Local sourcing and production efficiency*

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Preliminary and incomplete

Abstract

This paper examines how firms self-select into local sourcing based on their geography and their productivity. Using an exhaustive dataset on firms' buyer-seller linkages in Belgium, we show that firms strongly follow a predictable pecking order among Belgian districts. We also provide evidence that self-selection into importing exhibits complementarities with local sourcing. Our findings are consistent with an extension of the Antras et al. (2016) multi-country sourcing model with endogenous choice of tasks produced in-house.

*The views expressed in this paper are those of the authors and do not necessarily reflect the views of the National Bank of Belgium. Statistical evidence presented complies with the statistical legislation. No confidential information about individual firms is released in this document. Remaining errors are ours only.

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1 Introduction

Recent papers on international trade participation, among which Antras et al. (2016) and Bernard et al. (2015), are currently developing a new generation of sourcing theories. These theories are based on efficiency heterogeneity as the force that drives international trade. Bernard et al. (2007) show that US importers are on average larger and more productive than non-importers. Antras et al. (2016) show that their relative advantage is increasing in the number of countries from which they source. Similar arguments could also motivate the decision of local sourcing made by firms. However, studies on the organization of local network are much more parsimonious, due to lack of data. We intend to contribute to this relatively unexplored field by using an exhaustive dataset on firms' buyer-seller linkages in Belgium and by confronting it to these new theories.

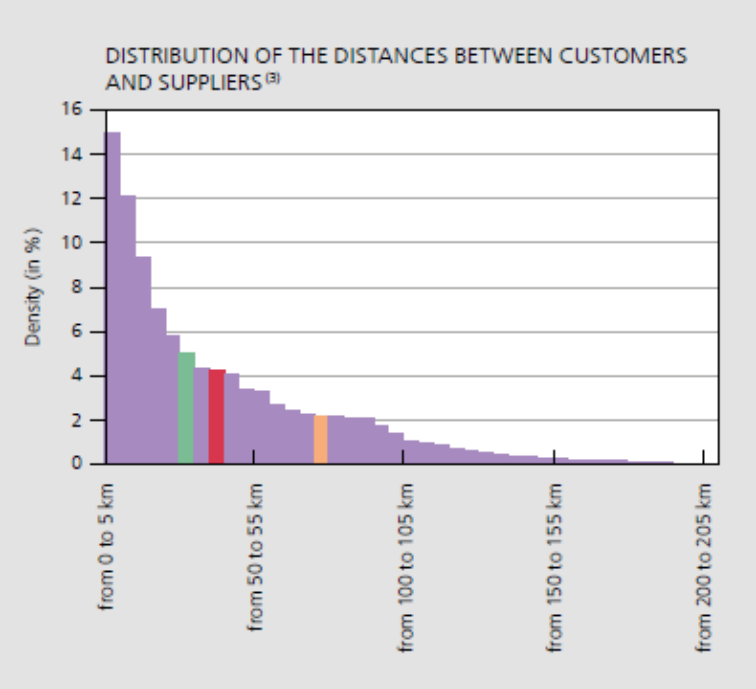
Dramatic advances in communication, information, and transportation technologies have revolutionized how firms produce their goods and services. Firms become increasingly specialized on their core activities, and outsource some production stages or supporting activities on which they have poor grasp. At the global level, this has lead to the rise of global value chains, a phenomenon that has been increasingly documented (see f.i. Yeats, 1998 or Baldwin, 2013). However, even in a very open economy as Belgium, where import and export amount to 80% of GDP, most of the trade between firms occurs locally. According to the 2010 national input-output, the value of domestic inputs purchases is twice as large as import value of intermediates. At a more microeconomic level, we also observe that only a small fraction of Belgian firms (around 5% in 2012) are sourcing inputs abroad. This phenomenon is observed worldwide. Using the WIOD table, we can show that trade in intermediate within countries accounted for 84% of total trade in intermediate in 2012.

Based on detailed firm level data described in the following sections, we observe that the organization of the domestic network is not random. Even in a small economy as Belgium, geography and its related trade frictions are important determinants of the inter-firms trading decisions. As not all importing firms source their inputs in the most distant or remote sourcing markets, firms do not source their domestic inputs from every Belgian district and tend to interact mostly with local partners (see Figures 1 and 2).

In this paper, we extend evidence on global sourcing to show not only that more efficient firms offshore more, but also that that their efficiency advantage is increasing in the number of domestic firms from which they source. These efficiency advantages are suggestive of fixed cost of sourcing at the supplying firm-level, which limits the ability of less efficient firms to select into sourcing from a large set of suppliers. We also show that selection into local sourcing exhibits complementarities across Belgian districts and foreign countries. As a result, Belgian firms strongly follow a predictable pecking order in their sourcing decision.

In contrast to canonical export models where firms profits are additively separable across destination markets (Melitz, 2003, Eaton and Kortum, 2002,

Figure 1: Distribution of distance between local trading partners (in 2014)

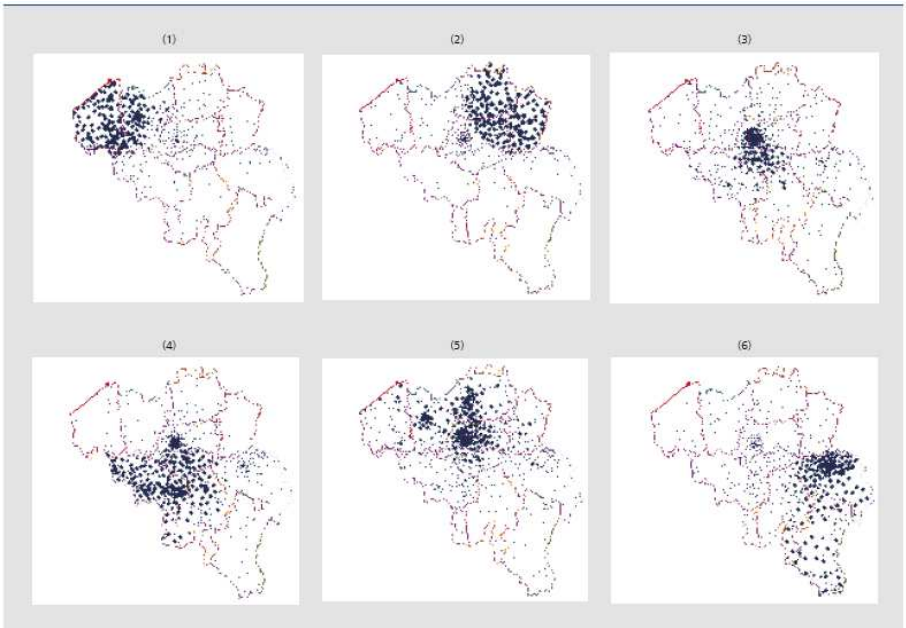


Source : Dhyne and Duprez (2016)
Note : The green bar locates the median distance (25km), the red bar the observed average distance (38) and the brown bar the expected distance that would be observed in a random network (72 km).

