overline{\varpi}_{it}^r$  is the cost share of input  $r$ . Firms are classified in two size groups of small and large firms. A bar over a variable indicates the arithmetic mean of the variable. The average value of variables with index  $\tau$  refers to a given size group of firms; otherwise, the average refers to the entire sample of small and large firms. The details of the definition of output and inputs can be found in the Appendix.

The index measures the proportional difference of total factor productivity for firm  $i$  at time  $t$  relative to a given reference firm. The reference firm varies across industries and therefore, when observations of different industries are pooled, average productivity differences across industries are removed. Firms are classified in 20 manufacturing industries corresponding to the NACE classification at the two-digit level. To be more precise about the meaning of expression (1), the first line on the right-hand side compares the productivity of firm  $i$  with the productivity of an average firm of the same size group and industry as firm  $i$ . Therefore, comparisons between observations corresponding to the same size group are transitive. The second set of terms measures productivity differences between the reference firm for the size group of either small or large firms, and the average firm of the entire sample of small and large firms

in a given industry. This second set of terms preserves transitivity of firms across the two size groups of small and large firms.

The second variable of interest is foreign sourcing. To measure foreign sourcing, we follow the definition of Feenstra and Hanson (1996), who identify this term with the practice of domestic firms importing intermediate inputs. We measure foreign sourcing intensity as the ratio of imported intermediate inputs to total purchases of intermediate inputs, thus giving a measure of the importance of imported intermediates in the production process. Görg and Hanley (2005) use the same ratio as a measure of international outsourcing intensity for Irish electronics firms.

The estimates of foreign sourcing are based on information reported directly by manufacturing firms in the ESEE survey. Firms report the value of total imports as well as additional information on the value of total intermediate purchases, production and other characteristics. This set of information permits the estimation of the value of intermediate materials and service inputs imported from abroad. In the following paragraphs, we explain this estimation procedure briefly.

Firms directly report information on three different concepts. First, they report the value of their total imports. Second, firms report the percentage of capital goods that have been manufactured abroad and used by the firm, as well as the annual value of investment in capital goods. Multiplying both measures, we calculate the value of imports of capital goods. The third piece of information supplied by the firm is the value of imports of goods that are similar to those produced by the firm in the domestic market coming from affiliated companies or subcontracted abroad with unaffiliated companies.

Given the previous information, we estimate the value of imports of intermediate inputs as equal to the value of total imports minus the value of imports of capital goods and minus the value of imports of similar goods from affiliated companies or subcontracted abroad. Our definition of imports of intermediate inputs includes both raw materials and components (materials) and services inputs, but energy is excluded.

Considering that goods that are similar to those produced by the firm are imported and additionally processed in the domestic market by the firm that provides marketing, quality control services, etc., it may be argued that removing imports of similar goods from the estimation of intermediate import underestimates foreign sourcing. However, it is not completely clear whether the activity of importing similar goods falls within the definition of foreign sourcing or not. Therefore, we have decided to maintain the previous definition of foreign sourcing, excluding imports of similar goods, while at the same time checking that the results presented in Section 5 are also robust to the inclusion of similar imports in the definition of foreign sourcing.

Finally, we illustrate the breakdown produced by the application of the previous definitions with some numbers. A total of 23.7 per cent of total imports correspond to imports of capital investment goods, 7.6 per cent are imports of similar goods from affiliated companies, and 68.7 per cent are imports of intermediate inputs, foreign sourcing according to our definition.

Table 1 shows a large increase in the percentage of manufacturing firms directly importing intermediate inputs from abroad. Between 1990 and 2002, the proportion of manufacturing firms performing foreign sourcing increased from 43.6 per cent to 55.0 per cent. The magnitude and timing of this increase are similar to those observed for total imports and total exports. Therefore, in terms of the proportion of firms, foreign sourcing has expanded by a large amount during the period and this increase is similar to the change observed in the number of exporting firms.

The intensity of foreign sourcing has also increased over the period 1990–2002. Table 2 shows that the share of imported intermediate inputs in the total purchase of intermediate inputs increases from 19.9 per cent in 1990 to 22.3 per cent in 2002. Both measures refer to foreign sourcing by firms with positive imports of intermediate inputs. Therefore, foreign sourcing has expanded through two channels: first, the participation rate in foreign sourcing has increased over the period and, second, the intensity of foreign sourcing within this group of firms is also larger. This confirms that foreign sourcing has evolved at two margins. First, firms already performing foreign sourcing have

TABLE 1  
Firms and Foreign Trade: 1990–2002

<i>Year</i>	<i>Participation Rate in Foreign Sourcing (%)</i>	<i>Participation Rate in Imports (%)</i>	<i>Participation Rate in Exports (%)</i>
1990	43.6	51.8	50.3
1991	42.8	50.8	50.5
1992	45.2	52.6	51.8
1993	45.4	52.8	52.4
1994	49.6	56.3	55.1
1995	50.4	58.1	58.6
1996	50.7	58.4	58.7
1997	51.2	60.2	60.7
1998	53.8	62.1	63.5
1999	53.7	63.1	62.4
2000	54.7	63.9	64.3
2001	55.0	63.6	64.0
2002	55.0	64.4	63.4
Average 1990–2002	50.3	58.6	58.5

Sources: ESEE and own calculations.

