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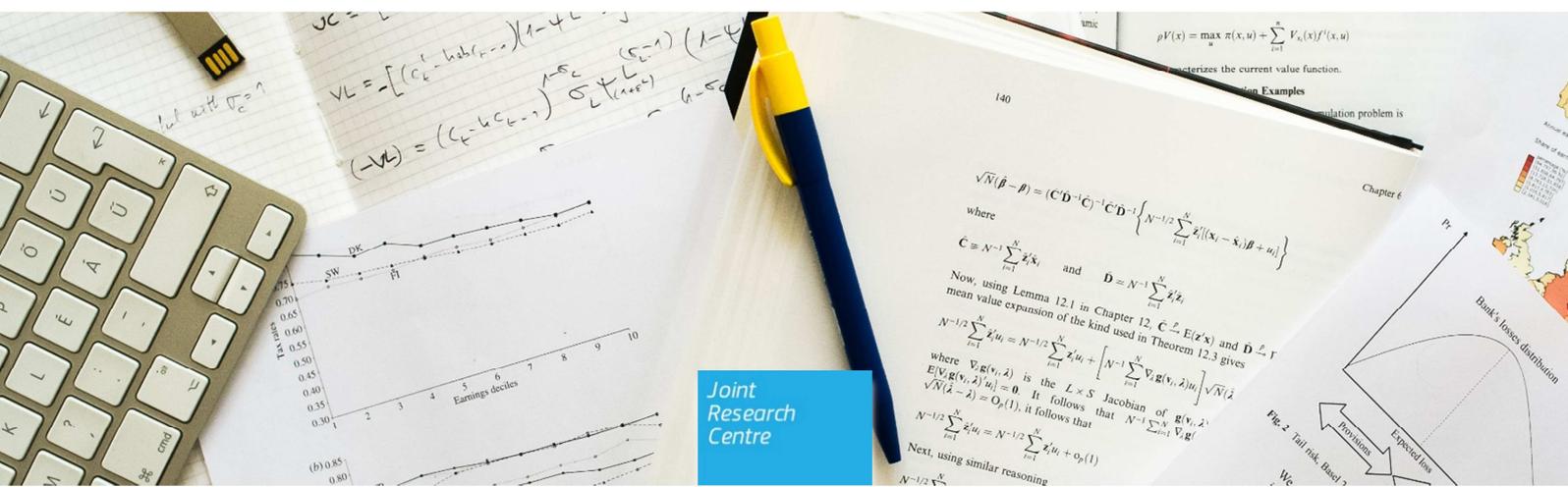
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# Product innovation by supplying in domestic and foreign markets

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## Abstract

This paper uses European firm-level survey data to provide some robust empirical evidence that suppliers engaged in production to order (PTO) for foreign firms are more likely to introduce product innovations than those engaged in PTO for domestic firms, even when differences in size, R&D and productivity are controlled for. We propose a demand-driven theoretical explanation based on the interactions between an upstream producer of a specialized input and a downstream producer in a framework of incomplete contracts, agency frictions, and imperfect information.

*JEL Classification* D21 · D22 · F10 · L23 · O31

*Keywords:* buyer, supplier, product innovation, production to order, foreign market

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## 1. Introduction and motivation

Starting from the abundant research on the impact of a firm's export status or export intensity on productivity (see, for instance, [Wagner, 2007](#); [Crespi et al., 2008](#); [Serti and Tomasi, 2008](#); [Fryges and Wagner, 2008](#); [Park et al., 2010](#); [Fabling and Sanderson, 2013](#)), several scholars have also demonstrated the effect of a firm's international activities on its ability to introduce product innovations. Recent contributions include [Baldwin and Gu \(2004\)](#), [Salomon and Shaver \(2005\)](#), [Liu and Buck \(2007\)](#), [Fafchamps et al. \(2008\)](#), [Criscuolo et al. \(2010\)](#), [Lileeva and Treffer \(2010\)](#), [Bustos \(2011\)](#), and [Bratti and Felice \(2012\)](#), among others. This strand of literature generally finds that exporters are more likely to introduce product innovations than non-exporters, but the literature does not distinguish between trade in final and intermediate goods.

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Trade is increasingly characterized by global value chains (GVCs) and the international fragmentation of production (WTO, 2008; WB et al., 2017; Lanz et al., 2009; Johnson and Noguera, 2012; Timmer et al., 2014). According to Baldwin and Lopez-Gonzalez (2015), trade in intermediate goods, the production of which usually involves complex buyer–supplier interactions, accounts for about two thirds of world exports and a large part of this trade is in specialized goods (Rauch, 1999; Artopoulos et al., 2013). Alongside GVCs, complex interactions are developed between upstream and downstream firms located in different countries, which are usually referred to as channels of knowledge exchange in the business literature (Hippel, 1988). The literature that looks at the innovation effects of GVC participation is only recent, but continues to grow (Pietrobelli, 2008; Pietrobelli and Rabellotti, 2011; Unctad, 2013; Kowalski et al., 2015; Taglioni and Winkler, 2016), and usually focuses on developing countries. Nevertheless, while north-south production networks started developing during the so-called “second unbundling” in the 1990s, in particular with the emerging role of Asian countries, supply chain trade among advanced countries (north-north networks) has been relevant since the 1960s (Baldwin and Lopez-Gonzalez, 2015). However, GVCs are still, for a large part, a regional more than a global phenomenon: intra-European trade accounts for around 70% of total European Union (EU) intermediate trade, both in terms of export and import. Hence, a large part of EU trade in intermediate inputs is within the EU supply chain, which is also called “Factory Europe” (WB et al., 2017).

Finally, there is also a rich body of business and management literature that stresses the role of buyer–supplier collaborative relationships as a fundamental source of innovation. It is described as a process that no longer happens exclusively within the firm, but which instead involves the entire supply chain or a network of actors (Bidault et al., 1998; Schiele, 2006; Alcacer and Oxley, 2014). This literature also stresses that as a result of needing to deal with rapid changes in customer preferences, and shorter product lives, there has been a gradual switch from a competitive model, in which buyers try to minimize costs and use several suppliers to reduce risk, to a cooperative model, in which buyer–supplier relationships play an important role for innovation (Roberts, 2001). Indeed, users with specific needs are a fundamental source of information for developing new products (Hippel, 1988; Herstatt and von Hippel, 1992; Baldwin and von Hippel, 2011; Alcacer and Oxley, 2014). In particular, cooperative relationships are likely to emerge when the buyer requires parts and components that must be adapted to its product or process, i.e. for specialized intermediate goods. Specialized goods are usually traded under a *production to order* (PTO) regime, i.e. goods that firms produce following an order by other firms (Casaburi and Minerva, 2011). The larger the role played by product characteristics, the greater the informational frictions and therefore the

greater the need to build a relationship in order to exchange the specific good. PTO entails complex buyer–supplier relationships and a non-negligible exchange of information between business partners, because highly differentiated goods, by definition, require specialization. What is worth noting in this framework is that any innovation carried out by a downstream firm to sell a new product in the final market, by inducing the need of new inputs, potentially generates some collaboration in terms of the innovation activities with the supplier providing the required intermediate input. In downstream firms, product innovation can be induced in response to consumer preferences, either directly through market research or indirectly through intermediaries. By contrast, in upstream firms the demand-side source of innovation is represented by the downstream firm’s demand, i.e. the needs of another firm.

In this paper, we make an attempt to bridge the gap between these three streams of literature and show how a supplier’s involvement in the PTO of intermediate inputs for foreign buyers can, under certain conditions, lead to more product innovation. The focus of our paper is “incremental innovations,” i.e. all the changes that firms develop in products in their day-to-day activities. Unlike most extant papers, e.g. those related to GVCs, we do not focus on suppliers located in developing countries, whose higher level of innovation is likely to be driven by the higher technological level of buyers located in advanced economies. We instead focus on buyer–supplier relationships between firms located in countries with similar levels of development, but which might have some technological differences. Our paper studies an important issue: owing to trade globalization and the diffusion of GVCs, an increasing share of trade in intermediate goods is of the form investigated in this paper, i.e. it is of a PTO nature and involves buyers and suppliers located in different countries.

In the first part of the paper, we provide some robust empirical evidence of the higher level of product innovation in firms engaged in PTO for foreign customers than in those engaged in PTO for domestic firms using the EFIGE (European Firms in a Global Economy) dataset, which was collected within the Seventh Framework Programme project “EFIGE — European Firms in a Global Economy: Internal policies for external competitiveness.” EFIGE data show that 86% of manufacturing firms produce to order, and about 79% produce for other firms. Among the latter, on average, 81% of the total turnover is produced to order. Thus, by analyzing buyer–supplier relationships, in this paper we study an innovation channel that is potentially relevant to the vast majority of manufacturing firms in Europe.

In the second part of the paper, we develop a theoretical model consistent with the empirical facts observed in the data. In our model, a buyer looks for a new or improved intermediate input to produce a new final good. The level of innovation required to develop the intermediate good depends on the distance

in the product characteristic space between the needs of the buyer and the characteristics of the existing input already produced by the supplier.

Innovation in the input emerges as an outcome of the collaboration between the buyer and the supplier, which is regulated by a contract specifying the (alternative) cost structure and the splitting of the profit. Since the features of the contract and the costs are not the same in domestic and international collaborations (Egan and Mody, 1992), we highlight how these differences affect the structure of the partners' incentives to innovate, singling out the conditions under which supplying to foreign buyers spurs innovation at a higher rate than supplying to domestic buyers.

By incorporating many of the real-world features highlighted by the literature outlined previously, our model is in line with some well-established empirical facts. First, it is consistent with the well-known evidence on firms' heterogeneous internationalization strategies. Buyers can collaborate with a domestic supplier or, alternatively, they can search for a supplier that would more closely meet their needs in foreign markets. First, as a result of whether or not a buyer decides to search abroad, different internationalization strategies emerge, depending on the distance between the buyer's needs and the characteristics of the supplier's good in the domestic match, which, in turn, implies some heterogeneity across suppliers, with some selling only domestically and some exporting. Second, in an international match, depending on the distance in the product space, decisions among buyers on whether to directly adapt the input or ask the supplier to do it are heterogeneous. This in turn generates heterogeneous innovation strategies among suppliers, with some selling the existing input and some renewing their products. Third, we show that under some conditions suppliers of specialized goods engaged in international collaborations with foreign buyers show a higher propensity to introduce product innovations and adapt their goods to buyers' needs than suppliers engaged in domestic matches (i.e. product innovation is more frequent in foreign than in domestic supplying). In our setting, this result stems from the characteristics of the buyers' and the suppliers' goods, namely their distance in the product space and the differences in the costs of adapting the goods in international vs. domestic business relationships.

Unlike the literature on export and innovation, which often stresses supply-side factors such as a firm's size and productivity, or R&D investment, our model puts the emphasis on demand-driven innovation, i.e. innovation originating from the demand of a new or an improved intermediate good, and on the strategic interaction between buyers and suppliers. Although supply-side factors are surely very relevant to explaining firms' exporting and innovation behaviors, through self-selection, they are not sufficient alone to explain the superior innovation of exporting firms. This is very evident in Europe, where small and low-productivity

Table 1: Firm size and unit labor costs, exporting and innovation

Firm characteristics	share of exporters	share of product innovators non-exporters	exporters
<i>Firm size</i>			
> 10 & < 20	0.46	0.31	0.53
≥ 20 & < 50	0.58	0.36	0.58
≥ 50 & < 250	0.72	0.44	0.65
≥ 250	0.803	0.47	0.71
<i>Deciles of unit labor costs</i>			
1	0.68	0.37	0.54
2	0.71	0.36	0.62
3	0.71	0.34	0.59
4	0.66	0.36	0.58
5	0.66	0.37	0.59
6	0.61	0.36	0.61
7	0.62	0.34	0.60
8	0.53	0.33	0.57
9	0.45	0.32	0.50
10	0.38	0.30	0.55

Notes. Our computations on the full EFIGE sample (see section 2.1). The EFIGE survey gathers data on about 15,000 firms located in Austria, France, Germany, Hungary, Italy, Spain and the UK. Firm size is defined as the number of employees. Unit labor costs are measured as total labor costs divided by firm turnover. All statistics are computed using survey weights.

firms often sell their goods abroad and introduce product innovations (see Table 1).

Some predictions of our model are that suppliers engaged in PTO for foreign buyers are more innovative than suppliers engaged in domestic PTO the lower the number of firms in the buyers' country, the lower the internationalization costs (i.e. the costs of maintaining a business relationship abroad) and the larger the technological differences across countries, which makes product adaptation more expensive for foreign than for domestic customers. We consider these predictions in the context of the data, and find some evidence that is broadly consistent with the predictions made.

Our paper highlights that a reduction in trade barriers (e.g. the costs of managing operations across countries, exchange rate risks) increases the chances of existing firms acting as suppliers or finding a trade partner in a foreign market, which requires a modified input (demand-pull mechanism), spurring innovation among suppliers, thus complementing the well-known self-selection (supply-push) mechanism by which only ex ante more productive suppliers enter foreign markets. The trade relationship may be either temporary or permanent, only the latter being a potential source of innovation. This is particularly relevant for those small to medium-sized enterprises that do not operate on a scale large enough to bear the high cost of R&D, and for which the interaction with foreign buyers represents a primary source of innovation.

The remainder of the paper is organized as follows. The next section provides some descriptive empirical evidence on the differential product innovativeness of firms producing to order for foreign firms vs. domestic

firms. Section 3 highlights the relationship between the existing theoretical literature and our main contribution. Section 4 develops the theoretical model and Section 5 tests some of the model’s implications. Section 6 summarizes the main findings and conclusions.

## 2. Empirical evidence

The aim of this section is to provide some new empirical evidence on the association between PTO for foreign firms and product innovation, which motivates our theoretical model. The theoretical explanation, which is developed later in this paper, focuses on the demand channel and is based on PTO relationships between buyers and suppliers of specialized intermediate goods. As far as we know, there is still a lack of studies focusing specifically on the association between export and product innovation for firms engaged in PTO. The theoretical analysis we propose will therefore try to match some of the empirical facts reported in this section and in previous literature.

### 2.1. The EFIGE data

We use the EFIGE dataset, which gathers data on a representative sample (at the national level for the manufacturing industry in 2008) of almost 15,000 firms (above 10 employees) in seven European economies: around 3,000 firms for France, Germany, Italy, and Spain; around 2,200 firms for the UK; and around 500 firms for Austria and Hungary. The survey’s questionnaire mainly focuses on 2008, with some questions on firms’ activities in 2009 and in previous years. The original dataset includes data on 14,911 firms. A general discussion of the characteristics of the dataset, its representativeness and some data cross-validation exercises using countries’ official statistics can be found in [Altomonte and Aquilante \(2012\)](#). The survey gathers a wealth of information about firms’ international activities, innovation, and organization, which is complemented with balance sheet data from AMADEUS, a database of comparable financial information for public and private European companies, collected by Bureau van Dijk.

The EFIGE dataset provides information about firms’ production mode; in particular, after firms were asked what percentage (on average) of their turnover was made up by sales of produced-to-order goods (question E1), firms were then asked the following question:

**E2.** In which of the following categories do your main clients, for whom the firm produced to order, belong to?

- intra-group
- other firms, in the same region
- other firms, in the rest of the country
- other firms, abroad
- public administration
- private customers.

In the EFIGE dataset, 86% of firms produce to order. There are differences among countries. The percentage of firms engaged in PTO is 71% for Austria, 92% for France, 81% for Germany, 92% for Hungary, 94% for Italy, 78% for Spain, and 85% for the UK.<sup>2</sup> Overall, the great majority of firms (79% in the overall sample) carries out PTO for other firms, and the average percentage of sales made from PTO for other firms is 81%. Detailed statistics on PTO by country are reported in Table B.1 in Appendix B.

As for innovation, the EFIGE questionnaire includes the following question:

**C14.** On average in the last three years did the firm carry out any (multiple answers allowed):

- product innovation (i.e. introduction of a good which is either new or significantly improved with respect to its fundamental characteristics; the innovation should be new to your firm, not necessarily to the market)
- process innovation (i.e. the adoption of a production technology which is either new or significantly improved; the innovation should be new to your firm; your firm has not necessarily to be the first to introduce this process)
- none of the above.

In particular, we define a dichotomous indicator for product innovation that takes on a value of one if the firm introduced product innovations and a value of zero otherwise. As is clear, our product innovation variable encompasses both radical and incremental innovations. The percentage of firms that made product innovations is 48% in the overall sample. Percentages by country are 58% for Austria, 48% for France, 48% for Germany, 43% for Hungary, 48% for Italy, 44% for Spain, and 56% for the UK.<sup>3</sup>

## 2.2. Sample selection criteria

Given that the focus of the current paper is on buyer-supplier relationships established between firms for the purchase/provision of a specialized intermediate good, we imposed some selection criteria on our sample before carrying out the empirical analysis. First, since we aim to explain differences in the level of product innovation between firms engaged in PTO for domestic firms and those engaged in PTO for foreign firms, from the survey we selected (a) firms engaged in PTO and (b) firms engaged in PTO for firms only (excluding PTO for public administration and final customers). These criteria are instrumental to the theoretical explanation that we provide in the second part of the paper, which focuses on the supply of intermediate goods. These criteria do not reduce the sample size to a large extent, given that most firms engage in PTO for other firms. Table B1 in Appendix B shows the sample sizes and average characteristics (e.g. percentage of turnover made as a result of PTO, percentage of product innovation) produced by the application of each selection criterion. Since there is already extensive literature on the effects of export on product innovation, and because we wanted to prevent the effect of being engaged in PTO for foreign firms

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<sup>2</sup>These figures include PTO for other firms, the public sector, and final consumers.