Bernard, Eaton, Jensen, and Kortum, 2003, Eaton, Kortum and Kramarz, 2011), sourcing decisions naturally interact through the firm's cost function. While this makes a model about sourcing much more complicated to solve theoretically and to estimate empirically, Antras et al. (2016) show that, under an empirically relevant condition, selection into importing exhibits complementarities across source markets.

To guide the empirical analysis, we modify the global sourcing model by Antras et al. (2016) to allow for the possibility that firms choose endogenously the tasks produced in-house. This enables our model to come to terms with some features of the data: most firms are selling at both intermediate and final demand. To keep the model as simple as possible, we introduce the concept of efficiency in tasks in light of the recent studies in management economics. We follow a growing literature showing that management competence is an important component of firms' total factor productivity (Bloom et al., 2017, Syverson, 2011). For example, better management practices are found to raise productivity in India through improved quality and efficiency and reduced inventory (Bloom et al., 2013). They also are one explanation behind the US IT related

Figure 2: The six main sub-components of the Belgian production network



Source : Dhyne and Duprez (2016)
Note: The sub-components were detected using the Louvain community detection algorithm applied to the domestic transactions observed in 2013 and 2014.

productivity advantage (Bloom et al., 2012). This assumption also takes its roots in the trade in value added literature (see Timmer et al., 2014, or Johson and Noguera, 2012 and 2017). This model of trade in tasks is the simplest one we can think of that can square with the facts. It enables us to abstract from complex solvability issues, arising in any model of trade in goods due to double marginalization.

Our paper relates to three strands of literature.

This paper is naturally related to a growing literature on the determinants of domestic (Bernard et al., 2015, Furusawa et al., 2017) and foreign sourcing (Amiti and Koning, 2007, Goldberg et al., 2010, Halpern et al., 2015, Bøler et al., 2015) and the impact on firms.

Second, our framework emphasizes the role of management in shaping the patterns of efficiency distribution. Generally speaking, this literature pins down that better managed companies source a wider range of distinct inputs. One possible channel is the complementarity between input quality and more skilled labor in the production of output quality (Verhoogen, 2008, Johnson, 2012).

Third, our paper contributes to the growing literature on the domestic production networks. Oberfield (2013) develops a general-equilibrium theory of the structure of production based buyer's optimal choices of suppliers to study how the endogenous network formation shapes the productivity and organization of

production. It also contributes to this very new and still very parsimonious literature on network formation.

The paper proceeds as follows. Section 2 introduces our theoretical model. Section 3 discusses our data sources. Sections 4 and 5 present our empirical design and results. The final section concludes.

2 Theoretical framework

The basic features of the model we are using in this paper are that in order to produce a given good, firms need to perform a continuum of tasks that they can decide to do in-house or to outsource, either locally or internationally. The motivation of outsourcing is production efficiency as firms are heterogeneous in their ability to perform a specific task. In our framework, firms will tend to specialize themselves in the set of tasks they are better at performing while they will outsource the remaining tasks to either domestic or foreign suppliers. The sourcing decision implies a fixed cost, which reflects the fact that outsourcing tasks requires some coordination or negotiation with the trading partners in order to set a trading relationship. Secondly, once the trading relation is established the amount of tasks performed is generating some variable costs due for instance to distance. Therefore, in this model, the domestic and international shipments of material inputs between firms will be implicitly embodied in the trade in tasks.

More specifically, the model extends Antras et al. (2016) to allow for the possibility that firms endogenously chose their tasks produced in-house. Second, we endogenize the value added ratio of firms and the intermediate sales by allowing all firms to sell both at final consumers and at any other firm[1]. As in Bernard et al. (2015) and in Furusawa et al. (2017), we also adapt the model to fit domestic firm-to-firm relationship.

Preferences

Consider a world consisting of C countries. In each country c, individuals value the consumption of differentiated varieties of products (goods and services) according to a standard symmetric CES utility function

$$U^c = \left(\int_{\omega \epsilon \Omega^c} q^c(\omega)^{\frac{(\sigma-1)}{\sigma}} d\omega \right)^{\frac{\sigma}{(\sigma-1)}} \tag{1}$$

where $\Omega_c$denotes the set of available products in country$c$. These preferences give rise to the following demand for variety ω:

$$q^c(\omega) = E^c (P^c)^{\sigma-1} p^c(\omega)^{-\sigma} \tag{2}$$

[1] In 2012, 67% of the firms in our dataset were selling to other domestic firms, 74% to final demand and 53% to both.

where $p^c(\omega)$ is the price of variety ω, P^c is the price index associated with (1), and E^c is aggregate spending on goods and services in country c.

Technology and market structure

There exists a fixed measure of firms in each country c, N^c, and each of these owns a blueprint to produce a single differentiated variety ω of final product. The market structure of final good is characterized by monopolistic competition, and there is no free entry into the industry. Production of final products therefore leave rents.

Production of final-product varieties require the assembly of a continuum of measure one of tasks, assumed to be imperfectly substitutable with each other, with a constant and symmetric elasticity of substitution equal to ρ. The marginal cost of a firm i is

$$c_i = \left(\int_0^1 z_i(t)^{1-\rho} dt \right)^{\frac{1}{(1-\rho)}} \tag{3}$$

where $z_i(t)$ is the price of an individual task t paid by firm i.