TABLE 2  
Foreign Sourcing Intensity (Only firms sourcing abroad, weighted averages)

<i>Year</i>	<i>Imported Intermediate Inputs/Total Intermediate Inputs (%)</i>	<i>Imported Intermediate Inputs/Production (%)</i>	<i>Imported Intermediate Inputs/Total Imports (%)</i>
1990	19.9	13.2	74.5
1991	17.9	12.3	66.2
1992	19.7	13.8	74.2
1993	20.7	14.6	71.7
1994	21.0	15.0	67.0
1995	21.6	15.6	63.6
1996	25.1	17.9	72.8
1997	22.5	16.9	64.5
1998	29.2	22.3	83.6
1999	32.2	24.9	81.6
2000	30.2	23.8	80.3
2001	24.1	18.8	75.0
2002	22.3	16.6	78.1
1990–2002	25.3	18.9	75.4

Sources: ESEE and own calculations.

increased its intensity (intensive margin) and, second, it has increased through the channel of new firms engaging in foreign sourcing (extensive margin).

Table 2 shows two additional measures related to foreign sourcing. The first refers to the share of imported intermediate inputs over the value of production. Foreign sourcing intensity has increased over the period 1990–2002 at a greater rate than production: the share of imported intermediate inputs in production has increased 3.4 percentage points. Finally, it is worth noting that there has been a large increase in the share of imports of intermediate inputs in the total value of imports: from 74.5 per cent to 78.1 per cent.

Table 3 shows a strong positive relationship between foreign sourcing and the size of firms. Small firms with 200 or fewer employees perform foreign sourcing with a lower probability (36.6 per cent) than larger firms with more than 200 employees, where the rate of participation is 80.2 per cent. After

TABLE 3  
Foreign Sourcing and Firm Size

	<i>Participation Rate in Foreign Sourcing (%)</i>	<i>Foreign Sourcing Intensity (%)*</i> <i>(Only Firms Sourcing Abroad)</i>
Firms with ≤ 200 employees	36.6	18.0
Firms with > 200 employees	80.2	19.0

Note:

\* Weighted averages of the ratios of the firms sourcing abroad.

Sources: ESEE and own calculations.

conditioning on foreign sourcing, the difference in the intensity of foreign sourcing between small and large firms is not too large. Small firms source from abroad 18 per cent of the total purchase of intermediate inputs, and for large firms, the intensity is 19 per cent.

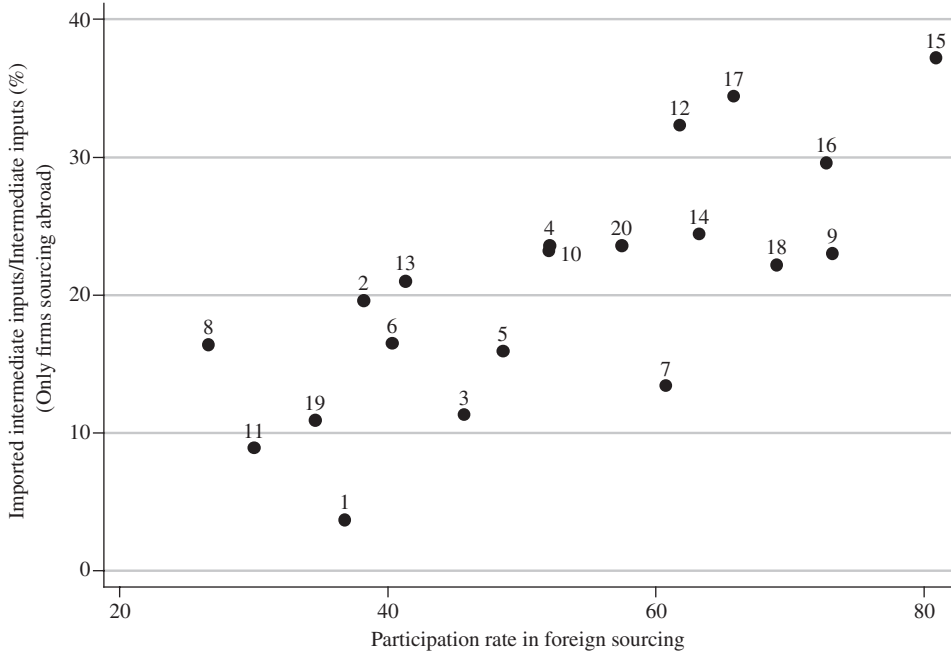
The previous estimates measure foreign sourcing at the firm level. Two recent papers offer estimates of foreign sourcing at the industry level for Spanish manufacturing. The first one, by Canals (2006), estimates a share of imported intermediate inputs in the total value of non-energy intermediate inputs that amounts to 27 per cent; the second one, by Díaz-Mora et al. (2007), estimates a share of imported intermediate inputs in the total value of production equal to 18 per cent. Consequently, our estimates, which are based on firm-level data, are very similar to the estimates reported at the industry level using the Feenstra and Hanson (1996) approach.

Foreign sourcing reported for the whole sample of manufacturing firms obscures the fact that particular industries exhibit a high degree of heterogeneity in the propensity to source abroad. This is illustrated in Figure 1, where the participation rate in foreign sourcing by industries is plotted against the intensity of foreign sourcing by industries. The set of industries that are near the upper right corner corresponds to those activities where the propensity to source abroad is higher. The list of industries includes: Office machinery, computers and precision instruments; Electrical machinery and communication equipment; Motor vehicles; Other transport equipment; and Chemicals and chemical products. As Feenstra and Hanson (1996) indicate, this set of industries with the highest propensity to source abroad shares the characteristic that their production processes can be separated into various stages. This characteristic favours the sourcing of different components across space.

## 5. EMPIRICAL RESULTS: FOREIGN SOURCING AND PRODUCTIVITY

In this section, we present the results on productivity differences between the group of firms sourcing abroad and the group which do not source abroad. The dataset we use to test for these differences corresponds to a sample of Spanish manufacturing firms over the period 1990–2002. Figure 2 illustrates the difference between the productivity distributions of firms sourcing abroad and firms which do not source abroad. These graphs show the kernel estimates of the cumulative distribution functions for both groups of firms for years 1990, 1994, 1998 and 2002, weighting the cumulative distribution functions of small and large firms (see the Appendix for details). The position of the productivity distribution of firms sourcing abroad is, in all years, to the right of the distribution of firms which do not source abroad. This position indicates

FIGURE 1  
Participation Rate in Foreign Sourcing vs Foreign Sourcing Intensity by Industry



Notes:

<sup>a</sup> Foreign sourcing intensity by industry is computed by the weighted averages of the individual ratios of the firms sourcing abroad.