<sup>3</sup> All the reported statistics make use of sample weights.

being confounded with that of other types of export activities, we imposed a further selection criterion: (c) PTO accounts for 100% of firm turnover. Criterion (c), albeit restrictive, ensures that our sample excludes firms that engage in non-PTO export activities. Since it is much more restrictive than the previous two criteria ((a) and (b)), causing more than 50% of the observations to be excluded from the sample in some countries, in [Appendix B](#) we report some robustness checks using the sample of all firms engaged in PTO for other firms irrespective of the percentage of turnover (i.e. the sample defined by criterion (b)). Finally, a limited number of observations are excluded from the sample because of missing values in the covariates (criterion (d) in [Table B.1, Appendix B](#)).

### 2.3. Methods

Assessing the causal effect of PTO for foreign buyers (foreign PTO, hereafter) on product innovation is complicated by a potential endogeneity issue. Indeed, let us consider the following linear regression model:

$$Y_i = \alpha_0 + \alpha_1 Forcust_i + \boldsymbol{\gamma}'\mathbf{X}_i + \epsilon_i \quad (1)$$

where  $Y_i$  and  $Forcust_i$  are dichotomous indicators for product innovation and foreign PTO, respectively,  $\mathbf{X}_i$  is a vector of control variables, and  $\epsilon_i$  is an error term capturing the effect of all determinants of product innovation (either observed or unobserved) that have been omitted from the regression.  $\alpha_1$  is our parameter of interest, and represents the average innovation premium of being engaged in PTO for foreign customers vs. domestic customers.

First, it is important to note that if all factors driving foreign PTO were observable and included in the regression, then, in this reduced-form model, we would expect  $Forcust_i$  to have no additional explanatory power over and above  $\mathbf{X}_i$  (i.e.  $\alpha_1 = 0$ ). Thus, finding a statistically significant estimate for  $\alpha_1$  implies that some variables determining PTO for foreign customers have been omitted from the regression, or, in other words, that  $Forcust_i$  has some residual variability explaining product innovation over and above the control variables.

Second, if this residual variability in foreign PTO is also correlated with the omitted variables affecting product innovation — the simplest case being when some omitted variables affect both outcomes (i.e. simultaneity) — this would lead to a correlation between  $Forcust_i$  and the error term  $\epsilon_i$ , generating an endogeneity problem: the coefficient  $\alpha_1$  estimated with ordinary least squares (OLS), or a method that assumes exogeneity, cannot be interpreted as the causal effect of foreign PTO on product innovation. Adding control variables to the regression reduces the set of factors potentially entering  $\epsilon_i$  and the likelihood of having omitted from the regression some relevant variables correlated with  $Forcust_i$ .

In addition to adding control variables in the regression (1), an alternative way of addressing selection on observed variables is to use matching estimators. We define the product innovation outcome for firm  $i$  in the presence of PTO for a foreign customer (our ‘treatment’ of interest) as  $Y_i(1)$ , and the outcome in the presence of PTO for a domestic customer as  $Y_i(0)$ . Thus, for each firm the potential outcome is  $Y_i = Forc_{i,t} Y_i(1) + (1 - Forc_{i,t}) Y_i(0)$ . There are two problems when aiming to estimate the *treatment effects*  $TE_i = Y_i(1) - Y_i(0)$ . First, for each firm we observe either the outcome in only the presence or the outcome in only the absence of treatment. Second, treated and untreated (control) firms may differ according to observable characteristics, which also affect the outcome, and this may happen because selection into treatment is not random (i.e. it is potentially endogenous with the outcome). Matching estimators provide a solution to both of these issues. By matching treated firms with untreated firms that are sufficiently similar in their observable characteristics, and are therefore taken as counterfactual evidence for the former, then taking the difference in the outcomes observed between these matched firms, and the average across the sample, we can obtain an estimate of the *sample average treatment effect on the treated* (SATT):  $SATT = \frac{1}{n_T} \sum_i TE_i$ , where  $n_T$  is the number of treated individuals. The main identifying assumption underlying matching estimators is the conditional independence assumption (CIA), i.e. the absence of selection into treatment according to unobserved variables, which may also affect the outcome.<sup>4</sup> The CIA cannot be tested and its plausibility mainly depends on the richness of the data used (i.e. information on a high number of variables makes selection on the unobservables very unlikely).

Several ways of matching treated and untreated units have been proposed in the literature. In what follows, we report the SATT computed using various matching procedures, in order to test the sensitivity of the estimates to the matching procedures. In particular, we report the results of:

1. propensity score (PS, hereafter) nearest neighbor matching (PS-NNM);
2. nearest neighbor matching (NNM), with exact matching on some variables that are difficult to balance using the propensity scores (PSs);
3. coarsened exact matching (CEM);
4. entropy balancing.

All methods have advantages and disadvantages. PS-NNM allows the curse of dimensionality to be reduced (since matching is only performed on one variable, i.e. the PS) and is useful when the sample is not very large. The principle is to estimate a parametric model (e.g. probit) for the treatment status and then match

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<sup>4</sup> For a detailed review on matching methods, see [Caliendo and Kopeinig \(2008\)](#).

firms on predicted probabilities (the PSs). In the case of PS-NNM, each treated firm is paired with the untreated one with the closest PS. The typical check of the quality of the matching is based on the balancing property for observable variables in the treated and control groups: after matching, the two groups should be practically indistinguishable according to their observed characteristics. NNM is based on matching treated and untreated firms using a measure of distance in the covariates used for matching. In some cases, some characteristics are difficult to balance, and the researcher may want to match these attributes exactly to try to limit the bias in the estimation of the SATT. The CEM pushes this idea further by imposing exact matching on all variables after coarsening the continuous variables in intervals (Blackwell et al., 2009). The CEM weights are then used in a regression. Both NNM with exact matching and CEM have the advantage of allowing for a better balancing of the matching covariates (by definition) at the cost of potentially causing a reduction in the estimation sample, as non-matched observations are discarded. The final method, entropy balancing, is based on a maximum entropy reweighting scheme that assigns weights to each data unit, such that the covariate distributions in the reweighted data satisfy a set of moment conditions chosen by the researcher (Hainmueller, 2012; Hainmueller and Xu, 2013). Like in the CEM case, these weights can be used in a regression. An advantage of entropy balancing, compared with exact NNM and CEM, is that all observations are retained in the estimation of the SATT.

All the matching procedures listed above require that a choice is made on the set of variables on which to perform matching.<sup>5</sup> Good candidates are variables that are likely to affect both the product innovation outcome and the selection into treatment (foreign vs. domestic PTO). On the basis of previous empirical studies on export and product innovation (see, for instance, Bratti and Felice, 2012) and to prevent the use of variables with too many missing values in the data (i.e. balance sheet data), we selected the following set of variables to perform matching: firm size (number of employees in five size groups: 10-19, 20-49, 50-249, 250 or more); two dummy variables for participating in domestic and foreign groups (i.e. defined according to the location of the headquarters), which are factors that may affect both innovation and the involvement in foreign markets; European Classification of Economic Activities (NACE) two-digit industry and country fixed effects capturing the different internationalization and technological opportunities existing in different industries and countries, respectively; some indicators of a firm's absorptive capacity, such as the percentage of university graduates in terms of the firm's total employment (i.e. graduate employment) and the percentage of those employed in R&D in terms of total employment (R&D employment); and, finally,

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<sup>5</sup> See Caliendo and Kopeinig (2008). The choice of a very large set of variables makes the CIA more likely to hold but at the expense of increasing the uncertainty in the estimated effects (in case of matching on irrelevant variables).

Table 2: Estimates of the Sample Average Treatment Effects on the Treated (SATT)

Matching method	N. observations.	SATT	st. err.	Remarks
1) OLS without controls	7,235	0.205***	0.011	
2) OLS with controls	7,235	0.115***	0.012	controls are the covariates used in matching estimators
3) Probit without controls	7,235	0.200***	0.011	
4) Probit with controls	7,235	0.110***	0.012	controls are the covariates used in matching estimators
5) PS-NNM	7,235	0.113***	0.018	one-to-one matching on PS
6) NNM	7,064	0.106***	0.017	one-to-one matching, exact matching on industry, country, FDI and foreign group dummies
7) CEM <sup>a</sup>	4,134	0.090***	0.018	exact matching on all variables (intervals for continuous variables)
8) Entropy balancing <sup>a</sup>	7,235	0.122***	0.011	balancing is made on the first moment

\*\*\* significant at the 1% statistical level.

Notes. PS-NNM, NNM and CEM stand for Propensity Score-Nearest Neighbor Matching, Nearest Neighbor Matching and Coarsened Exact Matching, respectively. The number of observations change across columns since the number of non-matched observations varies according to the method used. Standard errors are robust to heteroskedasticity in OLS and probit models, and are computed following [Abadie and Imbens \(2006\)](#), [Abadie and Imbens \(2011\)](#) and [Abadie and Imbens \(2016\)](#) in PS-NNM and NNM. The NNM estimates are corrected for the bias introduced by matching on more than one continuous variable ([Abadie and Imbens, 2006, 2011](#)).

<sup>a</sup> SATT are estimated by means of regressions using CEM or entropy balancing weights, controlling also for the matching variables to improve precision.

indicators of other forms of a firm’s internationalization, namely a dummy variable for having made foreign direct investments (FDIs) and a dummy variable for being an importer (of raw materials, intermediate goods, etc.), which are also potentially associated with product innovation (see, for instance, [Goldberg et al., 2010](#)). In Appendix [Appendix B](#) (Table B.3), we also report on some robustness checks performed using two additional variables coming from firms’ balance sheet data, but which have a non-negligible number of missing values: physical capital intensity (the value of physical capital stock divided by the number of employees) and unit labor costs (total labor costs divided by firm turnover) as a proxy of productivity. The results are equivalent to those reported in the main text.

## 2.4. Results

The first and second rows of Table 2 show the OLS estimates without and with control variables, respectively. In the first case, the estimated effect of foreign PTO is an increase of 0.205 in the probability of product innovation. When controls for other potential determinants of the level of product innovation are included in the regression, the effect falls to 0.115, showing that the controls included are significant predictors of foreign PTO and innovation. Rows three and four report the average marginal effects estimated from probit models with and without controls, respectively. Imposing the normality assumption does not lead to important changes in the estimates, which are 0.2 in the model, excluding covariates, and 0.11 in the model, including covariates. In all cases, the estimates are significant at the 1% statistical level.

Table B.2 in the Appendix [Appendix B](#) shows the results of the balancing tests carried out on the covariates used in the PS matching. Covariates are generally well balanced, except for a few industry and country dummy variables,<sup>6</sup> the foreign group, and the FDI dummy variables. For this reason, we also implement matching procedures that allow for exact matching on these variables. Figure B.1 in [Appendix B](#) shows the distribution of the PSs for treated and untreated firms. As expected, the distribution of the PSs for the treated units is shifted to the right with respect to that of the untreated ones, in line with the fact that the probit model used to compute the PSs includes significant predictors of foreign PTO.<sup>7</sup> The fifth row of Table 2 shows the SATT estimated using the PS-NNM method, which is 0.113 and is statistically significant at the 1% level.

Owing to the difficulties in balancing some of the covariates using the PS, in the sixth row we report the results of NNM using exact matching on the industry, country, FDI and foreign group dichotomous indicators. The estimated SATT is 0.106, which is statistically significant at the 1% level. In total, 171 observations do not have an exact match in terms of the variables specified and were dropped from the sample.

The seventh row of Table 2 reports the results of CEM. In this case, exact matching is performed after continuous variables have been coarsened in intervals. Although imposing exact matching on all variables minimizes the risk of bias due to potential bad matches, it also produces a noticeable decrease in the size of the matched estimation sample, which is smaller than for the two previous methods and includes 4,134 firms (2,351 control and 1,783 treated units). The SATT is 0.09 and is statistically significant at the 1% level. Thus, in spite of the reduction in the estimation sample, the SATT is very close to those estimated with the other matching methods.

The last row of Table 2 reports the results from the entropy-balancing estimation, which builds weights that balance the means of all covariates in the treated and untreated groups. Thus, the means of the covariates in the two groups are equal by construction. The advantage of this method is that it uses the whole sample. The estimated SATT is 0.122, which is statistically significant at the 1% level, and is slightly larger than that found with the previous matching estimators.

All in all, the estimates in Table 2 led us to conclude that a positive association between foreign PTO and the likelihood of introducing product innovations is a very robust feature of our data. Moreover, under

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<sup>6</sup> See Table B.2's footnotes for major details.

<sup>7</sup> As a consequence, the Kolmogorov-Smirnov test for the equality of the distributions of the PSs for treated and untreated firms rejects the null hypothesis ( $p$ -value=0). However, Figure B.1 shows that the PSs of the treated and control firms have a substantial overlap.

the CIA, this association can be interpreted as a causal effect. In the next section, we discuss potential biases produced by selection on unobserved variables.

## 2.5. Selection on unobserved variables

In order to fully address the issue of selection into foreign PTO driven by unobserved variables potentially correlated with product innovation, it is necessary to find a source of presumably exogenous variation in the treatment of interest. This is, however, a formidable task, especially when dealing with cross-country data. For this reason, in this section we limit the analysis to assessing the potential bias induced by selection on unobserved variables using the methodology described in [Altonji et al. \(2005\)](#).

For ease of notation, in what follows we define the treatment of interest (*Forcust*) as  $T$  and omit the firm indexes. Consider the following bivariate probit model:

$$T = 1(\mathbf{X}'\boldsymbol{\beta} + u > 0) \quad (2)$$

$$Y = 1(\mathbf{X}'\boldsymbol{\gamma} + \alpha_1 T + \epsilon > 0) \quad (3)$$

and

$$\begin{bmatrix} u \\ \epsilon \end{bmatrix} \sim N \left( \begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & \rho \\ \rho & 1 \end{bmatrix} \right). \quad (4)$$

where  $1(\cdot)$  is an indicator function.

[Altonji et al. \(2005\)](#) showed that, under the assumption of proportional selection between observable and unobservable variables, the bias generated by the omitted variables, can be written as<sup>8</sup>

$$\begin{aligned} \text{plim } \hat{\alpha}_1 &= \alpha_1 + \frac{\text{Var}(T)}{\text{Var}(\tilde{T})} [E(\epsilon|T=1) - E(\epsilon|T=0)] \\ &= \alpha_1 + \underbrace{\frac{\widehat{\text{Var}}(T)}{\widehat{\text{Var}}(\tilde{T})} \frac{[\hat{E}(\mathbf{X}'\hat{\boldsymbol{\gamma}}|T=1) - \hat{E}(\mathbf{X}'\hat{\boldsymbol{\gamma}}|T=0)]}{\widehat{\text{Var}}(\mathbf{X}'\hat{\boldsymbol{\gamma}})}}_{\text{bias}} \end{aligned} \quad (5)$$

where  $\tilde{T}$  represent the residuals of a regression of  $T$  on  $\mathbf{X}$ , and the last expression was obtained by exploiting the fact that, in the probit model,  $\text{Var}(\epsilon) = 1$ , and the assumption that the relationship between  $T$  and

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<sup>8</sup> See p. 176 in [Altonji et al. \(2005\)](#).

the mean of the distribution of the index of unobservables determining the outcome is the same as the relationship between  $T$  and the mean of the observable index, after adjusting for differences in the variance of these distributions (condition 4 in [Altonji et al., 2005](#)). Using our data with the expression (5), we obtain an estimate to bias ratio ( $\hat{\alpha}_1/\text{bias}$ ) equal to 0.95, meaning that the shift in the distribution of the unobservables has to be as large as the shift in the observables to explain the entire effect of foreign PTO.<sup>9</sup> However, on the grounds that the regressors were not chosen at random, but based on their potential explanatory power on product innovation and foreign vs. domestic PTO and on the findings of previous research on the link between export activities and innovation, we think it is unlikely that the selection on observable variables is as strong as the selection on unobservable variables.<sup>10</sup>

### 3. Position of our theoretical model in the literature

In the next section, we introduce a theoretical framework to explain the higher level of product innovation by firms engaged in PTO for foreign buyers than by firms engaged in PTO for domestic buyers. The contributions most similar to our work are those from the large body of literature on global sourcing, in particular those introducing the concept of contractual incompleteness and imperfect information in international trade models with product specialization ([Grossman and Helpman, 2005](#); [Rauch and Trinidad, 2003](#); [Puga and Trefler, 2010](#)). These papers are concerned with firms' decisions related to the geographical location of partners in production, when products are specialized and countries differ in labor costs, technological levels, and the quality of their institutions. Our contribution departs from those of [Grossman and Helpman \(2005\)](#) and [Rauch and Trinidad \(2003\)](#) mainly in the analysis of the innovation process. While our work encompasses the factors determining who adapts the input, since both upstream and downstream firms can do this, in [Grossman and Helpman \(2005\)](#) only the subcontractors adapt their inputs to match the buyers' needs, while in [Rauch and Trinidad \(2003\)](#) firms do not change location in the product space, i.e. they do not adapt their products. Therefore, in the scenarios considered in these previous studies, either the buyer never innovates or the decisions are not based on innovation strategies, but just on whether or not to collaborate and the geographical location of potential partners. Those works aimed to highlight the role of institutions (affecting the enforceability of contracts) in differently developed countries ([Grossman and Helpman, 2005](#)), the roles

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<sup>9</sup>  $\hat{\gamma}$  is estimated from a probit model imposing the constraint  $\alpha_1 = 0$  and  $\hat{\alpha}_1$  is estimated from a bivariate probit model leaving the correlation coefficient  $\rho$  (between the error terms  $\epsilon$  and  $u$ ) unconstrained.

