IMPERFECT COMPETITION IN FIRM-TO-FIRM TRADE

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Abstract
This paper studies the implications of imperfect competition in firm-to-firm trade. Exploiting data on the universe of sales relationships between Belgian firms, we document that firms' markups increase in the average input shares among their buyers. Motivated by this fact, we develop and estimate a model where firms charge buyer–supplier-specific markups that depend on the bilateral input shares. We find markup dispersion within firms across buyers creates substantial welfare loss: Aggregate welfare increases by around 6% when firms are banned from charging different markups across buyers. (JEL: F12, F14)

1. Introduction

Firms largely operate and compete in relationships with other firms. Firms often deliver their output to multiple firms, and they often purchase inputs from other firms. These buyer–supplier relationships generate a network of complex interactions. One such

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complexity is that the set of firms that a firm competes against when supplying to a certain buyer may be different from those when supplying to a different buyer. Hence, the degree of market power a firm can exercise is potentially heterogeneous across buyers. In this paper, we explore how firms compete in the context of firm-to-firm trade. We focus on the potential dispersion of market power firms have across buyers in the firm-to-firm network and analyze its welfare implications.

Our primary data source is the value-added tax (VAT) registry from the National Bank of Belgium. This dataset records the universe of yearly firm-to-firm transactions among all firms in Belgium. The most significant advantage of using this dataset is that in addition to the standard firm-level measures of market shares—how large firms are in terms of total sales, one can observe how large firms are in the relationships with each individual firm. To do this, we start by measuring a supplier's share in a buyer's input cost for all firm pairs in buyer–supplier relationships. We contrast this measure with firms' market shares within sectors—the standard measure of firms' market power. We find that firms tend to have much larger shares in their buyers' input purchases than the market shares they have within their sectors. While the average sectoral market share at the two-digit sector level in 2012 is close to 0, the average firm has an 8% share in its buyers' purchases of their same two-digit sector inputs. Moreover, while these two measures are positively correlated with each other, we show that large firms in terms of total sales do not always have large input shares in their buyers, and small firms do not always have small input shares in their buyers.

These input shares that firms have within buyers are relevant statistics for firms' market power. We correlate firm-level markups with the two measures of firms' market share and find that firms charge higher average markups when they have larger input shares amongst their buyers. This positive relationship holds conditional on firms' sectoral market shares. Firm-level average markups are measured by either computing accounting markups or by estimating markups following de Loecker and Warzynski (2012). These empirical findings suggest that firms compete as oligopolies to supply inputs to each buyer. In addition to the *firm-level* market share within a sector, the firm's input shares in each buyer capture the firm's *pair-level* pricing power against its buyers.

Our empirical findings have implications for the welfare costs of markups. Many studies have documented heterogeneities in markups across firms (see, e.g., de Loecker and Warzynski 2012). Standard models would predict that more productive firms obtain larger sectoral market shares and charge higher markups, leading to misallocation in resources (Edmond, Midrigan, and Xu 2015). Our findings suggest that there are potentially additional markup dispersions within firms that are correlated with firms' input shares in their buyers. Theoretically, price discrimination across buyers has ambiguous effects on welfare. When firms price discriminate to exploit differences in demand elasticities, price discrimination may improve welfare if the misalignment of wedges is offset by the increase in the total quantity produced. If the quantity produced does not increase through price discrimination, then banning price discrimination will result in a welfare improvement. Whether or not the quantities increase depends on the structures and magnitudes of the demand elasticities firms face, among others (Robinson 1933; Schmalensee 1981; Varian 1985; Stole 2007).

We therefore quantitatively analyze these welfare implications of within-firm markup dispersion. In doing so, we build a model of oligopolistic competition in firm-to-firm trade. With a nested constant elasticity of substitution (CES) structure in the production function that builds on Atkeson and Burstein (2008), firms charge different markups to each buyer based on the residual demand elasticities they face. These demand elasticities are equilibrium constructs determined by the CES parameters and shares that firms have in each buyer's input cost. Our setup is in contrast to the more conventional implementation, where a firm's sectoral market share determines its firm-level markup. As firms compete with different sets of firms when selling to each buyer, the shares that firms have in each buyer's input costs vary across buyers. Therefore, the model puts emphasis on firms' pricing powers, which are different depending on which firm they sell to.

We estimate the CES parameters in both preference and production functions by taking advantage of the pair-level input shares we observe in the data. Given a set of CES parameters, the structure of our model allows us to back out the level of pair-level markups and markups on final demand using the observed input shares. The parameters are estimated so that the model's implied firm-level costs—the sum of firms' sales with each component of sales deflated by the destination-specific markups that are constructed from the data and parameters—provide the best fit for those in the data. The estimated CES parameters and the observed input shares reveal that firms on average charge similar markups on their sales to other firms and their sales to final demand, while firms with large input shares in their buyers charge higher markups than what they charge on their sales to final demand.

With the estimated model, we study how the markups set at the pair-level alter aggregate welfare compared to the economy where firms charge firm-level markups. We compute the degree of distortions originating from firms setting different markups across buyers by asking how much the representative household would benefit or lose if the economy transitioned to one where firms are constrained to charge common markups across buyers. In this exercise, buyer–supplier pairs in which the supplier charges a higher markup than its own average markup—due to its large input share—will have lower markups, and vice versa.

The exercise reveals that the welfare of the representative household would improve by 5.6% when each firm is constrained to set the same price for its goods sold to any buyer. Real wages also increases by 2.5%. This increase in welfare is despite a typical firm pair seeing a slight increase in its associated markup. As the distribution of pair-level input shares exhibits a fat tail on the right, the increases in markups occur in a large number of links with very low input shares. The suppliers in these links have very low shares in the buyers' inputs, so the increases in markups contribute less to increasing buyers' costs. In contrast, markup reductions happen in fewer links but in links with large input shares. As a result, the majority of firms see a reduction in unit costs and increase their output quantities.

To tease out how much of the quantitative effects above are driven by banning price discrimination in firm-to-firm trade alone, we further conduct a similar exercise in which firms are constrained to set common markups only on their sales to other firms. In this exercise, firms equalize only the markups they charge to other firms and keep fixed the markups on sales to final demand, which typically accounts for a large fraction of most firms' sales. Compared to the previous exercise, markups of firm pairs in which suppliers have high input shares do not go down as much because they do not have to equalize with the lower markups on their sales to final demand. This leads to aggregate effects with smaller but still meaningful magnitudes: Welfare and real wages improve by around 1.2% and 0.6%, respectively. This second counterfactual exercise shows that while sales to other firms account for a small fraction of most firms' sales (Dhyne et al. 2021), within-firm markup dispersion in firm-to-firm relationships plays an important role generating the overall welfare cost. Reductions of markups in a small number of firm pairs with larger input shares result in a sizable aggregate effect, as they amplify firms' cost reductions through the input–output linkages.

Our findings indicate that markup dispersion within firms across buyers creates a sizable welfare cost, in addition to the across-firm markup dispersion that has been extensively studied in the literature. Empirical studies such as de Loecker and Warzynski 2012 and de Loecker et al. (2016) have recovered large dispersions in firm-level or firm-product-level markups. On the quantitative side, papers such as Epifani and Gancia (2011), Behrens et al. (2018), Edmond, Midrigan, and Xu (2018), and Dhingra and Morrow (2019) have studied welfare costs of markups that vary at the firm-level. Recent papers have also documented dispersion in prices within firm-product categories. Fontaine, Martin, and Mejean (2020) find that one-third of the cross-sectional dispersion of prices that French exporters charge is attributable to price discrepancies within an exporter. In this paper, we show suggestive evidence that firms charge different markups across buyers according to the input shares they have within these buyers. In this sense, our evidence is consistent with those of Halpern and Koren (2007), where they find that Hungarian importers pay a higher price to the same product if the product's share in intermediate goods is higher.[1] We take our empirical results to the model in which firms charge different markups across buyers and study the welfare implications of markup dispersion within firms.

The theoretical literature has found ambiguous welfare effects of price discrimination.[2] Several papers have investigated the welfare effects of banning price discrimination in specific markets on the quantitative side. Our counterfactual analysis is closely related to the analysis done by Villas-Boas (2009), where she investigates

1. We find a similar result using the Belgian import transaction data. Belgian importers pay a higher price to the same imported product from the same country if the imported good accounts for a larger share in their purchases of the same good, including their domestic purchases (Appendix A.2). For papers documenting price discrimination in other contexts, see, for example, Goldberg (1996), Leslie (2004), Busse and Rysman (2005), Mortimer (2007), Hendel and Nevo (2013), and Marshall (2020).

2. See, for example, Schmalensee (1981), Varian (1985), Katz (1987), Holmes (1989), Degraba (1990), Yoshida (2000), Armstrong and Vickers (2001), and Stole (2007).

the coffee market in Germany and finds that banning price discrimination has a positive welfare effect. Grennan (2013) looks at price discrimination and its interaction with bargaining in buyer–supplier relationships in the medical device market. In this paper, we take the empirical evidence suggesting that firms price discriminate according to buyer–supplier input shares and analyze the economy-wide effects of price discrimination.

We also contribute to the literature that studies the implications of imperfect competition in product markets with input–output linkages.[3] Grassi (2017) develops a model in which firms engage in oligopolistic competition in an economy with sectoral input-output linkages and studies the contribution of firm-level shocks on the aggregate dynamics. Along with Grassi (2017), we combine CES preference and production functions and imperfect competition in the style of Atkeson and Burstein (2008), Edmond, Midrigan, and Xu (2015), and Amiti, Itskhoki, and Konings (2019) to generate variable markups charged by firms. In their recent work, Baqaee and Farhi (2020) provide a framework for aggregating micro shocks at the first-order or second-order approximation, which allows for distortions such as markups and input-output linkages. Using US firm-level data, they find that eliminating firm-level markups would increase aggregate TFP by around 20%. In contrast to these papers that focus on markups at the firm-level, we propose a more granular view of the competition between firms. In addition to the *firm-level* market share within the sector being the determinant of the firm's market power, we suggest that the *pair-level* input shares across its buyers are also relevant metrics in capturing the firm's ability to charge markups.

Lastly, this paper is related to the literature on domestic production networks, which has grown in recent years due to the wider availability of data that record domestic firm-to-firm transactions. Topics studied with these rich datasets include the structure of production networks (Atalay et al. 2011), how firm-to-firm linkages contribute to generating observed firm-size heterogeneity (Bernard et al. 2019; Dhyne et al. 2021), firm agglomeration in firm-to-firm matching (Miyauchi 2019), how shocks transmit through production linkages (Barrot and Sauvagnat 2016; Alfaro-urena, Manelici, and Vasquez 2019; Boehm, Pandalai-Nayar, and Flaaen 2019; Carvalho et al. 2021; Huneeus 2018), and the role of endogenous network formation (Eaton, Kortum, and Kramarz 2018; Huneeus 2018; Lim 2018; Oberfield 2018; Taschereau-Dumouchel 2018), among others. In this paper, we specifically focus on firms' pricing strategies and their welfare implications in the context of firm-to-firm relationships.

This paper is organized as follows. Section 2 describes the data and documents evidence on pair-level input shares. Section 3 outlines the model of oligopolistic competition in firm-to-firm trade. In Section 4, we estimate the model's parameters.

3. Relatedly, there has been a growing focus on imperfect competition in firms' input markets. Papers such as Mackenzie (2021), Berger, Herkenhoff, and Mongey (2019), Huneeus et al. (2020), and Lu, Sugita, and Zhu (2020) focus on the role of oligopsonistic competition among firms in their labor markets, and Morlacco (2019) and Macedoni and Tyazhelnikov (2018) cast attention to firms' market power as buyers of intermediate goods in international markets.

Section 5 conducts the counterfactual analysis in which we analyze the effect of firms charging common markups across buyers. Finally, we conclude in Section 6.