<sup>b</sup> The list of industries is:

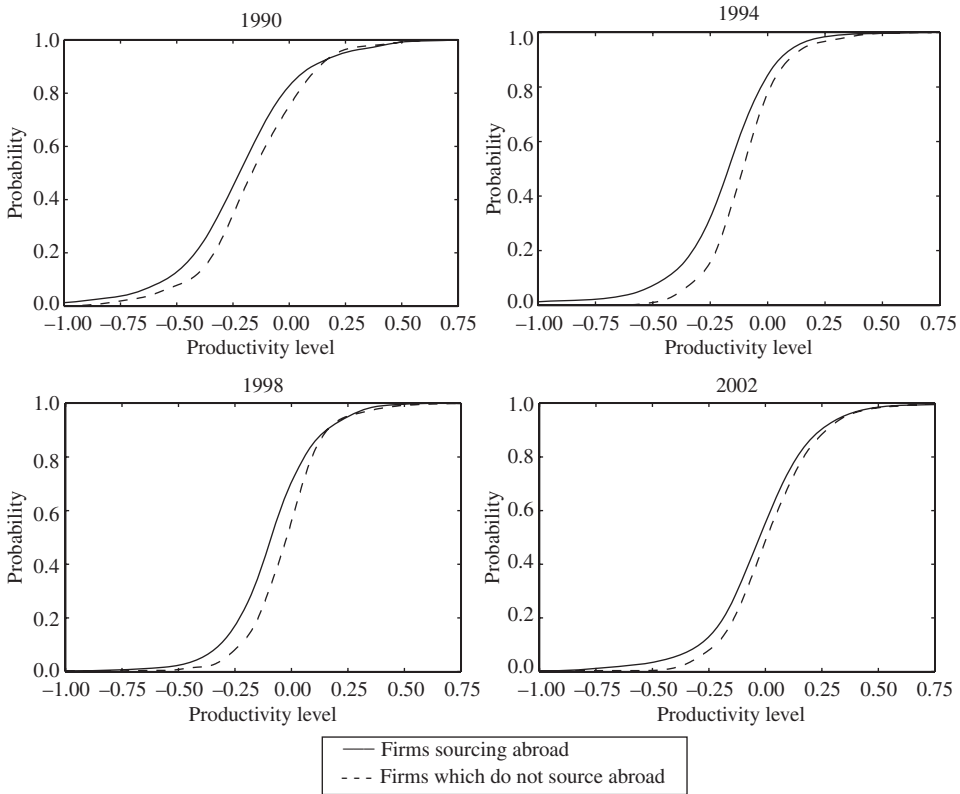
1. Meat and meat products. 2. Manufacture of food products. 3. Beverages. 4. Textiles and clothing. 5. Leather and footwear. 6. Products of wood, except furniture. 7. Paper products. 8. Publishing and printing. 9. Chemicals and chemical products. 10. Rubber and plastic products. 11. Non-metallic mineral products. 12. Basic metals. 13. Metal products. 14. Machinery and equipment. 15. Office machinery, computers and precision instruments. 16. Electrical machinery and communication equipment. 17. Motor vehicles. 18. Other transport equipment. 19. Manufacture of furniture. 20. Manufacturing n.e.c. and recycling.

that for any quartile of the distribution, firms sourcing abroad have higher productivity than firms which do not source abroad and therefore the productivity distribution of foreign sourcing firms stochastically dominates the distribution of firms which do not source abroad.

Given the assessed differences, we formally test whether productivity differences between firms that source abroad and firms which do not source abroad as depicted in Figure 2 are significant. One- and two-sided tests, as described in Section 3, are applied to compare the productivity of the two groups of firms.

Table 4 summarises the hypothesis test statistics for the whole set of firms. First, the productivity of firms that source abroad is higher than the productivity of firms which do not source abroad. Over the period, the average difference at

FIGURE 2  
 Productivity Differences between Firms Sourcing Abroad and Firms Which Do Not Source Abroad  
 (Smooth sample distribution function)



the median of the distribution is 7.5 per cent. At the first and the third quartiles, the differences are 8.6 per cent and 6.2 per cent, respectively. Second, the null hypothesis that the difference is as expected – higher productivity for foreign sourcing firms cannot be rejected at any reasonable significance level. Third, the null hypothesis of equality between both distributions can be rejected at the 0.01 per cent level for all years. Therefore, we confirm the hypothesis that the distribution of the productivity of firms that source abroad stochastically dominates the distribution of firms which do not source abroad. We have checked whether results presented in Table 4 hold when the definition of foreign sourcing includes the value of imports of similar goods from affiliated or sub-contracted firms. Results are almost identical to those reported in Table 4.