<sup>10</sup> We also used the method suggested by [Oster \(2017\)](#) to assess the sensitivity of our estimates to selection on unobserved variables. Assuming a maximum theoretical  $R_{max}^2 = 1.3R^2$  (i.e. 0.18), we obtain a coefficient of proportionality between unobservables and observables ( $\delta$ ) of 2.1, implying that unobservables must be twice as important as observables to explain the whole estimated effect of foreign PTO on product innovation.

of information barriers and of network ties in overcoming these barriers (Rauch and Trinidad, 2003), and the role of institutions in affecting the volume of trade across countries when products are differentiated.

However, different innovation strategies are investigated by Puga and Trefler (2010), where a buyer located in a northern technologically advanced country decides where to buy a component needed from among several developing countries differing in labor costs and technological levels, and whether or not to involve the supplier in the innovation process. In that paper, suppliers are heterogeneous in the “residual incompatibilities” they would generate for the buyer if they were to carry out the innovation activity, and the firms considered are involved in medium- to long-term relationships. Our paper makes extensive use of the analysis of the innovation process carried out by Puga and Trefler (2010); however, by abstracting countries’ differences in terms of the level of development, we depart from their work in two main directions. First, we focus on firm heterogeneity in the product characteristics space, highlighting how differences in firms’ locations in the product space induce different innovation and internationalization strategies, thus encompassing the case in which the supplier, too, might incur adaptation costs that are related to distance in the product space. Second, we also consider short-term relationships where temporary trade may emerge (i.e. when the relationship breaks down). Our model therefore incorporates another stylized fact recently highlighted by the empirical literature: the existence of temporary trade (Békés and Muraközy, 2012). In this context, suppliers may be engaged in a temporary match with foreign buyers; this match may break down later, as buyers may realize that the input is not appropriate for the production of their products, i.e. it would require excessive adaptation. So, a key factor is considered in our model, namely uncertainty in terms of the features of the intermediate good provided by the foreign supplier (and in terms of the related adaptation costs). Our work provides a potential interpretation of the existence of temporary trade relationships, and it is related to research stressing that asymmetric information and incomplete contracts emerge when the attributes or the reliability of the trading partner cannot be easily observed (Rauch and Watson, 2003; Besedes and Prusa, 2006; Aeberhardt et al., 2014; Araujo et al., 2016; Békés and Muraközy, 2012). This approach helps explain the initially small and then growing export values, the low survival rates of many export activities, and the positive relationship between the quality of institutions in the destination countries and the survival of export flows in the context of contractual incompleteness.

We depart from the existing contributions in the international trade literature on heterogeneous firms, which have endogenized firms’ decisions to invest in R&D to enhance either the quality of their goods (Costantini and Melitz, 2007; Atkeson and Burstein, 2010; Bustos, 2011), the number of product varieties in multiproduct firms (Bernard et al., 2011), or both (Eckel et al., 2015). Indeed, this previous literature

mainly emphasizes the asymmetries among the products on the final demand side, while product innovation induced by interactions between the needs of firms and buyers, as far as we know, has not yet been addressed. Since, in our work, we do not investigate the determinants of firms’ boundaries, we depart from the global sourcing literature that focuses on the determinants of firms’ offshoring modes (i.e. the “make or buy” decision: vertical integration vs. outsourcing to a foreign country) and looks in particular at either the role of international property rights protection in the destination countries (Glass and Wu, 2007) or the technological content of the goods (Acemoglu et al., 2010), or both (Naghavi et al., 2015).

Nevertheless, our model is related to these papers, because it focuses on what we call the “innovation boundaries,” and we deal with the issue of which of the two partners adapts the intermediate good.<sup>11</sup>

#### 4. A model of exporting and innovation when trade is in intermediate inputs

We have built a theoretical model along the lines of the literature considering incomplete contracts, agency frictions, and imperfect information in international trade related to the provision of specialized inputs (Rauch and Trinidad, 2003; Grossman and Helpman, 2005; Puga and Trefler, 2010). In our model, firms are heterogeneous in their product characteristics (i.e. location in the product characteristics space) and are involved in a PTO relationship. Like Araujo et al. (2016), we abstract from firm heterogeneity in terms of productivity, since we focus on a different mechanism based on the heterogeneity of firms’ products.

Our theoretical model explains why a product innovation premium related to producing to order for foreign customers could be observed, and what variables might strengthen or weaken such a positive association. We develop a partial equilibrium model with two identical countries (i.e. neither the income nor the level of technology differ, although the type of technology may be different) — except for (possibly) the number of suppliers and buyers — where, in order to produce, buyers and suppliers have to match.

##### 4.1. The need for new intermediate inputs

Firms can generally be involved in two types of innovation activity. The first type is the outcome of an R&D investment autonomously carried out by a firm: the “invention” of a new final good. This process generates an order for the second type (or step) of innovation activity, concerning a specialized intermediate good, which is our specific focus. The latter is a process through which a new product or a substantial

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<sup>11</sup> Innovation costs are an important consideration in the previous literature, as in our work, that analyzes the determinants of whether or not a firm will engage in RD activities offshore, particularly for firms with a multinational structure (Sanna-Randaccio and Veugelers, 2007). In addition to the fact that these previous works were developed in an oligopoly framework and deal with vertically integrated firms, we depart from them in the role we assign to firm heterogeneity in product characteristics.

change/improvement in an existing one is made. These are likely to be “incremental innovations,” i.e. those changes that firms develop in their products in their day-to-day activities.

In this paper, we do not analyze the first type of innovation, i.e. we are interested in neither the process of entry nor the (always possible) strategy for both a downstream firm and an upstream firm to invest in R&D in order to change its location on the product characteristics circle after entering or adding products (i.e. multiproduct firms). We are interested in identifying how a buyer’s needs may induce product innovation by a supplier (i.e. by inducing the supplier to adapt and specialize its good to match the buyer’s needs).<sup>12</sup>

In our setting, there are two types of agents engaged in production: upstream producers (i.e. the supplier) and downstream producers (i.e. the buyer), which purchase an input from the upstream producers. We have developed a model for analyzing the alternative innovation strategies adopted by firms, while taking as given their boundaries, i.e. we abstract from the “make or buy” decision.

Buyers and suppliers are distributed over the product characteristics unit circle according to their “core production”. For a new final good to be produced by the buyer, the buyer has to match with the supplier and some adaptation of the “core product” (incremental innovation) is needed, the amount of which depends on the distance between the characteristics of the buyer’s needs and the supplier’s core production.<sup>13</sup> The buyer can search for a suitable supplier either in the domestic market or abroad. For  $Z_{ij}$ , the first and the second subscripts refer to the country in which the buyer and supplier are located, respectively,<sup>14</sup> and this is the distance along the product circle between the buyer’s “needs” and the characteristics of the supplier’s good.  $Z_{ii}$  and  $Z_{jj}$  are the distances between the buyer and the supplier in a domestic match (D), in the buyer’s and the supplier’s countries, respectively; and  $Z_{ij}$  is the distance between buyer and supplier in an international match (I).  $Z_{ii} \sim U(0, 1/(2X_i))$ , and  $Z_{ij}, Z_{jj} \sim U(0, 1/(2X_j))$ , where  $X_i, X_j$  are the number of suppliers in the buyer’s and the supplier’s countries, respectively. Information about  $Z_{ij}$  is imperfect (symmetrically) before matching (see the section on timing below).

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<sup>12</sup> Both buyers and suppliers can engage in the first type of innovations: buyers invent a new product for the final market and suppliers invent a new core line, which is essential if they are to enter the (domestic) market. On the other hand, the production of a new final good always involves a supplier-specific input, which may or may not already exist in the market. So, the introduction of a new final good by a downstream firm (i.e. the first type of innovation activity by the buyer) may generate changes in an existing intermediate good.

<sup>13</sup>Our model does not consider multiple matches. In modelling a one-to-one relationship between the buyer and the supplier for the provision of a specialized input, we follow Casella and Rauch (2003) and Rauch and Trinidad (2003). The perception is that the relationship that we model is “firm-product” specific rather than “firm” specific. In other words, we are not assuming that a supplier serves only one buyer, but that the supplier does not provide the same specialized input to several buyers.

<sup>14</sup>This applies to all variables with a double subscript, unless stated differently.

## 4.2. Innovation strategies and costs

Adaptation can take place through two different innovation regimes: buyers can either purchase the intermediate good “as is” and then adapt it, or they can give suppliers a “project” (i.e. assistance) according to which the input must be adapted, with buyers bearing the related costs. In the case of a match, i.e. when the distance in the product space is not too large, a cooperative relationship starts, where buyers and suppliers exchange information. On the one hand, suppliers often collaborate with buyers’ product designers and may play a crucial role in developing new products, by cutting costs and improving quality; on the other hand, knowledge may be transferred to suppliers in a variety of forms, such as worker training or specific lessons on product details (Egan and Mody, 1992). This form of cooperation requires the bearing of some costs, even by actors that are not directly responsible for the implementation of the innovation (some costs are related to the distance in needs, i.e. “implementation costs,” while others are related to providing instructions and assistance). Implementing the innovation by means of the supplier following the buyer’s specifications is likely to be more costly when the new intermediate good to be produced is more distant from what is already being produced, i.e. from the “core competency.” So, in our framework, depending on this distance in the product characteristics space, the buyer may ask the supplier to adapt its good following specific instructions or the buyer can directly manage the adaptation process, assisted by the supplier. The first strategy is consistent with the fact that firms often find a suitable solution for their specific needs by themselves and then develop the product design; they often transfer their innovations (design or product), e.g. process equipment, to suppliers in order to obtain a source of supply for their innovation that is cheaper than in-house production. The second strategy is consistent with several studies reporting that firms modify the components produced by suppliers in-house to make them suitable for their own processes (see the work of Gault and von Hippel, 2009; de Jong and von Hippel, 2009, and the review of the literature included in their studies).

As a consequence of the successful introduction of a new final good by a buyer, there are therefore two alternative strategies from which the buyer can choose:

- *Buyer implementation (BI) strategy*: buyer B buys an existing good from supplier S, and adapts either its process or the good acquired from S to meet its needs, by bearing a distance-related fixed cost,  $b^{B_{ii}} Z_{ii}$  in a domestic match and  $b^{B_{ij}} Z_{ij}$  in an international match, where  $b^{B_{ii}}$  and  $b^{B_{ij}}$  are innovation costs per unit distance in the product space, domestically and abroad, respectively; in this case, S has to help B to adapt the input, by bearing a fixed cost,  $F_{ii}^S$  or  $F_{ij}^S$ , in a domestic match or in a foreign match, respectively (e.g. the cost of technical assistance);

- *Supplier innovation (SI) strategy*: buyer B bears a fixed cost,  $F_{ii}^B$  or  $F_{ij}^B$  in a domestic match or in a foreign match, respectively, to determine what input is needed to produce its good and to ask supplier S to produce it, i.e. this fixed cost is the cost related to providing the instructions for the design of the input to S. In this case, S bears the distance-related fixed cost,  $b^{S_{ii}} Z_{ii}$  in a domestic match and  $b^{S_{ij}} Z_{ij}$  in an international match, where  $b^{S_{ii}}$  and  $b^{S_{ij}}$  are innovation costs per unit distance in the product space, domestically and abroad, respectively. The concept is similar to that of “black box systems,” where the supplier of the intermediate good executes a detailed design of a component based on specifications provided by the buyer (Bidault et al., 1998), which, however, may assist the supplier through in-plant worker training or specific lessons on product details.

We assume that the cost to supplier S in relation to assisting buyer B in the BI strategy and the cost to buyer B in relation to providing a project for S in the SI strategy are the same, i.e.  $F^{B_{ii}} = F^{S_{ii}} = F^{B_{jj}} = F^{S_{jj}} = F^D$  and  $F^{B_{ij}} = F^{S_{ij}} = F^I$  in domestic and foreign matches, respectively. These costs may be dependent on, for instance, the language spoken in countries  $i$  and  $j$ . The costs of providing information in the native (domestic) language, which is also spoken by the supplier in a domestic match, will be the same irrespective of the countries in which the buyer and the supplier are located. The second assumption implies that the cost of B being located in  $i$  in relation to providing a project in the language of  $j$  is the same as the cost of S being located in  $j$  in relation to providing assistance in the language of  $i$  (i.e. the costs are symmetric). We assume in what follows that  $F^D \leq F^I$ , since the contrary would not be reasonable.

The BI and SI strategies are modeled following the insights provided by the business literature mentioned in the introduction and along the lines of Grossman and Helpman (2005) and Puga and Trefler (2010) for the SI strategy, and Hesley and Strange (2002) for the BI strategy.<sup>15</sup>

It is worth noting that only the SI strategy translates into product innovation from the supplier’s point of view (by “product” we refer to the output produced by the supplier), since the intermediate input sold by the upstream firm is modified or improved by the supplier. The BI strategy does not translate into product innovation from the point of view of the supplier.<sup>16</sup>

There are other costs that firms have to bear:

- a *search cost*:  $\eta$  (sunk cost); buyer B bears this cost when searching for a partner in the *foreign* market;

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<sup>15</sup>Hesley and Strange (2002) investigate the role of space and proximity in the innovation process where input sharing encourages innovation by reducing the cost of realizing ideas for firms, and where the buyer makes a decision on whether to buy existing inputs at lower costs or new inputs that better match its needs at higher costs. However, their model does not compare international and domestic matches.

<sup>16</sup>In the empirical analysis, we report evidence on product innovation by suppliers, but we do not have information on PTO buyers.

- a *per-period fixed internationalization cost*:  $\gamma_{int}$ , the sum of the costs that buyer B and supplier S have to bear when the firms building the relationship are located in different countries.

The role of the sunk search costs of internationalization ( $\eta$ ), i.e. in our framework, the cost of looking for a foreign partner, has been widely analyzed in the recent literature on global sourcing (Antràs and Helpman, 2004; Grossman and Helpman, 2005). The per-period internationalization cost  $\gamma_{int}$  is a collection of costs: the costs of insurance vs. exchange rate fluctuations, “bureaucratic” costs (e.g. the costs of obtaining permissions and documents from foreign public offices), the costs of managing operations, and the costs of exchanging information between different countries.

### 4.3. Timing

The timing of the model is displayed in Figure 1. The buyers and suppliers are initially involved in a domestic match; they are producing, respectively, a final good and a customized intermediate good (here we consider “innovation” by existing firms).<sup>17</sup> We assume that the buyer knows the actual distribution of the domestic suppliers and that the buyer is matched with the closest one (see Grossman and Helpman, 2005). The buyer introduces an innovation into its product, one requiring a new specific input (or adaptation of the one currently used).<sup>18</sup> Since the buyer knows the actual distribution of suppliers in its own domestic market, the buyer also knows the location of the closest supplier in the product characteristics space for the new input it needs; therefore, the buyer decides whether to match and produce with the closest supplier in the domestic market or look for a new supplier abroad. Since we are focusing on PTO relationships, we assume that the downstream producer, the buyer, is the one searching abroad for a “better” input.<sup>19</sup> Therefore, in our framework, the sunk cost of searching in the foreign market is borne by the buyer.<sup>20</sup>

Buyer B has imperfect information about the location of suppliers abroad: B only knows the number of suppliers and that they are symmetrically spaced in the product characteristics circle; so, when searching in the foreign market, B knows that it will match with a supplier at a random distance  $Z_{ij} \sim U(0, 1/(2X_j))$ . Buyers that go abroad pay a sunk cost to randomly match with one, and only one, foreign supplier S (Casella

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<sup>17</sup>Suppliers may serve multiple buyers. Our theoretical analysis refers to the buyer-supplier relationships related to a specialized input, and highlights under what conditions the buyers or the suppliers are more likely to modify that input. In the empirical analysis in the first part of the paper, however, we only have data on suppliers’ average behavior, which may be the result of multiple buyer-supplier relationships.

<sup>18</sup>The buyer may want to introduce a new good because of changes in demand conditions or in the competitive environment; it is beyond the scope of this paper to analyze the determinants of the buyer’s decision.

<sup>19</sup>Grossman and Helpman (2005) and Puga and Trefler (2010) also assume that the buyer is the one searching abroad.