2. Data and Empirical Evidence

2.1. Dataset and Sample Selection

Our primary dataset is the National Bank of Belgium (NBB) Business-to-Business (B2B) transactions database, a panel of VAT-ID to VAT-ID transactions among the universe of Belgian enterprises during 2002–2014. As explained in detail in Dhyne, Magerman, and Rubinova (2015), all enterprises in Belgium are assigned unique VAT-IDs and are required to report their yearly sales values to other VAT-IDs if they exceed 250 euro. We merge this dataset with the annual account filings and the international trade dataset. In the annual account filings, we observe the primary sector of each VAT-ID (NACE Rev. 2, up to four-digit), total sales, labor cost, ownership relations with other VAT-IDs, location (postal code), and other variables that are standard in the annual accounts. The international trade dataset contains the values of imports and exports at the VAT-ID-country-product (CN eight-digit)-year level.

The unit of observation in these datasets are VAT-IDs, and one firm can potentially have multiple VAT-IDs. In this paper, we focus on competition and pricing decisions that occur across firm boundaries, which may be different in nature from those within firm boundaries. Thus, we follow Dhyne et al. (2021) and aggregate VAT-IDs up to the firm-level using ownership filings in the annual accounts and foreign ownership filings in the Balance of Payments survey. The Balance of Payments survey reports for each VAT-ID, the name of foreign parent firms that own at least 10% share, along with the associated ownership share. We group all VAT-IDs into firms if they are linked with more than or equal to 50% of ownership or if they share the same foreign parent firm that holds more than or equal to 50% of their shares. See Online Appendix D.1 for further details.

The sample of firms used in our analysis is selected using the following criteria. First, we select private and non-financial sector Belgian firms that report positive sales, labor cost, and at least one full-time equivalent employee. Following de Loecker, Fuss and Van Biesebroeck (2014), we further select firms that report tangible assets of more than 100 euro and positive total assets for at least one year throughout our sample period.[4] Table 1 describes the coverage of our selected sample compared to the Belgian aggregate statistics. In Online Appendix D.2, we also report their sectoral compositions. Note that the total sales in our sample turn out to be larger than those in the aggregate statistics. The differences can be explained by the fact that the output

4. For example, out of 860,000 firms, only 98,745 firms satisfy these criteria in 2012. Most of this reduction is driven by the exclusion of self-employed firms without employees, which drops around 750,100 firms.

TABLE 1. Coverage of selected sample.

	Aggregate statistics				Selected sample						
	GDP	Output					Sales		Labor		
Year		(Excl. Gov. & Fin.)	Import	Export	Count	V.A.	Total	Network	cost	Import	Export
2002	182	458	178	194	88,301	119	604	199	112	175	185
2007	229	593	255	269	95,941	152	782	206	151	277	265
2012	248	672	310	311	98,745	164	874	225	195	292	292

Notes: All numbers except for the count are in billions of euro in current prices. Belgian GDP and output are for all private and non-financial sectors. Data for Belgian aggregate statistics are from Eurostat. Firms' value added is from the reported values from the annual accounts. Firms' sales consist of their sales to firms in the selected sample (network sales), sales to firms outside the selected sample, sales to households at home, and direct export to foreign markets.

values in the aggregate statistics sum up value-added for trade intermediaries instead of gross output.

Throughout this paper, we focus on firms in the selected sample described above and the firm-to-firm network among those firms. We apply the following re-classifications for other transactions in the dataset. First, we treat the sales of firms in the selected sample to firms outside the selected sample as their sales to domestic final demand. Hence, firms' sales to domestic final demand are measured as firms' total sales (in the annual accounts) less their sales to other selected firms and exports. On the input side, we classify input purchases by firms in the selected sample from firms outside the selected sample as labor costs. Thus, the labor cost in our analysis can be interpreted as a composite input that combines all inputs that are from the firms outside the selected sample and are not imported. Instead of dropping sales to and purchases from non-selected firms as done in Dhyne et al. (2021), we apply the above re-classifications in order to measure firm-level average markups better.[5] Firm-level average markups are computed as the ratio of their sales over total inputs and will be one of the key measures in the following sections. We report in Online Appendix D.2 the fractions of firms' sales to domestic final demand and their labor costs that are affected by these re-classifications.

2.2. *Input Shares within Buyers and Market Shares within Sectors*

With the data described above, we first construct a measure of firms' sales shares within their buyers' input purchases. Next, we compare them with firms' market shares within sectors, which is the standard measure capturing the degree of market power firms have.

Consider a firm j in sector v supplying to firm i. For all such buyer–supplier pairs in the economy, we can measure the input share $s_{ji}^{v(j)}$, which is defined as the supplier

5. Hence, the numbers for total sales and labor cost in Table 1 are larger than those in Table 1 of Dhyne et al. (2021).

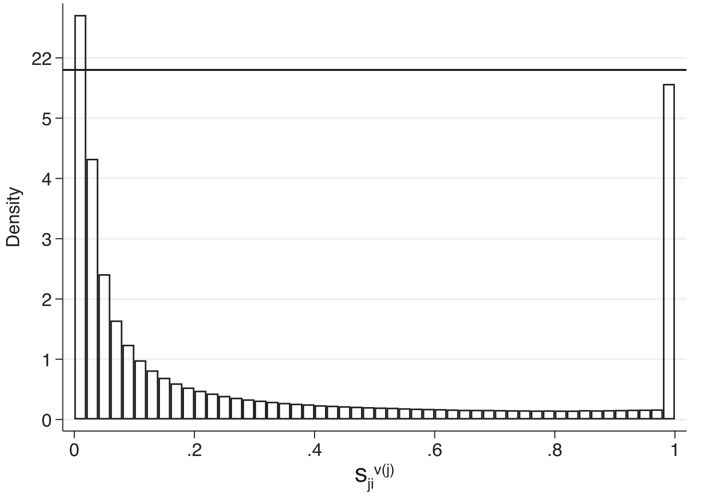


FIGURE 1. Distribution of pair-level input shares. This figure displays the distribution of pair-level input shares, $s_{ji}^{v(j)}$, in which sectors are defined at the two-digit level. The horizontal line represents scale break on the vertical axis. This figure is based on the cross-section of firms in 2012.

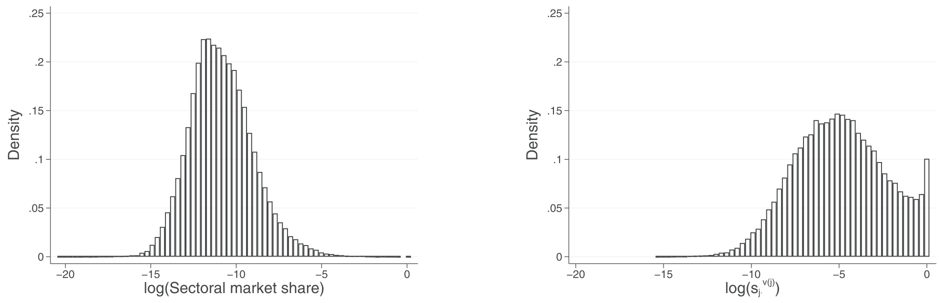
firm j's sales share in the buyer firm i's purchases of the supplier's sector goods:[6]

$$s_{ji}^{v(j)} = \frac{\text{Sales}_{ji}}{\text{InputPurchases}_{v(j)i}}. \tag{1}$$

We plot the distribution of the pair-level input shares, $s_{ji}^{v(j)}$, in Figure 1. Note that there is a scale break on its vertical axis, represented by a horizontal line. In the measurement, we use sectors that are defined at the two-digit level. The figure reveals that the pair-level distribution of these input shares exhibits a fat tail on the right. In the median buyer–supplier pair, the supplier has a 2.8% input share in the buyer's same sector purchases, while the average input share is 22%. There is also a substantial mass of buyer–supplier pairs with associated input shares of 1, representing pairs in which the suppliers are the only firms supplying the goods to the buyers in that sector.

We then compare this measure of firms' sales share in the firm-to-firm network with firms' standard sectoral market shares. To make this comparison, we aggregate the pair-level input shares, $s_{ji}^{v(j)}$, for each supplier firm across buyers, using input purchases of j's sector goods as the weight for each buyer. This aggregated firm-level share, $s_{j\cdot}^{v(j)}$, captures the share firm j has across all of its buyer firms on

6. Throughout this paper, we use the following convention in the notation of shares, prices, and quantities: If there are two subscripts in a term, then the first subscript indicates the origin of the trade flow, and the second indicates the destination of the trade flow. If there is a superscript in a term, then it represents the level of aggregation the share or price is computed at. The term $s_{ji}^{v(j)}$ thus represents the share of firm j's sales to firm i, out of firm i's total purchases of inputs that are in the same sector as firm j (sector v).



(a) Sectoral market shares (two-digit)

(b) Average input shares ($s_{j\cdot}^{v(j)}$, two-digit)

FIGURE 2. Sectoral market shares and input shares within buyers. The left panel displays the distribution of firm-level log market shares at the two-digit sector level. The right panel displays the distribution of firm-level log average input shares within buyers, $s_{j\cdot}^{v(j)}$, computed at the two-digit sector level. Both panels are based on the cross-section of firms in 2012.

average:

$$s_{j\cdot}^{v(j)} = \sum_{i \in W_j} \frac{\text{InputPurchases}_{v(j)i}}{\sum_{k \in W_j} \text{InputPurchases}_{v(j)k}} s_{ji}^{v(j)}$$

$$= \frac{\sum_{i \in W_j} \text{Sales}_{ji}}{\sum_{i \in W_j} \text{InputPurchases}_{v(j)i}}, \tag{2}$$

where W_j is the set of firm j's buyers. We plot the distributions of firm-level sectoral market shares and firm-level input shares within buyers, $s_{j\cdot}^{v(j)}$, in Figure 2. Both shares are computed using sectors defined at the two-digit level. As both firm-level distributions are concentrated at 0, in the figure, we take logs for both shares to make the comparison easier. Both firm-level shares have fat tails on the right, and similar to the pair-level input shares in Figure 1, the distribution of firm-level input shares has a mass at 1. We also find that there is a substantial difference in the levels of the two shares. Firms generally have much larger input shares within their buyers than their market shares within sectors. The average firm has close to a 0 market share within its two-digit sector, but the average firm has around an 8% input share within its buyers' purchases of the same two-digit sector goods. These patterns remain the same when we compute these two shares using sectors at the four-digit level. Even with narrowly defined sectors, the differences in the two shares remain significant: While the average sectoral market share is still close to 0, the average firm has a 27% share in its buyers' purchases of the same four-digit sector goods.[7]

Not surprisingly, these two firm-level shares are positively correlated with each other as both shares have components of firms' sales in their numerators. A firm's

7. See Online Appendix D.3.

sectoral market share has the firm's total sales on its numerator, and the average input share has the firm's total sales to other firms on its numerator (equation (2)). The correlation coefficient, however, is not close to one: The correlation between the log shares in 2012 was 22%.[8] This indicates that large firms in terms of total sales do not always have large input shares in their buyers, and small firms do not always have small input shares in their buyers.

In Appendix A.1, we further investigate the disconnect between firms' sectoral market shares (or firm-size) and firm's input shares using the variation of input shares at the firm pair level. For each buyer firm with multiple suppliers, we rank suppliers in terms of their total sales and also in terms of their input shares within that buyer. We show that these two rankings are oftentimes not aligned with each other: The median correlation coefficient across all buyer firms turns out to be −0.02. Even when we account for firms purchasing goods from different sectors by computing the correlation coefficients for each two-digit sector that firms supply, the median correlation coefficient increases only to 0.05. Taken together, these results show that a firm with a high input share of a particular buyer is not necessarily large in terms of its total sales, illustrating that pairwise match components play a large role in firm-to-firm trade in addition to firm-level components.[9]

2.3. Markups and Input Shares

The firm-level sectoral market shares and input shares constructed above both capture how large firms are: The sectoral market shares capture how large firms are in their relationships with all other firms in the sector, and the input shares capture how large firms are in their relationships with the buyer firms they supply to. It is well-documented, both theoretically and empirically, that firms with larger sectoral market shares tend to charge higher markups. Here, we explore whether the input shares that firms have in their buyers are relevant in explaining the patterns of firms' markups. To do so, in an ideal setting, one would correlate transaction prices or markups with input shares at the pair-level and see if there is any positive relationship. Since we do not observe transaction prices at the pair-level but only transaction values for each buyer–supplier pair, we investigate if firm-level average markups and their average input shares, $s_{j.}^{v(j)}$, are positively associated with each other, after controlling for their sectoral market shares. A positive relationship would suggest that firms' market power contains pair-level components that come from the relationships with each individual buyer, in addition to the firm-level components captured by their sectoral market shares.