Local and global sourcing

All firms can produce all tasks with labor under constant-returns-to-scale technologies. We denote by $a_i(t)$ the unit labor requirement associated with the production of task $t \in [0,1]$ by firm i. We treat the (infinite-dimensional) vectors of tasks efficiencies $1/a_i(t)$ as the realization of an extreme value distribution. More specifically, the efficiency of firm i located in country c in producing a task t is a realization of a random variable from the Frechet distribution $Pr(a_i(t) \geq a) = e^{-\varphi_i a^\theta}$. As in Eaton and Kortum (2002), θ determines the variability of productivity draws across tasks. These draws are assumed to be independent across firms and tasks. The firm's core efficiency φ which scales the ability to produce any task is the source of firm-level heterogeneity in our framework.

The firm can potentially produce all tasks in-house. Alternatively, the firm can decide to concentrate on its core activities (i.e. the tasks for which it gets good draws) and outsource the remaining tasks. A key feature of the equilibrium will be determining the location of production of different tasks. Trade in tasks however requires the payment of fixed and variable costs. To purchase a bundle of tasks from a particular firm j, firm i must incur a fixed cost f_{ij} paid in terms of labor[2]. Furthermore, trade in tasks is subject to iceberg trade costs τ_{ij}[3].

[2]This fixed cost may for instance represent the cost associated to the set-up of a specific contract between the two firms. In the Belgian context, these fixed cost may also reflect cultural barriers to trade if buyers and sellers are located in different Belgian regions.

[3]The iceberg trade costs may be related to the fact that some inputs (being either material, intangible or human capital) have to be send by firm i to firm j in order for the latter to be able to perform the tasks they agreed on, and j has to send back the outcome of those tasks.

To simplify matters, we assume that firms sell tasks at their marginal cost (i.e. we assume that in the Nash bargaining between buyer and supplier the buyer has the full bargaining power and extracts the entire surplus, as in Tintelnot et al., 2017, alternatively, we could assume that selling firm received a fixed or even a variable compensation). Firms make profits due to positive mark-ups in sales to final consumers. Since by assumption in any firm-to-firm trade the buyer has the full bargaining power, firms do not make profits from sales to other firms.

As a result, the price of an individual task t paid by the firm i is

$$z_i(t) = \min_{j \epsilon J_i} \{\tau_{ij} a_j(t) w_j\} \tag{4}$$

where w_j is the firm j wage, and J_i is the set of (local and foreign) firms for which firm i has paid the associated fixed cost of outsourcing $w_i f_{ij}$.

At this stage, it is worth discussing our framework. The way we introduce trade in tasks is close in spirit to the idea of trade in value-added. It is motivated by the empirical fact that local production chains look more like spiders than snakes (as labelled by Baldwin and Venables, 2013). The average length of international production chains is close to 3 (see Antras et al., 2012). In the 2012 Belgian network, the average number of suppliers is 21, with 10 percent of firms having more than 47 suppliers. One reason for that is that services need much less fragmented production chain. Once we consider the whole economy, one should note that trade in service accounts for the largest part of trade between firms. According to IO table for Belgium, trade in service amounts to 70% of the total value. Our framework is in contrast to the concept of sequential production stages, which comes from the way the manufacturing sector operates.

The firm can outsource tasks in its own country, or in any foreign country. However, not all suppliers are available. Among all N^c potential suppliers from country c, only a subset is exogenously avaible to a particular firm i[4]. We denote by $Z_i^c \subset N^c$ the set of firm i's potential suppliers from it own country c. Firms can also outsource tasks from abroad. A firm i in country c only acquires the capability to offshore tasks in a country d after incurring a fixed cost equal to f_i^{cd}. The payment of this fixed cost provides firm i with a set $Z_i^d \subset N^d$ of potential foreign suppliers from country d[5]. We assume that $f_i^{cc} = 0$, so that the set of domestic supplier is freely available.

Optimal sourcing strategy

Using the properties of the Frechet distribution, one can show that the firm will source a positive measure of tasks from each (domestic or foreign) supplier in its sourcing strategy set J_i. Furthermore, the share of tasks sourced from any supplier j (including the firm itself) is simply given by

[4]For instance, because these firms are part of the same "social" network or share similar social capital.

[5]This is typically the kind of information a firm can get from its international trade agency.

$$\chi_{ij} = \frac{\varphi_j \left(\tau_{ij} w_j\right)^{-\theta}}{\sum\limits_{k \epsilon J_i} \varphi_k \left(\tau_{ik} w_k\right)^{-\theta}} \tag{5}$$

Following Antras et al. (2016), we call $\Theta_i = \sum\limits_{k \epsilon J_i} \varphi_k \left(\tau_{ik} w_k\right)^{-\theta}$ the sourcing capability of firm i and J_i the sourcing strategy of firm i. The overall marginal cost faced by firm i can be expressed

$$c_i = \left(\gamma \Theta_i\right)^{-1/\theta} \tag{6}$$

where $\gamma = \left[\Gamma\left(\frac{\theta+1-\rho}{\theta}\right)\right]^{\theta/(1-\rho)}$ and Γ is the gamma function. We assume that every firm acts as a monopolistic competitor when selling its product to final consumers taking the aggregate price index as given and therefore charging a constant mark-up over marginal cost. Using (6), the properties of the Frechet distribution and the constant markup over marginal cost, firms maximize:

$$\underset{I_i^d, I_{ij}}{max} \pi_i^c = \left(\sum_{d \epsilon C} I_i^d \sum_{j \epsilon Z_i^d} I_{ij} \varphi_j \left(\tau_{ij} w_j\right)^{-\theta}\right)^{(\sigma-1)/\theta} B_i - w_i \left(\sum_{d \epsilon C} I_i^d f_i^{cd} + \sum_{j \epsilon Z_i} I_{ij} f_{ij}\right) \tag{7}$$

where $B_i = \gamma^{(\sigma-1)/\theta} \frac{1}{\sigma} \left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} E_i P^{\sigma-1}$.

Testable predictions

Equation (7) is analogous to the problem studied by Antras et al. (2016). We then have the following result:

If $\sigma - 1 > \theta$, then more efficient firms (i) have more suppliers, (ii) have more remoted suppliers, (iii) can choose less efficient suppliers.