<sup>20</sup>There are several reasons why the buyer may want to look for a new supplier abroad, as pointed out by Egan and Mody (1992). The buyer may want to preserve credibility in negotiating prices and/or to protect against a supplier’s non-performance; the buyer may be looking for a new supplier for either current or future needs foreseen. In this paper, we are interested in the case in which the buyer may be willing to introduce an innovation into its product, and therefore the buyer needs a new specific input.

and Rauch, 2003). In this first meeting, B and S exchange S’s existing good, and neither B nor S innovate. We assume that adaptation requires time and knowledge of each other’s characteristics (i.e.  $Z_{ij}$ ). This is the reason why they engage in this “first meeting. This is consistent with the evidence in Egan and Mody (1992). First, a relationship often begins with a short-term agreement between the buyer and the supplier through which they find out about each other’s demands and capabilities. The authors of this paper report, for instance, how “no matter how careful the selection process, the real test of a buyer’s decision comes when the buyer and the supplier are working together. For this reason, buyers tend to remain cautious after the final selection. For example, buyers often begin with small orders, perhaps for a simple product, and let the relationship build gradually” (p. 330). We will refer to this feature as “starting small” (see, among others, the contribution of Rauch and Watson, 2003): the buyer may want to buy the intermediate good provided by the supplier as it is, before starting a permanent relationship and asking for substantial modifications of it.

In our framework, “trying the good is necessary to reveal information about the location in the foreign product space (i.e. on the relative distance between a buyer’s needs and a supplier’s characteristics). The buyer does not know the characteristics of foreign inputs, and a successful match requires a first meeting in which suppliers sell their existing intermediate goods. Through this test (“start small), the buyer finds out about the characteristics of the product, i.e. the distance between the required intermediate good and the good provided by the foreign supplier. If the distance is too large in the foreign match, however, the first meeting will not lead to a successful match; the buyer that was looking for a partner in the foreign market will return home to continue searching for a suitable supplier in the domestic market. In such a case, firms will be involved in only temporary trade. There is indeed increasing evidence that export values are usually small when a firm enters a new market, that the export flows have a very short duration (of one or two years) with few surviving for long periods (Lawless, 2009), and that a high percentage of firm–product destinations are temporary (Békés and Muraközy, 2012). In our framework, temporary trade is generated by the supplier’s intermediate goods being bought by a foreign buyer with the purpose of testing the goods and the business relationship breaking down because the intermediate good supplied is too distant from the buyer’s needs.

The first match reveals  $Z_{ij}$ , the distance between buyer B and the randomly matched supplier S. By exchanging the existing good (i.e. from S’s point of view, by exporting in  $t_0$ ), B and S will learn about each other and B can decide whether or not to maintain the international match and, if continuing with the relationship, can choose which type of innovation strategy to adopt (i.e. either SI or BI). Only one

attempt at an international match is allowed under our framework; we assume that the costs of searching again for an international match are too high to be borne a second time. We allow firms ending up in an unsuccessful international match, i.e. a match where the distance is too large, to then match with a (possibly new) domestic partner.<sup>21</sup> The evidence suggests that firms may match in a first meeting without carrying out innovation, in order to find out about each other and decide whether or not it is worth matching internationally in a permanent way and how to do it. Not allowing for the possibility that the buyer may return home if an international match is unsuccessful would be at odds with the empirical evidence on the prevalence of temporary trade. In analogy with the job search literature, we assume that the knowledge of the exact location of suppliers in the domestic market at  $t_1$  is imperfect for buyers that went abroad to match in  $t_0$  (i.e. there is no recall of suppliers' locations), since the closest supplier, identified by the buyer in  $t_0$  before deciding to search abroad, might no longer be available. The supplier could have matched with another buyer that did not search abroad and may therefore no longer have the required productive capacity.<sup>22</sup>

Buyers that find it inconvenient to search abroad can match with the closest supplier under the BI or the SI strategy, in  $t_0$ , and continue the relationship in  $t_1$ .

To summarize, international buyer-supplier matches differ from domestic ones for the following reasons:

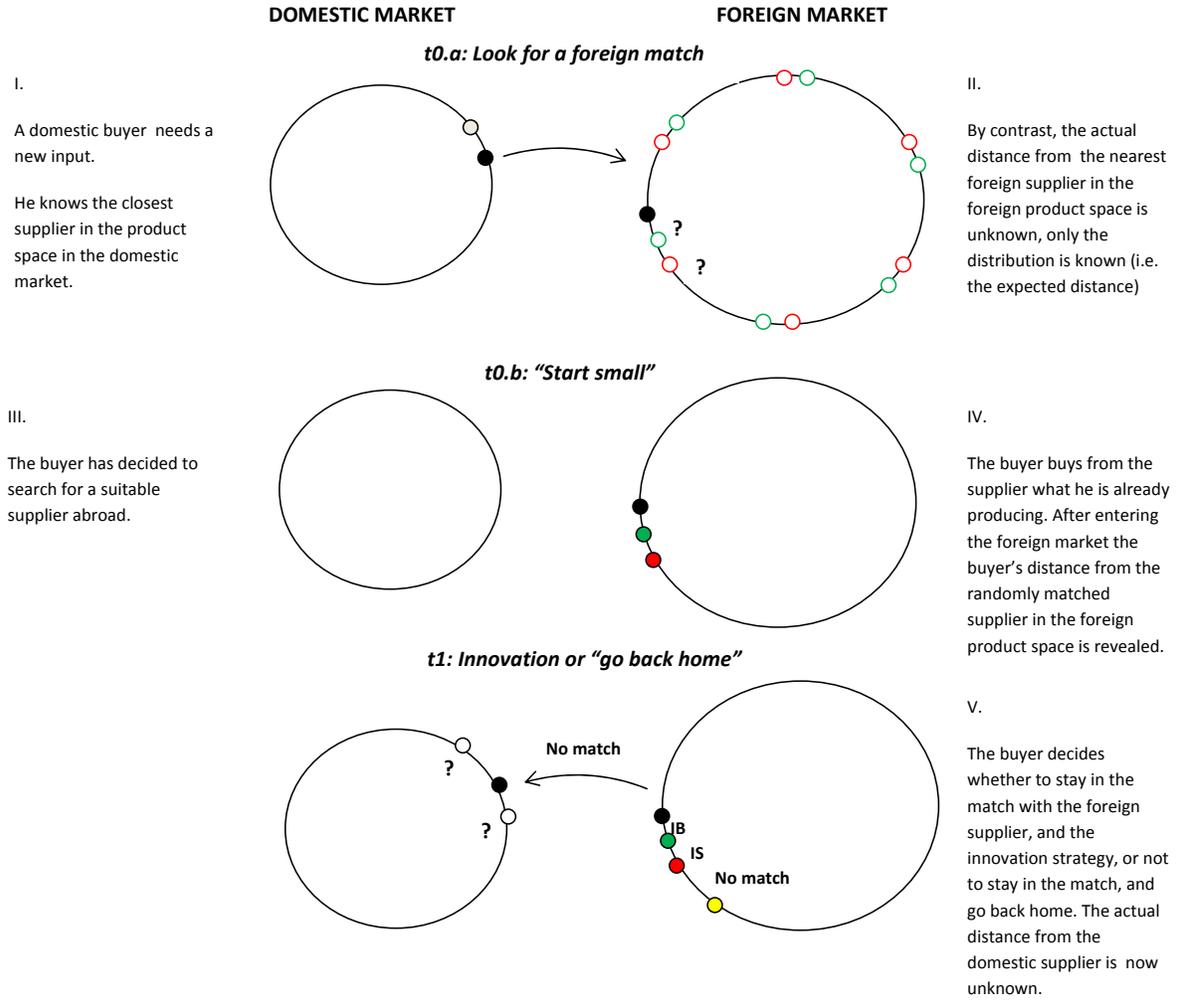
- (i) imperfect information about the location of suppliers in the foreign market. Buyer B initially knows the locations of all suppliers in its country and matches with the “closest supplier; B does not know the location of the suppliers in the foreign country, it only knows that suppliers are symmetrically distributed at the same distance under  $Z_{ij} \sim U(0, 1/(2X_j))$ ; they may be located at different points along the circle. A better match is potentially possible abroad, but this will only be known after “trying. Sunk search costs have to be borne by B in determining the distance  $Z_{ij}$  through a random match with only one foreign supplier. These costs are a determinant of B's decision to look for an international match.
- (ii) in international matches, firms ending up in an unsuccessful match can still return home and match domestically, while, in domestic matches, unsuccessful matches necessarily imply that the new good

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<sup>21</sup>By assuming that firms can return to the domestic market after one random match we follow [Casella and Rauch \(2003\)](#) and [Rauch and Trinidad \(2003\)](#), rather than [Puga and Trefler \(2010\)](#), where firms have to remain in the match. In [Appendix A.5](#), we show that our results are robust even if it is assumed that firms engaging in an unsuccessful match abroad cannot return home and therefore have no other options, as it happens in an unsuccessful match. In our framework, this assumption reduces the complexity of the results without adding realism.

<sup>22</sup>This implies that the exact location of suppliers in the domestic market becomes unknown after having been abroad, while buyers continue to know their distribution function.

Figure 1: Timing of the model



cannot be produced and that there will be zero profit for both the buyer and the supplier, since the information is perfect and the “closest” supplier (in the product space) is known: if the latter is too far from the buyer in the product space, no better match can be found.

- (iii) international matches imply an additional cost, comprising a per-period fixed internationalization cost, and innovation costs may differ across countries.

#### 4.4. Contract

Given that firms are involved in PTO relationships, we assume that the buyer is the “principal” in the business relationship (see also [Puga and Trefler, 2010](#)).<sup>23</sup> The relationship between buyer B and supplier S could conceptually be divided into two different stages. The first relates to the adaptation process, in which B and S bear the costs related to the adaptation of the input, i.e. the fixed cost borne by B (or S) in the SI (or BI) strategy and the distance-related cost borne by S (or B) in the SI (or BI) strategy. Once these costs are borne, the input is suitable for producing the new final good. In the second stage, S will produce the input, sell it to B, which in turn uses it to produce the final good, which is sold on the market to generate profits. The second stage can be regulated by a fully enforceable contract. The former cannot, since in both the BI and the SI strategies such a contract relates to types of investment that, in the literature, are called “relationship specific investments” (see, in particular, in a similar framework [Grossman and Helpman, 2005](#); [Antràs and Helpman, 2004](#); [Puga and Trefler, 2010](#)). The setting is one of incomplete contracts. We assume that firms cannot sign ex ante enforceable contracts specifying the innovation activity. Even if  $Z_{ij}$  is already revealed when the strategy is decided, because of the particular characteristics of the innovation activity, the contract cannot be contingent on  $Z_{ij}$ . The innovation activity is hardly verifiable by an external court and firms cannot commit to not renegotiating profit after the innovation costs are borne because the characteristics of the innovation activity (i.e. the quality of the technical assistance, the details of the project, and the implementation) are revealed only after the investment is sunk ([Grossman and Hart, 1986](#); [Hart and Moore, 1999](#)).<sup>24</sup> Since firms’ boundaries are given, the modified input is useless outside the relationship between the buyer and supplier. This framework generates a hold-up problem with potential underinvestment (or no investment in our case).

Since it would be too costly to sign an ex ante contract specifying all the “states of the world”, agents will get involved in a relationship if they expect to profit from it (such profit will be generated by selling the

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<sup>23</sup>This amounts to say that we do not model the decision on who should decide the innovation strategy.

<sup>24</sup>In contrast, the innovation activity is observable ex post by the buyer and the supplier symmetrically.

final good) after the input has been modified. In this ex post bargaining, we assume that the buyer and the supplier have the same bargaining power, and that they will split the profits according to a Nash bargaining sharing rule.

Both in domestic and in international matches, buyer B initially offers a contract to supplier S, which could be under either the SI or the BI strategy, depending on which maximizes B's profit under S's participation constraint (PC). When B chooses the strategy,  $Z_{ii}$  and  $Z_{ij}$ , the distances in a domestic and an international match, respectively, are known. After a decision is made, the innovation costs are borne individually by B and S, depending on the strategy. Under the SI strategy, B provides a project to S by bearing the fixed cost and S produces a prototype of the intermediate input following the order described in the project by bearing the distance-related costs. Under the BI strategy, S provides a sample of the intermediate input to B, together with the required technical assistance (bearing the fixed cost), and B learns how to make the input fit its production process, bearing the distance-related costs. The participation of B and S, and therefore their investment efforts, will depend on the size of the expected profit, the shares of the profit they receive, and the innovation costs.

Once the sunk costs of adapting the input are borne, having matched either domestically or internationally, B and S bargain over the operating profit  $\Pi$  that will possibly be generated from selling the final good to the market. In an unsuccessful match, the operating profit is  $\Pi = 0$ , since the new good is not produced, while in a good match, the profit is  $\Pi_{ij} = \Pi_{ji} = \Pi_{ii} = \Pi_{jj} = \Pi$  (the two countries have the same wages and prices, and therefore B's innovation provides the same profit).

At this stage the contract is signed, and S produces and sells to B the intermediate input at a competitive price.<sup>25</sup> It is worth noting that in order to produce, both partners have to contribute (since we take as given the boundaries of the firm). It would not be convenient for S to charge B a higher price, since B and S are involved in a production relationship and their incentives to maximize profits are aligned at this stage. B produces the new final good, the profit is realized, and all payments are made according to the strategy implemented. The contract specifies what the payment will be, contingent on production taking place, and the type of innovation strategy.

We assume that B and S have the same bargaining power at the stage the contract is signed in both innovation strategies.<sup>26</sup> Nevertheless, although in the domestic matches B and S equally split the "pie," the

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<sup>25</sup>Note that at this stage S's only costs are those of materially producing the input, since the innovation costs have already been borne.

<sup>26</sup>For the sake of space and simplicity, results for the generalization of the model where a parameter  $\beta$  governs the bargaining power distribution between B and S are available on request. A sufficient condition for all the theoretical results of the paper

share of the profit may differ in the international matches, since, in this case, B and S have the option to return home and look for a partner in their own countries. This will depend on the expected profit from domestic matches. For this reason, on the one hand, the parties negotiate a smaller profit in international matches, and, on the other hand, either B or S may get a larger share of the profit. It is worth noting that the outside options symmetrically affect what B and S receive in international matches under both BI and SI strategies. Therefore, choosing a certain strategy does not imply choosing a different distribution of the profit.

No bargaining takes place in the first exchange of the existing good ( $t_0$ ) in the international matches: B gets  $\Pi_{fm}$ , the operating profit from selling the new input directly, where  $fm$  stands for “first meeting”.

#### 4.5. Equilibrium

We express the unit distance-related cost of adapting the good for B in terms of the cost to S and we allow this to be different in international and domestic matches, in particular,  $b^{Bjj} = \alpha^D b^{Sjj}$ ,  $b^{Bii} = \alpha^D b^{Sii}$ , and  $b^{Bij} = \alpha^I b^{Sij}$ , where  $\alpha$ 's are the B to S cost ratios. The cost for B to adapt its process or final product to a foreign intermediate good will probably be different from (and most probably higher than) the cost to a domestic supplier of the same adaptation. Indeed, a buyer, which is already matched with a domestic supplier, is likely to be “less familiar” with a foreign supplier’s intermediate good.<sup>27</sup> Moreover, different countries, even if similarly developed, may have technical incompatibilities that need to be addressed.<sup>28</sup>

In what follows, we present the results under the assumption that both  $\alpha^D \geq 1$  and  $\alpha^I \geq 1$ : the cost of adapting for buyer B is at least as high as the cost of adapting for supplier S for a given distance  $Z$  in the product space. It is reasonable to assume that it is more costly for B to adapt the purchased input (for any given distance) than for S to modify its own good following an order by B. Table 3 summarizes the definitions of the variables and the parameters.

The model is solved by backward induction.

##### 4.5.1. Buyer’s decision on the innovation strategy in domestic matches (D)

Payments are derived through an ex post division of the surplus determined by the Nash bargaining solution, in this way obtaining:  $\pi_{iB}^{BI,D} = \frac{\Pi}{2} - \alpha^D b^{Sii} Z_{ii}$  and  $\pi_{iS}^{BI,D} = \frac{\Pi}{2} - F^D$ , which are the net total profits

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to be robust to considering a different bargaining power for B and S is that the former’s bargaining power is not smaller than the latter’s.

<sup>27</sup>This assumption is in line with [Puga and Trefler \(2010\)](#), in a slightly different framework.

<sup>28</sup>For instance, cars sold in the United States are larger than those sold in Italy; a US producer may find a components’ producer in Italy that produces exactly what they need for their new car model, but since the Italian components are designed for smaller cars, this would imply a higher per-unit distance cost of adapting the component to the buyer’s production process, which is designed for larger cars.