Firm-level markups, μ_j, are measured as the ratio of firms' total sales over input costs (the sum of input purchases and labor costs). This measure captures average

8. The correlation coefficient between the two shares without log transformation is 3.2%.

9. In Online Appendix D.4, we explore the persistence of firms' sectoral market shares and input shares over time. We find that both firms' sectoral market shares and input shares are highly persistent: Firms that are large within their sectors are likely to be large in the future, and a firm that is among the top suppliers to a buyer is likely to remain a top supplier for the buyer in the future.

markups or profit shares for each firm. It is consistent with the model we construct in Section 3, in which we consider a static model without fixed costs, featuring constant returns to scale production technologies.[10] However, if firms' production technologies do not exhibit constant returns or if part of the inputs are spent as fixed costs, then the accounting markups measure, μ_j, may not capture markups over marginal costs. To address this concern, as a robustness check in Online Appendix D.5, we also consider an alternative measure of firm-level markups following the method of de Loecker and Warzynski (2012). This method estimates production functions to identify markups from the wedge between the output elasticity of a variable input and its expenditure share out of total revenue.[11]

Firm-level sectoral market share, SctrMktShare_j, is computed as the firm's share of total sales among all firms in its two-digit sector. This sectoral market share captures firms' market power in standard models of oligopolistic competition in which firms compete with all other firms in the same sector in the output market. This measure captures firms' total sales, so controlling for this sectoral market share allows us to see the correlation between firms' average markups and their average input shares, conditional on their overall scale of production.

With these variables, we run the following regression:

$$\mu_{j,t} = \beta \, \text{SctrMktShare}_{j,t} + \gamma \, s_{j\cdot,t}^{v(j)} + \varphi \, X_{j,t} + \delta_t + \nu_{j,t}, \tag{3}$$

where firm-level controls, $X_{j,t}$, and year fixed effects, δ_t, are included. Firm-level controls include numbers of suppliers and buyers, number of employees, and total assets. We also add sector or firm fixed effects depending on the specification. We report in Table 2 the results where the dependent variable is firms' accounting markups, and in Online Appendix D.5, we report the robustness results where the dependent variable is firms' markups from de Loecker and Warzynski (2012). The specifications of the first two columns include sector fixed effects, and the other columns include firm fixed effects.

Unsurprisingly, in all specifications, we see a positive relationship between markups and firm-level sectoral market shares regardless of the inclusion of firms' average input shares. The result in the last column, for example, indicates that within each firm, an increase of one standard deviation in the firm's sectoral market share is associated with an increase of around 2.6 percentage points in the firm's average markup. More interestingly, even after controlling for these sectoral market shares, the

10. We exclude the user cost of capital from the calculation of markups in our baseline case. This is because the firm-to-firm trade data may capture purchases of capital goods. Since it is impossible to identify which transactions were capital input purchases, adding a measure of the user cost of capital may lead to double-counting of capital inputs. Nevertheless, in Online Appendix D.5, we account for capital usage costs by adding them as additional input costs.

11. We assume material inputs are the variable inputs in the markup estimation procedure. As the data do not record the physical output of Belgian firms, we rely on revenue data in estimating firm-level markups. This may lead to potential mismeasurement in the output elasticity, hence in markups. However, De Ridder, Grassi, and Morzenti (2021) show that the markups that are based on revenue data for firms under oligopolistic competition are estimated well in terms of dispersion, while they may be biased in levels.

TABLE 2. Firm-level markups and input shares.

	Average markups					
	(1)	(2)	(3)	(4)	(5)	(6)
SctrMktShare$_{j,t}$ (two-digit)	0.0189 (0.00207)	0.0181 (0.00201)	0.0154 (0.00220)	0.0150 (0.00220)	0.0268 (0.00375)	0.0263 (0.00374)
Average input share $s^{v(j)}_{j\cdot,t}$		0.0266 (0.00176)		0.0154 (0.00146)		0.0146 (0.00144)
N	1,061,724	1,061,724	1,033,805	1,033,805	1,033,805	1,033,805
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Sector FE	Four-digit	Four-digit	No	No	No	No
Firm FE	No	No	Yes	Yes	Yes	Yes
Controls	Yes	Yes	No	No	Yes	Yes
R^2	0.0846	0.0862	0.600	0.600	0.601	0.601

Notes: Standard errors in parentheses. The coefficients are X-standardized. Standard errors are clustered at the two-digit-year level. The regressions exclude outliers in the top and bottom 1% of the markup distribution. Controls include firms' number of suppliers, number of buyers, employment, and total assets.

coefficients on the firms' average input shares to buyers are positive. The last column indicates that within each firm, one standard deviation increase in the average input share to buyers corresponds to an increase of around 1.5 percentage points in the firm's average markup. We find similar results when using markups from de Loecker and Warzynski (2012) as the dependent variable. Controlling for firms' size in each sector, firms charge higher markups if they have larger shares of their buyers' inputs.[12]

It is worth noting that potential confounding factors such as productivity shocks will affect only the coefficient on the sectoral market shares and not the coefficient on the average input shares, as long as they are at the firm-level. Nevertheless, there may be confounding factors at the pair-level. To address this issue, we consider a specification in which we instrument the average input share with buyers' input purchases from other suppliers. This specification only considers the variations of firms' average input shares originating from the changes in buyers' purchases from other suppliers. As reported in Online Appendix D.5, the coefficients on average input shares in the second stage results remain positive.

Consistent with the results found in Section 2.2, the positive coefficient on the average input shares indicates that firms' sectoral market shares are not perfectly collinear with their average input shares to buyers. This means that large firms, in terms of total sales, are not necessary always large suppliers to their buyers, and vice

12. Though beyond the scope of this paper, one natural question is how firms' ability to charge markups depends on the oligopsonistic power of their buyers. One conjecture may be that if firm j's output is concentrated to the sales to a particular buyer i, firm j may charge lower markup to i. Because we do not observe firm-to-firm prices, we proxy these quantity output shares with revenue output shares and construct averages across buyers. When correlated with firms' average markups, we find that the coefficient is either insignificant or even positive.

versa. Firms' average input shares—constructed from pair-level input shares—contain important information about firms' market power beyond what is captured in the firm-level sectoral market shares. While the results show that buyer–supplier match-specific components play an important role in explaining firm-level markups, there are several forces that can be driving these results. One may rationalize these results with theories in which these match specific components develop over time, such as relation-specific sunk costs. To partly account for these time-varying components, we additionally control for the firm's age and also for the average relationship age across its buyers. The positive correlation between markups and average input shares is robust even after these additional controls are added, meaning that there are also time-invariant aspects in the match-specific components.[13] Another explanation could be non-homotheticities in buyers' production functions, as in Blaum, Lelarge, and Peters (2017). However, the positive correlation between markups and average input shares is robust after adding an additional variable controlling for buyers' size. Finally, one can view our results as potentially coming from firms' sales to final demand. A firm may be charging a high average markup because it has a large share in the final demand market. It can also be because a large share of its sales are delivered to final demand, which may have higher markups. However, the positive coefficient of average markups on average input shares is virtually unaffected even when we control for firm-level sales shares in the final demand market or for shares of firms' sales that are sold to final demand.[14]

We further investigate the underlying mechanism behind the positive relationship between markups and input shares. Following the spirit of the exercise done in Halpern and Koren (2007), in Online Appendix D.5, we split the sample of firms into firms in sectors in which varieties are highly substitutable and into firms in sectors in which varieties are less substitutable. We take the estimates of the sectoral CES parameters from the exercise done in Section 4, and for each sample, we run the regression specification (3) separately. Consistent with the results of Halpern and Koren (2007), we find that while both samples produce positive coefficients of markup on input shares, the coefficient for the sample of firms in sectors that are less substitutable is larger. This result is consistent with the model we build in Section 3, in which each firm charges different markups to each buyer depending on the elasticity of demand it faces, and where the demand elasticity partly depends on the substitutability of the variety the firm is producing.

Finally, we conduct a battery of other robustness checks in Online Appendix D.5 and show that the positive correlation between firm-level average markups and average input shares is robust to different specifications. In particular, we consider different measures of firms' average input shares, for example, using sectors defined at the

13. This is consistent with the time-invariant firm-country-specific factors determining the exporters' distribution of sales across countries, as documented in Bernard, Moxnes, and Ulltveit-Moe (2018). It is also consistent with our empirical results reported in Online Appendix D.4, in which we show that pair-level input shares are highly persistent over time.

14. See Online Appendix D.5 for the results with these additional controls.

four-digit level or using different types of aggregation from pair-level input shares to firm-level average input shares.

As stated at the outset, one drawback of our data is that it lacks price information for each firm pair. Our empirical results where we find a positive relationship between markups and average input shares at the firm-level are suggestive at most, of firms charging different markups to buyers depending on the input shares. To partly address this limitation, in Appendix A.2, we turn to the import transaction data. In the import transaction data, one can observe unit prices of imports at the level of the exporting country-product-Belgian importer. Using this price information, we find that Belgian importers pay higher prices for a product from a country if the imported products have a higher share of their input purchases.[15] The import transaction data aggregate all exporting firms at the country-product-level, while ideally, one would use transaction data that record prices and quantities at the level of individual buyer–supplier pair. Being aware of this limitation, we take this result as complementary evidence suggesting that firms price discriminate across buyers based on input shares. We construct such a model and quantify the welfare implications of price discrimination in the following sections.

3. Model

In this section, we set up a model of oligopolistic competition in firm-to-firm trade. With our focus being on firms' competition in their relationships with other firms, we take a stylized approach in modeling consumption and labor supply, abstracting from heterogeneities in final demand and imperfect competition in factor markets. We assume a representative household inelastically supplying a fixed amount of labor. We also model the economy as a small and open economy, where we take the foreign price p_F and the firm-level foreign demand shifters D_{jF} as given. All prices are normalized by the foreign wage; thus the domestic wage w is an equilibrium variable. Finally, we take the firm-to-firm linkages as given and fixed and consider the implications of oligopolistic competition within the observed network. While a growing number of papers consider the role of extensive margins in firm-to-firm linkages, many assume rigid surplus splitting rules between suppliers and buyers to obtain tractability (e.g., see Huneeus 2018; Lim 2018; Oberfield 2018; Taschereau-Dumouchel 2018; and Bernard et al. 2019).[16]

15. Halpern and Koren (2007) conduct a similar exercise using Hungarian data. Fontaine, Martin, and Mejean (2020) also find evidence of price discrimination: One-third of cross-sectional price dispersion in French exporters is attributable to price discrepancies within exporters across buyers.

16. In Online Appendix E.1, we outline a partial equilibrium model of price bargaining in firm-to-firm relationships, following the setup in Alviarez et al. (2021). The bargaining outcome of this model nests the outcome of the model outlined in Section 3. This general model allows for arbitrary outside options that the two firms have in each buyer–supplier relationship, such as the option to renegotiate with other firms they already source from or sell to, or the option to additionally source from or sell to firms that were previously not connected.

