Buyer Size, Price Discrimination, and Quality Differentiation in International Trade*

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Abstract

A surprising finding from firm-level customs data is that, in violation of the Law of One Price, different buyers of imported inputs pay different prices. The literature has attributed this fully to differences in the quality of inputs. Instead, in this paper I argue that this phenomenon can be explained by price discrimination in the input market. Using a unique dataset that identifies both the sellers and the buyers and provides detailed descriptions of the transacted products, I find substantial variation in prices charged by the same seller for the same product. I rationalize this finding by introducing oligopolistic input producers to a standard trade model, and show that the ability to backwards integrate allows larger buyers to obtain lower input prices. My analysis suggests that productivity gains from trade differ across firms and depend on the prices, quality and variety of inputs imported by a firm. It also implies that consumer gains from trade are larger under price discrimination in input markets.

JEL codes: F10, F11, F14, F23, L11
Key words: price discrimination, vertical integration, buyer size, oligopoly, imported inputs

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1 Introduction

In the face of new and more granular firm-level data, a recurring finding is that firms charge different prices to different buyers: a violation of the Law of One Price. The existing trade literature has overwhelmingly explained this through a theory that different destination countries demand different qualities of goods, and that the price variation across buyers is accounted for by differences in qualities. In other words, the Law of One Price is not in fact violated because the goods being sold are different. However, another and perhaps even more natural explanation for the firm-to-firm price variation, is that the goods are in fact the same but firms discriminate across different buyers. This alternative explanation for the price patterns in trade has been demonstrated to be valid in the firm-to-end-consumer context by Simonovska (2015), and has been studied extensively in an industrial organization literature that dates back as early as Robinson (1933). It would also seem natural then that discrimination could also occur in firm-to-firm transactions, which has been studied by industrial organization economists since at least Katz (1987). There are countless anecdotal examples of different firms obtaining different input prices from domestic suppliers: Wal-Mart, for example, is notorious for their lower input prices for identical goods. This paper argues that the variation of prices across buyers, conditional on the product's quality, is systematic in international firm-to-firm transactions.

In this paper, I use a new matched importer-exporter customs dataset from Paraguay to study the determinants of price variation across importers. To illustrate my main motivating finding, Figure 1 displays the extent of variation of unit-values across firms importing the same product (defined as an 8-digit Harmonized system, HS8, code) from the same seller. The documented variation is surprisingly large, with the average coefficient of variation of about 65%. I show that this variation is not entirely driven by the differences in quality of products by using extremely narrow product definitions at the level of brand and detailed commercial descriptions uniquely available in the new customs dataset from Paraguay. Furthermore, I find that conditional on quality, product prices vary systematically with the importer size: larger importers and importers purchasing in larger volumes consistently pay lower prices.

To rationalize these findings, I build a novel model of international trade, in which price discrimination arises as a result of strategic interaction of buyers and sellers of inputs. Building on the idea proposed in Katz (1987), in this model the production of final goods requires inputs that downstream producers can either buy from upstream producers and/or produce themselves. Learning the upstream technology is costly, and thus only more productive downstream firms find it worthwhile to produce inputs in-house. Because they can always substitute their own inputs for the expensive ones, firms that "backwards integrate" are more elastic to changes in inputs prices. Since input producers set prices inversely proportional to firm's demand elasticity, more productive downstream firms are predicted to obtain better input prices. Intuitively, the threat of losing large buyers, which can switch to their own inputs, is what makes input producers lower the prices they charge to large buyers.

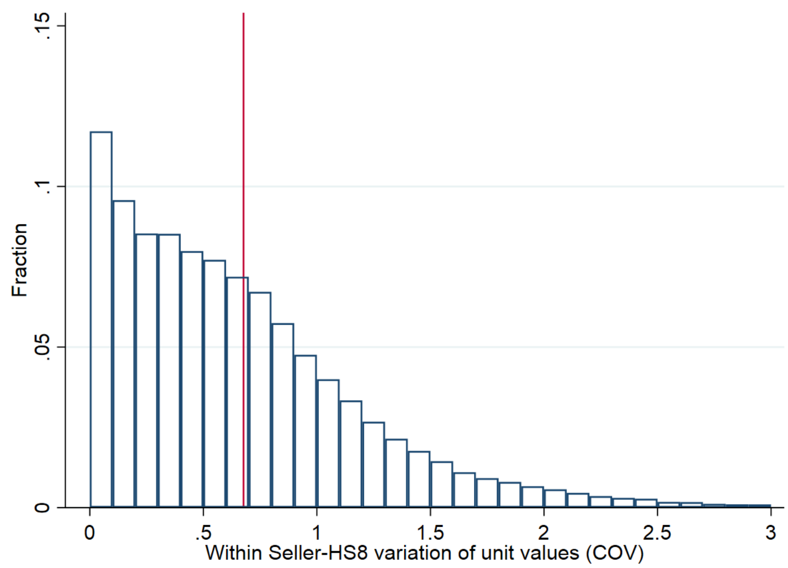


Figure 1: Unit values of imported goods sold by the same seller vary across importers