TABLE 4  
Productivity Level Differences between Firms Sourcing Abroad and Firms Which Do Not  
Source Abroad: Hypotheses Test Statistics

Year	Number of Firms		Per Cent Difference in Productivity Level between Firms Sourcing Abroad and Firms Which Do Not Source Abroad			Equality of Distributions <sup>a</sup>	Differences Favourable to Firms Sourcing Abroad <sup>b</sup>
	Sourcing Abroad	Non-sourcing Abroad	Median	25th Percentile	75th Percentile	p-Value	p-Value
1990	477	618	4.8	6.4	4.9	0.000	0.826
1991	574	768	8.7	10.4	4.8	0.000	0.814
1992	687	833	7.7	8.8	6.9	0.000	0.960
1993	655	787	7.5	7.5	4.4	0.000	0.939
1994	720	731	8.7	10.3	5.5	0.000	0.988
1995	690	678	8.6	10.7	7.4	0.000	1.000
1996	702	682	9.5	10.9	8.8	0.000	0.998
1997	820	782	8.8	8.6	8.5	0.000	1.000
1998	858	738	8.4	8.0	5.6	0.000	0.996
1999	858	741	9.0	8.9	7.7	0.000	0.986
2000	910	754	8.2	8.7	7.9	0.000	0.962
2001	824	674	5.5	6.2	4.2	0.000	0.969
2002	795	651	4.3	6.4	4.3	0.000	0.985

Notes:

<sup>a</sup> p-Value of the Kolmogorov–Smirnov equality of distributions test statistic. The null hypothesis is  $H_0: F(z) - G(z) = 0$ .

<sup>b</sup> p-Value of the Kolmogorov–Smirnov test statistic. The null hypothesis is  $H_0: F(z) - G(z) \leq 0$ .

Finally, Table 5 presents the results of various comparisons between the *ex ante* productivity distributions of firms that engage in foreign sourcing and the productivity distribution of firms which do not source abroad. The industry equilibrium predictions of the model by Antràs and Helpman (2004) indicate that the location and integration decisions of firms will depend on the level of firm productivity. The group of most productive firms self-select in the activity of sourcing in foreign markets. Therefore, we can test for this prediction by comparing the productivity distribution of future foreign sourcing starters and future non-foreign sourcing firms a year before some of them begin to perform foreign sourcing. The results indicate that the *ex ante* productivity difference between entering and non-entering firms is 4.4 per cent at the median of their distributions. The group of firms engaging in a foreign sourcing activity has a higher productivity than the group of non-entering firms. This difference exists before they start their sourcing activity in foreign markets. Formal tests of this difference indicate that it is not too large for some cohorts of starting firms. In particular, two-sided tests of equality of the distributions of both groups of

TABLE 5  
*Ex Ante* Productivity Level Differences between Firms Entering into a Foreign Sourcing Activity and Firms Which Do Not Source Abroad: Hypotheses Test Statistics

Year	Number of Firms		Per Cent Difference in <i>Ex Ante</i> Productivity Level between Firms Entering and Firms Which Do Not Source Abroad			Equality of Distributions <sup>a</sup>	Differences Favourable to Entering Firms <sup>b</sup>
	Entering Firm	Non-sourcing Abroad	Median	25th Percentile	75th Percentile	<i>p</i> -Value	<i>p</i> -Value
1990	74	516	4.6	0.7	3.8	0.403	0.936
1991	102	644	8.0	1.8	6.2	0.009	0.882
1992	81	620	0.8	5.1	-1.6	0.807	0.793
1993	106	552	6.4	3.7	4.6	0.044	0.883
1994	59	574	1.2	3.9	-0.7	0.516	0.862
1995	67	546	3.7	4.4	1.0	0.129	0.720
1996	74	548	5.8	3.8	3.4	0.018	0.998
1997	118	585	7.8	7.9	6.6	0.000	0.919
1998	78	590	4.8	4.3	6.6	0.080	0.968
1999	86	595	2.6	5.3	2.2	0.319	0.984
2000	76	587	3.9	5.5	0.5	0.064	0.954
2001	105	542	3.2	2.8	3.9	0.139	0.911

Notes:

<sup>a</sup> *p*-Value of the Kolmogorov–Smirnov equality of distributions test statistic. The null hypothesis is  $H_0: F(z) - G(z) = 0$ .

<sup>b</sup> *p*-Value of the Kolmogorov–Smirnov test statistic. The null hypothesis is  $H_0: F(z) - G(z) \leq 0$ .

firms cannot be rejected in six cohorts of entering firms, although the difference is favourable to firms engaging in foreign sourcing. These changes over the period may indicate the existence of some heterogeneity coming from the fact that the composition of cohorts of firms starting their sourcing activity in foreign markets is too different across years.

To further investigate the differences in productivity between firms that source abroad and firms which do not source abroad, we report a robustness check on the magnitude of the productivity difference. In particular, we check whether the productivity premium of firms that source abroad is robust to other characteristics that are associated with firm productivity. Furthermore, the regressions we estimate permit the computation of the so-called foreign sourcing productivity premia, defined as the *ceteris paribus* percentage difference of productivity between firms sourcing abroad and firms which do not source abroad. (For a similar application to exporting, see Fariñas and Martín-Marcos, 2007, and ISGEP, 2008.)

The foreign sourcing TFP premium is computed from a regression of  $\ln TFP$ , measured by the same index that was used in the previous section, on the current foreign sourcing status and a set of control variables:

$$\ln TFP_{it} = \alpha + \beta FS_{it} + \gamma Z_{it} + e_{it}, \quad (2)$$

where  $i$  is the index of the firm and  $t$  is the index of the year.  $\ln TFP$  is measured by  $\ln \lambda_{it}$  where average productivity differences across industries are removed.  $FS_{it}$  is a dummy variable for the current foreign sourcing status (1 if firm  $i$  sources abroad in year  $t$ , 0 otherwise).  $Z_{it}$  is a vector of control variables that includes the log of number of employees and its squared value to measure firm *Size*, a dummy variable indicating *Foreign ownership* (1 if the firm has 50 per cent or more of the equity owned by foreign capital), the log of firm *Age*, a full set of year dummies to control for common shocks to all firms, the log of wages and salaries per employee to proxy *Human capital intensity*, and a dummy variable of *Product/Process innovation* (1 if the firm obtains product and/or process innovations in the current year). The foreign sourcing productivity premium, computed from the estimated coefficient  $\beta$  as  $100 * (\exp(\beta) - 1)$ , shows the average percentage difference in TFP between firms that source abroad and firms which do not source abroad controlling the characteristics included in the vector  $Z_{it}$  and productivity differences across industries that are removed by the definition of the index of TFP. A variant of (2) is also estimated with fixed firm effects to control for unobserved firm heterogeneity due to time-invariant firm characteristics which might be correlated with the variables included on the right-hand side of the model and which might lead to a biased estimate of the foreign sourcing productivity premia. As the control variables *Foreign ownership* and *Product/Process innovation* are almost fixed effects, we drop them from the fixed effects estimation.