3.1. Preferences

There is a representative household providing L units of labor. The household has a CES preference over all firms' goods with a substitution parameter σ. We assume that firms' goods are substitutes, $\sigma > 1$. We also assume that the household does not directly consume foreign goods. The household's preference is denoted as

$$U = \left(\sum_{j \in \Omega} \beta_{jH} q_{jH}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}, \tag{4}$$

where Ω denotes the set of domestic firms. The term q_{jH} denotes the quantity of goods that firm j sells to the household. Given the price that j charges to the household, p_{jH}, the quantity q_{jH} can be written as

$$q_{jH} = \beta_{jH}^{\sigma} \frac{p_{jH}^{-\sigma}}{P^{1-\sigma}} E, \tag{5}$$

where E denotes the aggregate expenditure, and P denotes the aggregate price index:

$$P = \left(\sum_{j \in \Omega} \beta_{jH}^{\sigma} p_{jH}^{1-\sigma} \right)^{\frac{1}{1-\sigma}}. \tag{6}$$

Demand from abroad is modeled with the same structure as the domestic household. Let I_{jF} be an indicator of whether firm j is an exporter or not. Given the price that j charges on exported goods, p_{jF}, and the demand shifter it faces, D_{jF}, the export quantity, q_{jF}, can be written as

$$q_{jF} = I_{jF} p_{jF}^{-\sigma} D_{jF}. \tag{7}$$

3.2. Technology and Market Structure

Each firm produces a single differentiated good with a constant return to scale production technology. On the input side, firms combine labor inputs, inputs purchased from other firms, and/or imported goods in a nested CES production function. On the output side, they sell goods directly to domestic final demand, to other domestic firms, and/or export.

When considering firm-to-firm trade markets, the assumption of atomistic suppliers for each buyer is not consistent with the data. In 2012, the median firm purchased inputs from 33 suppliers, and the median number of suppliers per two-digit sector was 2. Moreover, in Section 2.3, we found that firms charge higher markups when they have higher average input shares to buyers. Therefore, we assume oligopolistic competition in firm-to-firm trade, where firms charge different markups to different buyers depending on the input shares they have in each buyer's goods purchases. In doing so, we apply the framework of Atkeson and Burstein (2008) to firms' pricing decisions in the relationships with each buyer. We also assume oligopolistic competition in the domestic final demand market. On the exporting side, we treat firms competing in the international market to be infinitesimal and assume Dixit and Stiglitz (1977) monopolistic competition.

Let Z_i be firm i's set of domestic suppliers and let I_{Fi} be the indicator for the importing status of firm i. We denote i's sector by u and j's sector by v. We assume nested CES structures in firms' production functions. A firm first combines domestically supplied goods into sector-level intermediate goods bundles. Then it combines these sectoral goods and imported goods into a single intermediate goods bundle. Finally, the firm combines labor inputs and the intermediate goods bundle to produce its output. We denote the elasticity of substitution across firms' goods in sector u by σ_u. The substitution parameter across sectoral goods and imported goods is ρ, and the substitution parameter across labor inputs and the intermediate goods bundle is η. We assume all substitution parameters to be above one.[17]

The implied unit cost of firm i can be written as

$$c_i = \varphi_i^{-1} \left(\omega_l^{\eta} w^{1-\eta} + \omega_m^{\eta} p_{mi}^{1-\eta} \right)^{\frac{1}{1-\eta}}, \tag{8}$$

where φ_i is i's core productivity. The terms ω_l and ω_m denote CES weights in the production function on labor inputs l_i and intermediate goods bundle q_{mi}. Nominal domestic wage is denoted by w, and p_{mi} is the firm-specific price index of intermediate goods. This intermediate goods bundle is an aggregate of firm i's sector-level domestic intermediate bundles q_{vi}^m with price indices p_{vi}^m and the foreign inputs q_{Fi} with price p_F. Prices p_{mi} and p_{vi}^m vary with firms' sourcing strategies, Z_i and I_{Fi}, along with the saliency parameters in production functions, α_{ji} and α_{Fi}:

$$p_{mi} = \left(\sum_v \alpha_v^{\rho} \left(p_{vi}^m \right)^{1-\rho} + I_{Fi} \alpha_{Fi}^{\rho} p_F^{1-\rho} \right)^{\frac{1}{1-\rho}}$$

$$p_{vi}^m = \left(\sum_{j \in Z_i, j \in \mathcal{V}} \alpha_{ji}^{\sigma_v} p_{ji}^{1-\sigma_v} \right)^{\frac{1}{1-\sigma_v}}, \tag{9}$$

where the term $\mathcal{V}$ denotes the set of firms in sector v.[18] The term p_{ji} denotes the price that firm j charges when selling its goods to firm i.

17. We do not impose any restrictions concerning the relative magnitudes among $\{\sigma_u\}$, ρ, and η when we estimate them in Section 4.

18. Under this nested CES structure, firms aggregate all imports into one bundle and combine them with sectoral bundles of domestic intermediate goods. We choose this structure because we only observe imports at the exporting country-product level and the parameter σ_v captures the substitutability of varieties across firms in the sector. We also assume that the substitutability parameters η, ρ, and σ_v are common across firms regardless of their sector. We do so to minimize the number of parameters to estimate. Instead, we have a flexible structure in the CES saliency parameters (α_{ji} and α_{Fi}) so that the model can explain the observed labor shares, import shares, and pair-level input shares in the data.

Before discussing the market structures of the final demand market and of the firm-to-firm markets, we derive the firms' shares of inputs implied by the above CES structures. The share of firm i's variable costs spent on labor, s_{li}, is

$$s_{li} = \frac{\omega_l^{\eta} w^{1-\eta}}{c_i^{1-\eta} \varphi_i^{1-\eta}}, \tag{10}$$

and the intermediate goods' share, s_{mi}, becomes

$$s_{mi} = 1 - s_{li} = \frac{\omega_m^{\eta} p_{mi}^{1-\eta}}{c_i^{1-\eta} \varphi_i^{1-\eta}}. \tag{11}$$

Among i's variable cost spent on intermediate goods, the share of sector v goods, s_{vi}^m, and the share of foreign goods, s_{Fi}^m, are, respectively,

$$s_{vi}^m = \alpha_v^{\rho} \frac{\left(p_{vi}^m\right)^{1-\rho}}{p_{mi}^{1-\rho}}$$

$$s_{Fi}^m = I_{Fi} \alpha_{Fi}^{\rho} \frac{p_F^{1-\rho}}{p_{mi}^{1-\rho}}. \tag{12}$$

Among i's variable cost spent on sector v goods, the share of firm j's goods, $s_{ji}^{v(j)}$, is

$$s_{ji}^{v(j)} = \alpha_{ji}^{\sigma_{v(j)}} \frac{p_{ji}^{1-\sigma_{v(j)}}}{\left(p_{v(j)i}^m\right)^{1-\sigma_{v(j)}}}, \tag{13}$$

with an empirical counterpart in equation (1).

Finally, we turn to the market structures. We assume oligopolistic competition when firms sell to domestic final demand and assume monopolistic competition when firms export. We take this stylized approach in the export market, as we do not observe the identity of foreign buyers. When firm i sells to domestic households, the firm chooses the price p_{iH} that solves the following maximization problem:

$$\max_{p_{iH}} \quad (p_{iH} - c_i) q_{iH} \tag{14}$$

$$\text{subj. to:} \quad q_{iH} = \beta_{iH}^{\sigma} p_{iH}^{-\sigma} P^{\sigma-1} E.$$

Firm i solves the above problem by taking as given prices of all other firms and aggregate income. At the same time, it takes into account the effect of its price on the aggregate price index, hence $\partial P / \partial p_{iH} \neq 0$. Solving the above yields the following optimal markup with the price being the markup μ_{iH} over the marginal cost c_i, $p_{iH} = \mu_{iH} c_i$:

$$\mu_{iH} = \frac{\varepsilon_{iH}}{\varepsilon_{iH} - 1}, \tag{15}$$

$$\varepsilon_{iH} = (1 - s_{iH})\sigma + s_{iH}. \tag{16}$$

The term s_{iH} represents the share firm i has in domestic final demand, $s_{iH} = \beta_{iH}^{\sigma} p_{iH}^{1-\sigma} / P^{1-\sigma}$. Equations (15) and (16) imply that as firm i has a larger share in the market, s_{iH}, the higher markup it charges. When firms export, monopolistic competition implies that they charge a constant markup over marginal cost, with the price being the product of the two, $p_{iF} = \mu_{iF} c_i$:

$$\mu_{iF} = \frac{\sigma}{\sigma - 1}. \tag{17}$$

We introduce oligopolistic competition in firm-to-firm trade in the following way. When selling to firm i, firm j sets price p_{ji} that maximizes variable profits by taking as given prices of all other firms, including those of i's other suppliers. Firm j also takes as given firm i's unit cost and output, c_i and q_i. Firm j does not internalize the effect that its price, p_{ji}, may affect other firms' prices. However, firm j does internalize the effect of its price, p_{ji}, on the buyer i's intermediate input costs and quantities, p_{mi}, p_{vi}^m, q_{mi}, and q_{vi}^m. The firm's problem is as follows:

$$\max_{p_{ji}} \quad (p_{ji} - c_j) q_{ji} \tag{18}$$

$$\text{subj. to:} \quad q_{ji} = \alpha_{ji}^{\sigma_{v(j)}} \alpha_{v(j)}^{\rho} p_{ji}^{-\sigma_{v(j)}} \left(p_{v(j)i}^m\right)^{\sigma_{v(j)}-1} \left(p_{v(j)i}^m\right)^{1-\rho} p_{mi}^{\rho} q_{mi}$$

$$q_{mi} = \omega_m^{\eta} p_{mi}^{-\eta} \varphi_i^{\eta-1} c_i^{\eta} q_i.$$

Solving the above problem while taking into account that $\partial p_{mi} / \partial p_{ji} \neq 0$ and $\partial p_{v(j)i}^m / \partial p_{ji} \neq 0$ yields the following markup, with the price being the markup over firm j's marginal cost, $p_{ji} = \mu_{ji} c_j$:

$$\mu_{ji} = \frac{\varepsilon_{ji}}{\varepsilon_{ji} - 1}, \tag{19}$$

$$\varepsilon_{ji} = \sigma_{v(j)} \left(1 - s_{ji}^{v(j)}\right) + \rho s_{ji}^{v(j)} \left(1 - s_{v(j)i}^m\right) + \eta s_{ji}^{v(j)} s_{v(j)i}^m. \tag{20}$$

Equations (19) and (20) imply that the markup firm j charges on firm i, μ_{ji}, depends on the input share that j's goods have in i's intermediate goods, $s_{ji}^{v(j)}$ and $s_{v(j)i}^m$. If the supplier j has an infinitesimally small share of buyer i's purchases of sector v goods ($s_{ji}^{v(j)} \to 0$), then all the competition the supplier j engages in is with the other suppliers in sector v that share the same buyer i. The price converges to the value obtained assuming monopolistic competition, with a constant markup of $\sigma_{v(j)} / (\sigma_{v(j)} - 1)$. As the supplier's input share on the buyer increases, then not only does the supplier compete with the other suppliers in sector v, but also with suppliers in other sectors and with the labor input that buyer firm i employs. Thus, the demand elasticity that j faces, ε_{ji}, becomes a weighted average of $\sigma_{v(j)}$, ρ, and η. The weights are constructed from the shares $s_{ji}^{v(j)}$ and $s_{v(j)i}^{m}$. When the supplier j is the only firm supplying the buyer ($s_{ji}^{v(j)}, s_{v(j)i}^{m} \to 1$), the markup converges to $\eta/(\eta-1)$. The intuition of how pair-level markups and prices depend on pair-level shares and how they are simultaneously determined in the equilibrium is identical to what is described in Atkeson and Burstein (2008). The key difference is that here the relevant shares and markups are defined for each buyer–supplier pair.