Note that buyer size has radically different implications for prices in the intermediate goods and final goods markets. In the later, consumers with higher willingness to pay are known to be charged higher prices (e.g. Simonovska (2015), Jung et al. (2015) in international trade literature, and Gerardi and Shapiro (2009), Chandra and Lederman (2015) in industrial organization literature). This paper suggests that this is because consumers, unlike final goods producers, can not credibly threaten the sellers with "backwards integration".

This paper is the first to rationalize the existence of third-degree price discrimination in firm-to-firm international trade transactions. The fist main insight of the proposed theoretical model is that more efficient firms have a viable threat of substitution when negotiating the price with any seller. The importance of intra-firm trade in global trade flows (e.g. Bernard et al. (2009)) suggests that "backwards integration" can be a natural threat point for many importers. International trade literature also offers other mechanisms resulting in more efficient firms to have more attractive alternative options of sourcing inputs. More efficient firms can afford to search more and find better suppliers (e.g. Bernard et al. (2015)). Larger importers can afford to pay fixed costs of importing from many more countries (e.g. Antras et al. (2017)). In line with these mechanisms, the main prediction of this paper can be interpreted more broadly as following: firms with larger extensive margin of sourcing are able to negotiate lower prices from their suppliers.

The second insight is that as importing firms import goods of varying quality and face different prices conditional on the same quality, productivity gains from trade are heterogeneous across buyers. Under CES production function, I apply the logic similar to Feenstra (1994) to decompose firm productivity into four components: exogenous productivity draw, price, quality and variety of imported inputs. Since larger firms are charged lower mark-ups due to price discrimination in input markets, they experience larger cost-shock pass-through. In other words, larger firms gain more from trade liberalization, and the overall gains from trade depend on the distribution of firm size in equilibrium. Specifically, more concentrated downstream sectors are expected to obtain larger gains from trade liberalization in the upstream sector.

I also study the implications of price discrimination in input markets for final goods consumers. In industries with free entry, the larger extent of price discrimination in input markets leads to higher expected profits of the downstream firms and fewer active firms on the market in equilibrium. Since only the most productive firms remain on the market, it benefits final goods consumers through lower prices of final goods.

The reminder of the paper is organized as follows. In Section 2, I document price variation in firm-to-firm transactions that is consistent with the existence of price discrimination. In Section 3, I introduce a new model of trade that explains such variation. In Section 4, I study the implications of price discrimination for the gains from trade, and in Section 5 I conclude.

2 Data and Stylized Facts

2.1 Data

The main dataset consists of the entire universe of import and export transactions of Paraguayan firms over the period 2013 - 2018. For each transaction, the data records information on the product transacted, free-on-board (FOB) and customs-insurance-freight (CIF) values (in US dollars), gross and net weight (in kilograms), quantity (in units), the date of transaction, as well as the importing/exporting firm's unique identifier. In contrast to many other firm-level customs data sets, the Paraguayan data also includes the name of the foreign supplier of imported goods, which I have cleaned and standardizing following the procedure described in Appendix A. Each import transaction is thus identified with a buyer identifier (b), a product code at the HS 8-digit level of disaggregation (p), a supplier name (s), a (foreign) country of purchase (c), and a date (t). On the other hand, each export transaction is described with an exporter identifier, a product code at the HS 8-digit level of disaggregation, a date, and a destination country.

Table 1 shows that, as in most developing countries, there are a lot more importing firms and import transactions than exporting firms and export transactions in Paraguay a year. While, on average, more than 6 000 firms engage in importing per year, only a thousand firms engage in exporting with 650 of them both importing and exporting. This results in more than 600 000 import transaction per year, and only 105 000 export transactions per year.

