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Bratti, Massimiliano

Felice, Giulia

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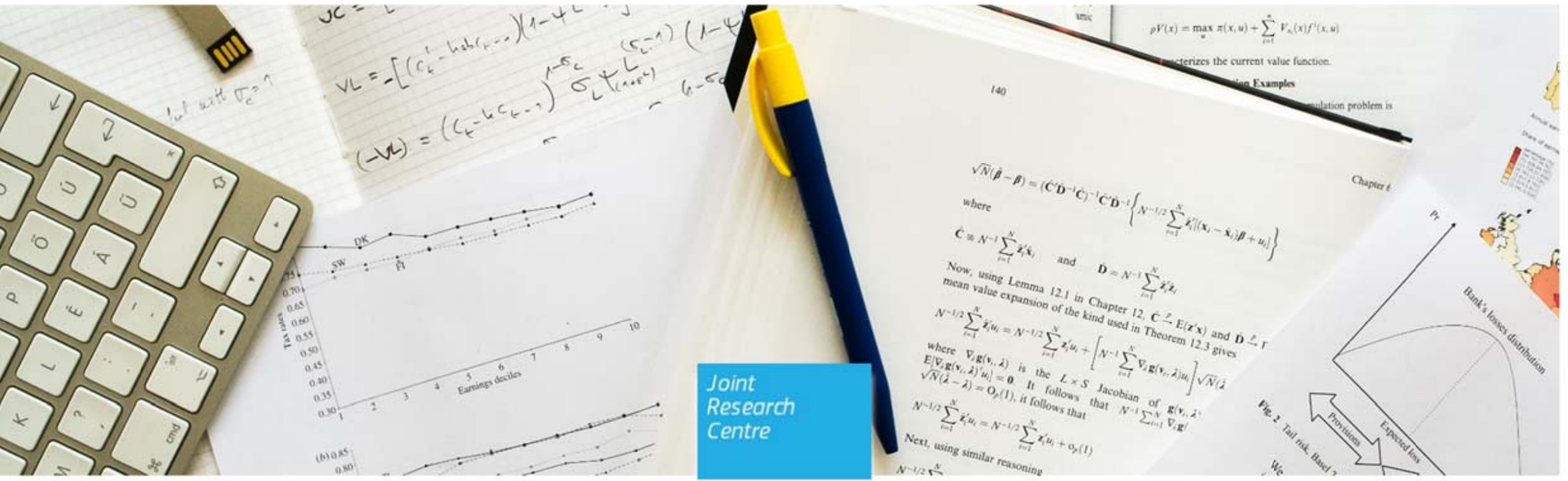

Contact information
Name: Massimiliano Bratti
Address: Via E. Fermi 2749, TP 361 Ispra (VA), I-21027, Italy
Email: massimiliano.bratti@ec.europa.eu
Tel.: +39 0332 785182

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Product innovation by supplying in domestic and foreign markets

Massimiliano Bratti[a,c,d,e], Giulia Felice[b,e,*]

[a]*DEMM, Università degli Studi di Milano, via Conservatorio 7, 20122 Milan, Italy*
[b]*Politecnico di Milano, via Lambruschini 4b, 20156 Milan, Italy*
[c]*European Commission Joint Research Centre (JRC), 21027 Ispra, Italy*
[d]*Institute of Labor Economics (IZA), 53113 Bonn, Germany*
[e]*Centro Studi Luca d'Agliano (LdA), 20122 Milan, Italy*

Abstract

This paper uses European firm-level survey data to provide some robust empirical evidence that suppliers doing production to order (PTO) for foreign firms are more likely to introduce product innovations than those doing 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 ('supplier') and a downstream producer ('buyer') 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, export

1. Introduction and motivation

Starting from the abundant research on the impact of a firms' 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 firms' international activities on their ability to introduce product innovations (see Baldwin and Gu, 2004; Salomon and Shaver, 2005; Liu and Buck, 2007; Fafchamps et al., 2008; Criscuolo et al., 2010; Lileeva and

*Corresponding author

Email addresses: massimiliano.bratti@unimi.it (Massimiliano Bratti), giulia.felice@polimi.it (Giulia Felice)

Comments from participants to presentations given at the RES (Manchester), ERSA (Saint Petersburg), SIE (Rome), SAEE (Malaga), ETSG (Copenhagen), ITSG (Rome), AFSE (Paris) annual meetings, at the conferences Offshoring Research Network (ORN) International Conference (Milan), 'Trade and Institutions' (Ferrara), XXVI Villa Mondragone International Economic Seminar FUET – Economics Foundation, University of Rome 'Tor Vergata' (Rome, July 2014), 'Structural Change, Dynamics and Growth' (Livorno), 'Re-Imagining Europe: Demand Driven Innovation and Economic Policy', Collegio Carlo Alberto (Turin) and 'Global Challenges' (Bocconi seminar series), and from two anonymous reviewers are gratefully acknowledged. Giulia Felice gratefully acknowledges financial assistance from the European Commission under Funding Scheme (Action) FP7-MC-IEF (GA 329153). The information reported and views set out in this paper are those of the authors and do not reflect the official opinion of the European Union. Neither the European Union institutions and bodies nor any person acting on their behalf may be held responsible for the use which may be made of the information contained herein. The usual disclaimers apply.

Trefler, 2010; Bustos, 2011; 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 does not distinguish between trade in final and intermediate goods.

Trade is increasingly characterized by global value chains (GVCs) and 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 trade is in specialized goods (Rauch, 1999; Artopoulos et al., 2013). Along GVCs, complex interactions are developed between upstream and downstream firms located in different countries, which are usually seen as channels of knowledge exchange by the business literature (Hippel, 1988). The literature looking at the innovation effects of GVCs participation is recent but continuously growing (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 '90s, in particular with the emerging role of Asian countries, supply chain trade among advanced countries (North-North networks) has been relevant since the '60s (Baldwin and Lopez-Gonzalez, 2015). GVCs still are for a large part a regional, more than a global phenomenon: the weight of intra-European trade in total EU intermediate trade is around 70%, in both export and import. Hence, a large part of EU trade in intermediate inputs is within the EU supply chain, what is also called "Factory Europe" (WB et al., 2017).

Finally, there is also a rich business and management literature that stresses the role of buyer–supplier collaborative relationships as a fundamental source of innovation. The latter is described as a process that no longer happens exclusively within the firm, but which rather 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 due to the need to deal with rapid changes in customer preferences, and shorter product life, there has been a gradual switch from a competitive model in which buyers were trying to minimize costs and to use several suppliers to reduce risk, towards 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 his product or process, i.e., for specialized intermediate goods. Specialized goods are usually traded under a *production to order* (PTO) regime, i.e., firms produce following an order by other firms (Casaburi and Minerva, 2011). The larger the role played by product characteristics, the higher the informational frictions and therefore 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 since 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 innovation activities with a supplier providing the required intermediate input. In downstream firms, product innovation can be induced by the interactions with 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 these three streams of literature and to show how a supplier's involvement in PTO of intermediate inputs for foreign buyers can, under certain conditions, lead to more product innovation compared to PTO for domestic buyers. The focus of our paper is on "incremental innovations," that is, in 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 innovativeness is likely to be driven by the interactions with 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 as owing to trade globalization and diffusion of GVCs, an increasing share of trade in intermediate goods has 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 on the higher product innovativeness of firms doing PTO for foreign customers compared with those doing PTO for domestic firms using the EFIGE dataset, which provides information on serven European countries and which was collected within the Seventh Framework Programme's 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 which 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 an improved intermediate input to produce a new final good. Innovation in the intermediate good depends on the distance in the product characteristics space between the needs of the buyer and the characteristics of the existing input already produced by the supplier.

Innovation in the intermediate good 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 splitting of the profit. Since the features of the contract and the costs are not the same in domestic and international matches (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 real-world features highlighted by the literature outlined above, 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 match with a domestic supplier, or, alternatively, they can search for a supplier closer to their needs in foreign markets. As a result of buyers' decisions on whether to search abroad or not, 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: some of them selling only domestically, and some of them exporting. Second, in an international match, depending on the distance in the product space, there are heterogeneous decisions across buyers on whether to directly adapt the input or to ask the supplier to do it. This in turn generates heterogeneous innovation strategies among the suppliers, some of them selling the existing input, and some of them renewing their products. Third, we show that under some conditions suppliers of specialized goods engaged in international matches with foreign buyers show a higher propensity to introduce product innovations and adapt their goods to the buyer's needs than do 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 buyer's and the supplier's goods, namely their distance in the product space, search and internationalization costs and the differences in the costs of adapting the goods in international vs. foreign business relationships.