Results for these with and without fixed firm effects are reported in Table 6. Looking at the results in the upper part of the table, we find that the estimated premia are always significantly different from zero, and higher for pooled data. If fixed firm effects are added to control for unobserved heterogeneity, the estimated premia are still statistically significant, but the estimates are smaller compared to the results based on pooled data only. The magnitude of the premium is around one percentage point when the fixed effects are included. Unobserved firm heterogeneity does matter, and, therefore, in the rest of this section, we will concentrate on the results from the model including fixed effects.

The pattern of the signs of the estimated coefficients for the set of control variables is as expected. *Size* exhibits a '+/-' pattern in its two terms, which indicates that productivity is increasing in size in general, as the minimum of the parabola is a rather low level of employment. *Foreign ownership*, *Age* and

TABLE 6  
Foreign Sourcing Productivity Premia by Type of Firm Ownership

Model	Firm Dummies		Control Variables							No. of Observation	$R^2$	
	Foreign Sourcing Firms	Multinational Firms Performing Foreign Sourcing	Domestically Owned Firms Performing Foreign Sourcing	Log(Size)	(Log(Size)) <sup>b</sup>	Foreign Ownership	Log(Age)	Log(Human Capital Intensity)	Product and/or Process Innovation			
Pooled	3.418 (0.000)			0.054 (0.000)	-0.004 (0.000)	0.054 (0.000)	0.021 (0.000)				19,007	0.165
Pooled	1.568 (0.000)			0.026 (0.000)	-0.004 (0.000)	0.001 (0.900)	0.002 (0.267)	0.227 (0.000)	0.010 (0.000)		19,007	0.036
FE	1.026 (0.022)			-0.066 (0.004)	0.004 (0.098)		0.023 (0.003)				19,007	0.130
FE	0.984 (0.028)			-0.020 (0.370)	0.002 (0.374)		0.010 (0.165)	0.202 (0.000)			19,007	0.280
Pooled		7.928 (0.000)	2.993 (0.000)	0.057 (0.000)	-0.004 (0.000)		0.022 (0.000)				19,007	0.163
Pooled		1.463 (0.004)	1.596 (0.000)	0.025 (0.000)	-0.004 (0.000)		0.002 (0.278)	0.227 (0.000)	0.010 (0.001)		19,007	0.287
FE		2.180 (0.005)	0.803 (0.089)	-0.066 (0.004)	0.004 (0.004)		0.004 (0.095)				19,007	0.041
FE		1.820 (0.019)	0.822 (0.081)	-0.020 (0.368)	0.002 (0.367)		0.011 (0.163)	0.201 (0.000)			19,007	0.279

## Notes:

This table presents the estimated coefficients from an OLS regression of  $\ln TFP$  on dummy variables for foreign sourcing firms and some control variables. All regressions include a full set of year dummies. Numbers in parentheses are probability values. The fixed effect model adds firm fixed effects. In order to facilitate the interpretation, the estimated coefficients for the foreign sourcing dummies have been transformed by  $100(\exp(\beta) - 1)$  where  $\beta$  is the OLS regression coefficient.

*Human capital intensity* are all positively associated with productivity, although the significance of *Foreign ownership* and *Age* vanishes when *Human capital* is included in the set of control variables. *Product/Process innovation* is not statistically significant.

In the lower part of Table 6, the results of a slightly modified version of model (2) are presented. The foreign sourcing productivity premia are estimated through the interaction of two dummy variables: *Foreign sourcing* and *Foreign ownership*. This decomposition permits the estimation of the foreign sourcing productivity premia for the group of foreign-owned firms and the group of domestically-owned firms. The estimates indicate that the productivity premium is higher for foreign-owned firms than for domestically-owned firms. The premium is 1.8 per cent for the first group and 0.8 per cent for the second group (with a *p*-value of 0.08 per cent when FE are included). Given that foreign-owned firms are multinationals that are usually engaged in intra-firm trade, the productivity difference between foreign- and domestically-owned firms shown in Table 6 is consistent with the difference resulting from Antràs and Helpman's (2004) model that predicts that firms integrating through intra-firm trade are at the top of the ranking of productivities. Therefore, this difference in foreign sourcing productivity premia between multinationals and domestically-owned firms is consistent with the model if our interpretation is correct: foreign-owned firms were conducting their sourcing abroad through intra-firm trade. However, the dataset we are using does not permit the observation of the channels through which firms engage in foreign sourcing.

## 6. FOREIGN SOURCING INTENSITY AND PRODUCTIVITY

In Section 5, we report evidence on the existence of large and significant differences in productivity between firms sourcing abroad and firms which do not outsource abroad. Furthermore, this productivity premium is robust to other characteristics associated with firm productivity, either observed or unobserved. In this section, we investigate the relationship between the intensity of foreign sourcing and productivity.