Both importers and exporters exhibit substantial heterogeneity in their size and sourcing/exporting strategies. An average importer imports 158 HS 8-digit products a year and sources imports from 7 different countries, while an average exporter exports 14 different HS 8-digit products to 10 destination countries. Importers that also export, on average, import more HS8 products, source goods from more countries, and, in general, have higher import expenditures than non-exporting importers. Exporting importers comprise only about 10% of importing firms, by count, but account for one third of the observed import transactions in the data.

	mean	sd	p10	p25	p50	p75	p90
				Importers			
# Importers/Year	6 159	282	5 524	6 083	6 273	6 373	6 408
# HS8 products/Year-Firm	158	147	15	39	106	244	409
# Countries/Year-Firm	7	6	1	2	5	11	16
FOB Value ('000 $US)/Year-Firm	12 441	22 792	246	982	3 982	15 187	32 888
N/Year	630 714						
N	3 730 018						
				Exporters			
# Exporters/Year	1 053	47	1 000	1 013	1 045	1 071	1 128
# HS8 products/Year-Firm	14	15	2	4	11	17	25
# Destinations/Year-Firm	10	12	1	3	4	11	30
FOB Value ('000 $US)/Year-Firm	58 060	105 347	701	3 272	22 984	55 147	224 089
N/Year	105 452						
N	589 605						
				Importers-Exporters			
# Firms/Year	651	35	596	626	654	668	709
# HS8 products/Year-Importer	214	163	28	67	172	341	457
# Countries/Year-Importer	11	7	2	6	11	16	21
FOB Value ('000 $US)/Year-Importer	20 968	24 671	1 152	3 682	13 367	29 707	48 617
# HS8 products/Year-Exporter	15	26	1	2	5	16	46
# Destinations/Year-Exporter	4	5	1	1	2	4	7
FOB Value ('000 $US)/Year-Exporter	11 482	49 335	4	33	209	1 722	29 511
N/Year	627 866						
N	1 062 048						

Table 1: Summary Statistics, 2013 - 2018

Most import and export transactions involve intermediate goods, as defined by the UN Classification of Broad Economic Caterogies (BEC). classification. Table 2 shows that intermediate goods comprise 50% of import and 58% of export transaction and account for 35% and 40% of the total yearly (FOB) value of imports and exports, respectively. As an agricultural economy, Paraguay imports mostly differentiated products (by value), and exports mostly homogeneous products (reference prices and goods traded on organized exchanges), as defined in the Rauch classification (Rauch (1999)).

In this paper, I study the determinants of import price variation across importers, yet the data does not record per-unit prices of imported goods. Following the literature, I first compute unit values as ratios of FOB value over volume imported as proxies for prices of imported goods:

$$p_{bspt} = Value_{bspt}/Volume_{bspt},$$

where the data provides two measures of volume - physical units and physical weight (gross and net of packaging weight). Since unit values are known to be a noisy measure of prices, below I discuss

	Imported goods		Exported goods	
	By count, %	By FOB value, %	By count, %	By FOB value, %
Consumption	27	20	22	4
Capital	14	22	2	1
Intermediate	50	35	58	40
Differentiated	83	59	71	14
Reference priced	12	20	6	3
Traded	1	3	21	45

Table 2: Imported and exported goods, by type, 2013 - 2018.

the potential sources of the measurement error and how I use my data to address them and, in certain cases, compute unit values very closely resembling per-unit prices.

A major critique of using unit values as a proxy for prices is that quality differences between goods and "hidden" varieties are not accounted for. When an actual product transacted is unknown, then differences in unobserved product characteristics and/or quality within a broad HS category can make problematic the comparison of unit values across importers. To mitigate this problem, I make use of the uniquely detailed nature of product descriptions available in the data. First, part from a country of purchase and a detailed HS 8-digit product code, the data includes the name of the seller in the foreign country and brand name of the product. Table 3 shows that across all 36 823 HS8-Country product categories only 10% are supplied by the only seller and come in only 2 different brands. The median number of sellers per HS8-Country category is equal to 16 for all products, 18 - for differentiated products, and 7 and 4 - for reference priced and traded on organized exchanges products, respectively. The large number of suppliers within HS8-Country categories, even among relatively homogeneous products, can only be sustained if there is enough product differentiation by the seller.In this case, seller identifier should be included in the product definition. Since 75% of foreign sellers supply only one brand within an HS8 product category, defining a product as an HS8-seller combination, will take into account brand differentiation within HS8-Country product categories.