As aforementioned, we assume that the supplier takes as given the buyer's unit cost and output, c_i and q_i, while all aggregations in the production functions are made with finite sums. This is consistent with the assumption of Bertrand competition, where firms take as given all others' prices, including the prices of their buyers. A plausible alternative would be to assume that the supplier firm internalizes the change in the buyer's quantity sold when determining its price. In this case, the supplier needs to know the output composition of the buyer firm to infer the elasticity of demand the buyer is facing, or the supplier needs to assume a value for the elasticity of demand. As firms are unlikely to observe the flow of goods distant in the production chain, we find our assumption to be reasonable. Nevertheless, in Online Appendix E.2, we discuss in detail the optimal prices that firms charge their buyers when relaxing this assumption.[19]

The assumption of firms taking as given prices and quantities that are distant in the production chain is also consistent with the empirical evidence. Section 2.3 confirmed that firms' markups are correlated with the firms' average input shares within their buyers. We further investigate if firms' markups are correlated with the average input shares their buyers have within those buyers' buyers. We find that the coefficient on these second-degree average input shares is not positive and close to zero. These results indicate that although firms charge higher markups when possessing higher input shares than their buyers, this is not necessarily the case when their buyers have higher input shares. See Online Appendix D.5 for details.

Finally, we describe firms' output and profits. A firm sells goods to households, abroad (if the firm is an exporter), and also to other domestic firms. Therefore we have

$$q_j = q_{jH} + q_{jF} + \sum_{i \in W_j} \underbrace{\alpha_{ji}^{\sigma_{v(j)}} \frac{p_{ji}^{-\sigma_{v(j)}}}{\left(p_{v(j)i}^{m}\right)^{1-\sigma_{v(j)}}} s_{v(j)i}^{m} s_{mi} c_i q_i}_{q_{ji}} . \tag{21}$$

19. The assumption where the firms take as given the prices and quantities that are distant in the production chain is similar to the assumption of incomplete information considered by Antràs and de Gortari (2020). In Online Appendix E.2, we show that when a firm internalizes the effect of its price on the demand for the buyer's goods, the markup it charges not only depends on the shares $s_{ji}^{v(j)}$ and $s_{v(j)i}^{m}$, but also on quantities that the buyer sells to other firms and the quantities that it sells to final demand. Alternatively, one can instead have an assumption in which the firm assumes that the buyer is facing a single demand elasticity. In this case, if one sets the demand elasticity buyers are facing to be η, then the markup equation collapses to that of equation (19). We also discuss optimal prices when firms engage in Cournot competition instead of Bertrand competition.

Firm j's profits come from three sources: sales to households, exports, and sales to other domestic firms. So the variable profit of firm j can thus be described as

$$\pi_j = \frac{1}{\varepsilon_{jH}} \underbrace{p_{jH} q_{jH}}_{\text{Sales to HH}} + \frac{1}{\sigma} \underbrace{p_{jF} q_{jF}}_{\text{Exports}} + \sum_{i \in W_j} \frac{1}{\varepsilon_{ji}} \underbrace{p_{ji} q_{ji}}_{\text{Sales to } i} . \tag{22}$$

3.3. Equilibrium

We close the model by assuming that firms' profits are ultimately distributed back to the representative household. We also assume balanced trade. The household's budget constraint becomes

$$E = wL + \underbrace{\sum_{j \in \Omega} \pi_j}_{\Pi} . \tag{23}$$

The trade balance and labor market clearing conditions are as follows:

$$0 = \underbrace{\sum_{j \in \Omega} I_{jF} p_{jH}^{1-\sigma} D_{jF}}_{\text{Exports}} - \underbrace{\sum_{j \in \Omega} I_{Fj} s_{Fj} c_j q_j}_{\text{Imports}}, \tag{24}$$

$$wL = \sum_{j \in \Omega} s_{lj} c_j q_j . \tag{25}$$

The equilibrium in this economy can be characterized by the set of variables, $\{w, q_j\}$ that satisfy equations (5)–(25), taking as given the foreign demand shifters D_{jF} and the foreign price p_F.

4. Estimation

The counterfactual exercises using the model constructed in the previous section require estimates of the CES parameters in the preference and production functions, together with observables from the firm-to-firm transactions data. In this section, we describe the estimation procedures for the CES parameters.

We estimate the CES parameters by exploiting the variations of sales and input shares observed in the data. Recall that in equation (19), pair-level markups, μ_{ji}, are functions of the CES parameters $\{\sigma_{v(j)}, \rho, \eta\}$, and observable input shares, $s_{ji}^{v(j)}$ and $s_{v(j)i}^{m}$. Similarly, equation (15) shows that firms' markups to domestic final demand, μ_{jH}, are functions of the CES parameter σ and observable shares s_{jH}. We have also assumed markups firms charge on exports, μ_{jF}, to be a function of the CES parameter, $\sigma/(\sigma - 1)$ (equation (17)).

Our estimation strategy starts by focusing on each firm's total variable input cost. Let C_j^E denote the empirical value of firm j's total variable input cost that is consistent with our static model without fixed costs. We measure C_j^E by taking the sum of labor costs, purchases from other firms, and imports. Analogously, let C_j^T denote the theoretical value of firm j's total variable input cost, which is the sum of firm's sales, with each component of sales deflated by the destination-specific markups:

$$C_j^T = \sum_i \frac{p_{ji} q_{ji}}{\mu_{ji}} + \frac{p_{jH} q_{jH}}{\mu_{jH}} + \frac{p_{jH} q_{jF}}{\mu_{jF}}. \tag{26}$$

The numerators of equation (26) are components of firm j's sales that are observed in the data, and the denominators are markups that can be constructed from observable shares and the CES parameters to be estimated (equations (15), (17), and (19)).

We estimate the CES parameters by exploiting the accounting identity that the two firm-level input costs must equal each other, $C_j^E = C_j^T$. We represent the deviations from this identity relative to the observed input cost as

$$\chi_j = \frac{C_j^E - C_j^T}{C_j^E}, \tag{27}$$

and choose the set of CES parameters, $\{\sigma_v, \rho, \eta, \sigma\}$, that minimize the squared sum of these errors:

$$\min_{\{\sigma_v\}, \rho, \eta, \sigma} \sum_j \left[\frac{C_j^E - C_j^T\left(\sigma_{v(j)}, \rho, \eta, \sigma\right)}{C_j^E} \right]^2. \tag{28}$$

This non-linear least squares method requires that these firms' inputs that are not fully accounted for in our model are uncorrelated with the observable shares that we use to construct the theory's implied firm-level input costs, C_j^T.[20]

We outline the intuition of how different combinations of variations in the data help identify different parameters. First, the value of σ is determined mainly by two moments. The first is the level of markups for firms that predominantly sell to domestic final demand and, at the same time, have infinitesimal shares in the final demand market s_{jH}. The second is the level of markups for firms that predominantly sell to foreign markets. Equations (15) and (17) show that these two sets of firms charge markups of $\sigma/(\sigma - 1)$ for almost all their output. Therefore, the value of σ can be identified from the average sales to input ratio of those firms.

In contrast, the values of σ_v, ρ, and η are determined by the average markups for firms that predominantly sell to other firms, as the firm-to-firm markups are all monotonically decreasing in these parameters (equation (19)). Among the firms that predominantly sell to other firms, different firms have different weights on how their markups help identify the three sets of parameters. The average sales to input ratio of firms that have infinitesimal input share in their buyers ($s_{ji}^{v(j)} \to 0$) determine the

20. One may argue that, for example, if firms pay fixed costs of entry, then the estimates will be biased. However, we note that the error is defined in terms of the firm's total input cost, C_j^E. Hence, if the various fixed costs that firms pay—including fixed costs of entry and establishing buyer–supplier relationships—are proportional to firm size, then the error would not be correlated with the observable shares that may correlate with firm size.

value of σ_v, as they will be charging markups of $\sigma_v/(\sigma_v - 1)$. The value of ρ is determined by the average sales to input ratio of firms that have high input shares within their sectors but with their sectors having low shares in the buyers' inputs ($s_{ji}^{v(j)} \to 1$, $s_{v(j)i}^{m} \to 0$). Lastly, firms with buyers purchasing most of their inputs from them ($s_{ji}^{v(j)} \to 1, s_{v(j)i}^{m} \to 1$) will be charging markups of $\eta/(\eta - 1)$, hence their average sales to input ratio determines the value of η.

Note that this estimation strategy relies on several key assumptions. The constant return to scale feature of the production functions allows us to interpret the deviations between revenues and input costs as markups over marginal costs. Moreover, we are not able to distinguish fixed costs from variable costs in the data. Consistent with the static model's assumption that there are no fixed costs and also with the assumption that there is no joint production, we use the sum of labor costs, purchases from other firms, and imports as firms' input costs. We use the two-digit sector categorization of "intermediate SNA/ISIC aggregation A∗38" in NACE Rev.2 classification.[21] This leaves us to estimate 29 sectoral substitution parameters of σ_v and three parameters of σ, ρ, and η. We report the estimation results in Table 3.[22]

In the production function, the substitution parameter across labor and goods is 1.67. Within intermediate goods, the substitution parameter across sectoral goods and imported inputs is 2.59. The substitution parameters across varieties within sectors are broadly in the range of 2 to 5. In the preference function, the substitution parameter across goods is 2.98. These estimated values fall into ranges not far from those obtained from different approaches. Chan (2017) finds labor and intermediates to be gross substitutes. The survey of Anderson and van Wincoop (2004) finds that, within sectors, the elasticity of substitution across goods in the production function ranges from around 5 to 10 depending on the aggregation. Our estimates of σ_v are slightly lower than this because our estimates pick up the substitutability of firms' goods among the small set of suppliers that firms source from in each sector, instead of the substitutability of goods among all firms in each sector.[23] We also find that these estimated parameters jointly explain 85% of the total variation in the observed input costs, C_j^E.

We explore how the estimates translate to the level of markups firms charge in Online Appendix F.1. We first analyze in the data whether the observed firm-level markups—measured as the ratio of firms' total sales over input costs—are different

21. See European Commission (2008) for details. We aggregate two A∗38 codes, CD and CE, into one sector.

22. To evaluate the sensitivity of estimates to firms in the network, for each sector, we draw firm-level samples from the data with replacements and compute the standard deviations of the estimates from the re-sampled data. However, as these firm-level observations are dependent on the activities of their suppliers and buyers, standard asymptotic properties may not hold with the re-sampled data. See Chandrasekhar (2015) for discussions on conducting inference using network data.

23. Our approach of estimating CES parameters is different from that of other papers that estimate substitution parameters at higher frequencies. For example, Boehm, Pandalai-Nayar, and Flaaen (2019), Barrot and Sauvagnat (2016), and Atalay (2017) find much lower estimates in the production function parameters. In contrast, Peter and Ruane (2020) estimate the elasticities of substitution at a longer time horizon and find estimates of similar magnitudes for firms' intermediate inputs.

TABLE 3. Estimated CES parameters.