The intuition behind Part (i) rests on the fact that, when $\sigma - 1 > \theta$, efficiency and outsourcing display complementarities, so that the marginal gain from adding a supplier is higher for more productive firm. This case is more likely to apply whenever demand is elastic and thus profits are particularly responsive to variable cost reductions (high σ), and whenever efficiency levels are relatively heterogeneous across tasks (low θ), so that a more productive firm achieves a relatively high reduction of costs by adding an extra supplier. If, instead, $\sigma - 1 < \theta$, more efficient firms outsource less tasks as they find more profitable to capitalize on their comparative advantage in producing tasks more efficiently. While absent from Antras et al. (2016), part (i) extends their results. In their framework, this proposition would mean that a country with a higher Frechet parameter T has more incentive to offshore intermediate inputs whenever $\sigma - 1 > \theta$. More productive firms add more suppliers along two lines. First, they add relatively more distant suppliers. This is consistent with Bernard et

al. (2015). Second, they add relatively less efficient suppliers. As a consequence of parts (i) and (ii), we have that:

If $\sigma - 1 > \theta$, then (iv) importers have more domestic suppliers than non-importers.

Parts (i) and (ii) rest on the fact that each individual firm $j \epsilon Z_i$ can be ranked according to its attractiveness as a supplier of firm i. Attractiveness of a potential supplier j is simply dictated by φ_j / τ_{ij}. In other words:

If $\sigma - 1 > \theta$, then (v) firms follow a predicted pecking order

Part (v) means that, if all N^c firms were available to all potential buyers, firms would strictly follow a pecking order. Empirically, it is impossible to check whether firms follow a pecking order because firms are endowed with an exogenous set of potential suppliers, which differ from one firm to another. However, we can note that geography matters as ordering is inversely related to distance. In Section 4, we therefore group firms within sub-areas and show that the pecking order holds for different geographic specifications. This pecking order is found in Antras et al. (2016) and is reminiscent of the one typically obtained in models of exporting with heterogeneous firms, such as Eaton et al. (2011).

According to the model, this pecking order is pre-determined

(vi) The rank of a supplying area is increasing in efficiency of the firms within this area and in the number of firms, decreasing in the distance between supplying and buying area.

The prediction of a pecking order is very strong and partly violated in the data. First, as stated by Antras et al (2016), fixed cost of sourcing might be heterogeneous across firms. Second the probability of having a firm j included in the subset of potential suppliers Z_i might be specific to firm i. The fixed cost associated with sourcing from firm j could also be an increasing function of firm j's productivity:

If $\frac{\partial f_{ij}}{\partial \varphi_j} > 0$, then (vii) more efficient firms have more efficient suppliers

Note that, with (iii) and (vii), the relation between the firm's own productivity and the average productivity of its suppliers is ambiguous.

From Equation (5), we also have a prediction on the intensive margin of outsourcing

(viii) The share of inputs is increasing in (a) the supplier's productivity and in (b) the geographic distance between the supplier and the buyer and, decreasing in the buyer's number of suppliers

A more empirical question which naturally emerges

(ix) Is the ranking of intermediate purchases (intensive margin) the same as the pecking order for the extensive margin?

Finally, our model also enables us to make predictions on the sales side.

If the probability of being included in the subset of firms proposed to buyers which pay the fixed cost is uniform across firms and equal to $\frac{1}{N^c}$, then more efficient firms have (x) more domestic clients and (xi) are more likely to be a tasks exporter.

Closing the model

We can now close the model. We assume for simplicity that final products are prohibitively costly to trade across borders. Each country has its own price index which only depends on domestic final products. The aggregate expenditure in country c is given by

$$E^c = w^c L^c + \sum_{k \epsilon N^c} \pi_k^c$$

Because we have assumed that final goods are non tradable, balanced trade implies that, for any country c, aggregate exports of tasks are equal to aggregate imports of tasks

$$\sum_{i \epsilon N^c} \sum_{d \epsilon C^{-c}} I_i^d \sum_{j=1}^{J_i^d} I_{ij}^d \varphi_j T^d \left(\tau_{ij} w_j^d\right)^{-\theta} = \sum_{d \epsilon C^{-c}} \sum_{i \epsilon N^d} I_i^c \sum_{j=1}^{J_i^c} \varphi_i T^c \left(\tau_{ij} w_i^c\right)^{-\theta}$$

Taking wages in country c as a numeraire, the system of C equations provides a unique equilibrium vector of wages.

3 The Data

To confront our model with data, one has to have a full description of the sourcing strategy of firms, both at the domestic and international level. Such dataset is very rarely available. If in most countries, researchers can access to firm level information on imports by country of origin and by products but only few information are available regarding domestic transactions between firms (f.i. the Compustat data for the US provide some information about the 10 largest suppliers of their sampled firms, and the Japanese data used in Bernard et al. only provide qualitative data on Japanese firms domestic linkages). For this paper, we use two detailed firm level dataset for Belgium. The first one, referred to as the NBB B2B dataset in Dhyne, Magerman and Rubinova (2015), provides a full description of all the domestic transactions between any pair of Belgian VAT affiliates, as long as one of these two affiliates is buying from the second one for at least 250 EUR in any year in our sample period. Still, in this paper, we impose a minimum transaction of 1,000 EUR per year for considering any transaction. This dataset has been used in recent papers (f.i. Dhyne and Rubinova, 2016, Magerman et al., 2016, Bernard et al., 2017, Tintelnot et al., 2017, or Dhyne and Duprez, 2016 and 2017). The second one is the more traditionally available firm level imports data by country of origin and broad product categories (CPA Rev 2. 2 digit level).