Unlike the literature on exporting 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 explain firms' exporting and innovation behavior, e.g. through self-selection, they are not sufficient alone to explain the superior innovativeness of exporting firms. This is very evident in Europe where also small and low productive firms often sell their goods abroad and introduce product innovations (see Table 1). Hence, an important source of firm unobserved heterogeneity may concern the characteristics of the goods they produce, and the relationships with their foreign partners, which are often unobservable and omitted from the export-innovation regressions commonly estimated in the literature.

Some predictions of our model are that suppliers doing PTO for foreign buyers are more innovative than suppliers doing domestic PTO, the lower the number of firms in the buyers's 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 make product adaptation more expensive for foreign than for domestic customers. We bring some of these predictions to the data, and find some broadly consistent evidence.

Our paper highlights that a reduction in trade barriers (e.g. costs of managing operations across countries, exchange rate risk) increases the chances of the existing firms acting as suppliers of finding a trade partner in foreign markets which asks for 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 the foreign markets. The trade relationship may be either temporary or permanent, the latter only being a potential source of innovation. This is particularly relevant for those small-medium enterprises which 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 relation with 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 concludes.

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 innovativeness, 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

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

Firm characteristics	share of exporters	share of product innovators non-exporters	exporters
Firm size			
> 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
Deciles of unit labor costs			
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.

of studies specifically on the association between exporting and product innovation for firms carrying out PTO. The theoretical analysis we propose will then try to match some of the empirical facts reported in this section and in the past literature.

2.1. The EFIGE data

We use the EFIGE dataset, which gathers data on a representative sample (at the country 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 for the UK; and around 500 for Austria and Hungary. The survey's questionnaire is mainly focused on 2008, with some questions on the firms' activities in 2009 and in previous years. The original data set 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 are complemented with balance sheet data from AMADEUS, a database of comparable financial information for public and private European companies, collected by the Bureau van Dijk.

EFIGE provides information about the firm's production mode, in particular, after being asked which percentage (on average) of firm's turnover was made up by sales of produced-to-order goods (question E1), firms are also asked the following question:

E2. In which of the following categories 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 data 86% of firms produce to order. There are differences among countries. The percentage of firms doing 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.[2] Overall the great majority of firms (79% in the overall sample) does PTO for other firms, and the average percentage of sales made of 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 which takes on the value one if the firm introduced product innovations and 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.[3]

2.2. Sample selection criteria

Given the focus of the current paper on buyer-supplier relationships established between firms for the purchase/provision of a specialized intermediate good, we impose some selection criteria on our sample before carrying out the empirical analysis. First, since we aim at explaining differences in product innovativeness between firms doing PTO for domestic and those doing PTO for foreign firms, from the survey we select: (a) firms doing PTO; (b) firms doing PTO for firms only (excluding PTO for the public administration and final customers). These criteria are instrumental to the theoretical explanation that we will provide in the second part of the paper and that focuses on the supply of intermediate goods. Both criteria do not

[2] These figures include PTO for other firms, the public sector and final consumers.
[3] All the reported statistics make use of sample weights.

produce a very large drop in the sample size, given that most firms engage in PTO for other firms. Table B1 in Appendix B shows the sample sizes and average characteristics (e.g., % of turnover made by PTO, % of product innovation) produced by the application of each selection criterion. Since there is already an extensive literature studying the effects of exporting on product innovation and we want to avoid the effect of PTO for foreign firms being confounded with that of other types of export activities, we impose a further selection: (c) firms have to produce to order 100% of their turnover. This last criterion, albeit being restrictive, ensures that our sample excludes firms engaging in non-PTO export activities. Since it is much more restrictive than the previous two, causing in some countries more than 50% of observations dropping from the sample, in Appendix B we report some robustness checks using the sample of all firms doing PTO for other firms irrespective of the percentage of turnover (i.e. the sample defined by criterion (b)). Finally, there is a limited number of observations that drop 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 foreign PTO on product innovation is complicated by a potential endogeneity issue. Indeed, let us consider the following linear regression model

$$Y_i = \alpha_0 + \alpha_1 Forcust_i + \boldsymbol{\gamma}'\mathbf{X_i} + \epsilon_i \tag{1}$$

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 ϵ_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. α_1 is our parameter of interest, and represents the average innovation premium of doing 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 α_1 implies that some variables determining PTO for foreign customers have been omitted from the regression, or put it 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 ϵ_i generating an endogeneity problem: the coefficient α_1 estimated with 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 ϵ_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 using matching estimators. Let us 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 $Y_i = Forcust_i Y_i(1) + (1 - Forcust_i) Y_i(0)$. There are two problems when one aims to estimate the *treatment effects* $TE_i = Y_i(1) - Y_i(0)$. First, for each firm we only observe either the outcome in the presence or the outcome in 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 the treatment is non random (i.e. it is potentially endogenous with the outcome). Matching estimators provide a solution to both these issues. The main idea is to match treated firms with untreated firms which are sufficiently similar in their observable characteristics, and are therefore taken as the counterfactual evidence for the former, then take the difference in the observed outcomes between these matched firms, and average across the sample. In this way, 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 is the Conditional Independence Assumption (CIA), that is absence of selection into the treatment according to unobserved variables, which may also affect the outcome.[4] 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).

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

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

[4] For a detailed review on matching methods see Caliendo and Kopeinig (2008).

4. entropy balancing.

All methods have advantages and disadvantages. Propensity score (PS, hereafter) matching allows to reduce the course of dimensionality (since matching is only performed on one variable, i.e. the PS) and is useful when the sample is not very large. The main idea is to estimate a parametric model (e.g., probit) for the treatment status and then match firms on the predicted probabilities (the propensity scores). In the case of PS-NNM each treated firm is paired with the untreated one with the closest PS. The typical check of the goodness of matching is that 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 using a measure of distance in the covariates used for matching. It happens sometimes that some characteristics are difficult to balance, and the researcher may want to match exactly on these attributes trying 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 last 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 to exact NNM and CEM, is that all observations are retained in the estimation of the SATT.

All the matching procedures listed above require the choice of the set of variables on which to perform matching.[5] Good candidates are the variables which are likely to affect both the product innovation outcome and the selection into the treatment (foreign vs. domestic PTO). On the basis of previous empirical studies on exporting and product innovation (see, for instance, Bratti and Felice, 2012) and avoiding to use 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 headquarter), respectively, which are all factors which may affect both innovation and involvement in

[5] See on this Caliendo and Kopeinig (2008). The choice of a very large set of variables makes the CIA more likely to hold but at the cost 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[a]	4,134	0.090***	0.018	exact matching on all variables (intervals for continuous variables)
8) Entropy balancing[a]	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).

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

foreign markets; NACE 2-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 over total employment (i.e. graduate employment) and the percentage of R&D employees over total employment (R&D employment); finally, indicators of other forms of firm's internationalization, namely a dummy for having made foreign direct investments and a dummy 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 some robustness checks using two additional variables coming from firm's balance sheet data but which have a non-negligible number of missing: physical capital intensity (the value of physical capital stock divided by the number of employees) and the unit labor costs (total labor costs divided by firm turnover) as a proxy of productivity. 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 of increasing the probability of product innovation by 0.205. When controls for other potential determinants of product innovativeness 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 reports the balancing tests on the covariates used in the PS matching. Covariates are generally well balanced, except for a few industry and country dummies,[6] the foreign group, and the FDI dummies. For this reason, we also implement later in this section matching procedures which allow for exact matching on these variables. Figure B.1 in Appendix B shows the distribution of the PS for treated and untreated firms. As expected, the distribution of the PS 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 PS includes significant predictors of foreign PTO.[7] The fifth row of Table 2 shows the estimated SATT using the PS-NNM method, which is 0.113 and 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, the country, the FDI and the foreign group dichotomous indicators. The estimated SATT is 0.106, statistically significant at the 1% level. 171 observations do not have an exact match on the variables specified and are 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 fall 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 statistically significant at 1%. Thus, in spite of the reduction of 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 entropy balancing estimation, which builds weights that balance the means of all covariates in the treated and untreated groups. Thus, the mean 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, statistically significant at the 1%, a bit larger than that found with the previous matching estimators.

[6] See Table B.2's footnotes for major details.