η, ρ, and σ			
	η (Labor and goods)	ρ (Sectoral goods and imports in production)	σ (Firms' goods in consumption)
Estimate	1.67	2.59	2.98
Standard errors	0.14	0.31	0.66

Sectoral estimates of σ_v

Description of sector	Estimate	Standard errors
Agriculture, forestry, and fishing	2.79	0.35
Mining and quarrying	2.85	1.16
Manufacture of food products, beverages, and tobacco products	4.12	0.60
Manufacture of textiles, apparel, leather, and related products	2.41	0.31
Manufacture of wood and paper products and printing	3.11	0.41
Manufacture of coke, refined petroleum products, chemicals, and chemical products	2.84	0.82
Manufacture of pharmaceuticals, medicinal chemical, and botanical products	7.32	1.82
Manufacture of rubber and plastics products, and other non-metallic mineral products	3.99	0.58
Manufacture of basic metals and fabricated metal products, except machinery and equipment	3.16	0.42
Manufacture of computer, electronic, and optical products	4.26	0.76
Manufacture of electrical equipment	4.60	1.50
Manufacture of machinery and equipment n.e.c.	3.14	1.79
Manufacture of transport equipment	5.14	2.48
Other manufacturing, and repair and installation of machinery and equipment	2.92	0.43
Electricity, gas, steam, and air-conditioning supply	2.88	1.11
Water supply, sewerage, waste management, and remediation	2.91	0.37
Construction	3.79	0.54
Wholesale and retail trade, repair of motor vehicles and motorcycles	2.98	0.38
Transportation and storage	3.46	0.48
Accommodation and food service activities	5.10	0.83
Publishing, audiovisual and broadcasting activities	2.85	0.87
Telecommunications	2.80	0.45
IT and other information services	2.49	0.29
Real estate activities	2.34	0.30
Legal, accounting, management, architecture, engineering, technical testing, and analysis activities	1.91	0.18
Scientific research and development	4.91	1.53
Other professional, scientific and technical activities	2.92	0.37
Administrative and support service activities	2.81	0.35
Other services	2.35	0.51

Notes: Standard errors are based on 25 bootstrap samples drawn with replacements. The samples are drawn at the firm-level for each sector.

between different groups of firms. In particular, we consider firms that primarily sell to other firms and firms that primarily sell to final demand. We show that the distributions of firm-level markups for the two groups largely overlap. In addition, among the firms that primarily sell to other firms, we focus on those that have large input shares in their buyers' purchases (as measured by large $s_{j\cdot}^{v(j)}$) and compare their firm-level markups with those of firms that primarily sell to final demand. Consistent with both our theory and the findings in Section 2.3, firms with large input shares generally have higher markups than other firms that primarily sell to other firms and hence charge higher markups than those that primarily sell to final demand. To confirm these empirical findings with our estimates, we back out the model implied markups for each firm pair, μ_{ji}, and the model implied markups on firms' sales to domestic final demand, μ_{jH}, using the estimates and the observed shares. We plot the differences in the two markups, $\mu_{ji} - \mu_{jH}$, and find that the distribution largely centers around 0. We also show that the differences in the two markups are larger for firm pairs with larger input shares. Overall, our empirical findings suggest that firms on average charge similar markups to final demand and to other firms, with firms with large input shares charging higher markups. Our estimated CES parameters are able to capture these features in the data at the pair-level.

Lastly, we turn to the estimates under alternative setups. Instead of having firms engage in price competition in firm-to-firm relationships, we obtain similar estimates of the CES parameters under the assumption of firms engaging in quantity competition (Online Appendix F.2). Next, we consider an alternative way of treating firms' capital usage costs. In our baseline case, we sum firms' total labor costs, purchases from other domestic firms, and imported goods in our measurement of firms' total inputs, C_j^E. As mentioned in footnote 10, some firm-to-firm transactions may capture purchases of capital goods, and adding computed measures of the user cost of capital will lead to double-counting of these inputs. Nevertheless, in Online Appendix F.3, we account for firms' user costs of capital in two ways: scaling up labor costs of firms uniformly by assuming a common labor-to-capital share or computing firm-level capital costs from balance sheet data.

5. Counterfactual Analysis

With the estimated parameters, in this section we explore how the markups set for each buyer affect aggregate welfare by comparing with the economy, where firms charge firm-level markups regardless of who the buyer is. We compute how much the representative household would benefit or lose if the economy transitioned to one where firms are constrained to charge the same markup for its good sold to any buyer. We do so by solving for the changes in firm-level costs and aggregate welfare using the system of equations defining the equilibrium outlined in Section 3.

In the counterfactual economy where each firm is constrained to set one price on its good, the firm's profit maximization problem yields the following price:

$$p_j = \frac{\varepsilon_j}{\varepsilon_j - 1} c_j$$

$$\varepsilon_j = \sum_{i \in W_j} \frac{p_j q_{ji}}{p_j q_j} \varepsilon_{ji} + \frac{p_j q_{jH}}{p_j q_j} \varepsilon_{jH} + \frac{p_j q_{jF}}{p_j q_j} \sigma, \tag{29}$$

where ε_{jH} and ε_{ji} are as defined in equations (16) and (20), evaluated at the equilibrium with the constraint of firm-level markups.[24] In this economy, each firm sets a common markup for all buyers that reflects the weighted average of the demand elasticities it faces from each of its buyers. The associated weight assigned to each buyer is the share of the firm's revenue that the buyer accounts for. We solve for the equilibrium changes while keeping fixed all firm-level and pair-level primitives, such as firm productivity and saliency parameters in production functions. We implement the technique developed by Dekle, Eaton, and Kortum (2007), which requires only the firm-level and pair-level shares directly observed in the data and the estimated CES parameters.[25] We present the full system of equilibrium changes and the steps to solve for them in Appendix C.1.

We note that under the estimated parameters obtained in Section 4, firms' total input costs implied by the model, C_j^T, do not necessary match the observed input cost, C_j^E. For some firms, the observed input costs are larger than the model's implied values. For other firms, the observed input values seem lower than what is necessary to produce what is sold. To be consistent with the estimation strategy, in our baseline analyses, we take the error term in equation (27), χ_j, as firm-level constants. With this assumption, the changes in the observed input costs, $\widehat{C}_j^E$, are equal to the changes in the model implied input costs, $\widehat{C}_j^T$. To ensure robustness of the counterfactual results, we explore two alternative approaches to treating the differences in the input costs. The first approach is to treat the absolute differences in the input costs, $\xi_j = C_j^E - C_j^T$, as constant numbers. Under this approach, one could solve for the equilibrium changes using the following relationship: $\widehat{C}_j^E = (C_j^T / C_j^E)\widehat{C}_j^T + \xi_j / C_j^E$. The second approach is to follow that of Ossa (2014) and first purge the differences in the two input costs.[26] We first solve for the counterfactual changes by forcing the observed differences to zero, $\hat{\xi}_j = 0$. The resulting economy would be fully consistent with the model, with which we then solve for the counterfactual changes. We report the results of these two approaches in Online Appendix G.5, where we find that the quantitative results are very similar regardless of how we treat the differences in the input costs.[27]

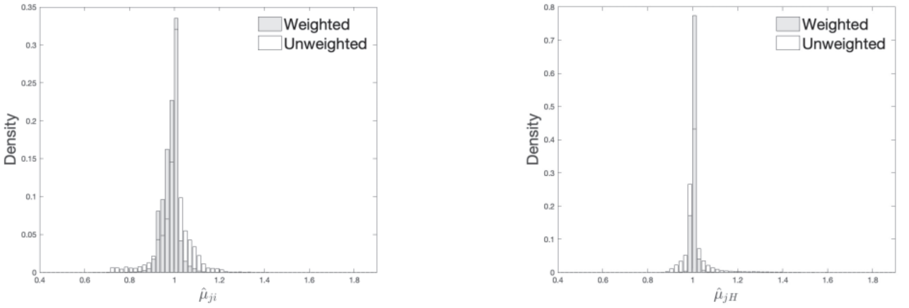
In this counterfactual exercise, buyer–supplier pairs in which the supplier charges a higher markup than its own average markup will have lower markups, and vice versa. We compute these changes in pair-level markups along with the changes in firms' markups on domestic final demand and plot their distributions in Figure 3. The left panel shows the unweighted and weighted distributions of the changes in pair-level

24. See Appendix B.1 for the derivation.

25. While we do not directly observe the underlying weight parameters in the preference and production functions, the technique ensures that as long as these underlying parameters are fixed, one can solve for the counterfactual changes in variables using the observed shares.

26. Ossa (2014) purges bilateral trade data of country-level trade imbalances before solving for countries' optimal tariffs.

27. In all three approaches, we have experimented with multiple starting values without finding any differences in the counterfactual results.



(a) Changes in pair-level markups (b) Changes in markups to final demand

FIGURE 3. Distribution of changes in markups upon banning price discrimination. The left panel displays the unweighted and weighted density distributions of the changes in pair-level markups firms charge to their buyers, $\hat{\mu}_{ji}$. The right panel displays the unweighted and weighted density distributions of the changes in firm-level markups firms charge to final demand, $\hat{\mu}_{jH}$. The weight used in the left panel is the input share of the pair $s_{ji}^{v(j)}$, and the weight used in the right panel is the firm's share in domestic final demand s_{jH}.

markups, $\hat{\mu}_{ji}$, and the right panel shows the unweighted and weighted distributions of the changes in firm-level markups on domestic final demand, $\hat{\mu}_{jH}$. We use the pair's input share as the weight in the left panel and the firm's share in domestic final demand as its weight in the right panel. Both unweighted distributions center around 1, with a typical firm pair experiencing a slight increase in their associated markup. But once weighted with the associated shares, the distribution of $\hat{\mu}_{ji}$ has a larger mass to the left of 1 while the distribution of $\hat{\mu}_{jH}$ is largely unchanged. This implies that firm pairs that saw reductions in the associated markup are ones where suppliers have much larger input shares than in pairs that saw increases in markups.[28]

These differences in the input shares among the two sets of firm pairs have implications for the aggregate outcomes. In Online Appendix G.2, we discuss in detail the mechanisms through which equalizing markups across buyers have welfare impacts. In particular, we closely follow the framework of Baqaee and Farhi (2020) and consider a hypothetical firm j equalizing the markup it charges its two buyers, i and k, with firm j initially charging a higher markup to firm i than what it charges to firm k. We describe that the combined effect of firm j lowering its markup to firm i, μ_{ji}, and raising its markup to firm k, μ_{jk}, depends on the relative magnitudes of the two input shares that firm j has in the two buyers, and also on the relative importance of the two firms i and k as suppliers in the overall economy (as measured by the cost-based Domar weight). Aside from the heterogeneity in the cost-based Domar weights and

28. In Online Appendix G.1, we plot the distributions of the input shares separately for firm pairs that saw reductions in markups and for firm pairs that saw increases in markups. While the supplier in a typical firm pair among which markup saw an increase has an input share of only 0.01, the supplier in a typical firm pair among which markup decreased has an input share of 0.35.

TABLE 4. Aggregate changes upon banning price discrimination.

		Change
Aggregate welfare	$\widehat{U} = \widehat{E}/\widehat{P}$	1.056
Real wage	$\widehat{w}/\widehat{P}$	1.025
Aggregate income	$\widehat{E}$	1.043
Aggregate profit	$\widehat{\Pi}$	1.052

Note: This table reports the changes in aggregate variables when each firm is constrained to set one price for its goods regardless of the buyer.

other general equilibrium effects, our theory implies that firm j is initially charging a higher markup to firm i due to the larger input share it has in firm i. Hence, everything else equal, the effect of firm j lowering its markup on firm i dominates the effect of firm j raising its markup on firm k, leading to a reduction in double marginalization and raising output in the overall economy. As a result of this counterfactual exercise, 84% of firms experience reductions in their unit costs, and over 88% of firms increase their output quantities.[29] Overall, aggregate welfare improves when firms are banned from price discrimination and constrained to charge common prices for their goods. The changes in aggregate variables reported in Table 4 reveal that the welfare of the representative household would improve by 5.6% and that the real wage increases by 2.5%.[30]

To tease out how much of the quantitative effects above are driven by shutting down price discrimination in firm-to-firm trade, we conduct a similar exercise in which firms are constrained to equalize only their markups with other firms. We outline firms' optimal prices under this constraint in Appendix B.2. In this exercise, we find that the distribution of the changes in pair-level markups slightly shifts to the right from the same distribution in the previous exercise (Online Appendix G.4). Markups of firm pairs in which suppliers have high input shares do not go down as much because they do not have to equalize with the lower markups on the suppliers' sales to final demand, which typically accounts for a large fraction of most firms' sales.[31] This leads to a smaller aggregate effect in which 64% of firms experience a reduction in unit costs and 65% of firms increase their output quantities.[32] As we report in Table 5, the improvement in welfare is around a quarter of the welfare increase seen when

29. See Online Appendix G.3 for the distributions of the changes in firms' unit costs, $\widehat{C}_j$, output quantities, $\hat{q}_j$, and sales, $\widehat{p_j q_j}$.

30. To ensure a fixed trade balance, the nominal wage increases by 1.2%. The wage increases because the export demand is relatively elastic compared to import demand.

31. Consistent with the findings from Dhyne et al. (2021), in Online Appendix G.8, we show that firm-to-firm trade accounts for a small share in most firms' sales. The median firm sells around 83% of its output to final demand (including both sales to domestic final demand and exports).