The empirical literature which has investigated the effect of foreign sourcing on productivity has considered that the practice of outsourcing abroad can be identified as a 'shifter' of the production function. This interpretation implies that a change in the intensity of foreign sourcing is a technology shifter for firms, which has a direct impact on their total factor productivity. For example, Görg and Hanley (2005) and Amiti and Wei (2009) follow this approach to justify the existence of an empirical relationship between the intensity of foreign sourcing and productivity. These authors have identified two channels through

which foreign sourcing can affect productivity. First, the reallocation of production within the firm due to foreign sourcing may have a positive effect on the level of productivity. Amiti and Wei (2009) consider this effect a 'compositional change', given that firms reallocate relatively inefficient parts of their production process to a foreign supplier. Second, productivity can increase due to the use of new internationally traded materials, which may be available at lower cost or at higher quality than those available in the domestic market, and, more generally, outsourcing makes it possible for firms to restructure their activities in such a way as to increase the productivity of the remaining labour force.

An alternative explanation of the relationship between productivity and the intensity of foreign sourcing is found in the literature of heterogeneous firms and international trade (see Helpman, 2006). If fixed organisational costs increase with an increase in the number of foreign countries a firm chooses to outsource from and, furthermore, this number of foreign countries is directly associated with the intensity of foreign sourcing, then a positive association is also expected between productivity and the intensity of foreign sourcing at the firm level. As in the analysis by Antràs and Helpman (2004) of the decision to engage in foreign sourcing, the link between productivity and the intensity of foreign sourcing is a self-selection mechanism.

TABLE 7  
Importer Premia and Foreign Sourcing Intensity

	<i>OLS (Pooled)</i>	<i>OLS (FE)</i>	<i>GMM (Differences)</i>
<i>Foreign sourcing intensity</i>	0.033 (0.057)	0.109 (0.000)	0.164 (0.054)
<i>Non-sourcing abroad dummy</i>	-0.010 (0.082)	-0.005 (0.384)	
$(\text{Log}(\text{Size}))^2$	0.022 (0.077)	-0.031 (0.330)	-0.123 (0.001)
$(\text{Log}(\text{Size}))^2$	-0.003 (0.015)	0.004 (0.207)	0.011 (0.005)
<i>Log(Age)</i>	0.001 (0.715)	0.044 (0.000)	0.019 (0.244)
<i>Log(Human capital intensity)</i>	0.226 (0.000)	0.216 (0.000)	0.167 (0.000)
<i>Foreign ownership</i>	-0.005 (0.595)		
<i>Product and/or process innovation</i>	0.010 (0.021)		
<i>Start foreign sourcing dummy</i>			0.011 (0.062)
<i>Stop foreign sourcing dummy</i>			-0.012 (0.042)
Sargan test ( <i>p</i> -value)			42.840 (0.310)
$m_1$ ( <i>p</i> -value)			-10.992 (0.000)
$m_2$ ( <i>p</i> -value)			-0.961 (0.337)
No. of observations (firms)	17,480 (2,405)	15,075 (2,405)	12,670 (2,405)

Notes:

This table presents the estimated coefficients from the model (3). All regressions include a full set of year dummies. Numbers in parentheses are probability values. The instruments used in GMM estimation are: for *Human capital intensity*, the lagged level of the variable as instrument and lagged levels  $t - 2$ ,  $t - 3$  and  $t - 4$  for *Foreign sourcing intensity*.

To address this issue, we introduce an additional variable in equation (2): the intensity of foreign outsourcing for those firms already performing this activity. Then, equation (2) is rewritten as follows:

$$\ln TFP_{it} = \alpha + \beta_1 FSI_{it} + \beta_2 NFS_{it} + \gamma Z_{it} + e_{it}, \quad (3)$$

where  $FSI_{it}$  represents foreign sourcing intensity and  $NFS_{it}$  is a dummy variable that takes the value 1 for those firms not performing sourcing abroad in year  $t$ , and 0 otherwise. This specification allows the distinction between the effect on productivity of the decision to source abroad and the effect of the intensity of this phenomenon. This distinction is consistent with our finding that there are large and significant differences in productivity between firms that source abroad and firms which do not outsource abroad.  $Z_{it}$  is the same vector of control variables as in equation (2).

Table 7 presents the results for the estimation of equation (3). Results in the two first columns correspond to OLS estimates, while the third column corresponds to GMM estimates. The sample of firms used in the estimation includes all firms with information available over at least three consecutive years.

OLS estimates, both controlling and not controlling for unobserved heterogeneity, confirm a positive relationship between the intensity of foreign sourcing and the productivity premia: the higher the intensity of sourcing abroad is, the higher the productivity premium is. The estimated coefficient of foreign sourcing intensity is 0.1 when including fixed effects in the model.

An econometric concern of previous estimates is potential endogeneity of foreign outsourcing. More productive firms might self-select into foreign outsourcing, as theoretical arguments suggest and empirical evidence confirms, and therefore we can expect a downward bias in estimating the effect of foreign sourcing intensity and productivity. The OLS fixed effect coefficient attached to the intensity of foreign sourcing can be biased due to the endogeneity of this decision.

As unobserved heterogeneity might be present, equation (3) is estimated in differences using GMM techniques. The estimation in differences implies that any level individual time-invariant effect is eliminated. Given that differences of the dummy variable  $NFS_{it}$  (non-foreign sourcing decision) take the values:

$$dNFS_{it} = \begin{cases} 1, & \text{if the firm stops sourcing abroad,} \\ 0, & \text{if the firm does not change their decision,} \\ -1, & \text{if the firm starts sourcing abroad,} \end{cases}$$

a convenient way to specify equation (3) in first differences is to distinguish between the change in outsourcing intensity and the change in the decision to outsource abroad. Therefore, for the variable that captures *Foreign sourcing intensity*, first differences are defined as follows:

$$dFSI_{it} = \begin{cases} FSI_{it} - FSI_{it-1}, & \text{if the firm continues sourcing abroad,} \\ 0, & \text{otherwise.} \end{cases}$$

And secondly, the change in the decision to outsource abroad is defined by two dummy variables: *Stop foreign sourcing dummy*, with a value of 1 if the firm ceases to outsource abroad (i.e.  $dNFS_{it} = 1$ ), and 0 otherwise; and *Start foreign sourcing dummy*, with a value of 1 if the firm begins to outsource in foreign markets (i.e.  $dNFS_{it} = -1$ ), and 0 otherwise.