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

All in all, the estimates in Table 2 lead 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 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, one has to find a source of presumably exogenous variation in the treatment of interest. The latter is, however, a formidable task, especially when dealing with cross-country data. For this reason, in this section we will limit ourselves 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 treament of interest ($Forcust$) as T and drop the firm indexes. Consider the bivariate probit model:

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

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

and

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

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

Altonji et al. (2005) show that under the assumption of proportional selection between observable and unobservable variables the bias due to the omitted variables can be written as[8]

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

[8] See p. 176 in Altonji et al. (2005).

where $\tilde{T}$ represent the residuals of a regression of T on $\mathbf{X}$, and the last expression has been obtained by exploiting the fact that in the probit model $\text{Var}(\epsilon) = 1$ and the assumption that the relationship between T and 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). Computing the expression (5) with our data, we obtain an estimate to bias ratio ($\hat{\alpha_1}$/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 away the entire effect of foreign PTO.[9] 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.[10]

3. Position of our theoretical model in the literature

In the next section, we introduce a theoretical framework to explain the higher product innovativeness of firms doing PTO for foreign buyers compared to those doing it for domestic buyers. The contributions closest to our work are those belonging to the large literature on global sourcing, in particular those introducing contractual incompleteness and imperfect information in international trade models with product specialization (Grossman and Helpman, 2005; Rauch and Trinidade, 2003; Puga and Trefler, 2010). These papers are concerned with firms' decisions on the geographical location of the partner 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 Trinidade (2003) mainly in the analysis of the innovation process. While our work encompasses the decision on who adapts the input, since both upstream and downstream firms can do it, in Grossman and Helpman (2005) only the subcontractors adapt their inputs to match the buyers' needs, while in Rauch and Trinidade (2003) firms do not change location in the product space, i.e., they do not adapt their product. Therefore, in those contributions, either the buyer never innovates or the decisions do not involve innovation strategies, but just whether and where to match. Those works aim at highlighting the role of institutions (affecting the

[9] $\hat{\gamma}$ 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 ρ (between the error terms ϵ and u) unconstrained.

[10] 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 $R^2_{max} = 1.3R^2$ (i.e. 0.18), we obtain a coefficient of proportionality between unobservables and observables (δ) of 2.1 implying that unobservables must be twice as important as observables to explain away the whole estimated effect of foreign PTO on product innovation.

enforceability of contracts) in differently developed countries (Grossman and Helpman, 2005) and the roles of information barriers and of network ties in overcoming these barriers (Rauch and Trinidade, 2003), and in affecting the volume of trade across countries when products are differentiated.

Different innovation strategies are instead investigated by Puga and Trefler (2010), where a buyer located in a Northern technologically advanced country decides where to buy the component needed 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 to the buyer if they carry out the innovation effort, and firms are involved in medium-long term relationships. Our paper borrows extensively from the analysis of the innovation process carried out by Puga and Trefler (2010), while, abstracting from countries' differences in the level of development, we depart from their work in two main directions. Firstly, we focus on firm heterogeneity in the product characteristics space, highlighting how firms' location in the product space induces different innovation and internationalization strategies, this encompassing the case where the supplier, too, might incur adaptation costs which are related to distance in the product space. Secondly, 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 our framework, 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, that is, it would require excessive adaptation. So a key role is played in our model by uncertainty in the features of the intermediate good provided by the foreign supplier (and in the related adaptation costs). Our work provides a potential interpretation of the existence of temporary trade relationships, and it is related to research stressing asymmetric information and incomplete contracts emerging 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, the positive relation between the quality of institutions in the destination countries and export flows surviving in a framework 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), or the number of product varieties in multi-product firms (Bernard et al., 2011), or both (Eckel et al., 2015). Indeed, this literature has mainly emphasized asymmetries between the products on the final demand side, while product innovation induced by interactions with firm-buyers' needs, 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 focusing on the determinants of firms' offshoring mode (i.e., "make or buy" decision: vertical integration vs. outsourcing in a foreign country) and looking in particular either at the role of International Property Rights' protection in the destination countries (Glass and Wu, 2007) or at the technological content of the goods (Acemoglu et al., 2010), or at both (Naghavi et al., 2015).

Nevertheless, our model is related to these papers, because it focuses on what we may call the "innovation boundaries," and we deal with who between the two partners adapts the intermediate good.[11]

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

We build a theoretical model along the lines of the literature introducing incomplete contracts, agency frictions, and imperfect information in international trade related to the provision of specialized inputs (Rauch and Trinidade, 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 productivity since we focus on a different mechanism based on heterogeneity in firms' products.

Our theoretical model explains why one could observe a product innovation premium from producing to order for foreign customers, and what are the variables that might strengthen or weaken such a positive association. We develop a partial equilibrium model with two identical countries (i.e., neither 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 be generally involved in two types of innovation effort. A 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 the innovation effort, concerning a specialized intermediate good, which is our specific focus. The latter is a process through which a new product or a substantial

[11] Innovation costs are a relevant determinant of firms' decisions, like in our work, in the literature analyzing the determinants of firms' R&D offshoring given the multinational structure of the firm (Sanna-Randaccio and Veugelers, 2007). Beyond the fact that these works are 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 are made. These are likely to be "incremental innovations," that is, those changes that firms develop in their products in their day-to-day activities.

In this paper, we do not analyse the first type of innovation, i.e., we are not interested in the process of entry, nor in the (always possible) strategy for both a downstream firm and an upstream firm of investing in R&D in order to change their location on the product characteristics space after entering, or to add products (i.e., multi-product firms). We are interested in singling out how a buyer's needs may induce product innovation by a supplier (i.e., inducing him to adapt and specialize his good to match the former's needs).[12]

In our setting, there are two types of agents engaged in production: upstream producers (i.e., suppliers, S hereafter), and downstream producers (i.e., buyers, B hereafter), who purchase an input from the upstream producers. We develop a model for analyzing the alternative innovation strategies adopted by firms, while taking as given their boundaries, i.e. we abstract from the so called "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, he has to match with a 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.[13] The buyer can search for a suitable supplier either in the domestic market or abroad. Z_{ij}, where the first and the second subscripts refer to the country in which B and S are located, respectively,[14] is the distance along the product circle between B's "needs" and S's good's characteristics. Z_{ii} and Z_{jj} are the distances between B and S in a domestic match (D), in B's and S's countries, respectively; Z_{ij} is the distance between B and S 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 B's and in S's countries, respectively. Information about Z_{ij} is imperfect (symmetrically) before matching (see the section on timing, below).

[12] 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. In particular, in order to enter the (domestic) market, they have to. 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 effort by the buyer) may generate changes in an existing intermediate good.

[13] Our model does not consider multiple matches. In modelling a one to one relationship between the buyer and the supplier for a provision of a specialized input, we follow Casella and Rauch (2003) and Rauch and Trinidade (2003). The intuition 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 is serving only one buyer, but that he is not providing the same specialized input to several buyers.

[14] 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, 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 bearing some costs, even in the case where an actor is not directly responsible for the implementation of the innovation (some costs are related to the distance in needs, "implementation costs," while others are related to providing instructions and assistance). Implementing the innovation by 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., the "core competency." So in our framework, depending on this distance in the product characteristics space, the buyer may ask the supplier to adapt his 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 by themselves the suitable solution for their specific needs and develop the product design; they often transfer their innovations (design or product), for instance 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 in-house the components produced by suppliers in order to make them suitable for their process (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 the buyer, there are therefore two alternative strategies between which B can choose, when firms are located in the same or in different countries:

- *Buyer implementation (BI) strategy*: B buys an existing good of S, and adapts either his process or the acquired S good to his 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 in adapting the input, by bearing a fixed cost F_{ii}^S and F_{ij}^S in a domestic and in a foreign match respectively (for instance, the cost of technical assistance);

– *Supplier innovation (SI) strategy*: B bears the fixed cost F_{ii}^{B} and F_{ij}^{B} in a domestic and in a foreign match, respectively, to solve the problem of figuring out what input exactly he needs to produce his good and asking S to produce it; it is the cost of providing the instructions for the design of the input he needs to another firm (i.e., the supplier). 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. As for the SI strategy, think 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), who however may assist the supplier through in-plant worker training or specific lessons on product details.

We assume that the cost for S of assisting B in the BI strategy and the cost for B to provide a project for S in the SI strategy are the same, i.e. $F^{Bii} = F^{Sii} = F^{Bjj} = F^{Sjj} = F^{D}$ and $F^{Bij} = F^{Sij} = F^{I}$ in domestic and foreign matches, respectively. These costs may be related, for instance, with the language spoken in the countries i and j. 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 country in which B and S are located. The second assumption implies that the cost of B located in i of providing a project in the language of j is the same as the cost of S located in j of providing assistance in the language of i (i.e., costs are symmetric). We assume in what follows that $F^{D} \leq F^{I}$, since the contrary would not be reasonable.

The two 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.[15]

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.[16]

There are other costs which firms have to bear:

– a *search cost*: η (sunk cost); B bears this cost when searching for a partner in the *foreign* market;

– a *per-period fixed "internationalization" cost*: γ_{int}, the sum of the costs that B and S have to bear

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

[16] In the empirical analysis we reported evidence on product innovation by suppliers, while we do not have information on PTO buyers.

whenever the firms building the relationship are located in different countries.