The NBB B2B dataset can be viewed as a kind of input-output matrix where each row and each column is a firm. In that respect, it is therefore a very suited tool to analyze the organization of production chains at the national level, in the same way world input output tables (Timmer et al., 2014) provide a description of the contribution of a given industry in a given country to the global value chains. Still, this dataset departs from traditional input output tables in many dimensions. First, we have no information of what is traded between two firms. It can be material inputs, services or capital goods. This means that the total deliveries to firm i may be much larger than its total

Table 1: Descriptive statistics - Sourcing strategies in 2012

	p10	p25	p50	p75	p90	Mean
Number of domestic suppliers	1	4	9	23	47	21.2
Share of importers (in %)	-	-	-	-	-	5.1
Number of sourcing foreign countries (conditional on international sourcing)	1	1	2	4	9	3.8

Note : Sample size = 797,596 Belgian firms in 2012.

sales, because firm i may have invest a lot in a given year. Second, the way trade intermediaries are recorded is fundamentally different from standard IO. In standard IO and national accounts, the contribution of the wholesalers and retailers to the economy and their intermediate deliveries to other sectors is measured in terms of the value added provided by wholesalers and retailers to the economy. In our transaction data, we observe gross transactions to or from trade intermediaries. The contribution of wholesalers and retailers in the network is therefore much larger than in standard IO. Third, there is no intra-firm trade in our dataset, which means that the diagonal of our firm-to-firm IO matrix is 0.

Merging the two datasets allows us to know for any Belgian firm how many outsourcing relations it manages, both domestically and internationally. At the domestic level, for each outsourcing relation, we have the total amount traded between the two firms but we have no information on what services or goods are provided by the supplying firm. Similarly, the international sourcing relations are aggregated by country of origin and can cover the supply of different goods by foreign suppliers. In addition, for international transactions, the foreign counterpart is not observed at the foreign firm level but at the level of the country of origin of imports.

So the data we have departs somehow from the model structure, as we do not observe trade in task but trade in goods and services. Still, we believe that it does not alter the prediction of our model as, when a firm source intermediate inputs from a supplier, this can be viewed as the fact that the firm is sourcing the tasks needed to produce those inputs to the supplier. For instance, when a car manufacturer sources the tires of its cars to a tire producer, it in fact outsources the task of designing and producing those tires instead of performing those tasks itself. The determinants of the trade relationship between those two firms are still the same than those highlighted in our model.

The domestic and international transaction data are also merged with other firm level information such as its location, its number of establishments, its international trade status, its size and its productivity, and the fact that it may be part of a domestic or international group[6]. Data on domestic and

[6]Belgian firms are localized according to the ZIP code of their headquarter. Concerning the international trade status, we define three status based on the fact that firm may only import, only export or be involved in both types of foreign trade. The firm size is measured by its employment in full time equivalent and its productivity by the TFP estimated at the NACE Rev.2. 2 digit level using the Wooldridge LP estimator (Wooldridge, 2009). Using

Table 2: Ranking of Belgian provinces by outsourcing area

	Outsourcing area											
	BXL	BRW	BRF	ANV	LIM	LIG	NAM	HAI	LUX	FLC	FLR	BE
BXL	1	2	3	2	4	2	2	2	2	3	3	1
BRW	4	1	7	9	9	10	7	8	11	9	8	9
BRF	2	3	1	3	3	4	4	3	5	5	4	3
ANV	3	5	2	1	2	3	6	4	6	4	2	2
LIM	10	10	5	5	1	7	11	10	9	6	6	6
LIG	8	7	9	8	7	1	5	9	4	8	9	8
NAM	9	6	10	10	10	6	1	5	3	10	10	10
HAI	5	4	7	7	8	5	3	1	7	7	7	7
LUX	11	11	11	11	11	11	8	11	1	11	11	11
FLC	7	8	6	6	6	9	9	6	8	1	5	5
FLR	6	9	4	4	5	8	10	7	10	2	1	4

Note : BXL stands for Brussels, BRW for Walloon Brabant, BRF for Flemish Brabant, ANV for Antwerp, LIM for Limburg, NAM for Namur, HAI for Hainaut, LUX for Luxemburg, FLC for West Vlaanderen, FLR for Oost Vlanderen. Each column shows the ranking for a particular province. The last column presents the ranking at the national level.

international transactions are available from 2002 up to 2014. However, as some characteristics were not available for the entire period we restricted our empirical exercises to the 2002-2012 period.

4 The geography of domestic sourcing

If selection into sourcing features complementarity across suppliers, firms follow a hierarchical pecking order in their sourcing behavior. To test so, we rank the Belgian province according to the number of firms that source from this particular area. Table 2 illustrates the ranking at the province level, based on the number of firms purchasing inputs. Given geography matters, this ranking differs from one province to another. Each column gives the ranking for purchasing firms located in a specific province. In particular, the diagonal is equal to 1, any province is the most popular supplying area for its own firms. The last column present the ranking at the national level. As Eaton et al. (2011) and Antras et al. (2016), we count the number of firms that source from the top-ranked province and no other provinces, the number that source from the top two provinces and no others, and so on. In 2012, 37.2% of firms follow the pecking order. If we calculate the share of firms that would follow this hierarchy if firms selected into provinces randomly, we would observe a share of 15.8%. The results are similar to those in Antras et al. (2016) where the authors show that 36 percent of US importers follow a pecking order for the top ten destina-

data on domestic and international financial linkages, we also observe if a firm belongs to a group or not.

Table 3: Compliance with the peaking order in actual data and counterfactual

	Data	Random entry
At the firm level:		
Belgian provinces	37.2%	15.8%
At the relation level:		
Belgian provinces	67.4%	39.1%
Belgian provinces+ foreign countries	64.5%	37.2%
Belgian districts	44.2%	23.5%
Belgian districts + foreign countries	42.7%	22.7%
Belgian Province/Sectors of activity	26.5%	13.5%
Belgian district/Sectors of activity	16.8%	8.2%

Note : Each cell represents the fraction of firms or transactions that follow exactly the peaking order of suppling areas (either provinces or districts, crossed or not with NACE sectors) in the data and in a counter-factual exercise of random selection of supplying areas. Bootstraps based on 1,000 replications of both measures show that the two measures are significantly different at the 1% level.

tions, which is higher by a factor 1.8 than what would be predicted under the same random entry calculation.

In order to test whether firms follow a pecking order at a more disaggregated level, such as the district level possibly coupled with the supplier's sector of activity, we assess the extent to which the observed relations follow the hierarchical pecking order. The focus on relations instead of firms relaxes our method, since the ranking is established among up to more than 500 districts/sectors. To do so, we count the largest number of relations that follow the pecking order. In our previous example, a BXL firm would have a 40% relations correctly ranked if it is sourcing in BXL, in BRW and in 3 other provinces but BRF (ANV, LIM and LIG for example). Table 3 presents the results at different levels of geographical and sectoral disaggregation. Again, the number of relations following the pecking order is compared with a scenario of random entry.