Table 3: Legend of variables and parameters

variable/parameter	definition
$Z_{ii}$	distance between B and S in domestic matches for B
$Z_{jj}$	distance between B and S in domestic matches for S
$Z_{ij}$	distance between B and S in international matches
$b^{B_{jj}}, b^{B_{ii}}$	cost of adapting per unit distance for B in domestic matches
$b^{B_{ij}}$	cost of adapting per unit distance for B in international matches
$b^{S_{jj}}, b^{S_{ii}}$	cost of adapting per unit distance for S in domestic matches
$b^{S_{ij}}$	cost of adapting per unit distance for S in international matches
$F_{ij}^B$	B's cost of providing a "project" to S in foreign matches
$F_{ij}^S$	S's cost of assisting B in foreign matches
$F_{ii}^B$	B's cost of providing a "project" to S in domestic matches
$F_{ii}^S$	S's cost of assisting B in domestic matches
$\alpha^D$	ratio between costs in domestic matches ( $b^{B_{jj}}/b^{S_{jj}}$ )
$\alpha^I$	ratio between costs in international matches ( $b^{B_{ij}}/b^{S_{ij}}$ )
$\gamma^{int}$	sum of B's and S's costs of internationalization
$\eta$	B's search cost
<i>assumptions/further definitions</i>	
$b^{B_{jj}} = (\alpha^D)b^{S_{jj}}, b^{B_{ii}} = (\alpha^D)b^{S_{ii}}$	
$b^{B_{ij}} = (\alpha^I)b^{S_{ij}}$	
$F_{ij}^B = F_{ij}^S = F^I$	fixed costs of assistance in international matches are the same for B and S
$F_{ii}^B = F_{ii}^S = F^D$	fixed costs of assistance in domestic matches are the same for B and S
$F^D \leq F^I$	fixed costs of assistance are not larger in domestic than in international matches

Note. B and S stand for buyer and supplier, respectively. The first variables' subscript refers to the country of B, and the second to the country of S.

under BI received by B and S, respectively, located in a domestic match in country  $i$ ; and  $\pi_{iB}^{SI,D} = \frac{\Pi}{2} - F^D$  and  $\pi_{iS}^{SI,D} = \frac{\Pi}{2} - b^{Sii} Z_{ii}$ , which are the net total profits received by B and S, respectively, in a domestic match in country  $i$  under SI; and where  $\Pi$  is the total operational profit (see [Appendix A.1](#)). In our framework, B chooses between the BI and the SI strategies based on whichever one yields the highest operational profit net of the innovation costs under S's PC.

**Lemma 1.** *In domestic matches: (i) BI is implemented for shorter distances in the product space; (ii) SI is implemented for intermediate distances; and (iii) no match takes place if the distance is too great.*

**Proof.** The solution to B's decision problem allows us to identify the intervals of distance in the product space, where either the BI or the SI strategy is implemented, or where no match takes place. The thresholds delimiting the intervals are:

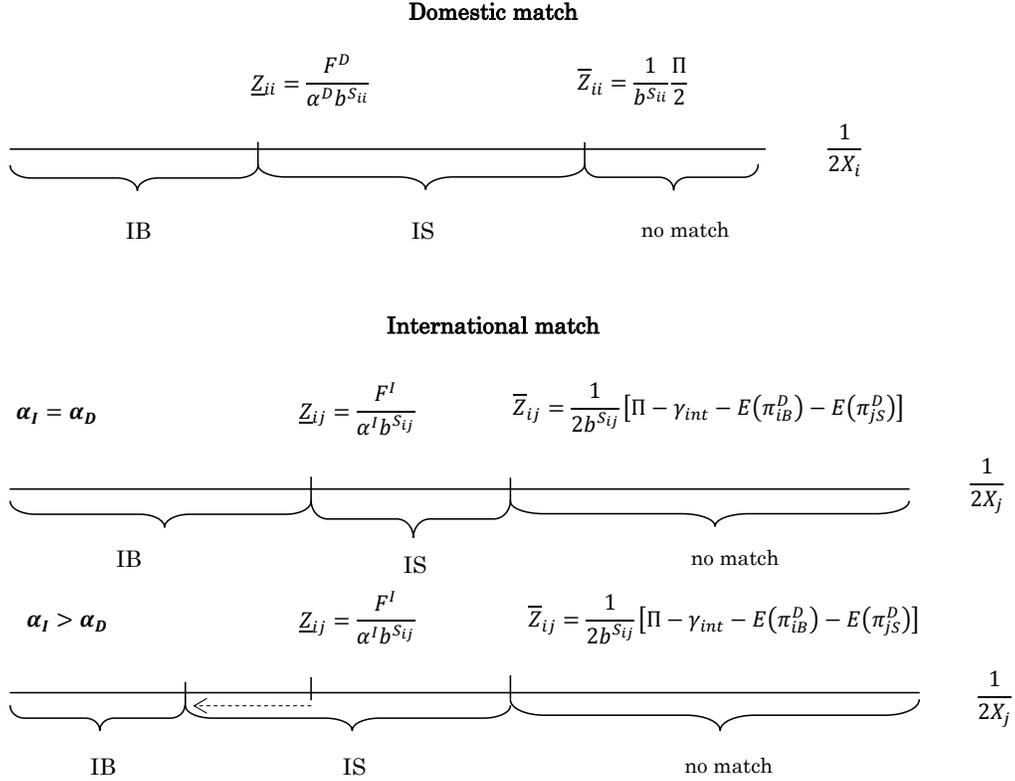
$$\underline{Z}_{ii} = \frac{F^D}{\alpha^D b^{Sii}} \quad (6)$$

$$\bar{Z}_{ii} = \frac{1}{b^{Sii}} \left( \frac{\Pi}{2} \right). \quad (7)$$

Whenever  $Z_{ii} \in [0, \underline{Z}_{ii}]$ , the BI strategy is implemented in a domestic match, but whenever  $Z_{ii} \in (\underline{Z}_{ii}, \bar{Z}_{ii}]$ , the SI strategy is implemented. If instead  $Z_{ii} \in (\bar{Z}_{ii}, \frac{1}{2X_i}]$ , with  $X_i$  being the number of suppliers in B's domestic market, no match takes place (See [Appendix A.1](#) for the derivations). ■

This outcome is the consequence of the Nash bargaining solution and the fact that the two strategies differ in terms of who bears the distance-related costs and who bears the fixed costs. Since B is the “principal”, making decisions in order to maximize the profit under S's PC, for relatively short distances it is more convenient for B to buy the input as it is and bear the distance-related costs associated with introducing it to the production process, since the distance-related cost of innovation is smaller than the cost of providing a project to S, and vice versa for larger distances. When the distance is too great, and the costs are too high, the match fails. In this last case, the new final good is not introduced by B. The top part of [Figure 2](#) shows the intervals in the product space in domestic matches where the different innovation strategies are implemented.

Figure 2: Strategies' intervals



We consider the ratio of the no-match interval to the match interval (where either the BI or the SI strategy is implemented) to assess what affects the likelihood of a successful match.

**Corollary 2.** *The no-match outcome in domestic markets is more likely: the lower the expected profit generated by selling the new final good ( $\Pi$ ), the higher the per-unit distance cost of adapting the input for the supplier in a domestic match ( $b^{S_{ii}}$ ), and the lower the number of suppliers ( $X_i$ ) in the buyer's country.*

**Proof.** See the proof in [Appendix A.1](#). ■

The lower the expected profit, the lower the incentive to match; (i) the lower the number of suppliers in the buyer's country, (ii) the larger the distance in needs, (iii) the higher the innovation costs, and therefore the profitability of a match, (iv) the higher the per-unit distance cost of adapting the input for the supplier, the lower the likelihood that the supplier will agree to modify the input.

It is worth noting that it follows that economies with a larger number of specialized suppliers, and where suppliers have more “flexible” production processes, i.e. lower costs of adapting the goods they produce,

more frequently experience successful matches, and therefore are more likely to introduce new final goods.

#### 4.5.2. Buyer's decision on the innovation strategy in international matches (I)

As discussed above, when a buyer and a supplier end up in a “bad” international match, they can always return home and look for a (possibly new) partner in the domestic market. After the intermediate period in which they are involved in the international match, information about the exact locations of the domestic suppliers and buyers, for the buyer and the supplier, respectively, is imperfect. Therefore, the outside options in an international match are the expected profits of the domestic matches ( $OUT_{vk}^I = E(\pi_{vk}^D)$ , where  $v = i, j$  and  $k = S, B$ ).<sup>29</sup>

These outside options, which are derived by solving the expressions in (A.13) and in (A.14) in Appendix A.2, read as:

$$E(\pi_{iB}^D) = \frac{X_i}{b_{Sii}} \left[ \frac{(F^D)^2}{\alpha^D} + \Pi \left( \frac{\Pi}{2} - F^D \right) \right] \quad (8)$$

and

$$E(\pi_{jS}^D) = \frac{X_j}{b_{Sjj}} \left[ \left( \frac{\Pi}{2} \right)^2 + \frac{(F^D)^2}{\alpha^D} \left( \frac{1}{\alpha^D} - 2 \right) \right]. \quad (9)$$

Payments derive from an ex post division of the surplus determined by the Nash bargaining solution, with this giving:

$$\pi_B^{BI,I} = \frac{1}{2} [\Pi - \gamma_{int} - E(\pi_{iB}^D) - E(\pi_{jS}^D)] + E(\pi_{iB}^D) - \alpha^I b^{Sij} Z_{ij},$$

and

$$\pi_S^{BI,I} = \frac{1}{2} [\Pi - \gamma_{int} - E(\pi_{iB}^D) - E(\pi_{jS}^D)] + E(\pi_{jS}^D) - F^I,$$

i.e. the net total profit received by buyer B and supplier S, respectively, in an international match under BI, and

$$\pi_B^{SI,I} = \frac{1}{2} [\Pi - \gamma_{int} - E(\pi_{iB}^D) - E(\pi_{jS}^D)] + E(\pi_{iB}^D) - F^I,$$

and

$$\pi_S^{SI,I} = \frac{1}{2} [\Pi - \gamma_{int} - E(\pi_{iB}^D) - E(\pi_{jS}^D)] + E(\pi_{jS}^D) - b^{Sij} Z_{ij},$$

i.e. the net total profit received by B and S, respectively, in an international match under SI (see Appendix A.2).<sup>30</sup>

<sup>29</sup>See Appendix A.5 for the results under the alternative assumption that the buyer cannot return home, i.e.  $OUT_{vk}^I = 0$ , where  $v = i, j$  and  $k = B, S$ .

<sup>30</sup>We omit subscripts indicating the country of the match in the cases of payoffs in international matches, since they are always  $ij$ , with the country of the international match being the one in which S is located.

Only after  $Z_{ij}$  is revealed, a buyer that has decided to look for a better match (i.e. a closer supplier) in the international market either will decide to stay in the randomly drawn match, and will choose the most appropriate innovation strategy, or will return to the domestic market. B chooses the strategy that yields the highest operational profit (net of the innovation costs) under the S's PC.

**Lemma 3.** *(i)  $b^{S_{ij}} \geq b^{S_{ii}}$  is a sufficient condition for international matches to be implemented for shorter distances in the product space than domestic matches; and (ii) in international matches, the strategies are implemented in the same way as in domestic matches: BI is implemented for shorter distances in the product space, and SI for intermediate distances, and no match takes place when the distance is too great.*

**Proof.** The outcome of B's decision process allows us to identify the intervals where either one of the two strategies is implemented or where no international match takes place. The thresholds delimiting the relevant intervals are given by:

$$\underline{Z}_{ij} = \frac{F^I}{\alpha^I b^{S_{ij}}} \quad (10)$$

$$\bar{Z}_{ij} = \frac{1}{2b^{S_{ij}}} [\Pi - \gamma_{int} - E(\pi_{iB}^D) - E(\pi_{jS}^D)], \quad (11)$$

where  $X_j$  is the number of suppliers in the foreign market in which B is searching.

Whenever  $Z_{ij} \in [0, \underline{Z}_{ij}]$ , the BI strategy is implemented, while when  $Z_{ij} \in (\underline{Z}_{ij}, \bar{Z}_{ij}]$ , B chooses the SI strategy; for distance in the interval  $Z_{ij} \in (\bar{Z}_{ij}, \frac{1}{2X_j}]$ , B chooses to go back home and look for a domestic supplier (See [Appendix A.2](#) for the derivations). ■

The bottom part of [Figure 2](#) shows the intervals in the product space in international matches in which the different innovation strategies are adopted.

The condition  $b^{S_{ij}} \geq b^{S_{ii}}$  is likely to always be satisfied, since it would not be reasonable for the costs of adapting per-unit distance for the supplier to be higher in domestic than in international matches; therefore, international matches are implemented for shorter distances than domestic matches because, on the one hand, matching internationally is more costly (i.e. both the buyer and the supplier bear the fixed internationalization cost  $\gamma_{int}$ ), and, on the other hand, both the buyer and the supplier have the option of returning home. Therefore, firms stay in an international relationship only when they have found a match abroad that is better than the options for a domestic match, i.e. when the distance in the product space is shorter internationally than it is domestically.

We then consider the ratio of the no-match interval to the match interval in international matches to assess what affects the probability of a successful match.

**Corollary 4.** *The no-match outcome in international markets is more likely: the larger the cost of managing operations abroad ( $\gamma_{int}$ ), the larger the per-unit distance cost for the supplier to adapt in an international match ( $b^{Sij}$ ), and the larger the number of suppliers in the buyer's country ( $X_i$ ).*

**Proof.** See [Appendix A.2](#). ■

A larger cost of managing operations abroad implies a smaller “pie” and therefore a lower incentive to match. The larger the number of suppliers in the buyer's country, the larger the outside options for a buyer looking for a supplier abroad, and the closer the foreign supplier must be for a match to take place, i.e. the “pie” is smaller again. The higher the per-unit distance cost of adapting the input for the supplier, the lower the likelihood that the supplier will agree to modify the input.

From the above results, it follows that reducing the cost of managing operations between countries and increasing the efficiency of suppliers, i.e. lowering their costs of adapting the intermediate input, increase the number of matches in international markets.

#### 4.5.3. Buyer's internationalization decision

As described in [Section 4.3](#), at  $t_0$ , buyer B decides whether or not to look for an international match. When making this decision, B knows the actual distribution of suppliers in the domestic market, and therefore  $Z_{ii}$ , but not the actual distribution in the foreign market. By solving the expression in [\(A.30\)](#), we obtain the expected profits in the foreign matches:

$$E(\pi_B^I) = \frac{X_j}{b_{Sij}} \left[ \frac{(F^I)^2}{\alpha^I} + \frac{(\Pi - \gamma_{int} - E(\pi_{iB}^D) - E(\pi_{jS}^D))^2}{2} - F^I(\Pi - \gamma_{int} - E(\pi_{iB}^D) - E(\pi_{jS}^D)) \right] + E(\pi_{iB}^D). \quad (12)$$

In making a decision on whether to search abroad or not, B compares the potential profit resulting from matching for two periods in the domestic market with the profit from searching in the international market.

$\pi_{B,0}^I = \Pi_{fm} - \eta$  is the total net profit (net of import costs) that B gets at  $t_0$ , in the “first meeting” if it decides to look for an international match; B bears the sunk cost of searching in the foreign market ( $\eta$ ), and, in the first meeting, B, if randomly matched with supplier S, buys the existing input. This implies the profit  $\Pi_{fm} < \Pi$ , because no adaptation takes place and as a consequence the B's new (final) good cannot be produced; still, there could be a non-negative  $\Pi_{fm}$ , since B could, for instance, resell the input.  $\pi_{iB,0}^{BI,D}$  ( $\pi_{iB,0}^{SI,D}$ ), is the operating profit for B at  $t_0$  if it decides to match domestically, under the BI (or SI) strategy, depending on the domestic distance with its nearest supplier.  $\pi_{iB,1}^D = \frac{\Pi}{2}$  is what B gets at  $t_1$  if it continues

with the existing relationship in the domestic market. At this stage, B and S have already matched at  $t_0$  and so do not have to bear the innovation costs again.

At  $t_0$ , the buyers whose nearest suppliers in the domestic market are at a distance  $Z_{ii} \in [0, \underline{Z}_{ii}]$ , i.e. buyers that would be involved in a BI strategy in the domestic market, will go and look for an international match if

$$\pi_{B,0}^I + E(\pi_B^I) \geq (\pi_{iB,0}^{BI,D} + \pi_{iB,1}^D). \quad (13)$$

A buyer whose nearest supplier in the domestic market is at a distance  $Z_{ii} \in (\underline{Z}_{ii}, \bar{Z}_{ii}]$ , i.e. a buyer that would be involved in an SI strategy in the domestic market, will go and look for an international match if

$$\pi_{B,0}^I + E(\pi_B^I) \geq (\pi_{iB,0}^{SI,D} + \pi_{iB,1}^D). \quad (14)$$

Finally, buyers whose nearest supplier in the domestic market is at a distance such that they will not produce the new good ( $Z_{ii} \in (\bar{Z}_{ii}, \frac{1}{2X_i}]$ ) will go and look for an international match if

$$\pi_{B,0}^I + E(\pi_B^I) \geq 0. \quad (15)$$

**Lemma 5.** (i) when search costs are above  $\eta_0$ , there will be some firms matching only domestically under different innovation strategies (BI, for shorter distances, SI for intermediate ones); (ii) for search costs below  $\eta_0$  all firms that would have implemented either BI or SI in domestic markets try to look for a partner abroad; (iii) when search costs are below  $\eta_1$  all firms who would have not matched domestically try to look for a partner abroad; (iv) when search costs are above  $\eta_1$  no firms search abroad even if no match is available domestically.