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

4.3. Timing

The timing of the model is displayed in Figure 1. Buyers and suppliers are initially involved in a domestic match; they are producing, respectively, a final good and a customized intermediate good (what we deal with here is "innovation" by existing firms).[17] We assume that B knows the actual distribution of the domestic suppliers and he is matched with the closest one (see Grossman and Helpman, 2005). B introduces an innovation in his product, one requiring a new specific input (or adaptation of the one he is using).[18] Since B knows the actual distribution of suppliers in his domestic market, he also knows the location of the closest one in the product characteristics space for the new input he needs; therefore B decides whether to match and produce with the closest supplier in the domestic market or to look for a new supplier abroad. Since we are focusing on PTO relationships we assume that the downstream producer, B, is the one searching abroad for a "better" input.[19] Therefore in our framework, the sunk cost of searching in the foreign market is borne by the buyer, B.[20]

B has imperfect information about the location of suppliers abroad: he 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 he will match with a supplier at a random distance $Z_{ij} \sim U(0, 1/(2X_j))$. Buyers who go abroad pay a sunk cost to randomly match with one and only one foreign supplier (Casella and Rauch, 2003). In this first meeting, they exchange the existing S good, and neither B nor S innovate. We assume

[17] 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 the result of multiple buyer-supplier relationships.

[18] B 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 his decision.

[19] Grossman and Helpman (2005) and Puga and Trefler (2010) also assume that the buyer is the one searching abroad.

[20] There are several reasons why B may want to look for a new supplier abroad, as pointed out by Egan and Mody (1992). B may want to preserve credibility in negotiating prices and/or to protect against S's non-performance; B may be looking for a new supplier for either current or future needs he foresees. What we are interested in this paper is the case in which B may be willing to introduce an innovation in his product, and therefore he needs a new specific input.

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 learn each other's demands and capabilities. The authors 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 B's needs and S's characteristics). Buyers do 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 learns the characteristics of the product, i.e., the distance between the required intermediate good and the one provided by the foreign supplier. In case the distance is too large in the foreign match, however, the first meeting will not lead to a successful match, and the buyer who was looking for a partner in the foreign market will go back home to continue searching for a suitable supplier in the domestic market. In this case, firms will only be involved in 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 (one or two years) while few survive for a longer period (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 good's being bought by a foreign buyer to test it with the possibility of the business relationship breaking down in case the intermediate good supplied is too distant from the buyer's needs.

The first match reveals Z_{ij}, the distance between B and the randomly matched S. By exchanging the existing good (i.e., from the S point of view, by exporting in t_0), B and S know each other and B decides whether to stay in the international match or not and, if staying, under which type of innovation agreement (i.e., either SI or BI). Only one attempt at an international match is allowed: 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 distance is too large, to go back and match domestically, with a (possibly new) domestic partner.[21] The intuition is that firms may match in a first meeting without carrying out innovation, in order to know each other and see whether it is worth matching internationally in a permanent way and how to do it. Not allowing B to go back home in case of bad international matches 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 those who went abroad in t_0 (i.e., there is no "recall" of suppliers' locations), since the closest supplier, identified by B in t_0 before deciding to search abroad, might no longer be available. He could have matched with another B who did not search abroad and could have not anymore the required productive capacity.[22]

Buyers who do not find it convenient to search abroad, can match with the closest supplier under BI or SI, in t_0, and keep on with the relationship in t_1.

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

i) imperfect information about the location of suppliers in the foreign market. B initially knows the locations of all suppliers in his country and matches with the "closest" supplier; B does not know the location of suppliers in the foreign country, he 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 be known only after "trying." Sunk search costs have to be borne by B to know 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.

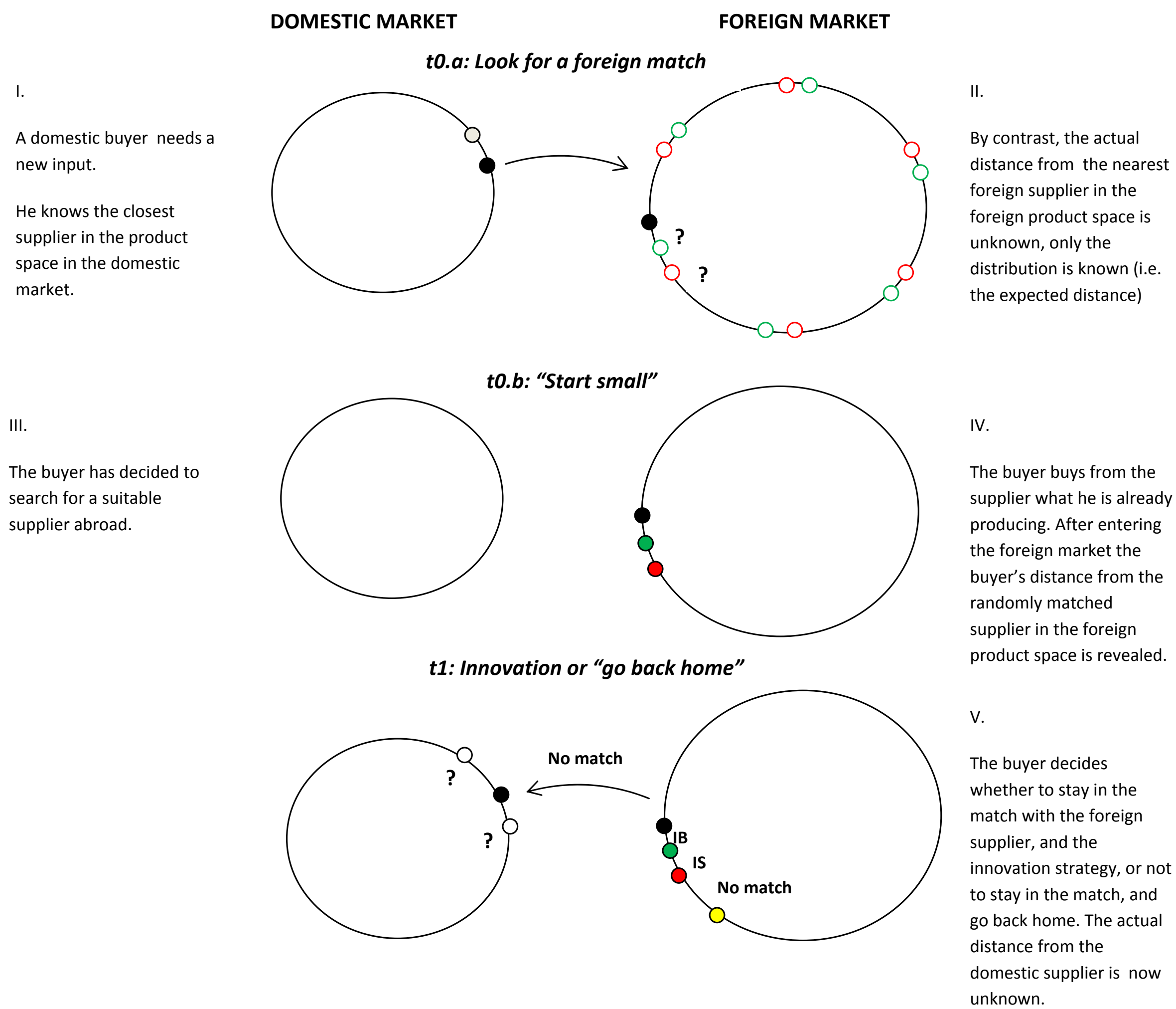
ii) in international matches firms ending up in an unsuccessful match can still go back home and match domestically, while in the domestic matches, unsuccessful matches necessarily imply no production of the new good and zero profit for both B and S, since information is perfect and the "closest" (in the product space) supplier is known: if the latter is too far, no better match can be found.

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

[21]By assuming that firms can go back in the domestic market after one random match we follow Casella and Rauch (2003) and Rauch and Trinidade (2003), unlike Puga and Trefler (2010) where firms have to remain in the match. In Appendix A.5 we show that our results are robust to assuming that firms ending up in an unsuccessful match abroad cannot go back 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.

[22]This implies that the exact location of suppliers in the domestic market becomes unknown after having been abroad, while B continues to know their distribution function. We show in Appendix A.5 that our results are qualitatively robust to assuming that B ended up in an unsuccessful match abroad can go back and match with a domestic supplier under perfect information.

Figure 1: Timing of the model



4.4. Contract

Given that firms are involved in PTO relationships, we assume that B is the principal (see also Puga and Trefler, 2010).[23] The relationship between B and S could be conceptually divided into two different stages. The first one regards 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 (S) in the SI (BI) strategy and the distance related cost borne by S (B) in the SI (BI) strategy. Once these costs are borne in the successful matches, the input is suitable for producing the new final good. In the second stage, S will produce the input, sell it to B, who in turn uses it to produce the final good which is sold in the market generating profits. The latter stage can be regulated by a fully enforceable contract. The former not, since in both innovation strategies it regards the types of investment that in the literature are called "relationship specific" (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 effort. Even if Z_{ij} is already revealed when the strategy is decided, due to the particular characteristics of the innovation effort the contract cannot be contingent on Z_{ij}. The innovation effort is hardly verifiable by an external court and firms cannot commit not to renegotiate about profit after the innovation costs are borne because the characteristics of the innovation effort (i.e., the quality of the technical assistance, the details of the project, the implementation) are revealed only after the investment is sunk (Grossman and Hart, 1986; Hart and Moore, 1999).[24] Since firms' boundaries are given, the modified input is useless outside the relationship. 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 get involved in a relationship where they bargain over the profit of the relationship (which will be generated by selling the final good) after that the input has been modified. In this ex post bargaining we assume that B and S have the same bargaining power and they split the profits according to a Nash bargaining sharing rule.