Table 4: Determinants of the peaking order of domestic sourcing area

	OLS	Ordered logit
$Distance_{ij}$	7.63***	3.34***
$MedianTFP_j$	-10.73***	-4.88***
$Number\ of\ firms_j$	-6.95***	-2.83***
Common language	-6.59***	-2.41***
Constant	157.7***	/
(Pseudo-)R^2	0.85	0.28
Obs.	1,849	1,849

Note : The dependent variable is the ranking of Belgian districts. It takes values between 1 (top ranking) to 43 (last rank). Average distance between districts i and j, median TFP and number of firms in the sourcing district j are in logs.

To explain the observed ranking, we use the 43 Belgian districts. We allow

the ranking of supplying Belgian districts to be buying district-specific and depend on the gravity variables. Table 4 shows that the ranking is more favorable when the (log) average distance between the buying and the supplying district is low, the quality of the supplying district proxied by its firm's median TFP is high, the (log) number of firms in the supplying district is high, and when the supplying and buying districts share a common language.

5 Econometric results

Section 4 provides a first set of some evidence that the domestic organization of the Belgian production system does not seem to follow a random pattern and is to some extent the results of both geography and economic performance, when transaction data are aggregated at a given geographical unit. In this section, we now move to some econometric results obtained when analyzing directly individual transactions or data aggregated at the level of the outsourcing firms or at the level of outsourcing firms x sourcing district only.

5.1 Investigating local trade costs at the transaction level

In our model, firms that trade domestically may face some trade costs. Geography, as illustrated in Figures 1 and 2 or in Section 4, shapes the structure of the Belgian production networks. As documented, most business relations involve domestic trading partners located very close from each other, even in a small country as Belgium where the largest distance between two cities is 277 km. As suggested in Table 4, culture may also be an important determinant of the organization of the domestic production network. Belgium is indeed a country with 3 regions, with Flanders being Dutch-speaking, Wallonia French-speaking and Brussel bilangual. Therefore, even if there is no tariff barriers to trade within Belgium, there can be sizeable fixed costs of trade between firms located in different regions (Flanders versus Wallonia). We first address the issue of trade costs by looking at how regional trade barriers affects the sourcing decision of a firm. To do, we estimate the probability for a given firm i to source inputs from firm j using a Probit equation. According to Equation (7), this probability will be among other a function of the distance between those two firms and whether they share a common language, as it may affect both the fixed and the variable trade cost. To control for the fact that firm i may more likely source from a subset of Belgian firms, for instance because they have common social capital, we control for the fact that both firms belong to the same "community", which means they both belong to a subset of firms that tend to know each other[7], for the fact that both firms are financially linked or the degree of internationalization of i and j.

[7] These communities of firms are detected according to a clustering algorithm, called the Louvain algorithm, that identifies subparts of the networks that tend to be more intensively connected.

Table 5: Probit equation : firm i sources inputs from supplier j[1]

	Estimated coefficient	AME
$Distance_{ij}$[2]	-0.246***	-0.315***
	(0.001)	(0.001)
TFP_i[3]	0.119***	0.153***
	(0.004)	(0.005)
TFP_j[3]	0.146***	0.187***
	(0.001)	(0.002)
Common language	0.104***	0.120***
	(0.001)	(0.002)
Firm i and supplier j are financially linked	2.921***	218.9***
	(0.423)	(112.3)
Firm i and supplier j in same sub-network	0.380***	0.606***
	(0.002)	(0.003)
Firm i has multiple establishments	0.133***	0.196***
	(0.004)	(0.007)
Supplier j has multiple establishments	0.250***	0.408***
	(0.001)	(0.003)
Number of observations	13,469,723	
Pseudo R^2	0.193	

[1] The equation also include two sets sectoral dummies, the first one for firm$i$ and the second for supplier j ,two sets of dummies identifying in which sub-network i or j belong and dummies for the degree of internationalization of i or j (exporter, importer, MNE). Clustered standard errors by firms are in brackets. *** means significant at the 1% level. Average Marginal Effects are multiplied by 1,000.
[2] Inverse hyperbolic sin of the "as the crow fly" distance between firm i and supplier j.
[3] Total factor productivity, in log, estimated using the Wooldridge LP method.

Table 6: Heckman 2 stage estimation : Share of annual deliveries from supplier j in turnover of firm i[(1)]

	Linear regression
$Distance_{ij}^{(2)}$	-0.038***
	(0.002)
$TFP_i^{(3)}$	-0.313***
	(0.007)
$TFP_j^{(4)}$	0.072***
	(0.002)
Common language	0.013***
	(0.004)
Firm i and supplier j are financially linked	1.738***
	(0.023)
Firm i has multiple establishments	-0.084**
	(0.008)
Supplier j has multiple establishments	0.044***
	(0.003)
Inverse Mills Ratio	-0.018**
	(0.007)
# of observations	1,791,3728
R^2	0.096

[(1)] In log. The data include all annual deliveries which amount at least to 1,000 euros and which represents at least 0.1% of the turnover of firm i. The equation also include two sets sectoral dummies, the first one for firm i and the second for supplier j and dummies for the degree of internationalization of i or j (exporter, importer, MNE). Clustered standard errors by firms are in brackets. *** means significant at the 1% level, ** at the 5% level.
[(2)] Inverse hyperbolic sin of the "as the crow fly" distance between supplier i and firm j.
[(3)] Total factor productivity, in log, estimated using the Wooldridge LP method.