**Proof.** The solution to B's decision problem allows us to determine the intervals in the domestic product characteristics space in which B either continues with a domestic match or looks for a foreign match by engaging in a first meeting abroad. The relevant thresholds in the domestic product characteristics space for B's decision on whether or not to search abroad are given by:

$$\begin{aligned} \widehat{Z}_{ii} &= \frac{1}{\alpha^D b_{Sii}} [\Pi - \Pi_{fm} + \eta - E(\pi_B^I)] \\ \underline{Z}_{ii} &= \frac{F^D}{\alpha^D b_{Sii}} \\ \bar{Z}_{ii} &= \frac{1}{b_{Sii}} \frac{\Pi}{2}. \end{aligned} \quad (16)$$

The thresholds in the search costs that evenly affect all buyers are given by:

$$\begin{aligned}\eta_0 &= \Pi_{fm} - \Pi + F^D + E(\pi_B^I) \\ \eta_1 &= \Pi_{fm} + E(\pi_B^I).\end{aligned}\tag{17}$$

For  $Z_{ii} \in [0, \widehat{Z}_{ii})$ , the buyer matches in the domestic market under the BI strategy; for  $Z_{ii} \in [\widehat{Z}_{ii}, \underline{Z}_{ii}]$ , the buyer — which would implement a BI strategy in the domestic market — searches for a foreign partner if the search costs are low enough ( $\eta < \eta_0$ ). For  $Z_{ii} \in (\underline{Z}_{ii}, \overline{Z}_{ii}]$ , the buyer — which would implement an SI strategy in the domestic market — searches for a foreign partner if and  $\eta < \eta_0$ . When the distances in the domestic market are too large, i.e.  $Z_{ii} \in (\overline{Z}_{ii}, 1/(2X_i)]$ , the buyer — which would not find a domestic partner — searches for a foreign partner iff  $\eta < \eta_1$  (see [Appendix A.3](#) for the derivations). ■

It is worth noting that the sign of the relationship between the density of suppliers in B’s country and the probability that B will attempt to search for a foreign match is ambiguous, since two contrasting forces are at work (see [Appendix A.3](#)). On the one hand, the higher the density of suppliers in B’s country, the lower the need to search abroad for a match. On the other hand, the higher the density of the suppliers in B’s country, the higher the share of the potential profit B will receive in a successful international match. In the same way, the relationship between the density of suppliers in S’s country, where B would search, and the probability that buyers will attempt to search for a foreign match is ambiguous, since the higher the density of suppliers in the foreign market, the higher the probability of finding a match, but also the higher the share of the profit the potential partner will receive.

#### 4.5.4. A condition for larger “product innovation by supplying” in international than in domestic matches

We focus on firms that have achieved a match and implemented either the BI or the SI strategy in order to study which of the two strategies is more likely to occur in domestic and foreign matches. To analyze how the set of distance intervals for which the SI strategy is implemented differs between international and domestic matches, we considered the measure of the relative share of the SI interval in the sum of the SI+BI distance intervals:  $(SIsh)^D = (1 - \frac{Z_{ij}}{Z_{jj}})$  and  $(SIsh)^I = (1 - \frac{Z_{ij}}{Z_{ij}})$ . We compare this measure in domestic and international matches. The difference between  $(SIsh)^I$  and  $(SIsh)^D$  is given by

$$(SIsh)^I - (SIsh)^D \equiv \Delta(SIsh) = \frac{2F^D}{\alpha^D \Pi} - \frac{2F^I}{\alpha^I \left[ \Pi - \gamma_{int} - E(\pi_{iB}^D) - E(\pi_{jS}^D) \right]}.\tag{18}$$

When this difference is positive (or negative), the share of the set of distance intervals for which SI is implemented over the total match interval is higher (or lower) for an international match than for a domestic

one (i.e. product innovation is more likely in the case of foreign than in domestic supplying).

**Proposition 6.** *In order for S to have a higher probability of adapting to B's needs in an international match than in a domestic one, the unit distance to adaptation cost ratio in an international match has to be above a certain threshold, i.e.  $\alpha^I > \bar{\alpha}$ , where*

$$\bar{\alpha} \equiv \frac{\alpha^D \Pi F^I}{F^D [\Pi - \gamma_{int} - E(\pi_{iB}^D) - E(\pi_{jS}^D)]}, \quad (19)$$

and where  $E(\pi_{iB}^D) \equiv H(X_i, F^D, \Pi, \alpha^D, b^{Sii})$  and  $E(\pi_{jS}^D) \equiv G(X_j, F^D, \Pi, \alpha^D, b^{Sjj})$  as in (8) and (9).

Product innovation is more frequent in international than in domestic matches the smaller the number of suppliers in B's country of origin ( $X_i$ ), and the lower the internationalization cost  $\gamma_{int}$ .

**Proof.** This immediately follows from  $\Delta(SIsh) > 0$  and from taking the derivatives of  $\bar{\alpha}$  with respect to  $X_i$  and  $\gamma_{int}$ , as reported in [Appendix A.4](#). ■

It is worth noting that, with  $\alpha^I \leq \alpha^D$ , B is more likely to buy the existing good provided by S and adapt it to its needs in an international match than in a domestic one.<sup>31</sup> This is because the SI strategy is implemented for relatively large distances both in domestic and in international matches (when  $Z$  is large, B asks S to adapt), and, since international matches are successful for shorter distances (as a result of the effect of  $\gamma_{int}$  and the outside options), the SI strategy set is smaller in this type of match. However, if  $\alpha^I > \alpha^D$ , the higher cost of adapting in an international match can revert the previous result, causing a “shrinkage” of the BI strategy set, and increasing the relative share of the SI strategy set.

We can interpret  $\alpha^I = \alpha^D$  as the limit case in which goods (e.g. inputs) are perfectly standardized (in international markets as well), and therefore  $b^{Bjj} = b^{Bij}$  and  $b^{Sjj} = b^{Sij}$ . In this case, by rewriting the condition  $\alpha_I > \bar{\alpha}$  as

$$\frac{\alpha_I}{\alpha_D} > \frac{\Pi F^I}{F^D [\Pi - \gamma_{int} - E(\pi_{iB}^D) - E(\pi_{jS}^D)]}, \quad (20)$$

it is clear that this inequality is never satisfied under  $\alpha^I = \alpha^D$ , i.e. in standardized sectors, since the right-hand side is always greater than 1 (because  $F^I > F^D$  and  $GFT > 0$ ), while it is more likely to hold the more specialized the sectors are. So, we obtain the following corollary:

**Corollary 7.** *SI is more likely to occur in foreign than in domestic markets if PTO involves specialized goods.*

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<sup>31</sup>This holds whenever  $F^D \leq F^I$ , which we have assumed in [Section 4.5](#), since the opposite would not be realistic.

Our theoretical framework highlights that some *technological incompatibilities* between countries, i.e.  $\alpha^I \neq \alpha^D$ , not related to the level but to the type of technology used, are always necessary to induce higher (product) innovation by supplying to foreign rather than to domestic markets. By contrast, when the unit distance cost ratios are the same for both domestic and foreign markets (e.g. B and S are equally familiar with the technology of all countries), it is B that is relatively more likely to adapt the input in international than in domestic matches.

Moreover, the product innovation induced by “foreign supplying” is smaller the higher the probability of B finding a match in the domestic market, i.e. the higher  $X_i$ , since this increases the outside option of B, and the higher the cost of managing operations abroad, i.e. the higher  $\gamma_{int}$ . By increasing the actual and opportunity costs of international matches, both mechanisms reduce the distances for which international matches occur, this way reducing the likelihood of the buyer asking the supplier to adapt the input.

## 5. Back to empirics

Our theoretical model has a number of testable implications. The ideal data to test the model would be micro-level data on individual buyer-supplier transactions. For instance, Proposition 6 stated that PTO for foreign customers should induce more product innovation the smaller the number of potential suppliers in the foreign market for the good subject to the transaction (e.g. number of suppliers defined in terms of detailed product or industry codes in the buyer’s country). Unfortunately, we do not have such ideal data, and in this section we provide only some tentative evidence using the EFIGE survey.

Proposition 6 stated that a higher internationalization cost ( $\gamma_{int}$ ) should lead to *lower* innovation by suppliers engaged in PTO for foreign customers compared with those supplying to domestic firms. We operationalize this test as follows. Using bilateral trade data at the three-digit industry level (International Standard Industrial Classification of All Economic Activities (ISIC) revision 2), for developing and developed countries for the period 1980-2006 from Cepii TradeProd database (de Sousa et al., 2012), we estimate industry-specific export gravity models in a sample that includes the seven countries in the EFIGE dataset. The gravity models include common language, colonial relationships, population-weighted bilateral distances, and origin-year and destination-year fixed effects.<sup>32</sup> After estimating the gravity models for the period 1980-2006, we compute the predicted values based only on the logorathim of distance, and colonial and common official language dummy variables, and average them by country and industry (pooling all years).<sup>33</sup> These

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<sup>32</sup>These variables are taken from the GeoDist database from Cepii, described in Mayer and Zignago (2011).

<sup>33</sup> Common official language and the existence of a historical colonial relationship can also be considered as proxies of  $F_I$ . In particular, they should reduce the  $F_I/F_D$  cost ratio.

average predicted values are then standardized to have zero mean and unit variance, and can be considered the internationalization costs stemming from geographical distance and language, and cultural or institutional proximity only. Column 1 of Table 4 shows the OLS estimates of a linear regression including the same covariates (or matching variables) of the models described in Section 2.3, and an interaction term between *Forcust* (the dummy for PTO for foreign customers) and the latter. The interaction term is statistically significant and negative, as predicted by our empirical model. It is worth noting that such an evidence cannot be explained by the standard self-selection argument, according to which firms that export to countries in which internalization costs are higher are on average more productive, and produce more innovations.

In sectors producing more specialized goods, there are larger differences in goods both within and between countries compared with sectors with a more standardized production. Furthermore, the technical solutions adopted in production are likely to differ across countries according to the level of good specialization. In our model, this is mirrored by a larger  $\alpha_I/\alpha_D$  ratio and we expect PTO for foreign buyers to be more frequent in specialized sectors (see Corollary 7). We test this implication by constructing the share of differentiated goods according to the definition in Rauch (1999) at the ISIC (revision 2) three-digit level,<sup>34</sup> and interact it with *Forcust*. The results of this regression are shown in column 2 of Table 4, and point to a significant effect of *Forcust*, which increases with the level of differentiation of an industry’s production, and is statistically zero in industries that do not produce differentiated products.<sup>35</sup>

Finally, we test if the innovation effect of PTO for foreign customers depends negatively on the number of potential suppliers existing in the buyer’s market of origin,  $X_i$  (Proposition 6). We do not have a good measure for the latter, and we use as a proxy the number of firms by sector in 2005 (source: OECD, Structural Business Statistics). We estimate a regression by adding interaction terms between *Forcust* and the number of firms in the first destination country of the supplier’s exports reported in the EFIGE dataset, and operating in the supplier’s sector. The sample size is reduced because of the missing data on the number of firms for some destination countries. The interaction term is negative, consistent with our model prediction, but is statistically insignificant at conventional levels.<sup>36</sup>

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<sup>34</sup> We use a similar procedure to Conconi et al. (2016).

<sup>35</sup> The estimation sample decreased because of missing values in firms’ ISIC codes. Indeed, the EFIGE dataset provides ISIC (revision 2) three-digit codes, which are linked to NACE (revision 1.1) four-digit codes by means of a concordance table. However, a one-to-one concordance is not provided for all NACE industries.

<sup>36</sup> As we show in Appendix A.5, the lack of a significant correlation is predicted by the versions of the model in which the outside option is zero in case of an unsuccessful match abroad.

Table 4: Test of some model implications

Variables	(1)	(2)	(3)
<i>Forcust</i>	0.156*** (0.020)	0 .010 (0.045)	0.122*** (0.017)
<i>Forcust</i> × Internationalization costs <sup>a</sup>	-0.023*** (0.009)		
<i>Forcust</i> × % Differentiated products <sup>b</sup>		0.104** (0.050)	
% Differentiated products		-0.095** (0.044)	
<i>Forcust</i> × N. firms (industry) <sup>c</sup>			-0.004 (0.007)
N. observations	6,195	5,864	5,750

<sup>a</sup> Interaction term between supplier’s PTO for foreign customers and a proxy of internationalization cost for the first destination country of firm exports. The latter is estimated using an export gravity model with CEPII data.

<sup>b</sup> Interaction term between supplier’s PTO for foreign customers and percentage of differentiated goods in the firm industry according to Rauch (1999), conservative classification.

<sup>c</sup> Interaction term between supplier’s PTO for foreign customers and number of firms in the firm’s industry.

Note. *Forcust* is a dichotomous variable which equals one if the supplier does PTO for a foreign customer and zero otherwise. All models control for the variables described in Section 2.3. The number of observations is different from that in the baseline estimation sample in Table 2 (7,235 firms) because of missing values in the first destination country of firm exports or in CEPII trade data (column 1 and column 3), in the concordance between ISIC and NACE industry codes (column 2), or in the number of firms by industry (column 3).

## 6. Concluding remarks

Using the EFIGE dataset, a survey that gathers firm-level data on manufacturing firms in seven European countries, we have shown that PTO for foreign firms is positively associated with greater product innovativeness than PTO for domestic firms. The association is not only statistically significant, but also economically significant.

We have provided a theoretical model that gives a potential explanation for this evidence in the framework of the literature on incomplete contracts and imperfect information related to the provision of specialized inputs in international trade.

Two sources of firm heterogeneity are present in our model. The first source of (ex ante) firm heterogeneity is in the location of buyers in the domestic product space. This source of heterogeneity determines heterogeneous buyer behaviors in terms of searching for a business partner abroad. A second source of (ex post) heterogeneity concerns the location in the foreign product space, which is revealed after the first meeting with a foreign buyer takes place, and which determines heterogeneity in the innovation strategies. As a consequence, in the model some firms match only domestically, under different innovation strategies, either the buyer implementation of the supplier innovation strategies); other firms look for a partner abroad;

some firms continue in their foreign match under either the buyer implementation or the supplier innovation strategy; and some firms, after having engaged in only the first meeting abroad, return home to look for a new domestic partner (“temporary trade”). This in turn implies some heterogeneity across suppliers: some of them sell only domestically, some of them export their existing intermediate goods only temporarily without introducing innovations, and others engage in long-term relationships both domestically and abroad, either by selling the existing input and assisting the buyer or by adapting their input to the buyer’s needs.

We singled out the distance thresholds in the product space, delimiting the intervals for which the different innovation and internationalization strategies are implemented, which depend on the innovation costs, the internationalization costs, and the number of suppliers in the different countries. We found the conditions under which suppliers are more likely to adapt their products for foreign firms than for domestic ones, thus highlighting a specific channel through which trade in intermediate goods may induce product innovation by firms already operating in the market. Finally, we considered some of the model’s predictions in the context of the available data, and found evidence that is broadly consistent with the model.

As regards further research, two main possible developments of our analysis are worth mentioning. From an empirical point of view, it would be interesting to explore buyer-supplier matched data with information on product and input innovations to better assess the empirical relevance of the mechanism we put forward in this paper. From a theoretical point of view, our model provides a framework by which firms may implement different innovation and internationalization strategies, which depend on the characteristics of their products and not on differences in productivity. Although in this paper our main aim was to stress the “engines” that can drive different innovation and internationalization strategies between firms located in similarly developed economies, a natural extension of our work would be to also consider the role of countries’ differences in technological (and productivity) levels, factor costs, income levels, and the quality of their institutions.

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## Appendix A. Main derivations

### Appendix A.1. Derivation of the pay-offs and thresholds in the domestic matches

The outside options in a domestic match are represented by  $OUT_{vk}^D = 0$ , where  $v = i, j$  and  $k = S, B$ , since no production will take place. By assuming an ex-post splitting rule, with  $\Pi = \Pi_B + \Pi_S$ , we obtain  $\Pi_B = \Pi_S = \frac{\Pi}{2}$ . The pay-offs in the domestic matches under the BI strategy are given by

$$\pi_{iB}^{BI,D} = \frac{\Pi}{2} - \alpha^D b^{Sii} Z_{ii} \quad (\text{A.1})$$

$$\pi_{iS}^{BI,D} = \frac{\Pi}{2} - F^D, \quad (\text{A.2})$$

where  $\Pi$  is the total operational profit, and where  $\pi_{iB}^{BI,D}$  and  $\pi_{iS}^{BI,D}$ , are the net total profits received by B and S in a domestic match under BI, respectively. It is worth noting that a general equilibrium condition on non-negatives gains from trade (*GFT*) must hold and the participation constraints (PCs) have to be satisfied:

$$GFT: \frac{\Pi}{2} \geq 0$$

$$\pi_{iB}^{BI,D} \geq 0 : Z_{ii} \leq \left(\frac{\Pi}{2}\right) \frac{1}{\alpha^D b^{Sii}}$$

$$\pi_{iS}^{BI,D} \geq 0 : \frac{\Pi}{2} \geq F^D.$$

The pay-offs in the domestic matches under the SI strategy are given by

$$\pi_{iB}^{SI,D} = \frac{\Pi}{2} - F^D \quad (\text{A.3})$$

$$\pi_{iS}^{SI,D} = \frac{\Pi}{2} - b^{Sii} Z_{ii}, \quad (\text{A.4})$$

where  $\Pi$  is the total operational profit, and where  $\pi_{iB}^{SI,D}$  and  $\pi_{iS}^{SI,D}$  are the net total profits received by B and S in a domestic match under SI, respectively. Also in this case, the *GFT* must be non negative and the PCs have to be satisfied:

$$GFT: \frac{\Pi}{2} \geq 0$$

$$\begin{aligned}\pi_{iB}^{SI,D} &\geq 0: \frac{\Pi}{2} \geq F^D \\ \pi_{iS}^{SI,D} &\geq 0: Z_{ii} \leq \frac{\Pi}{2} \left( \frac{1}{b^{S_{ii}}} \right).\end{aligned}$$

In this framework, B chooses the BI strategy if

$$\pi_{iB}^{BI,D} \geq \pi_{iB}^{SI,D} \quad (\text{A.5})$$

under the S participation constraint (PC<sup>S</sup>),

$$\pi_{iS}^{BI,D} \geq 0. \quad (\text{A.6})$$

B chooses instead the SI strategy if

$$\pi_{iB}^{SI,D} > \pi_{iB}^{BI,D}, \quad (\text{A.7})$$

under the S participation constraint (PC<sup>S</sup>),

$$\pi_{iS}^{SI,D} \geq 0. \quad (\text{A.8})$$

As a result of B's decision, we single out the thresholds delimiting the relevant intervals where different strategies are implemented, as reported in Section 4.5.1. It is worth noting that  $\underline{Z}_{ii} < \bar{Z}_{ii}$  whenever  $\Pi > \frac{2F^D}{\alpha^D}$  (when  $\alpha^D > 1$ , this condition is always satisfied if the participation constraints are).