Both in the domestic and in the international matches, initially B offers a contract to S that can either be SI or BI, depending on what maximizes B's profit, under S's participation constraint (PC, hereafter). When B decides 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

[23] This amounts to say that we do not model the decision on who should decide the innovation strategy.

[24] In contrast, the innovation effort is ex-post observable by B and S, symmetrically.

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 finds out how to make the input fit his production process, bearing the distance related costs. B and S participation and therefore their investment effort will depend on the size of the expected profit, on the share they get and on 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 Π which 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 the buyer's innovation provides the same profit).

At this stage the contract is signed, S produces and sells to B the intermediate input at a competitive price.[25] 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 a higher price to B since they are involved in a production relationship and their incentive to maximize the profit 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's taking place, and on the type of innovation strategy.

We assume that B and S share the same bargaining power at the stage the contract is signed in both innovation strategies.[26] Nevertheless, while in the domestic matches B and S equally split the "pie," the profit share may differ in the international matches since B and S in this case have the option of going back home and look for a partner in their own country. These options are the expected profit from domestic matches. For this reason, on the one hand, the parties negotiate over a smaller profit in international matches, and on the other hand, either B or S may get a larger profit share. It is worth noting that the outside options affect symmetrically what B and S receive in international matches under both BI and SI strategies. Therefore, choosing a 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

[25]Note that at this stage S's costs are only the costs of materially producing the input, since the innovation costs have already been borne.

[26]For the sake of space and simplicity, results for the generalization of the model where a parameter β governs the bargaining power distribution between the buyer and the supplier are available upon request. A sufficient condition for all the theoretical results of the paper to be robust to considering a different bargaining power for the buyer and the supplier is that the bargaining power of the former is larger.

gets Π_{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 for B in terms of the cost for S and we allow it 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 the α's are the buyer–supplier cost ratios. The cost for B to adapt his process or final product to a foreign intermediate good will probably be different (and most probably higher) from the cost of adapting for a domestic supplier. Indeed B, who is already matched with a domestic supplier, is likely to be "less familiar" with a foreign supplier's intermediate good.[27] Moreover, different countries, even if similarly developed, may have technical incompatibilities which need fixing.[28]

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 B is at least as big as the cost of adapting for S for a given distance Z in the product space. We think 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 his 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, 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 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 Π is the total operational profit (see Appendix A.1). In our framework, B chooses between the BI and the SI strategies whichever one yields the higher operational profit net of the innovation costs under the S participation constraint.

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

[27] This assumption is in line with Puga and Trefler (2010), in a slightly different framework.

[28] For instance, cars sold in the US are bigger than those sold in Italy; a US producer may find a components' producer in Italy producing exactly what he needs for his new car's 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 its production process, which is targeted to 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
α^D	ratio between costs in domestic matches ($b^{B_{jj}}/b^{S_{jj}}$)
α^I	ratio between costs in international matches ($b^{B_{ij}}/b^{S_{ij}}$)
γ^{int}	sum of B's and S's costs of internationalization
η	B's search cost
assumptions/further definitions	
$b^{B_{jj}} = (\alpha^D) b^{S_{jj}}$, $b^{B_{ii}} = (\alpha^D) b^{S_{ii}}$	
$b^{B_{ij}} = (\alpha^I) b^{S_{ij}}$	
$F_{ij}^B = F_{ij}^S = F^I$	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.

Proof. The solution of 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, respectively, or no match takes place. The thresholds delimiting the intervals are

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

$$\overline{Z}_{ii} = \frac{1}{b^{Sii}}(\frac{\Pi}{2}). \tag{7}$$

Whenever $Z_{ii} \in [0, \underline{Z}_{ii}]$, the BI strategy is implemented in a domestic match, but whenever $Z_{ii} \in (\underline{Z}_{ii}, \overline{Z}_{ii}]$, the SI strategy is implemented. If instead $Z_{ii} \in (\overline{Z}_{ii}, \frac{1}{2X_i}]$, 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 who bears the distance related costs versus the fixed ones. Since B is the principal, making the decision in order to maximize the profit under the S participation constraint, for relatively shorter distances it is more convenient for him to buy the input as it is and bear the distance related costs to introduce it in his production process, since the distance related cost of innovation is relatively smaller than the cost of providing a project to S. Viceversa for larger distances. When distance is too large, costs are too high, and 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.

We consider the ratio between the no-match interval and the match interval (where either BI or SI are 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* (Π)*; the higher the per unit distance cost of adapting the input for the supplier in a domestic match* (b^{Sii})*; 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; the lower the number of suppliers in the buyer's country, the larger the distance in needs, the higher the innovation costs and therefore the profitability of a match; the higher the per unit distance cost of adapting the input for the supplier, the lower the likelihood that the supplier accepts 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 good they produce, experience more frequently successful matches, and therefore show a higher probability to introduce new final goods.

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

As we said, when B and S end up in a "bad" international match, they can always go back home and look for a (possibly new) partner in the domestic market. After the intermediate period in which they have been involved in the international match, information about the exact locations of the domestic suppliers and buyers, for B and S, respectively, is imperfect. Therefore the outside options in an international match are the expected profits of the domestic matches ($OUT^I_{vk} = E(\pi^D_{vk})$, where $v = i, j$ and $k = S, B$).[29]

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

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

and

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

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

$\pi^{BI,I}_B = \frac{1}{2} \left[\Pi - \gamma_{int} - E(\pi^D_{iB}) - E(\pi^D_{jS} \right] + E(\pi^D_{iB}) - \alpha^I b^{Sij} Z_{ij}$

and

$\pi^{BI,I}_S = \frac{1}{2} \left[\Pi - \gamma_{int} - E(\pi^D_{iB}) - E(\pi^D_{jS}) \right] + E(\pi^D_{jS}) - F^I$,

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

$\pi^{SI,I}_B = \frac{1}{2} \left[\Pi - \gamma_{int} - E(\pi^D_{iB}) - E(\pi^D_{jS}) \right] + E(\pi^D_{iB}) - F^I$

and

$\pi^{SI,I}_S = \frac{1}{2} \left[\Pi - \gamma_{int} - E(\pi^D_{iB}) - E(\pi^D_{jS}) \right] + E(\pi^D_{jS}) - b^{Sij} Z_{ij}$,

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

Only after Z_{ij} is revealed, a buyer who has decided to look for a better match (i.e., a closer supplier) in the international markets will decide either to stay in the randomly drawn match, and under which innovation

[29] See Appendix A.5 for the results under the alternative assumption that B cannot go back home, i.e., $OUT^I_{vk} = 0$, where $v = i, j$ and $k = B, S$.

[30] We omit subscripts indicating the country of the match in the case of pay offs in international matches since they are always ij, being the country of the international match the one in which S is located.

strategy, or to go back to the domestic market. B chooses the strategy which yields the highest operational profit (net of the innovation costs) under the S participation constraint.

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; ii) in international matches the strategies are implemented in the same order as in domestic matches: BI is implemented for shorter distances in the product space, SI for intermediate distances, no match takes place when distance is too large.*

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

$$\underline{Z}_{ij} = \frac{F^I}{\alpha^I b^{Sij}} \tag{10}$$

$$\overline{Z}_{ij} = \frac{1}{2b^{Sij}} \left[\Pi - \gamma_{int} - E(\pi^D_{iB}) - E(\pi^D_{jS}) \right], \tag{11}$$

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

Whenever $Z_{ij} \in [0, \underline{Z}_{ij}]$, the BI strategy is implemented, while when $Z_{ij} \in (\underline{Z}_{ij}, \overline{Z}_{ij}]$, B chooses the SI strategy; for distance in the interval $Z_{ij} \in (\overline{Z}_{ij}, \frac{1}{2X_j}]$, 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 be always 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 we can claim that international matches are implemented for shorter distances than domestic matches since, on the one hand, matching internationally is more costly (i.e., both B and S bear the fixed internationalization cost γ_{int}), and, on the other hand, both B and S possess the alternative option of going back home. Therefore, firms stay in an international relationship only when they find a better match abroad, i.e., when the distance in the product space is shorter than that at home.

We then consider the ratio between the no-match interval and 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 (γ_{int}); the larger the per unit distance cost of adapting for the supplier in an international match ($b^{S_{ij}}$); 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 of a buyer looking for a supplier abroad, and the closer must be the foreign supplier 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 accepts 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, improve the number of matches in international markets.