In order to estimate a Probit, one needs both "0"s and "1"s. If our transaction dataset provides us with all the "1"s in a given year, we need to sample the "0"s. Indeed, we cannot put all the "0" in our sample when estimating the Probit equation. Considering only the 2012 cross-section and the subset of 110,129 firms for which we observe TFP, this would involve the 5,023,543 observed transactions and 12,123,262,969 pairs of buyers and potential sellers that did not trade together. Such a large amount of data cannot be handled in Stata and prohibits the estimation of a Probit equation using our panel of transactions. To perform our estimation, we therefore randomly selected at most 100 "0" representing no trade between i and j for any Belgian firm in our dataset. We ended up with a set of 8,659,331 "0"s in our sample and 4,810,392 transactions for which we observe all our explanatory variables . We then estimated a weighted Probit equations that controls for the fact that the "1" are over-represented in our es-

timation sample compared to the true network. Results are summarized Table 5. The results obtained are basically in line with the predictions of our model. Most productive firms tend to source from more suppliers, and better suppliers are more likely to be selected. Distance is also a key determinant of the likelihood of a business relationship.

Our results are also consistent with the fact that trade costs may embodied cultural barriers to trade as a common language increases the probability to trade. Firms and suppliers that operate in multiple establishments tend to trade more as the distance between the two headquarters may not be the smallest distance between firm i and its supplier, reducing both the fixed and variable costs of trade. In addition, as expected, share some common social capital (reflected by the fact that both firms belong to the same sub network) or being financially integrated naturally reduced the trade costs.

Now, in a second stage, we model the relative importance of a business relation for firm i, controlling for selection. We estimate a linear regression explaining the log of the share of annual deliveries from supplier j in turnover of firm i. We exclude economically insignificant relations by only considering total annual deliveries which amount at least 1,000 euros and which represent at least 0.1% of the turnover of firm i. We based our estimation strategy on the fact that the communities to which firm i and supplier j belong only affect the probability that both firms trade, not the amount of the transaction. Such an assumption is consistent with our modeling strategy where firms select their suppliers within a predefined subset of firms, but conditional on being in that subset, it does not affect the amount traded between i and j. We therefore model the amount trade between i and j by the distance between them, the productivity of both supplier j and firm i. A common language dummy is also included with sectoral dummies for the supplier and the firm and variables indicating the degree of internationalization (not reported in the paper).We also introduce the inverse Mills ratio computed from the selection equation presented above. Because, our model is a model of trade in value added between firms, we only considered transactions of inputs and services and not transactions associated to investments. For instance if the supplier is operating in the building sector, the transaction between j and i is mostly related to an investment of firm i and not to the delivery of intermediate inputs or services. Based on IO tables, we corrected our raw transaction data and remove the delivery of capital goods. Results are presented in Table 6.

The results obtained are in line with Equation (5) of our model. When firms source from remote locations, they tend to trade less because of increasing variable costs. Similarly, variable costs are associated to the cultural barriers. Better firms have lower shares, both because they have more suppliers and they produce more tasks in-house. Firms naturally source more tasks to more efficient suppliers. The positive impact of the variable indicating that the supplier has multiple establishments is also in line with the assumption that multiple establishments reduce the trade costs, while the negative impact of this variable for firm i is likely a scale effect.

So far, we have analyzed variable trade costs in Table 6 and both fixed and

Table 7: Difference between supplier rank based on number of customers and supplierrank based on total annual deliveries

Dependent var.	Ranking difference	
$TFP^{(1)}_{j;t-1}$	0.148***	0.028***
	(0.006)	(0.002)
$Size^{(2)}_{j,0}$	0.055***	-
	(0.003)	-
$Importer_{jt}$	-0.100***	-0.007**
	(0.009)	(0.003)
$Exporter_{jt}$	0.008	-0.002
	(0.010)	(0.003)
$Two\,way trader_{jt}$	0.008	-0.017***
	(0.008)	(0.003)
$Belgian\,group_{jt}$	0.064***	-0.014***
	(0.008)	(0.004)
$Belgian\,MNE_{jt}$	0.285***	0.002
	(0.056)	(0.031)
$Foreign\,MNE_{jt}$	0.592***	-0.006
	(0.047)	(0.031)
$Multiple\,establishments_{jt}$	-0.156***	-0.037***
	(0.013)	(0.0105)
Firm FE	No	Yes
# observations	489,088	513,440
R^2	0.202	0.925

Note : The dependant variable is the log difference. All specifications include a set of sectoral dummies at the NACE rev 2. 2 digit level, a set of geographical dummies at the zip code level and a set of year dummies for the 2002-2012 period. Clustered standard errors by firms are in brackets. *** means significant at the 1% level, ** at the 5% level..
(1) Total factor productivity, in log, estimated using the Wooldridge LP method.
(2) Initial size, in log, measured by the level of employment in the first year of observation of the firm in our estimation sample.

variable trade costs in Table 5. In order to take up a stance on fixed trade cost alone, our strategy is to compare the supplier rank based on the number of customers and its rank based on total annual deliveries to all customers. We rest our analysis on the fact that, given the complementarity across suppliers, all comparable firms have a similar ranking and would buy a similar amount of tasks to any supplier. Accordingly, a supplier which exhibits a high fixed cost has only a few customers when controlling for its quality. The difference between the supplier rank based on the number of customers ans its rank based on the total annual deliveries therefore enables us to highlight the determinants of the supplier's fixed costs. The results presented in Table 7 show that productive and large suppliers have a large fixed cost.

5.2 Analyzing the sourcing strategy at the firm level

The results presented in Section 5.1 looks at the determinants of individual transactions. However, because of the large amount of observations in any given year, this analysis can only be done for a specific cross-section. Even if the results presented above are consistent with those obtained for other cross-sections during the 2002-2012 period, we decided to complement this estimation by an econometric investigation of data aggregated at the firm level. We first analyse the number of suppliers managed by any given firm in each of the Belgian province. We do a similar exercise with the number of customers managed by any firm. This is done using the panel of firms observed between 2002 and 2012. Using a linear regression, we explain both the number of suppliers and customers managed by a firm in a given year with its productivity in the previous year, its initial size and some variables characterizing the degree of internationalization of the firm. Alternatively, we considered a linear model with firm fixed effects, without controlling for the initial size. The results are presented in Table 8.

Considering the specifications without fixed effects, we find that larger firms and more productive firms tend to source from more suppliers in any Belgian province and tend to be more selected by firms located in the entire country. Firms operating multiple establishments or being active on international market have also more domestic supplier and a higher probability to be selected as a supplier by another Belgian firm. All these results are in line with the prediction of our model and also hold when firm fixed effects are introduced. However, in that setting, the results have to be considered in a more dynamic way, as firm that tend to become more efficient, tend to increase both their number of suppliers and customers in all Belgian provinces. The positive coefficients associated to most variables characterizing the internationalization strategy of a firm are consistent with the prediction of our model that international sourcing is more a complement to domestic sourcing than a substitute.