### ***Proof of Corollary 2***

The ratio between the no-match interval and match interval (where either the BI or the SI strategies are implemented) in domestic markets is defined as

$$NMsh^D \equiv \frac{\frac{1}{2X_i} - \bar{Z}_{ii}}{\bar{Z}_{ii}} = \frac{1}{2X_i} \frac{1}{\bar{Z}_{ii}} - 1. \quad (\text{A.9})$$

Thus,

$$\frac{\partial NMsh^D}{\partial \Pi} = -\frac{1}{4b^{S_{ii}}} < 0 \quad (\text{A.10})$$

$$\frac{\partial NMsh^D}{\partial b^{S_{ii}}} = \frac{\Pi}{4(b^{S_{ii}})^2 \bar{Z}_{ii}^2} > 0 \quad (\text{A.11})$$

$$\frac{\partial NMsh^D}{\partial X_i} = -\frac{1}{2X_i^2 \bar{Z}_{ii}} < 0. \quad (\text{A.12})$$

## Appendix A.2. Derivation of the pay-offs and thresholds in the international matches

$$E(\pi_{jS}^D) \equiv \int_0^{\underline{Z}_{jj}} \pi_{jS}^{BI,D} \cdot g(Z_{jj}) dZ_{jj} + \int_{\underline{Z}_{jj}}^{\bar{Z}_{jj}} \pi_{jS}^{SI,D} \cdot g(Z_{jj}) dZ_{jj} \equiv G(X_j, F^D, \Pi, \alpha^D, b^{Sjj}) \quad (\text{A.13})$$

and

$$E(\pi_{iB}^D) \equiv \int_0^{\underline{Z}_{ii}} \pi_{iB}^{BI,D} \cdot h(Z_{ii}) dZ_{ii} + \int_{\underline{Z}_{ii}}^{\bar{Z}_{ii}} \pi_{iB}^{SI,D} \cdot h(Z_{ii}) dZ_{ii} \equiv H(X_i, F^D, \Pi, \alpha^D, b^{Sii}), \quad (\text{A.14})$$

are the expected profits of the domestic matches for S in country  $j$  and B in country  $i$ , respectively;  $g(Z_{jj}) = 2X_j$  and  $h(Z_{ii}) = 2X_i$  are the densities of the distance in the S and B domestic markets, respectively.

Assuming again an ex-post profit splitting rule, from

$$\Pi - \gamma_{int} = \Pi_B + \Pi_S$$

and

$$V = (\Pi_B - E(\pi_{iB}^D))(\Pi - \gamma_{int} - \Pi_B - E(\pi_{jS}^D))$$

we obtain the following net total profits received by B and S in an International match under BI:

$$\pi_B^{BI,I} \equiv \Pi_B - \alpha^I b^{Sij} Z_{ij} = \frac{1}{2} [\Pi - \gamma_{int} - E(\pi_{iB}^D) - E(\pi_{jS}^D)] + E(\pi_{iB}^D) - \alpha^I b^{Sij} Z_{ij} \quad (\text{A.15})$$

and

$$\pi_S^{BI,I} \equiv \Pi_S - F^I = \frac{1}{2} [\Pi - \gamma_{int} - E(\pi_{iB}^D) - E(\pi_{jS}^D)] + E(\pi_{jS}^D) - F^I. \quad (\text{A.16})$$

In order for the international match to be profitable, we require a non-negative *GFT*:

$$GFT : [\Pi - \gamma_{int} - E(\pi_{iB}^D) - E(\pi_{jS}^D)] \geq 0.$$

We obtain the following net total profits received by B and S in an international match under SI:

$$\pi_B^{SI,I} \equiv \Pi_B - F^I = \frac{1}{2} [\Pi - \gamma_{int} - E(\pi_{iB}^D) - E(\pi_{jS}^D)] + E(\pi_{iB}^D) - F^I \quad (\text{A.17})$$

and

$$\pi_S^{SI,I} \equiv \Pi_S - b^{Sij} Z_{ij} = \frac{1}{2} [\Pi - \gamma_{int} - E(\pi_{iB}^D) - E(\pi_{jS}^D)] + E(\pi_{iS}^D) - b^{Sij} Z_{ij} \quad (\text{A.18})$$

(again non-negative *GFT* must hold).

B chooses BI internationally if

$$\pi_B^{BI,I} \geq \pi_B^{SI,I} \quad (\text{A.19})$$

under

$$\pi_S^{BI,I} \geq E(\pi_{jS}^D) \quad (\text{A.20})$$

$$\pi_B^{BI,I} \geq E(\pi_{iB}^D). \quad (\text{A.21})$$

B chooses SI internationally if

$$\pi_B^{SI,I} > \pi_B^{BI,I} \quad (\text{A.22})$$

under

$$\pi_S^{SI,I} \geq E(\pi_{jS}^D) \quad (\text{A.23})$$

$$\pi_B^{SI,I} \geq E(\pi_{iB}^D). \quad (\text{A.24})$$

As a result of B's decision, we single out the thresholds delimiting the relevant intervals where different strategies are implemented in the international matches, as reported in Section 4.5.2.

$\underline{Z}_{ij} < \bar{Z}_{ij}$  whenever *GFT* are such that  $\alpha^I [\Pi - \gamma_{int} - E(\pi_{iB}^D) - E(\pi_{jS}^D)] > 2F^I$  (when  $\alpha^I > 1$  this condition is always satisfied once the participation constraints are).

#### ***Proof of Corollary 4***

The ratio between the no-match interval and the match interval (where either the BI or the SI strategies are implemented) in international markets is defined as

$$NMs h^I \equiv \frac{\frac{1}{2X_j} - \bar{Z}_{ij}}{\bar{Z}_{ij}} = \frac{1}{2X_j} \frac{1}{\bar{Z}_{ij}} - 1. \quad (\text{A.25})$$

Thus,

$$\frac{\partial NMsh^I}{\partial \gamma_{int}} = \frac{1}{4X_j b^{S_{ij}} \bar{Z}_{ij}^2} > 0 \quad (\text{A.26})$$

$$\frac{\partial NMsh^I}{\partial b^{S_{ij}}} = \frac{GFT}{4X_j b^{S_{ij}} \bar{Z}_{ij}^2} > 0 \quad (\text{A.27})$$

under the condition of non-negative  $GFT$

$$GFT : [\Pi - \gamma_{int} - E(\pi_{iB}^D) - E(\pi_{jS}^D)] \geq 0 \quad (\text{A.28})$$

$$\frac{\partial NMsh^I}{\partial X_i} = \frac{1}{X_j} \left[ -\frac{1}{\bar{Z}_{ij}^2} \frac{\partial \bar{Z}_{ij}}{\partial X_i} \right] > 0 \quad (\text{A.29})$$

since  $\frac{\partial \bar{Z}_{ij}}{\partial X_i} < 0$  under the supplier's participation constraint.

### Appendix A.3. Derivation of the determinants of the buyer searching abroad

The expected profits in a international match reads as

$$\begin{aligned} E(\pi_B^I) &\equiv L(X_i, X_j, F^D, F^I, \Pi, \Pi, \alpha^D, \alpha^I, b^{S_{ii}}, b^{S_{ij}}, \gamma_{int}) = \\ &= \int_0^{Z_{ij}} \pi_B^{BI,I} \cdot g(Z_{ij}) dZ_{ij} + \int_{\underline{Z}_{ij}}^{\bar{Z}_{ij}} \pi_B^{SI,I} \cdot g(Z_{ij}) dZ_{ij} + \int_{\bar{Z}_{ij}}^{\frac{1}{2X_j}} E(\pi_{iB}^D) \cdot g(Z_{ij}) dZ_{ij}, \end{aligned} \quad (\text{A.30})$$

where  $E(\pi_{iB}^D)$  is B's expected profit from domestic matches (A.14);  $\pi_B^{BI,I}$  and  $\pi_B^{SI,I}$  are the net total profits received by B under BI and SI in the international matches (A.15, A.17 in Appendix A.2), respectively; and  $g(Z_{ij}) = 2X_j$  is the density of the distance in the foreign market in which B is searching.

From (A.30) we derive

$$\frac{\partial E(\pi_B^I)}{\partial X_i} = \frac{\partial E(\pi_{iB}^D)}{\partial X_i} \left[ 1 - \frac{X_j}{b^{S_{ij}}} (GFT - F^I) \right], \quad (\text{A.31})$$

and

$$\frac{\partial E(\pi_B^I)}{\partial X_j} = \frac{E(\pi_B^I)}{X_j} - \frac{X_j}{b^{S_{ij}}} (GFT - F^I), \quad (\text{A.32})$$

where  $GFT : \alpha^I [\Pi - \gamma_{int} - E(\pi_{iB}^D) - E(\pi_{jS}^D)]$ , both showing ambiguous sign.

Under BI in a domestic match ( $0 < Z_{ii} < \underline{Z}_{ii}$ ), B will search abroad iff

$$\pi_{B,0}^I + E(\pi_B^I) \geq \pi_{iB,0}^{BI,D} + \pi_{iB,1}^D, \quad (\text{A.33})$$

that is,

$$\Pi_{fm} - \eta + E(\pi_B^I) \geq \Pi - \alpha^D b_{Sii} Z_{ii}, \quad (\text{A.34})$$

from which we obtain

$$Z_{ii} \geq \frac{1}{\alpha^D b_{Sii}} [\Pi - \Pi_{fm} + \eta - E(\pi_B^I)] \equiv \hat{Z}_{ii}. \quad (\text{A.35})$$

In order to have an interval in which some buyers choose to look for an international partner instead of matching domestically under the BI strategy, we must have  $\hat{Z}_{ii} < \underline{Z}_{ii}$ , implying a condition on  $\eta$ :

$$\eta < \Pi_{fm} - \Pi + F^D + E(\pi_B^I) \equiv \eta_0. \quad (\text{A.36})$$

Under SI in a domestic match ( $\underline{Z}_{ii} < Z_{ii} < \bar{Z}_{ii}$ ), B will search abroad iff

$$\pi_{B,0}^I + E(\pi_B^I) \geq \pi_{B,0}^{SI,D} + \pi_{B,1}^D, \quad (\text{A.37})$$

that is,

$$\Pi_{fm} - \eta + E(\pi_B^I) \geq \Pi - F^D, \quad (\text{A.38})$$

which implies that whenever  $\eta < \Pi_{fm} - \Pi + F^D + E(\pi_B^I) \equiv \eta_0$ , all buyers who would implement an SI strategy in their domestic matches will make an attempt to look abroad for a better match.

In case of no match in the domestic market ( $\bar{Z}_{ii} < Z_{ii} < \frac{1}{2X_i}$ ), B will search for a partner in a foreign country iff

$$\pi_{B,0}^I + E(\pi_B^I) \geq 0, \quad (\text{A.39})$$

that is,

$$\Pi_{fm} - \eta + E(\pi_B^I) \geq 0, \quad (\text{A.40})$$

which implies that whenever  $\eta < \Pi_{fm} + E(\pi_B^I) \equiv \eta_1$ , all the buyers who would not find a partner in the domestic market will make an attempt to match in international markets.

In order to investigate how the probability of searching abroad for a foreign supplier varies with  $X_i$ , we consider the ratio between the interval where B decides to search abroad  $[\hat{Z}_{ii}, 1/2X_i]$  and the overall distance interval  $[0, 1/2X_i]$ . This share is given by  $SEARCHsh = 1 - \hat{Z}_{ii}(2X_i)$ , from which we derive

$\frac{\partial SEARCHsh}{\partial X_i} = -2\hat{Z}_{ii}(\epsilon_{\hat{Z}_{ii}} + 1)$ , where  $\epsilon_{\hat{Z}_{ii}}$  is the elasticity of the threshold to  $X_i$ . As one can immediately check,  $\frac{\partial SEARCHsh}{\partial X_i} > 0$  for  $\epsilon_{\hat{Z}_{ii}} < -1$  and  $\frac{\partial SEARCHsh}{\partial X_i} \leq 0$  for  $\epsilon_{\hat{Z}_{ii}} \geq -1$ , since  $\frac{\partial \hat{Z}_{ii}}{\partial X_i} = -\frac{1}{\alpha^D b_{Sii}} \frac{\partial E(\pi_B^I)}{\partial X_i}$  has an ambiguous sign as shown by (A.31).

Therefore, in general, the sign of the relation between  $SEARCHsh$  and  $X_i$  is ambiguous, depending on  $\epsilon_{\hat{Z}_{ii}}$ .

The relation between  $SEARCHsh$  and  $X_j$ , given by  $\frac{\partial SEARCHsh}{\partial X_j} = -2X_i \frac{\partial \hat{Z}_{ii}}{\partial X_j}$ , where  $\frac{\partial \hat{Z}_{ii}}{\partial X_j} = -\frac{1}{\alpha^D b_{Sii}} \frac{\partial E(\pi_B^I)}{\partial X_j}$  has an ambiguous sign, as shown by (A.32).

#### Appendix A.4. Derivatives for Proposition 6

By solving  $\Delta SISH > 0$  in (18) for  $\alpha^I$ , we derive

$$\alpha^I > \bar{\alpha} \equiv \frac{\alpha^D \Pi F^I}{F^D [GFT]} \quad (\text{A.41})$$

where  $GFT : [\Pi - \gamma_{int} - E(\pi_{iB}^D) - E(\pi_{jS}^D)] \geq 0$ .

By taking the partial derivative of  $\bar{\alpha}$  with respect to the number of suppliers in B's country ( $X_i$ ), we obtain

$$\frac{\partial \bar{\alpha}}{\partial X_i} = \frac{\alpha^D \Pi F^I \left[ \frac{\partial E(\pi_{iB}^D)}{\partial X_i} \right]}{F^D [GFT]^2} > 0, \quad (\text{A.42})$$

since, under  $\frac{\Pi}{2} \geq F^D$ :

$$\frac{\partial E(\pi_{iB}^D)}{\partial X_i} = \frac{1}{b_{ii}} \left[ \frac{(F^D)^2}{2} + \Pi \left( \frac{\Pi}{2} - F^D \right) \right] > 0. \quad (\text{A.43})$$

By taking the partial derivative of  $\bar{\alpha}$  with respect to the internationalization costs ( $\gamma_{int}$ ), we obtain

$$\frac{\partial \bar{\alpha}}{\partial \gamma_{int}} = \frac{\alpha^D \Pi F^I}{F^D [GFT]^2} > 0. \quad (\text{A.44})$$

#### Appendix A.5. Derivation of the main results under alternative assumptions on the outside options in international matches

*B and S cannot go back home and match with a domestic partner after trying an international match*

In this case the outside options in an international match, like in a domestic match, are represented by  $OUT_{vk}^I = 0$ , where  $v = i, j$  and  $k = S, B$ . It is straightforward to derive the following pay offs in international matches under different innovation strategies, as the Nash bargaining solution:

$$\pi_B^{BI,I} = \frac{1}{2} [\Pi - \gamma_{int}] - \alpha^I b^{Sij} Z_{ij}$$

$$\begin{aligned}\pi_S^{BI,I} &= \frac{1}{2} [\Pi - \gamma_{int}] - F^I \\ \pi_B^{SI,I} &= \frac{1}{2} [\Pi - \gamma_{int}] - F^I \\ \pi_S^{SI,I} &= \frac{1}{2} [\Pi - \gamma_{int}] - b^{Sij} Z_{ij}.\end{aligned}$$

As a consequence of B decision as in [Appendix A.2](#), we obtain the thresholds in the international matches under this assumption. One can easily check that what stated in [Lemma 3](#) holds also in this case. The same applies to [Corollary 4](#), except for the last sentence: in this case the no-match outcome does not depend on the number of suppliers in the buyer's country ( $X_i$ ), while instead is negatively related with the number of suppliers in the supplier's country ( $X_j$ ). By deriving [\(18\)](#) and [\(20\)](#) under the new assumptions, it is easy to check that

$$\alpha^I > \bar{\alpha}' \equiv \frac{\alpha^D \Pi F^I}{F^D [\Pi - \gamma_{int}]}.\tag{A.45}$$

This implies that under the assumption that B cannot go back and match at home, the interval of values for which SI is more likely in foreign than in domestic matches is larger. This result is intuitive since here B and S will match for larger distances, where the SI strategy is implemented (the no-match interval is smaller than under the assumption that they can match again in the domestic market, to the benefit of the SI interval). What stated in [Proposition 6](#) still holds with respect to the internationalization costs  $\gamma_{int}$ , the higher these costs the less frequent is product innovation in international matches with respect to domestic matches, while the relative probability of product innovation in the two types of matches is not related in this case neither with the number of suppliers in B's country ( $X_i$ ), nor with that in the S's country ( $X_j$ ).