4.5.3. Buyer's internationalization decision

As described in Section 4.3, at t_0, B decides whether to look for an international match or not. 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:

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

where $E(\pi_{iB}^D)$ and $E(\pi_{jS}^D)$ are defined in equations (8) and 9), respectively. In making a decision on whether to search abroad or not, B compares the profit 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 he decides to look for an international match; B bears the sunk cost of searching in the foreign market (η) and in the first meeting B, randomly matching with S, buys the existing input. This implies a profit $\Pi_{fm} < \Pi$ because no adaptation takes place and as a consequence the new B's (final) good cannot be produced; still, there could be a non-negative Π_{fm} since B could, for instance, re-sell the input. $\pi_{iB,0}^{BI,D}$ ($\pi_{iB,0}^{SI,D}$), is the operating profit for B at t_0 in case he decides to match domestically, under the BI (SI) strategy, depending on the domestic distance with his nearest supplier; $\pi_{iB,1}^D = \frac{\Pi}{2}$ is what B gets at t_1, when he 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 again the innovation costs.

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

$$\pi^{I}_{B,0} + E(\pi^{I}_{B}) \geq (\pi^{BI,D}_{iB,0} + \pi^{D}_{iB,1}). \tag{13}$$

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

$$\pi^{I}_{B,0} + E(\pi^{I}_{B}) \geq (\pi^{SI,D}_{iB,0} + \pi^{D}_{iB,1}). \tag{14}$$

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

$$\pi^{I}_{B,0} + E(\pi^{I}_{B}) \geq 0. \tag{15}$$

Lemma 5. *i) When search costs are above η_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 η_0 all firms that would have implemented either BI or SI in domestic markets try and look for a partner abroad; iii) when search costs are below η_1 all firms who would have not matched domestically try and look for a partner abroad; when search costs are above η_1 none searches abroad even if no match is available domestically.*

Proof. The solution of B's decision problem allows us to determine the intervals in the domestic product characteristics space where B either stays in 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 to go abroad or not are given by:

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

The thresholds in the search costs evenly affecting 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 —who would implement a BI strategy in the domestic market— searches for a foreign partner if the search costs are small enough ($\eta < \eta_0$). For $Z_{ii} \in (\underline{Z}_{ii}, \overline{Z}_{ii}]$, the buyer — who would implement an SI strategy in the domestic market — searches for a foreign partner iff $\eta < \eta_0$. When the distances in the domestic market are too large, i.e., $Z_{ii} \in (\overline{Z}_{ii}, 1/(2X_i)]$, the buyer —who 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 relation between the density of suppliers in B's country and the probability that buyers make an 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 the buyers will receive in a successful international match. In the same way, the relation between the density of suppliers in S's country, where B would search, and the probability that buyers make an 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 profit share of the potential partner.

4.5.4. A condition for larger "product innovation by supplying" in international than in domestic matches

We focus on firms which have achieved a match and implementing either BI or SI to study which of the two strategies is more likely in domestic or foreign matches. To analyze how the set of distance intervals for which the SI strategy is implemented differs between international and domestic matches, we consider the measure of the relative share of the SI interval in the sum of the SI+BI distance intervals: $(SIsh)^D = (1 - \frac{\underline{Z}_{jj}}{\overline{Z}_{jj}})$ and $(SIsh)^I = (1 - \frac{\underline{Z}_{ij}}{\overline{Z}_{ij}})$. 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 (negative) the share of the set of distance intervals for which SI is implemented over the total match interval is higher (lower) for an international match than for a domestic one (i.e., product innovation is more likely in case of foreign than 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 adaptation cost ratio in an international match has to be higher than a certain threshold, i.e.* $\alpha^I > \bar{\alpha}$, *where*

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

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

Product innovation is relatively more frequent in international than in domestic matches the smaller the number of suppliers in the country of origin of B (X_i)*, and the internationalization cost* γ_{int}*.*

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

It is worth noting that with $\alpha^I \leq \alpha^D$, B would be more likely to buy the existing good provided by S and adapt it to his needs in an international match than in a domestic one.[31] This is due to the fact that the SI strategy is implemented for relatively larger 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 (due to the effect of γ_{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 for B 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 $\alpha^I = \alpha^D$ the limit case in which goods (e.g., inputs) are perfectly standardized (also in international markets), and therefore $b^{B_{jj}} = b^{B_{ij}}$ and $b^{S_{jj}} = b^{S_{ij}}$. In this case, by rewriting the condition $\alpha_I > \bar{\alpha}$ as

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

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 one (because $F^I > F^D$ and $GFT > 0$) while it is relatively more likely to hold the more specialized are the sectors. So we obtain the following corollary:

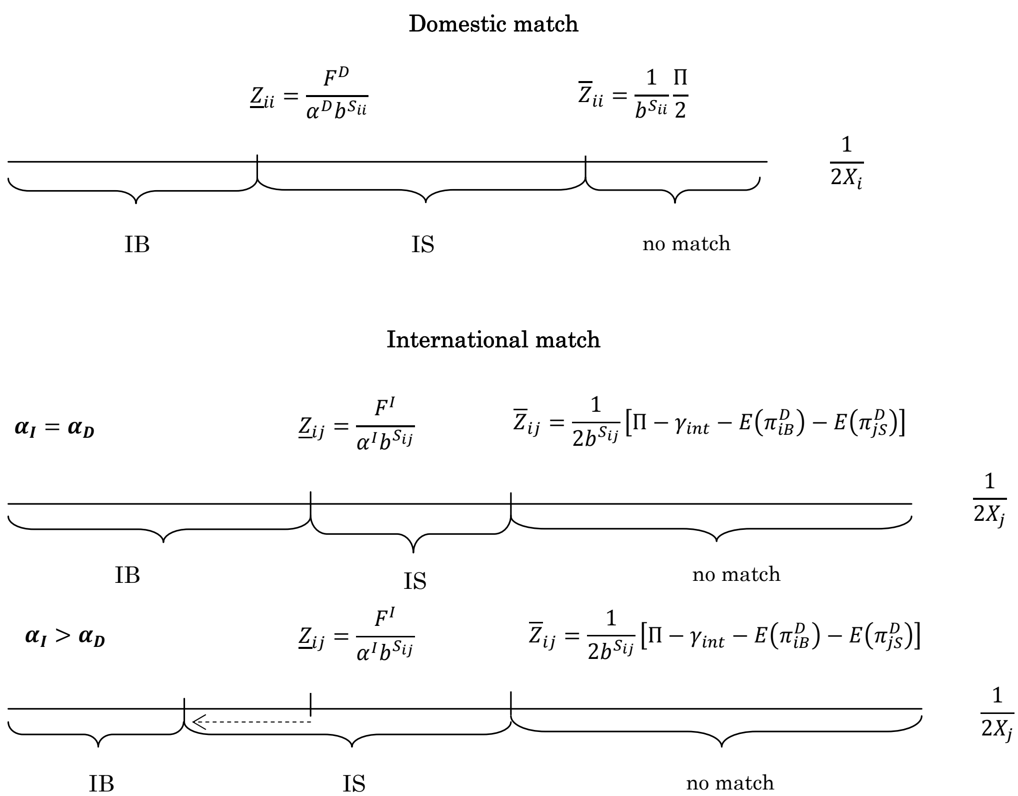
Corollary 7. *Supplier Innovation (SI) is more likely in foreign than in domestic markets if PTO involves specialized goods.*

[31] 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 in foreign than in domestic matches. By contrast, when the unit distance costs 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 the buyer who 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 for B to find a match in the domestic market, i.e. the higher X_i, since this increases the outside option of the buyer, and the higher the cost of managing operations abroad, i.e. the higher γ_{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.

Figure 2: Strategies' intervals



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 states that PTO for foreign customers should induce more product innovation the smaller the number of potential suppliers in the foreign market for the good subjected 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 just provide some tentative evidence using the EFIGE survey.

Proposition 6 states that a higher internationalization cost (γ_{int}) should lead to *lower* innovation by suppliers doing PTO for foreign customers compared to those supplying to domestic firms. We operationalise this test as follows. Using bilateral trade data at the three digit industry level (ISIC rev. 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 including the seven countries in EFIGE. The gravity models include common language, colonial relationships, population-weighted bilateral distances and origin-year and destination-year fixed effects.[32] After estimating the gravity models for the period 1980-2006, we compute the predicted values only based on log-distance, and colonial and common official language dummies, and average them by country and industry (pooling all years).[33] These average predicted values are then standardized to have zero mean and unit variance, and can be considered as the internationalization costs stemming from geographic 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 standardized measure of internationalization costs. The interaction term turns out to be 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 manage to export to countries in which internalization costs are higher, are more productive on average, and produce more innovations.