The third column of Table 7 presents the results of a GMM estimation of model (3) in differences including the three variables that measure foreign outsourcing intensity. The estimated equation is a linear equation with predetermined and endogenous variables. The estimation is carried out taking the proxy for *Human capital intensity* as a predetermined variable, and we use the lagged level of the variable as the instrument. The *Foreign sourcing intensity* variable is assumed to be an endogenous variable, and we use the lagged levels  $t - 2$ ,  $t - 3$  and  $t - 4$  as instruments. The Sargan test of overidentifying restrictions is reported and test statistics for first- and second-order serial correlations ( $m_1$  and  $m_2$ ) are also reported (see Arellano and Bond, 1991).

As expected, the coefficient attached to the variable *Foreign sourcing intensity* is positive and significant at the 5 per cent level. The magnitude of the coefficient is larger than the OLS estimate, confirming the downward bias. Furthermore, it is not only that the intensity of foreign sourcing has a positive effect on firm productivity, but also the foreign sourcing decision. As expected, the signs of *Start and stop foreign sourcing dummies* are positive and negative, respectively. In the first case, the decision to start foreign sourcing has a positive influence on productivity. The decision of firms that decide to stop sourcing abroad has a negative influence on productivity. The impact on firm productivity produced by the decision to start sourcing in foreign markets favours the 'compositional change' hypothesis, which considers that this decision permits a reallocation of production within the firm, which has a positive effect on the level of productivity.

The reported specification tests confirm the validity of the estimation: the Sargan test indicates the validity of the moment conditions, and  $m_1$  and  $m_2$  test statistics show a significant negative first-order autocorrelation and the absence of second-order correlation.

The GMM estimated coefficient (0.164) permits us to get an idea of the magnitude of the effect of foreign sourcing on firm productivity. As foreign sourcing increased by almost 0.025 percentage points on average over the period, from 0.165 to 0.188, the estimated coefficient implies that foreign sourcing leads to an average increase of 0.4 per cent of total factor productivity at the firm level. Given that firms increased their average total factor productivity by 18 per cent over the period, foreign sourcing accounted for almost 2.5 per cent of the growth of the total factor productivity at the firm level.

## 7. CONCLUSIONS

This paper examines the relationship between foreign sourcing and productivity at the firm level using a panel of Spanish manufacturing firms. We follow the tradition of Feenstra and Hanson (1996) in defining foreign sourcing as the practice by domestic firms of importing intermediate inputs.

We are able to identify some characteristics that can be summarised as follows. First, there is a large increase in the number of manufacturing firms directly importing intermediate inputs from abroad over the period 1990–2002. The increase is of more than 10 percentage points, with 55 per cent of manufacturing firms performing foreign sourcing at the end of the period. The intensity of foreign sourcing also increases. The propensity to source abroad increases through two channels: the proportion of firms that perform foreign sourcing increases (extensive margin) and the intensity of foreign sourcing within this group of firms is also larger (intensive margin). Second, foreign sourcing is positively related to the size of firms. Small firms perform foreign sourcing with a lower probability (36.6 per cent) than larger firms, where the rate of participation is 80.2 per cent. However, after conditioning on the realisation of foreign sourcing, the intensity of this is very similar for small and large firms. Third, foreign sourcing exhibits a high degree of heterogeneity across industries. Sectors with the highest propensity to source abroad include: Office machinery, computers and precision instruments; Electrical machinery and communication equipment; Motor vehicles; Other transport equipment; and Chemicals and chemical products. This set of industries shares the characteristic that their production processes can be separated into various stages, which favours the sourcing of different components across space.

We apply non-parametric procedures to compare the productivity distributions of various groups of firms. The evidence reported is consistent with Antràs and Helpman's (2004) model, which predicts that high-productivity firms source intermediate inputs in international markets, whereas low-productivity firms acquire them at home. Firms that source abroad have greater TFP than firms which do not outsource abroad. Therefore, the main conclusion is that high-productivity firms are more likely to engage in global production strategies.

Three additional results have been obtained concerning the previous conclusion. First, the evidence reported is consistent with the self-selection of the most productive firms engaged in the practice of sourcing abroad. The *ex ante* productivity distribution of firms that engage in foreign sourcing stochastically dominates the distribution of firms that do not source abroad. Second, we confirm that the productivity premium of firms that source abroad is robust to other characteristics that are associated with firm productivity. Third, our IV estimates suggest that foreign sourcing accounted for 2.5 per cent of total factor productivity growth at the firm level over the period.

Our analysis suggests a number of possible avenues for future research. The first one is based on Antràs and Helpman's (2004) model, which suggests the possibility of testing additional predictions regarding vertical integration of firms through foreign direct investment and intra-firm trade. Therefore, the testing procedure can also be applied to the ranking of productivities of integrated firms vs outsourcing firms in domestic/foreign markets. The second one refers to the notion that self-selection is not inconsistent with the fact that firms engage in foreign sourcing with the expectation that it will improve productivity. Foreign sourcing permits firms to reallocate the relatively inefficient parts of their production process to other countries where they can be produced more cheaply. Our work has concentrated on productivity-level differences between firms that source abroad and firms which do not source abroad, but it can equally be applied to the analysis of productivity growth as in Section 6. A more structural model is required to estimate this effect more precisely, allowing us to more completely address the potential endogeneity of foreign sourcing.