We derive the new expression for the expected profits in the foreign market under the assumption  $OUT_{vk}^I = 0$ , as done in [Appendix A.3](#):

$$E'(\pi_B^I) = \frac{X_j}{b^{Sij}} \left[ \frac{(F^I)^2}{\alpha^I} + (\Pi - \gamma_{int}) \left( \frac{\Pi - \gamma_{int}}{2} - F^I \right) \right]\tag{A.46}$$

from which it is easy to derive

$$\frac{\partial E'(\pi_B^I)}{\partial X_i} = 0\tag{A.47}$$

and

$$\frac{\partial E'(\pi_B^I)}{\partial X_j} > 0.\tag{A.48}$$

This allows us to also check that

$$\frac{\partial SEARCHsh}{\partial X_i} = -2\hat{Z}_{ii} < 0\tag{A.49}$$

iff  $\widehat{Z}_{ii} > 0$  where  $\widehat{Z}_{ii}$  reads as in (16),

and

$$\frac{\partial SEARCHsh}{\partial X_j} = -2X_i \left( -\frac{1}{\alpha^D b_{Si i}} \frac{\partial E'(\pi_B^I)}{\partial X_i} \right) > 0. \quad (\text{A.50})$$

Differently from the baseline case in the text, under these new assumptions, the sign of the relationship between the probability to search in the foreign market and the number of suppliers in B's and in S's countries is determined, in particular, negative and positive, respectively. The higher the number of suppliers in B's country ( $X_j$ ) the less the incentives for B to search abroad for a closer supplier, while the larger the number of suppliers in S's country ( $X_i$ ) where B searches, the higher the incentives for B to search abroad. Those relationships were ambiguous in the main text due to the contrasting effects generated by  $X_j$  and  $X_i$  in the expected profits in the international matches, as explained in Section 4.5.3 .

***B and S keep perfect information about their own domestic market after having tried a first international match***

If we assume that both B and S keep information on the actual firm distribution in their domestic market, the outside options would be the profits of the domestic matches: they could find either the match identified as the closest partner in  $t_0$  or another one at a larger distance, in case the latter is not available anymore. Since both B and S have three possibilities in the domestic matches, BI, SI and unsuccessful match (NM), depending on the distance with their closest partner, we have to consider nine potential combinations of B and S involved in a match abroad. In these nine combinations what changes is the combination of the outside options of B and S, and therefore the *GFT* expression in the pay offs resulting from the ex-post Nash bargaining in the international matches derived as in Appendix A.2. As a solution of B decision in all the nine cases, as in Appendix A.2, we obtain the thresholds in the international matches delimiting the intervals where different innovation strategies are implemented:

$$\underline{Z}_{ij} = \frac{F^I}{\alpha^I b^{Si j}}$$

$$\overline{Z}_{ij}^{rs} = \frac{GFT^{rs}}{2b^{Si j}}$$

where  $r = BI, SI, NM$  for B in country  $i$  and  $s = BI, SI, NM$  for S in country  $j$ . For the SI interval to be not empty ( $\overline{Z}_{ij}^{rs} > \underline{Z}_{ij}$ ),  $GFT^{r,s} > 2F^I$  must hold, which is always satisfied when the PCs are, where the  $GFT^{r,s}$ s read as:

$GFT^{r,s}$	distance interval buyer (B)	distance interval supplier (S)
$GFT^{BI,BI} = [\Pi - \gamma_{int} - \pi_{iB}^{BI,D} - \pi_{jS}^{BI,D}] = -\gamma_{int} + \alpha^D b^{Si} Z_{ii} + F^D$	$0 \leq Z_{ii} \leq \underline{Z}_{ii}$	$0 \leq Z_{jj} \leq \underline{Z}_{jj}$
$GFT^{BI,SI} = [\Pi - \gamma_{int} - \pi_{iB}^{BI,D} - \pi_{jS}^{SI,D}] = -\gamma_{int} + \alpha^D b^{Si} Z_{ii} + b^{Sjj} Z_{jj}$	$0 \leq Z_{ii} \leq \underline{Z}_{ii}$	$\underline{Z}_{jj} < Z_{jj} \leq \overline{Z}_{jj}$
$GFT^{BI,NM} = [\Pi - \gamma_{int} - \pi_{iB}^{BI,D} - 0] = \frac{\Pi}{2} - \gamma_{int} + \alpha^D b^{Si} Z_{ii}$	$0 \leq Z_{ii} \leq \underline{Z}_{ii}$	$\overline{Z}_{jj} < Z_{jj} \leq \frac{1}{2\overline{X}_j}$
$GFT^{SI,BI} = [\Pi - \gamma_{int} - \pi_{iB}^{SI,D} - \pi_{jS}^{BI,D}] = -\gamma_{int} + 2F^D$	$\underline{Z}_{ii} < Z_{ii} \leq \overline{Z}_{ii}$	$0 \leq Z_{jj} \leq \underline{Z}_{jj}$
$GFT^{SI,SI} = [\Pi - \gamma_{int} - \pi_{iB}^{SI,D} - \pi_{jS}^{SI,D}] = -\gamma_{int} + F^D + b^{Sjj} Z_{jj}$	$\underline{Z}_{ii} < Z_{ii} \leq \overline{Z}_{ii}$	$\underline{Z}_{jj} < Z_{jj} \leq \overline{Z}_{jj}$
$GFT^{SI,NM} = [\Pi - \gamma_{int} - \pi_{iB}^{SI,D} - 0] = \frac{\Pi}{2} - \gamma_{int} + F^D$	$\underline{Z}_{ii} < Z_{ii} \leq \overline{Z}_{ii}$	$\overline{Z}_{jj} < Z_{jj} \leq \frac{1}{2\overline{X}_j}$
$GFT^{NM,BI} = [\Pi - \gamma_{int} - \pi_{iB}^{BI,D} - 0] = -\gamma_{int} + 2F^D$	$\overline{Z}_{ii} < Z_{ii} \leq \frac{1}{2\overline{X}_i}$	$0 \leq Z_{jj} < \underline{Z}_{jj}$
$GFT^{NM,SI} = [\Pi - \gamma_{int} - \pi_{iB}^{SI,D} - 0] = -\gamma_{int} + F^D + b^{Sjj} Z_{jj}$	$\overline{Z}_{ii} < Z_{ii} \leq \frac{1}{2\overline{X}_i}$	$\underline{Z}_{jj} < Z_{jj} \leq \overline{Z}_{jj}$
$GFT^{NM,NM} = [\Pi - \gamma_{int}] = \frac{\Pi}{2} - \gamma_{int} + F^D$	$\overline{Z}_{ii} < Z_{ii} \leq \frac{1}{2\overline{X}_i}$	$\overline{Z}_{jj} < Z_{jj} \leq \frac{1}{2\overline{X}_j}$

What stated in Lemma 3 still holds. Under the condition on GFTs above, BI is implemented for shortest distances, BI for intermediate ones and no match occurs if the distance is too large. Nevertheless, the threshold  $\overline{Z}_{ij}$  will vary depending on the type of buyer and supplier, i.e. on the distance with their potential partner in the domestic market, this generating the nine cases.

In this framework (18) and (20) read as

$$\Delta SIsh = \frac{2F^D}{\Pi\alpha^D} - \frac{2F^I}{\alpha^I[GFT^{rs}]}$$

$$\alpha^I > \overline{\alpha}'' \equiv \frac{\Pi\alpha^D F^I}{F^D[GFT^{rs}]}$$

This shows that what is stated in Proposition 6 still holds, but the level of the threshold  $\overline{\alpha}''$ , and therefore the probability of higher SI in international matches will depend on the type of B and S, i.e. there will be nine different thresholds and in five cases the  $\overline{\alpha}''$  itself is a function of the distance of B and S from their partner in the domestic market,  $Z_{jj}$  or  $Z_{ii}$ . It is easy to check that the largest  $Z_{jj}$  or  $Z_{ii}$ , i.e. the worst the domestic matches for either B or S, the lower  $\overline{\alpha}''$ , the more SI would be higher in international matches than in domestic ones.

## Appendix B. Supplementary tables and figures

Table B.1: Sample selection and descriptive statistics

	Austria	France	Germany	Hungary	Italy	Spain	UK	All countries
<i>Starting sample</i>								
N. obs.	482	2,973	2,973	488	3,021	2,832	2,142	14,911
% firms doing PTO for firms	63.36	85.10	72.21	87.48	86.75	69.05	79.94	78.79
% product innovation	58.06	47.77	47.99	43.41	47.78	44.27	56.20	48.45
% turnover PTO (firms doing PTO)	72.13	86.82	72.17	87.74	88.12	77.33	74.61	80.69
<i>(a) Sample doing PTO</i>								
N. obs.	354	2,742	2,434	451	2,819	2,204	1,808	12,812
% firms doing PTO for firms	89.75	92.98	89.18	95.28	92.45	88.60	94.22	91.46
% product innovation	60.94	47.76	47.11	45.50	47.58	44.62	56.43	48.34
% turnover PTO (firms doing PTO)	72.13	86.82	72.17	87.74	88.12	77.33	74.61	80.69
<i>(b) Sample doing PTO only for firms</i>								
N. obs.	315	2,623	2,228	433	2,605	1,947	1,699	11,850
% firms doing PTO for firms	100	100	100	100	100	100	100	100
% product innovation	60.20	47.30	48.44	44.56	47.83	45.29	56.10	48.71
% turnover PTO (firms doing PTO)	73.79	88.62	74.19	87.91	88.80	78.09	74.63	81.88
Sample as % of sample doing PTO (a)	88.98	95.66	91.54	96.01	92.41	88.34	93.97	92.49
<i>(c) Sample doing 100% PTO for firms</i>								
N. obs.	167	1,984	1,095	263	1,819	1,071	844	7,243
% firms doing PTO for firms	100	100	100	100	100	100	100	100
% product innovation	54.54	45.35	41.76	39.20	44.17	39.64	48.37	43.82
% turnover PTO (firms doing PTO)	100	100	100	100	100	100	100	100
<i>(d) Sample doing 100% PTO for firms with non-missing covariates</i>								
N. obs.	167	1,984	1,095	263	1,812	1,070	844	7,235
% firms doing PTO for firms	100	100	100	100	100	100	100	100
% product innovation	54.54	45.35	41.76	39.20	44.05	39.67	48.37	43.78
% turnover PTO (firms doing PTO)	100	100	100	100	100	100	100	100
Sample as % of sample doing PTO (a)	47.18	72.36	44.99	58.31	64.28	48.55	46.68	56.47

Note. This table reports the samples' sizes and the associated descriptive statistics for some key variables produced by progressively applying the sample selection criteria leading to the definition of the final estimation sample. All statistics are computed using survey weights.

Table B.2: Test of the balancing property for some selected variables (PS-NNM)

variable	sample	mean		% bias	% reduction  bias	t-test	
		treated	control			t	p >  t
<i>size class</i>							
20 - 49 employees	Unmatched	0.41302	0.43001	-3.4		-1.46	0.143
	Matched	0.41344	0.39726	3.3	4.7	1.41	0.159
50 - 249 employees	Unmatched	0.25164	0.13803	29		12.31	0
	Matched	0.2513	0.25926	-2	93	-0.78	0.436
250 or more employees	Unmatched	0.08671	0.0285	25.2		10.68	0
	Matched	0.08587	0.09355	-3.3	86.8	-1.15	0.251
RD employment	Unmatched	8.194	6.2536	14.2		6.05	0
	Matched	8.1485	8.4625	-2.3	83.8	-0.89	0.375
Graduate employment	Unmatched	9.9509	6.4014	29.9		12.7	0
	Matched	9.784	9.4851	2.5	91.6	0.93	0.352
Importer status (D)	Unmatched	0.58589	0.28751	63.1		26.81	0
	Matched	0.58464	0.59726	-2.7	95.8	-1.1	0.273
FDI status (D)	Unmatched	0.07139	0.01257	29.6		12.56	0
	Matched	0.07023	0.05761	6.4	78.5	2.2	0.028
Domestic group (D)	Unmatched	0.16193	0.1126	14.4		6.11	0
	Matched	0.16132	0.16214	-0.2	98.3	-0.1	0.924
Foreign group (D)	Unmatched	0.11761	0.04778	25.6		10.85	0
	Matched	0.11715	0.13059	-4.9	80.8	-1.74	0.082

<sup>(a)</sup> Sample before matching.

Note. The Probit model used to compute the PS also includes NACE (rev. 1.1) aggregate industry and country fixed effects. They are generally balanced except for industries including a small number of firms in the sample (DH), or smaller country samples (Austria, Hungary and the UK).

Table B.3: Robustness checks: Estimates of the Sample Average Treatment Effects on the Treated (SATT) on different samples or with balance sheet covariates

Matching method	N. observations.	SATT	st. err.	Remarks
a) <i>Sample also including firms producing less than 100% on PTO</i>				
OLS without controls	11,834	0.194***	0.009	
OLS with controls	11,834	0.104***	0.010	controls are the same covariates used in matching estimators
Probit without controls	11,834	0.190***	0.008	
Probit with controls	11,834	0.101***	0.009	controls are the same covariates used in matching estimators
PS-NNM	11,834	0.097***	0.014	one-to-one matching on PS
NNM	11,802	0.074***	0.013	one-to-one matching, exact matching on industry, country, FDI and foreign group dummies
CEM <sup>a</sup>	6,873	0.088***	0.014	exact matching on all variables (intervals for continuous variables)
Entropy balancing <sup>a</sup>	11,834	0.101***	0.009	balancing is made on the first moment
b) <i>Baseline sample (Section 2.2), covariates include balance sheet data<sup>b</sup></i>				
OLS without controls	5,455	0.209***	0.013	
OLS with controls	5,455	0.113***	0.014	controls are the same covariates used in matching estimators
Probit without controls	5,455	0.204***	0.012	
Probit with controls	5,455	0.107***	0.013	controls are the same covariates used in matching estimators
PS-NNM	5,455	0.119***	0.022	one-to-one matching on PS
NNM	5,413	0.104***	0.019	one-to-one matching, exact matching on industry, country, FDI and foreign group dummies
CEM <sup>a</sup>	2,778	0.095***	0.021	exact matching on all variables (intervals for continuous variables)
Entropy balancing <sup>a</sup>	5,455	0.133***	0.013	balancing is made on the first moment

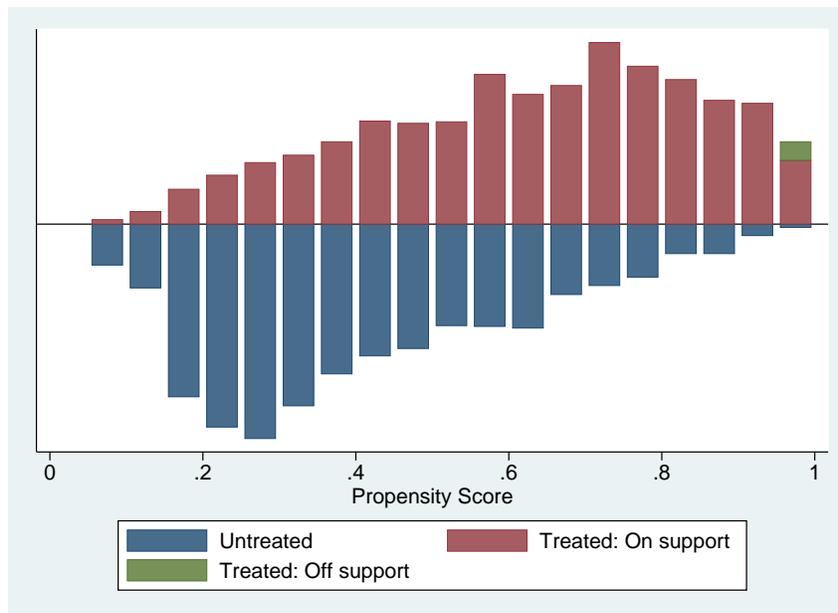
\*\*\* significant at the 1% statistical level.

Notes. PS-NNM, NNM and CEM stand for Propensity Score-Nearest Neighbor Matching, Nearest Neighbor Matching and Coarsened Exact Matching, respectively. The number of observations change between columns since the number of non-matched observations varies according to the method used. Standard errors are robust to heteroskedasticity in OLS and probit models, and are computed following [Abadie and Imbens \(2006\)](#), [Abadie and Imbens \(2011\)](#) and [Abadie and Imbens \(2016\)](#) in PS-NNM and NNM. The NNM estimates are corrected for the bias introduced by matching on more than one continuous variables ([Abadie and Imbens, 2006, 2011](#)).

<sup>a</sup> SATT are estimated by means of regressions using CEM or entropy balancing weights, controlling also for the matching variables to improve precision.

<sup>b</sup> These models include also two variables taken from balance sheet data, namely physical capital per worker and revenue per worker, as proxies of a firm's capital intensity and worker productivity, respectively.

Figure B.1: Distribution of the propensity scores



Note. Treated firms are those making PTO for foreign firms and untreated firms are those making PTO for domestic firms only.

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