In sectors producing more specialized goods, there are larger differences in goods both within and between countries compared to sectors with a more standardized production. Also the technical solutions adopted in production are likely to differ across countries according to the level of goods specialization. In our model

[32] These variables are taken from the GeoDist database from Cepii, described in Mayer and Zignago (2011).

[33] Common official language and the existence of a historical colonial relation can also be considered as proxies of F_I. In particular, they should reduce the F_I/F_D cost ratio.

this is mirrored by a larger α_I/α_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) 3-digit level[34] 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 $Forcust$ that is increasing with the level of differentiation of an industry's production, and is statistically zero in industries that do not produce differentiated products.[35]

Finally, we test if the innovation effect of PTO for foreign customers depends negatively on the number of potential suppliers existing in the origin market of B, 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 adding interaction terms between $Forcust$ and the number of firms in the first destination country of the supplier's exports reported in EFIGE, and operating in the supplier's sector. The sample size is reduced because of the missing number of firms for some destination countries. The interaction term is negative, consistently with our model prediction, but is statistically insignificant at conventional levels.[36]

6. Concluding remarks

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

We 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 specialized inputs provision in international trade.

Two sources of firm heterogeneity are present in our model. A first source of (ex-ante) firm heterogeneity is in the location of buyers in the domestic product space. This source of heterogeneity determines heterogeneous buyers' 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

[34] We use a similar procedure to Conconi et al. (2016).

[35] The estimation sample falls because of missing values in the firms' ISIC codes. Indeed, EFIGE provides ISIC (revision 2) 3-digit codes, which have been linked to NACE (revision 1.1) 4-digit codes by means of a concordance table. However, a one-to-one concordance is not provided for all NACE industries.

[36] 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)
Forcust	0.156***	0 .010	0.122***
	(0.020)	(0.045)	(0.017)
Forcust × Internationalization costs[a]	-0.023***		
	(0.009)		
Forcust × % Differentiated products[b]		0.104**	
		(0.050)	
% Differentiated products		-0.095**	
		(0.044)	
Forcust × N. firms (industry)[c]			-0.004
			(0.007)
N. observations	6,195	5,864	5,750

[a] 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.

[b] Interaction term between supplier's PTO for foreign customers and percentage of differentiated goods in the firm industry according to Rauch (1999), conservative classification.

[c] 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).

with the foreign buyer takes place, and which determines heterogeneity in the innovation strategies. As a consequence, we have some firms matching only domestically, under different innovation strategies (either buyer's or supplier's innovation); other firms looking for a partner abroad; some firms continuing in their foreign match under either the buyer's or supplier's innovation strategy; and some firms, after having engaged in only a first meeting abroad, going back home and looking for a new domestic partner ("temporary trade"). This in turn implies some heterogeneity across suppliers: some of them selling only domestically, some of them exporting their existing intermediate goods only temporarily and not introducing innovations, others engaging in long-term relationships both domestically and abroad, either by selling the existing input and assisting the buyer or 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, this way highlighting a specific channel through which trade in intermediate goods may induce product innovation by firms already operating in the market. We finally took some of the model implications to the data, finding broadly consistent evidence.

As for future research, two main possible developments of our analysis are worth mentioning. From the empirical point of view, it would be interesting to find 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 the theoretical point of view, our model provides a framework in which firms may implement different innovation and internationalization strategies depending on the characteristics of their products and not on differences in productivity. Although in this paper our main aim was to stress the "engines" which can drive different innovation and internationalization strategies between firms located in similarly developed economies, a natural extension of our work would consider also the role of countries' differences in technological levels (and productivity), 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

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

$$\pi_{iS}^{BI,D} = \frac{\Pi}{2} - F^D, \tag{A.2}$$

where Π 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: $\frac{\Pi}{2} \geq 0$
$\pi_{iB}^{BI,D} \geq 0 : Z_{ii} \leq (\frac{\Pi}{2})\frac{1}{\alpha^D b^{Sii}}$
$\pi_{iS}^{BI,D} \geq 0 : \frac{\Pi}{2} \geq F^D$.

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

$$\pi_{iB}^{SI,D} = \frac{\Pi}{2} - F^D \tag{A.3}$$

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

where Π is the total operational profit, and where $\pi_{B}^{SI,D}$ and $\pi_{S}^{SI,D}$ 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: $\frac{\Pi}{2} \geq 0$

$\pi_{iB}^{SI,D} \geq 0$: $\frac{\Pi}{2} \geq F^D$

$\pi_{iS}^{SI,D} \geq 0$: $Z_{ii} \leq \frac{\Pi}{2}(\frac{1}{b^{S_{ii}}})$.

In this framework, B chooses the BI strategy if

$$\pi_{iB}^{BI,D} \geq \pi_{iB}^{SI,D} \tag{A.5}$$

under the S participation constraint (PC^S),

$$\pi_{iS}^{BI,D} \geq 0. \tag{A.6}$$

B chooses instead the SI strategy if

$$\pi_{iB}^{SI,D} > \pi_{iB}^{BI,D}, \tag{A.7}$$

under the S participation constraint (PC^S),

$$\pi_{iS}^{SI,D} \geq 0. \tag{A.8}$$

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 $\underline{Z}_{ii} < \overline{Z}_{ii}$ 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

$$NMsh^D \equiv \frac{\frac{1}{2X_i} - \overline{Z}_{ii}}{\overline{Z}_{ii}} = \frac{1}{2X_i}\frac{1}{\overline{Z}_{ii}} - 1. \tag{A.9}$$

Thus,

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

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

$$\frac{\partial NMsh^D}{\partial X_i} = -\frac{1}{2X_i^2\overline{Z}_{ii}} < 0. \tag{A.12}$$

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

$$E(\pi_{jS}^{D}) \equiv \int_{0}^{\underline{Z}_{jj}} \pi_{jS}^{BI,D} \cdot g(Z_{jj})dZ_{jj} + \int_{\underline{Z}_{jj}}^{\overline{Z}_{jj}} \pi_{jS}^{SI,D} \cdot g(Z_{jj})dZ_{jj} \equiv G(X_j, F^D, \Pi, \alpha^D, b^{Sjj}) \tag{A.13}$$

and

$$E(\pi_{iB}^{D}) \equiv \int_{0}^{\underline{Z}_{ii}} \pi_{iB}^{BI,D} \cdot h(Z_{ii})dZ_{ii} + \int_{\underline{Z}_{ii}}^{\overline{Z}_{ii}} \pi_{iB}^{SI,D} \cdot h(Z_{ii})dZ_{ii} \equiv H(X_i, F^D, \Pi, \alpha^D, b^{Sii}), \tag{A.14}$$

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, respectively, in an International match under BI:

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

and

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

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

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

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

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

and

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

(again non-negative GFT must hold).

B chooses BI internationally if

$$\pi_B^{BI,I} \geq \pi_B^{SI,I} \tag{A.19}$$

under

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

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

B chooses SI internationally if

$$\pi_B^{SI,I} > \pi_B^{BI,I} \tag{A.22}$$

under

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

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

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.

$\underline{Z}_{ij} < \overline{Z}_{ij}$ whenever GFT are such that $\alpha^I \left[\Pi - \gamma_{int} - E(\pi_{iB}^D) - E(\pi_{jS}^D\right] > 2F^I$ (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

$$NMsh^I \equiv \frac{\frac{1}{2X_j} - \overline{Z}_{ij}}{\overline{Z}_{ij}} = \frac{1}{2X_j}\frac{1}{\overline{Z}_{ij}} - 1. \tag{A.25}$$

Thus,

$$\frac{\partial NMsh^I}{\partial \gamma_{int}} = \frac{1}{4X_j b^{S_{ij}} \overline{Z}_{ij}^2} > 0 \tag{A.26}$$

$$\frac{\partial NMsh^I}{\partial b^{S_{ij}}} = \frac{GFT}{4X_j b^{S_{ij}} \overline{Z}_{ij}^2} > 0 \tag{A.27}$$

under the condition of non-negative GFT

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

$$\frac{\partial NMsh^I}{\partial X_i} = \frac{1}{X_j}\left[-\frac{1}{\overline{Z}_{ij}^2}\frac{\partial \overline{Z}_{ij}}{\partial X_i}\right] > 0 \tag{A.29}$$

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

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

The expected profitsin a international match reads as

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

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 (12) and differentiating it we obtain

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

and

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

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

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

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

that is,

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

from which we obtain

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

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 $\widehat{Z}_{ii} < \underline{Z}_{ii}$, implying a condition on η:

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

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

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

that is,

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

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 ($\overline{Z}_{ii} < Z_{ii} < \frac{1}{2X_i}$), B will search for a partner in a foreign country iff

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

that is,

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

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 α^I, we derive

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

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

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

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

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

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

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

$$\frac{\partial \overline{\alpha}}{\partial \gamma_{int}} = \frac{\alpha^D \Pi F^I}{F^D \left[GFT\right]^2} > 0. \tag{A.44}$$

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 $OUT^I_{vk} = 0$, where $v = i, j$ and $k = S, B$. It it straightforward to derive the following pay offs in international matches under different innovation strategies, as the Nash bargaining solution:

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

$\pi_S^{BI,I} = \frac{1}{2}\left[\Pi - \gamma_{int}\right] - F^I$

$\pi_B^{SI,I} = \frac{1}{2}\left[\Pi - \gamma_{int}\right] - F^I$

$\pi_S^{SI,I} = \frac{1}{2}\left[\Pi - \gamma_{int}\right] - b^{Sij} Z_{ij}\,.$

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

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

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 γ_{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 $OUT^I_{vk} = 0$, as done in Appendix A.3:

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

from which it is easy to derive

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

and

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

under non-negative GFT. This allows us to also check that

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

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

and

$$\frac{\partial SEARCHsh}{\partial X_j} = -2X_i\left(-\frac{1}{\alpha^D b^{S_{ii}}}\frac{\partial E'(\pi_B^I)}{\partial X_j}\right) > 0. \tag{A.50}$$

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 cases for buyers and suppliers involved in a match abroad. In these nine cases 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.