#### APPENDIX

##### *a. Data*

The dataset is a longitudinal survey of Spanish manufacturing firms that comes from the Encuesta sobre Estrategias Empresariales (ESEE), collected by the Fundación Empresa Pública and sponsored by the Spanish Ministry of Industry. This dataset contains a longitudinal sample of firms from 1990 to 2002. As we mention in the text, the panel of firms contains 21,098 observations that correspond to an average number of 3,462 manufacturing firms. From this set of firms, 19,007 observations that correspond to 1,462 firms on average were available for estimation. The units included for estimation were required to contain information on the whole set of the variables that were used in the analysis. The definition of the variables used in the analysis is as follows:

*Total factor productivity:* firm productivity is defined by an index of total factor productivity for each firm over the period 1990–2002. Total factor productivity for firm  $i$ , at time  $t$ , in a given industry is estimated according to expression (1) in Section 4 in the text. The definition of output and inputs in expression (1) is as follows:

The output  $y_{it}$  is measured by the annual value of gross production of goods and services expressed in real terms using price indices for each firm reported by the ESEE. The estimation of the index considers three inputs ( $x'_{it}$ ): labour, materials and the stock of capital. Labour input is measured by the number of effective hours of work per year, which is equal to normal hours plus overtime hours minus non-working hours. Material inputs are measured by the cost of

intermediate inputs, including raw material purchases, energy and fuel costs and other services paid for by the firm. The value of material inputs is measured in real terms using individual price indices in the three categories of intermediate inputs for each firm reported by the ESEE. The stock of capital is calculated according to the perpetual inventory formula for each firm:

$$k_{it} = I_{it} + k_{it-1}(1 - d_{it}) \frac{P_t}{P_{t-1}},$$

where  $I_{it}$  corresponds to the value of investment in equipment of firm  $i$  at time  $t$ ,  $d_{it}$  stands for depreciation rates, and  $P_t$  is an aggregate price index for equipment investment published by the Spanish Institute of Statistics. Finally, input cost shares,  $\omega_{it}^r$ , are defined as the fraction of the cost of each input in total input costs. Total input costs are defined by the sum of labour costs, intermediate input costs and the cost of capital. The cost of labour is measured by the sum of wages, social security contributions, and other labour costs paid by the firm. The cost of intermediate inputs is measured by the sum of costs of raw material purchases, energy and fuel costs and other services paid for by the firm. The user cost of capital is measured for each firm by the cost of the long-term external debt of each firm as reported by the ESEE plus the depreciation rate,  $d_{it}$ , minus the variation of the aggregate price index for capital goods.

*Age:* firm age is computed as the difference between the calendar year at  $t$  and the birth-year reported by the firm.

*Exporting firm:* dummy variable indicating that the firm exports in the current year.

*Foreign ownership:* dummy variable indicating that foreign ownership is 50 per cent or more of total equity.

*Human capital intensity:* proxied by the log of the ratio of labour cost to the number of yearly effective hours of work. The labour cost is measured by the sum of wages, social security contributions, and other labour costs paid for by the firm.

*Product and/or process innovation:* dummy variable with value equal to 1 if during the year the firm obtained product innovations (completely new products or with such modifications that they are different from those produced earlier) and/or introduced a process innovation (some important modification in the process).

*Size:* log of employment defined by the average number of workers.

### *b. Smooth Cumulative Distribution Functions*

In this section, we describe the approach that has been used for the estimation of the univariate cumulative distribution functions represented in Figure 2. Let  $F$  be the distribution function of TFP of a sample of firms of size  $N$ , where the

sample is a combination composed of two random samples of small firms and large firms of sizes  $NS$  and  $NL$  ( $NS + NL = N$ ), respectively. Given the characteristics of the dataset, we can distinguish between large and small firms. For a given group of firms (say, firms sourcing abroad), the cumulative distribution function for the whole population,  $F(\cdot)$ , can be defined in terms of the conditional cumulative distribution functions for the two size groups,  $F(\cdot|\tau)$ , where  $\tau$  is a dummy variable equal to 0 for small firms and equal to 1 for large firms.  $F(\cdot)$  can be expressed as

$$F(\cdot) = p \times F(\cdot|\tau = 0) + (1 - p) \times F(\cdot|\tau = 1),$$

where  $p$  represents the probability of being a small firm in the group of importing firms. Therefore, the cumulative distribution function of the whole population of firms is a mixture of the conditional cumulative distribution functions corresponding to the two size groups of firms, where the parameter of the mixture is the probability of being a small firm in the corresponding population group. Then, the univariate cumulative distribution function for the whole population of firms can be estimated as a weighted average of some estimators of the cumulative distribution functions corresponding to both size groups. The weighted kernel distribution estimate,  $\hat{F}_h$ , of a univariate cumulative distribution function for the whole population of firms,  $F$ , can be expressed as:

$$\hat{F}_h(z_0) = \hat{p} \int_{-\infty}^{z_0} \left( \frac{1}{NS} \sum_{i=1}^N \cdot K\left(\frac{z - Z_i}{h}\right) \right) dz + (1 - \hat{p}) \int_{-\infty}^{z_0} \left( \frac{1}{NL} \sum_{i=1}^N \cdot K\left(\frac{z - Z_i}{h}\right) \right) dz,$$

where  $h$  is the bandwidth and  $K(\cdot)$  is the kernel function, and  $\hat{p}$  represents the estimated probability of being a small firm in the considered group.<sup>1</sup>

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<sup>1</sup> The estimation of marginal probabilities for the population of firms takes into account the sampling proportions of the dataset. For the group of non-foreign outsourcing firms, the estimated probability of being a small firm is  $\hat{p} = 0.995$  and the probability of being a large one is  $(1 - \hat{p}) = 0.005$ . For the group of foreign outsourcing firms, the estimated probability of being a small unit is  $\hat{p} = 0.934$  and the probability of being a large one is  $(1 - \hat{p}) = 0.066$ .

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