The fact that the most productive firms have more domestic suppliers and simultaneously are also providing inputs to more domestic customers has implications for the organization of domestic value chains. The most efficient firms may therefore be contributing to many more production stages along the value chains than less efficient ones.

Finally, we ran some regressions to characterize the set of domestic suppliers of Belgian firms. We considered three characteristics of the suppliers's set : the largest distance between a firm and one of its supplier, the level of productivity of the less and most efficient supplier measured respectively as the lowest and highest deciles of the productivity distribution at the sector level observed in the set of suppliers. The three characteristics are modeled using the same set of explanatory variables as the determinants of the number of suppliers / customers.

This last set of results, presented in Table 9, confirm that most productive or larger firms are able to source from more remote domestic locations. They also tend to have a more heterogeneous set of suppliers than the less productive / smaller firms. Efficient or large firms are indeed able to source both from more

Table 8: Analysis of the characteristics of firm i's suppliers or customers located in province j

Dependent var.	# of suppliers		# of customers	
$TFP^{(1)}_{i;t-1}$	1.511***	0.322***	3.141***	0694***
	(0.045)	(0.009)	(0.364)	(0.051)
$Size^{(2)}_{i,0}$	1.776***	-	3.141***	-
	(0.030)	-	(0.181)	-
$Importer_{it}$	1.164***	0.301***	1.708***	0.461***
	(0.067)	(0.016)	(0.348)	(0.093)
$Exporter_{it}$	0.676***	0.133***	0.979***	0.253***
	(0.061)	(0.017)	(0.268)	(0.083)
$Two\,way\,trader_{it}$	1.396***	0.442***	2.675***	0.516***
	(0.041)	(0.014)	(0.184)	(0.076)
$Belgian\,group_{it}$	0.908***	0.194***	1.079***	-0.109
	(0.042)	(0.020)	(0.179)	(0.141)
$BelgianMNE_{it}$	12.593***	0.883***	5.619	3.138
	(1.240)	(0.310)	(5.607)	(2.004)
$ForeignMNE_{it}$	6.737***	0.407	21.071***	1.366
	(0.560)	(0.311)	(4.507)	(1.946)
$Multiple\,establishments_{it}$	1.658***	0.927***	6.455***	2.775***
	(0.086)	(0.065)	(0.520)	(0.425)
Firm FE	No	Yes	No	Yes
# observations	10,568,690	10,568,690	9,108,803	9,108,803
R^2	0.294	0.482	0.073	0.449

Note : All specifications include a set of sectoral dummies at the NACE rev 2. 2 digit level, a set of dummies indicating the peaking order of Belgian provinces that prevail in the province of firm i and a set of year dummies for the 2002-2012 period. Clustered standard errors by firms are in brackets. *** means significant at the 1% level.

(1) Total factor productivity, in log, estimated using the Wooldridge LP method.

(2) Initial size, in log, measured by the level of employment in the first year of observation of the firm in our estimation sample.

Table 9: Analysis of the characteristics of firm i's suppliers

Dependent var.	Largest distance between		TFP of ...			
	i and suppliers in j		less productive supplier		most productive supplier	
$TFP^{(1)}_{i;t-1}$	8.951***	2.262***	-0.259 ***	-0.087***	0.079***	0.018***
	(0.128)	(0.090)	(0.005)	(0.006)	(0.002)	(0.002)
$Size^{(2)}_{i,0}$	7.949***	-	-0.333***	-	0.046***	-
	(0.074)	-	(0.003	-	(0.001)	-
$Importer_{it}$	9.782***	2.053***	-0.388***	-0.097***	0.027***	0.011***
	(0.264)	(0.146)	(0.009)	(0.008)	(0.002)	(0.002)
$Exporter_{it}$	7.896***	1.379***	-0.381***	-0.068***	0.035***	0.013***
	(0.327)	(0.191)	(0.011)	(0.010)	(0.003)	(0.002)
$Two\ way\ trader_{it}$	5.320***	1.200***	-0.214***	-0.139***	0.004*	0.018***
	(0.215)	(0.140)	(0.008)	(0.008)	(0.002)	(0.002)
$Belgian\ group_{it}$	0.748***	0.641***	0.131***	-0.011	-0.0301***	-0.003
	(0.216)	(0.188)	(0.009)	(0.010)	(0.002)	(0.003)
$Belgian\ MNE_{it}$	1.455*	1.429*	0.139***	-0.051	-0.034***	0.006**
	(0.861)	(0.853)	(0.036)	(0.040)	(0.006)	(0.003)
$Foreign\ MNE_{it}$	-5.561***	1.260*	0.351***	-0.037	-0.090**	-0.0003
	(0.648)	(0.725)	(0.026)	(0.036)	(0.005)	(0.004)
$Multiple\ establishments_{it}$	1.159***	2.593***	-0.050***	-0.079***	-0.016***	-0.001
	(0.265)	(0.361)	(0.010)	(0.018)	(0.003)	(0.006)
Firm FE	No	Yes	No	Yes	No	Yes
# observations	808,534	996,908	954,266	954,266	954,266	954,266
R^2	0.436	0.784	0.142	0,596	0.041	0,452

Note : All specifications include a set of sectoral dummies at the NACE rev 2. 2 digit level and a set of year dummies for the 2002-2012 period. Clustered standard errors by firms are in brackets. ***, ** and * mean significant at respectively the 1%, the 5% and the 10% level, .

(1)Total factor productivity, in log, estimated using the Wooldridge LP method.

(2)Initial size, in log, measured by the level of employment in the first year o, f observation of the firm in our estimation sample.

efficient firms, being able to pay the potentially higher fixed trade costs with those firms, and from the less efficient ones, as they can marginally source more locally. Less efficient and smaller firms can only operate a small set of suppliers and, as they may not be able to afford sourcing from the most efficient firms, they will focus on suppliers located below the top deciles of the productivity distribution.

6 Conclusion

To be done.

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