$\pi_B^{BI,I} = (1/2)[GFT^{r,h}] + \pi_{iB}^{r,D} - \alpha^I b^{S_{ij}} Z_{ij}$

$\pi_B^{SI,I} = (1/2)[GFT^{r,h}] + \pi_{iB}^{r,D} - F^I$

$\pi_S^{BI,I} = (1/2)[GFT^{r,h}] + \pi_{jS}^{h,D} - F^I$

$\pi_S^{SI,I} = (1/2)[GFT^{r,h}] + \pi_{jS}^{h,D} - b^{S_{ij}} Z_{ij}$
$\pi_B^{NM,I} = \pi_{iB}^{r,D}$
$\pi_S^{NM,I} = \pi_{jB}^{h,D}$
where $r = BI, SI, NM$ for B in country i and $h = BI, SI, NM$ for S in country j.

As a solution of B's 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:

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

$$\overline{Z}_{ij}^{r,h} = \frac{GFT^{r,h}}{2b^{S_{ij}}}$$

For the SI interval to be not empty ($\overline{Z}_{ij}^{r,h} > \underline{Z}_{ij}$), $GFT^{r,h} > 2F^I$ must hold, which is always satisfied when the PCs are, where the $GFT^{r,h}$s read as:

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

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 $\overline{Z}_{ij}^{r,h}$ 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

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

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

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 larger Z_{jj} or Z_{ii}, i.e. the worse 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.

As for the decision of B to search abroad, we derive the expected profit as in Appendix A.3. We have three cases for B depending on the strategy he would choose in the domestic market, which in turn depends on the distance from the closest domestic supplier

$$E^r(\pi_B^I) = \int_0^{\underline{Z}_{ij}} \pi_B^{BI,I} \cdot g(Z_{ij}) dZ_{ij} + \int_{\underline{Z}_{ij}}^{\overline{Z}_{ij}} \pi_B^{SI,I} \cdot g(Z_{ij}) dZ_{ij} + \int_{\overline{Z}_{ij}}^{(1/(2X_j)} \pi_B^{NM,I} \cdot g(Z_{ij}) dZ_{ij} \tag{A.51}$$

where $r = BI, SI, NM$ for B in country i

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

and

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

since, ex-ante, although B has a perfect knowledge of its outside option $\pi_{iB}^{r,D}$, the type of S (BI, SI or NM) which will be drawn in the foreign market j is unknown to B before searching abroad. Hence, he will consider the expected value of the profit, which depends on the probability of drawing the different types of suppliers. From which we can derive the expected profit in international matches for the three types of B:

$E^{BI}(\pi_B^I) = \Omega(Z_{ii}, X_j, b^{S_{ii}}, b^{S_{ij}}, \alpha^I, \alpha^D, F^I, F^D, \gamma_{int}, \Pi)$, for B in the interval $0 \leq Z_{ii} \leq \underline{Z}_{ii}$

$E^{SI}(\pi_B^I) = \Upsilon(X_j, b^{S_{ii}}, b^{S_{ij}}, \alpha^I, F^I, F^D, \gamma_{int}, \Pi)$, for B in the interval $\underline{Z}_{ii} < Z_{ii} \leq \overline{Z}_{ii}$

$E^{NM}(\pi_B^I) = \Phi(X_j, b^{S_{ii}}, b^{S_{ij}}, \alpha^I, \alpha^D, F^I, F^D, \gamma_{int}, \Pi)$, for B in the interval $\overline{Z}_{ii} < Z_{ii} \leq \frac{1}{2X_i}$.

As in Appendix A.3, we then distinguish three cases:

i) B whose closest supplier in the domestic market is at a distance in $0 \leq Z_{ii} \leq \underline{Z}_{ii}$, will search abroad if $\pi_{B,0}^I + E^{BI}(\pi_B^I) \geq \pi_{iB,0}^{BI,D} + \pi_{iB,1}^D$

ii) B whose closest supplier in the domestic market is at a distance in $\underline{Z}_{ii} < Z_{ii} \leq \overline{Z}_{ii}$, will search abroad if $\pi_{B,0}^I + E^{SI}(\pi_B^I) \geq \pi_{iB,0}^{BI,D} + \pi_{iB,1}^D$

iii) B whose closest supplier in the domestic market is at a distance in $\overline{Z}_{ii} < Z_{ii} \leq \frac{1}{2X_i}$, will search abroad if $\pi_{B,0}^I + E^{NM}(\pi_B^I) \geq \pi_{iB,0}^{BI,D} + \pi_{iB,1}^D$.

The solution of B's decision problem allows us to determine the intervals in the domestic product characteristics space where B either stays in a domestic match or looks for a foreign match by engaging in a first meeting abroad and the relevant thresholds in the sunk costs η. Differently from the baseline case, in the first interval, we have an expression which is non-linear in Z_{ii}. In general, the results in the baseline model are robust to assuming that B and S keep information on the actual distribution of partners in the domestic market, but the computation are much more complex and the results less readable.

Appendix B. Supplementary tables and figures

Table B.1: Sample selection and descriptive statistics

	Austria	France	Germany	Hungary	Italy	Spain	UK	All countries
Starting sample								
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
(a) *Sample doing PTO*								
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
(b) *Sample doing PTO only for firms*								
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
(c) *Sample doing 100% PTO for firms*								
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
(d) *Sample doing 100% PTO for firms with non-missing covariates*								
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 treated	mean control	% bias	% reduction |bias|	t-test t	t-test $p > \|t\|$
size class							
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

[a] 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) *Sample also including firms producing less than 100% on PTO*				
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[a]	6,873	0.088***	0.014	exact matching on all variables (intervals for continuous variables)
Entropy balancing[a]	11,834	0.101***	0.009	balancing is made on the first moment
b) *Baseline sample (Section 2.2), covariates include balance sheet data*[b]				
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[a]	2,778	0.095***	0.021	exact matching on all variables (intervals for continuous variables)
Entropy balancing[a]	5,455	0.133***	0.013	balancing is made on the first moment

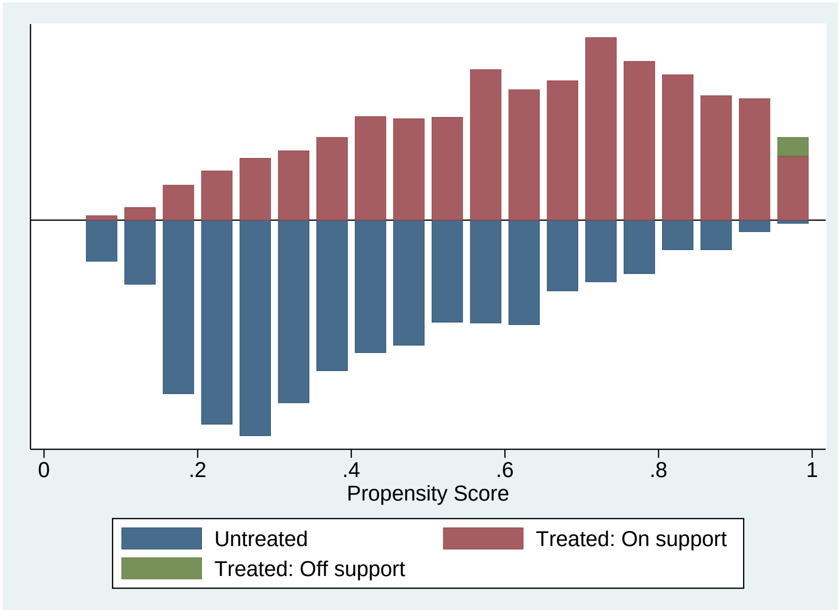
*** significant at the 1% statistical level.

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).

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

[b] 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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