32. See Online Appendix G.7 for the distributions of the changes in firms' unit costs, $\widehat{C}_j$, output quantities, $\hat{q}_j$, and sales, $\widehat{p_j q_j}$.

TABLE 5. Aggregate changes upon banning price discrimination in firm-to-firm trade.

		Change	Fraction of banning full price discrimination
Aggregate welfare	$\widehat{U} = \widehat{E}/\widehat{P}$	1.015	27%
Real wage	$\widehat{w}/\widehat{P}$	1.006	24%
Aggregate income	$\widehat{E}$	1.010	23%
Aggregate profit	$\widehat{\Pi}$	1.010	19%

Notes: This table reports the changes in aggregate variables when firms equalize only their markups charged on their sales to other firms. The final column reports what fraction these changes account for of the changes reported in Table 4.

firms are banned from price discrimination to all buyers—welfare and real wage of the representative household improve by 1.5 and 0.6%, respectively.[33]

The results from the counterfactual exercises suggest that markup dispersion within firms across buyers creates a sizable welfare cost.[34] As firms in the counterfactual economies were still charging heterogeneous markups at the firm-level, the welfare cost we find is in addition to the welfare cost of across-firm markup dispersion that has already been found to be substantial in the literature. Moreover, our second exercise, in which we ban price discrimination in firm-to-firm trade, shows that within-firm markup dispersion in firm-to-firm transactions contributes around one-quarter of the overall welfare cost of within-firm markup dispersion in all markets. This result is despite the fact that sales to other firms account for a small fraction of most firms' sales.

6. Conclusion

In this paper, we studied the implications of imperfect competition in firm-to-firm trade. We proposed a novel view of competition between firms. In addition to the firm-level market shares within sectors determining firms' market power, we suggest that the relative size of the firm in the input sourcing of its buyers is also a relevant metric. The data on firm-to-firm transactions support this view; firms charge higher markups if they have higher average input shares within their buyer firms, controlling for their firm-level sectoral market shares.

33. Another statistic that may affect changes in aggregate variables is the correlation between upstreamness of the buyer–supplier pair and its change in the associated markup. For example, if upstream firm pairs tend to see larger reductions in markups, then the aggregate price index will decrease more as their markup reductions will have amplifying effects further downstream. We investigate this in Online Appendix G.6 and find that changes in markups and upstreamness measures (as in Antràs et al. 2012) have correlations very close to 0.

34. In Online Appendix G.7, we report the counterfactual results analogous to Tables 4 and 5. There we use the alternative assumptions described in Online Appendices F.2 and F.3, where we discuss the CES estimates when one assumes Cournot competition or when one accounts for capital usage costs in firms' inputs.

Using a model of oligopolistic competition in firm-to-firm trade, we analyzed the implications of firms' charging different markups to different buyers. We estimate key CES parameters by exploiting variations of input shares at the pair-level, and using these estimates, we quantified how much a representative household would be affected if the economy transitioned to one where firms charge common markups across buyers. The exercise reveals a large welfare loss due to markup dispersion within firms: Aggregate welfare would improve by 5.6% when firms are banned from price discrimination.

Our findings add to the discussion over regulations on price discrimination. Previous research that looked at the quantitative effects of banning price discrimination was often constrained to particular markets. Here we exploit the unique data on firm-to-firm transactions within an entire economy and compute aggregate outcomes. We find that because firms tend to charge higher markups on their sales to other firms than on their sales to final demand, small reductions in markups in firm pairs result in a larger aggregate effect, as they amplify firms' cost reductions through the input-output linkages.

One potential limitation is that, given that the data only record transaction values between firms and not prices and quantities of those transactions, we are not able to incorporate richer surplus splitting rules among firm pairs. For example, the model we used assumes all bargaining power is on the supplier side. Investigating the implications of these richer surplus-splitting rules is an avenue for future research.

Appendix A: Appendix on Empirical Results

A.1. Disconnect between Sectoral Market Shares and Input Shares

In this section, we investigate the disconnect between firm size and firms' input shares within buyers. In particular, we ask if large firms in terms of total sales are the ones also having large input shares within their buyers' purchases. Consider the firm on the left of Figure A.1. This firm is purchasing goods worth 10, 5, and 1 euro from its three suppliers, a, b, and c, respectively. The three suppliers' total sales are 100, 50, and 10 euros. The ordering of the firm's suppliers according to the input shares aligns

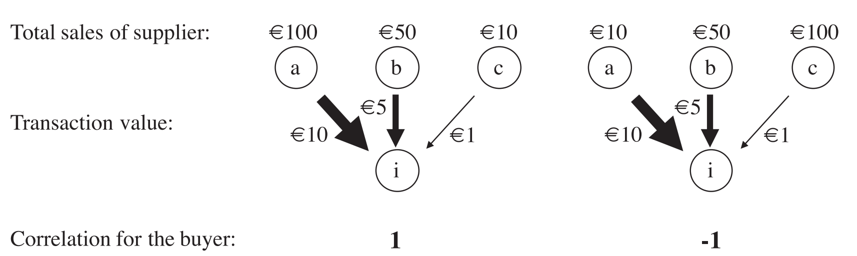
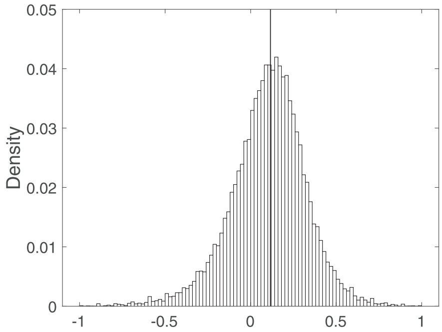
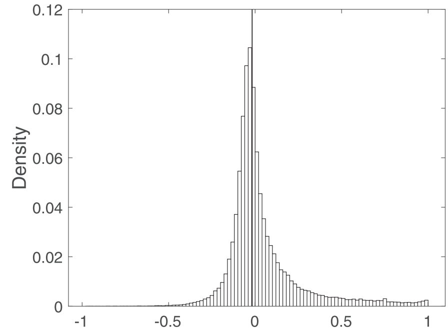


FIGURE A.1. Example for computing correlations.



(a) Rank correlations



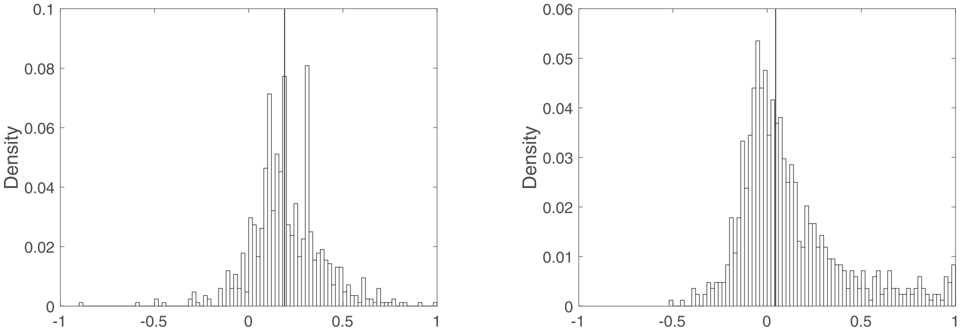
(b) Pearson correlations

FIGURE A.2. Distribution of correlation coefficients. The left panel shows the distribution of Spearman's rank correlation coefficients between suppliers' input shares and their total sales for all buyer firms with five or more suppliers. The right panel shows the analogous distribution of Pearson correlation coefficients. The input shares are computed as the supplier's sales share of the buyer's total input purchases. The vertical lines depict the median correlation coefficients of 0.12 on the left panel and of −0.02 on the right panel. Both panels are based on the cross-section of firms in 2012.

with the ordering of their total sales. Therefore, the correlation between the suppliers' size and input shares is 1. In contrast, consider the firm on the right of the figure. The transaction values are identical to the firm on the left, but the three suppliers' total sales are now 10, 50, and 100 euros, respectively. Here the ordering of the two is opposite, so the correlation is now close to −1.

We compute the correlation coefficients for a set of firms that have five or more suppliers and display their distributions in Figure A.2. The left panel shows the distributions of the rank correlations, and the right panel shows the distributions of the Pearson correlations. In both distributions, firms' correlations are centered around 0. The median firm's rank correlation coefficient is 0.12, and 28% of firms have rank correlation coefficients that are zero or negative. The median Pearson correlation is −0.02 and 58% of firms have Pearson correlation coefficients that are zero or negative. The result indicates that a firm with a high input share on a particular buyer is not necessarily large, illustrating that pairwise match components play a large role in firm-to-firm trade in addition to firm-level components.

The results in Figure A.2 do not take into account the difference in the goods produced by firms' suppliers. The low correlations in the figure may come from the fact that a supplier's good is heavily used by firms from one sector but not by firms in others. Therefore, we then take into account this heterogeneity of input compositions across sector-to-sector relationships. We calculate the same correlations for each firm, but now for each group of suppliers in each sector at the two-digit level. We compute the correlation coefficients for suppliers in a sector if there are five or more suppliers in that sector supplying to the firm. We obtain distributions of those correlations for each sector-to-sector pair. The left panel in Figure A.3 plots the distribution of the median rank correlations, and the right panel plots the distribution of the median Pearson



(a) Median rank correlations (b) Median Pearson correlations

FIGURE A.3. Distribution of median correlation coefficients, accounting for different sector inputs. This figure plots the distribution of the median correlation coefficients between suppliers' input shares and their total sales. For each buyer firm, we compute the correlations between suppliers' input shares and their total sales for each two-digit sector in which five or more suppliers supply the buyer. The left panel displays the distribution of the median rank correlations across each sector-to-sector pair, and the right panel displays the distribution of the median Pearson correlations. The vertical lines depict the median correlation coefficient of 0.19 on the left panel and of 0.05 on the right panel. Both panels are based on the cross-section of firms in 2012.

correlation coefficients for each sector-to-sector pair. The median values of these median correlations are larger than the unconditional median values from Figure A.2, with 0.19 for the median rank correlation and 0.05 for the median Pearson correlation. However, they are still far from 1, and we still see a large role that pairwise match components play, even within the same sector-to-sector relationships.

A.2. Positive Relationship between Prices and Input Shares Using Import Transaction Data

In this section, we use the Belgian import transaction data to supplement the empirical analysis done in Section 2.3. The import transaction data contain information about the values and quantities of Belgian imports at the level of exporting country-product-importer, allowing us to compute unit prices of these transactions. Using this data, we ask whether import prices that Belgian importers pay for a good from a country are positively correlated with the share of the imports in the importers' inputs.

The import transaction data record products at the eight-digit level; hence we first compute the transaction-level price at the level of exporting country c-product k-Belgian importer i-year t, p^k_{cit}. We regress this price on the transaction's share in the importer's total imports of the product. In particular, we consider the following input share as the independent variable:

$$s^{k,IMP}_{cit} = \frac{p^k_{cit} q^k_{cit}}{\sum_{\tilde{c}} p^k_{\tilde{c}it} q^k_{\tilde{c}it}}.$$

TABLE A.1. Transaction-level prices and input shares (out of total imports).

	(1)	(2)	(3)	(4)
Input share $s_{cit}^{k,IMP}$	0.0398 (0.00529)	0.0385 (0.00530)	0.0466 (0.00519)	0.0457 (0.00522)
N	19,489,123	19,460,875	19,333,088	19,304,777
Product FE	Six-digit	Eight-digit	Six-digit	Eight-digit
Other FE	Importer, exporting country-year	Importer, exporting country-year	Importer-exporting country, year	Importer-exporting country, year
Controls	Yes	Yes	Yes	Yes
R^2	0.666	0.675	0.694	0.702

Note: Standard errors in parentheses. The coefficients are X-standardized. Standard errors are clustered at the exporting country level. The regressions exclude outliers in the top and bottom 1% of the price distribution. Controls include importer firms' total imports.

TABLE A.2. Transaction-level prices and input shares (out of all purchases).

	(1)	(2)
Input share s_{cit}^{v}	0.0230 (0.00616)	0.0381 (0.00599)
N	9,645,118	9,486,718
Sector FE	Four-digit	Four-digit
Other FE	Importer, exporting country-year	Importer-exporting country, year
Controls	Yes	Yes
R^2	0.587	0.637

Notes: Standard errors in parentheses. The coefficients are X-standardized. Standard errors are clustered at the exporting country level. The regressions exclude outliers in the top and bottom 1% of the price distribution. Controls include importer firms' total imports.

We add the importer's overall imports to control for the importers' size. We also include product fixed effects at the level of either six-digit or eight-digit and add importer and exporting country-year fixed effects or year and importer-exporting country fixed effects. We report the results in Table A.1. The table shows that there is a positive relationship between the transaction-level import price and the transaction's share in the importer's purchases from abroad. Belgian importers pay a higher price for a product imported from the same country if the country accounts for a larger share in their total imports of the product.

We also consider an alternative definition of the transaction's input share. The above share, $s_{cit}^{k,IMP}$, computes the share out of the total imports purchased by the Belgian importer. As the importer is also likely purchasing inputs from other Belgian suppliers, we now consider the transaction's share in the importer's total purchases of the product—including both imports and domestic purchases. To merge the international transaction dataset with the domestic firm-to-firm transaction data, we aggregate eight-digit product codes into four-digit NACE codes. The independent variable now becomes

$$s^v_{cit} = \frac{p^v_{cit} q^v_{cit}}{\sum_{j \in v} p_{jit} q_{jit} + \sum_{\tilde{c}} p^v_{\tilde{c}it} q^v_{\tilde{c}it}},$$

which captures the share of the import transaction in the importer's total purchases of goods in sector v. As above, we add the importer's overall imports to control for the importers' size and include product sector fixed effects and add importer and exporting country-year fixed effects or year and importer-exporting country fixed effects. The results reported in Table A.2 show that the positive relationship between prices and input shares remains robust under this alternative measure of the input share.

Appendix B: Appendix on Theoretical Results

B.1. Derivation of Equation (29)

Here, we consider an economy in which each firm is constrained to set one price for its good. Firm j chooses p_j to maximize its overall profits, taking into account the effect of p_j on its buyer firms' price indices and quantities of its intermediate goods. Firm j also takes into account the effect of p_j on the final consumption bundle's price index, P. The firm takes as given its buyer firms' unit cost and production quantities. The firm's problem is as follows:

$$\begin{aligned}
\max_{p_j} \quad & (p_j - c_j) q_j \\
\text{subj. to:} \quad & q_j = \sum_{i \in W_j} \alpha_{ji}^{\sigma_{v(j)}} \alpha_{v(j)}^{\rho} p_j^{-\sigma_{v(j)}} \left(p^m_{v(j)i}\right)^{\sigma_{v(j)}-1} \left(p^m_{v(j)i}\right)^{1-\rho} p^{\rho}_{mi} q_{mi} \\
& \qquad + \beta^{\sigma}_{jH} p_j^{-\sigma} P^{\sigma-1} E + p_j^{-\sigma} D_{jF} \\
& q_{mi} = \omega^{\eta}_m p_{mi}^{-\eta} \varphi_i^{\eta-1} c_i^{\eta} q_i .
\end{aligned}$$

Solving the above problem while taking into account that $\partial p_{mi}/\partial p_j \neq 0$, $\partial p^m_{v(j)i}/\partial p_j \neq 0$, and $\partial P/\partial p_j \neq 0$ yields the following price:

$$\begin{aligned}
p_j &= \frac{\varepsilon_j}{\varepsilon_j - 1} c_j \\
\varepsilon_j &= \sum_{i \in W_j} \frac{q_{ji}}{q_j} \left(\sigma_{v(j)} \left(1 - s^{v(j)}_{ji}\right) + \rho s^{v(j)}_{ji} \left(1 - s^m_{v(j)i}\right) + \eta s^{v(j)}_{ji} s^m_{v(j)i}\right) \\
& \quad + \frac{q_{jH}}{q_j} \left(\sigma (1 - s_{jH}) + s_{jH}\right) + \frac{q_{jF}}{q_j} \sigma \\
&= \sum_{i \in W_j} \frac{p_j q_{ji}}{p_j q_j} \varepsilon_{ji} + \frac{p_j q_{jH}}{p_j q_j} \varepsilon_{jH} + \frac{p_j q_{jF}}{p_j q_j} \sigma .
\end{aligned}$$

B.2. Banning Price Discrimination Only in Firm-to-Firm Transactions

In this section, we consider an economy in which each firm is constrained to set one price for its sales to other buyers. Firm j chooses p_{jB}, which is the common price it charges to other firms. It does so to maximize its profits from its sales to other firms, taking into account the effect of its price on its buyer firms' price indices and quantities of its intermediate goods. Denoting firm j's quantity sold to other firms by q_{jB}, the firm's problem can be written as follows:

$$\max_{p_{jB}} \quad (p_{jB} - c_j) q_{jB}$$

$$\text{subj. to:} \quad q_{jB} = \sum_{i \in W_j} \alpha_{ji}^{\sigma_{v(j)}} \alpha_{v(j)}^{\rho} p_{jB}^{-\sigma_{v(j)}} \left(p_{v(j)i}^{m}\right)^{\sigma_{v(j)}-1} \left(p_{v(j)i}^{m}\right)^{1-\rho} p_{mi}^{\rho} q_{mi}$$

$$q_{mi} = \omega_m^{\eta} p_{mi}^{-\eta} \varphi_i^{\eta-1} c_i^{\eta} q_i.$$

Solving the above problem while taking into account that $\partial p_{mi}/\partial p_j \neq 0$ and $\partial p_{v(j)i}^{m}/\partial p_j \neq 0$ yields the following price:

$$p_{jB} = \frac{\varepsilon_{jB}}{\varepsilon_{jB} - 1} c_j$$

$$\varepsilon_{jB} = \sum_{i \in W_j} \frac{q_{ji}}{q_{jB}} \left(\sigma_{v(j)} \left(1 - s_{ji}^{v(j)}\right) + \rho s_{ji}^{v(j)} \left(1 - s_{v(j)i}^{m}\right) + \eta s_{ji}^{v(j)} s_{v(j)i}^{m}\right)$$

$$= \sum_{i \in W_j} \frac{p_{jB} q_{ji}}{p_{jB} q_{jB}} \varepsilon_{ji}.$$

Appendix C: Appendix on Counterfactual Results

C.1. System of Counterfactual Changes

Here, we present the system of equations that pins down changes in the equilibrium variables upon banning price discrimination.

The total variable inputs observed in the data are denoted by C_j^E. Also, denote total input cost of firm j implied from the model, C_j^T, as in equation (26). The difference between the two is denoted as $\xi_j = C_j^E - C_j^T$. Consistent with the assumption made when estimating the CES parameters, we take the error term in equation (27), $\chi_j = \xi_j / C_j^E$, as constants. With this assumption, the changes in the observed inputs, $\widehat{C}_j^E$, are equal to the changes in the model implied inputs, $\widehat{C}_j^T$, and also to the changes in the difference between the two, $\hat{\xi}_j$. We also denote the trade balance as *TB* and treat it as fixed.

We follow the steps below to solve for the changes in equilibrium variables.

1. Guess the change in nominal wage, $\widehat{w}$.
2. Guess the vector of firm-level markups in the counterfactual economy, $\bar{\mu}_j$.
3. With the new firm-level markups, compute the changes in buyer-specific markups, $\hat{\mu}_{ji} = \bar{\mu}_j/\mu_{ji}$, $\hat{\mu}_{jH} = \bar{\mu}_j/\mu_{jH}$, and $\hat{\mu}_{jF} = \bar{\mu}_j/\mu_{jF}$.
4. Solve for firm-level changes in marginal costs, $\widehat{C}_j$, with

$$\widehat{C}_i^{1-\eta} = s_{li}\widehat{w}^{1-\eta} + s_{mi}\widehat{p}_{mi}^{1-\eta}$$

$$\widehat{p}_{mi}^{1-\rho} = \sum_v s_{vi}^m \left(\widehat{p}_{vi}^m\right)^{1-\rho} + s_{Fi}^m$$

$$\left(\widehat{p}_{vi}^m\right)^{1-\sigma_v} = \sum_{j\in Z_i, j\in\mathcal{V}} s_{ji}^v \hat{\mu}_{ji}^{1-\sigma_v}\widehat{C}_j^{1-\sigma_v}.$$

5. Compute the changes in the other variables with

$$\hat{s}_{ji}^{v(j)} = \hat{\mu}_{ji}^{1-\sigma_{v(j)}}\widehat{C}_j^{1-\sigma_{v(j)}}\left(\widehat{p}_{v(j)i}^m\right)^{\sigma_{v(j)}-1}$$

$$\hat{s}_{vi}^m = \left(\widehat{p}_{vi}^m\right)^{1-\rho}\widehat{p}_{mi}^{\rho-1}$$

$$\hat{s}_{mi} = \widehat{p}_{mi}^{1-\eta}\widehat{C}_i^{\eta-1}$$

$$\hat{s}_{li} = \widehat{w}^{1-\eta}\widehat{C}_i^{\eta-1}$$

$$\hat{s}_{ji} = \hat{s}_{ji}^{v(j)}\hat{s}_{v(j)i}^m\hat{s}_{mi}$$

$$\widehat{P} = \left(\sum_j s_{jH}\hat{\mu}_{jH}^{1-\sigma}\widehat{C}_j^{1-\sigma}\right)^{\frac{1}{1-\sigma}}$$

$$\hat{s}_{iH} = \hat{\mu}_{jH}^{1-\sigma}\widehat{C}_i^{1-\sigma}\widehat{P}^{\sigma-1}$$

$$\widehat{V}_{iF} = \hat{\mu}_{jF}^{1-\sigma}\widehat{C}_i^{1-\sigma}.$$

6. Solve for $\widehat{C}_j^T$ from

$$C_j^T\widehat{C}_j^T = \frac{V_{jH}}{\mu_{jH}\hat{\mu}_{jH}}\hat{s}_{jH}\widehat{E} + \frac{V_{jF}}{\mu_{jF}\hat{\mu}_{jF}}\widehat{V}_{jF} + \sum_i \frac{s_{ji}\hat{s}_{ji}}{\mu_{ji}\hat{\mu}_{ji}}C_i^T\widehat{C}_i^T$$

$$\widehat{E} = \frac{1}{1-\sum_j \frac{1}{E}\frac{\mu_{jH}\hat{\mu}_{jH}-1}{\mu_{jH}\hat{\mu}_{jH}}V_{jH}\hat{s}_{jH}}\left\{\frac{wL}{E}\widehat{w} - \frac{TB}{E} - \frac{\sum_j \xi_j\widehat{C}_j^T}{E}\right.$$

$$\left. + \sum_j \frac{1}{E}\left(\sum_i V_{ji}\frac{\hat{\mu}_{ji}\mu_{ji}-1}{\hat{\mu}_{ji}\mu_{ji}}\hat{s}_{ji}\widehat{C}_i^T + \frac{\mu_{jF}\hat{\mu}_{jF}-1}{\mu_{jF}\hat{\mu}_{jF}}V_{jF}\widehat{V}_{jF}\right)\right\}.$$

7. Update $\bar{\mu}_j$ with equation (29), and iterate from Step 2 until $\bar{\mu}_j$ converges.

8. Update $\widehat{w}$ from

$$\widehat{w} = \frac{1}{wL} \sum_j s_{lj} c_j q_j \hat{s}_{lj} \widehat{C}_j^T,$$

and iterate from Step 1 until $\widehat{w}$ converges.

9. Check if trade balance *TB* remains unchanged.

In implementing the above steps, we have experimented with multiple starting values without finding any differences in the counterfactual results.

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Supplementary Data

Supplementary data are available at *JEEA* online.