When individual products are defined as an HS8-seller combination, the number of products increases to 158 294, which substantially limited the extent of within product differentiation. At this level of disaggregation, the only remaining source of measurement error in the unit values can be due to sellers vertically differentiating products within HS 8-digit codes across buyers. To assess the relevance of this concern, I rely on word descriptions of products provided by foreign sellers. According to customs regulation in Paraguay, commercial invoices upon importing must include a full and accurate (non-generic) descriptions of goods and their country of origin (which can be different from the source country). Table 4 provides several examples of product descriptions (translated from Spanish to English) and brand names that I obtain after applying methods of textual data cleaning to them (for details, see Appendix A). It suggests that in some cases, product descriptions can be used to identify different varieties within a given HS8-seller or HS8-seller-brand

	mean	sd	count	p10	p25	p50	p75	p90
	Number of sellers per HS8-Country							
All products	27	30	36 823	2	5	16	40	70
Differentiated	29	30	28 693	2	6	18	43	73
Reference priced	16	24	6 351	1	3	7	19	43
Traded	6	5	506	1	2	4	8	13
	Number of brand names per HS8-Country							
All products	35	59	36 823	2	5	16	40	81
Differentiated	38	62	28 693	2	6	17	43	86
Reference priced	15	19	6 351	1	3	8	19	42
Traded	7	9	506	1	2	4	8	14
	Number of brand names per HS8-Seller							
All products	4	13	158 294	1	1	1	2	5
Differentiated	4	14	135 192	1	1	1	2	6
Reference priced	2	3	17 643	1	1	1	2	4
Traded	2	2	1 064	1	1	1	2	3

Table 3: Within HS8-Country product differentiation, 2013 - 2018.

combinations.

HS code	Seller	Description	Brand
32149000	Autocolor LTDA	Mortar type ACI 20 kg bag	Votorantim
32149000	Autocolor LTDA	Mortar type ACI 20 kg bag	Quartzolit
33021000	Bebidas Refrescantes	Acid solution colorants	Coca-Cola
33021000	Bebidas Refrescantes	Aspartame	Coca-Cola
33051000	Euro 2000 SA	Shampoo Keratin Lift x 960cc	Question Professional
33051000	Euro 2000 SA	Shampoo Nutrition x 960cc	Question Professional
33051000	Euro 2000 SA	Shampoo Retention x 960cc	Question Professional
84833029	Data Tech Inc	Vehicle bearings	Ford
84833029	Data Tech Inc	Vehicle bearings	Toyota
87019490	Agco Maq Agricola	Tractor model A990 4x4 yellow 2017	Valtra
87019490	Agco Maq Agricola	Tractor model A750 4x4 yellow 2017	Valtra
87019490	Agco Maq Agricola	Tractor model BM110 4x4 yellow 2017	Valtra

Table 4: Examples of brands and commercial descriptions in the data

The second concern that can cause measurement error in the unit value proxies for prices is imprecision with which the volume of trade is recorded. Physical units can be reported by the seller in any unit type[1], which makes the comparison of unit values across transactions problematic. Physical weight, on the other hand, is required to be reported in kilograms, which makes it uniformity across a more suitable measure of volume. However, if unit weight (weight/quantity) varies substantially across sub-varieties within HS8-seller categories, it can lead to imprecise unit values. To minimize the measurement error in the unit values, for each HS8-seller combination, I choose the measure of volume of trade which minimizes the within HS8-seller coefficient of variation of unit values. Although this procedure helps reducing the measurement error at the HS8-seller error, it can make unit values incomparable *across* different sellers of the same HS8 product category, if they use different units to measure the volume of trade. It is not a problem for the main results, as my analysis is concerned mainly with *within* HS8-seller variation of prices across buyers. However, to put some of my results in perspective of the previous literature that defines a product at the HS8-country level, I make unit values comparable across sellers within HS8-country category by choosing a volume measure that minimizes the within HS8-country variation of unit values.

Another source of measurement error in the unit value proxies for prices, especially in developing countries, is VAT fraud and unfair trade practices ranging from fallacious declaration of value to mis-classifications of high tariff products as lower tariffs goods. Since the customs value of imported goods is the tax base for imposing customs duty and VAT taxes, importers might provide incentives to their foreign supplier to under-report the true value of goods imported. To address this problem, Paraguayan customs authorities use reference values as selectivity filters to determine cases where a detailed analysis of the declared customs value if required. If the declared value is lower than the reference value, the importer must pay the difference between the duty payable on the basis of the declared value and that which maybe due on the basis of the reference value, unless he/she can provide documents justifying the price. If mis-reporting of declaration values exists in my data, it it is unlikely to drive the entire variation of imported goods prices across buyers for the following reasons. First, if foreign sellers under-reports declaration values, they are likely to do it by under-reporting both prices and quantities, which is unlikely to cause a systematic bias of unit-values upwards or downwards. Second, if a foreign seller indeed engages in fraud, he/she is likely to agree to do so for every buyer, which can possibly lead to the bias in firm-level average unit values, without affecting the distribution of unit values across buyers. In any case, I use insights from tax/tariff evasion literature (Javorcik and Narciso (2008), Mishra et al. (2008)) and check that my results hold in the subsample of goods with low tariffs and homogeneous goods, where fraud is less likely to occur. Additionally, I remove imported goods that cleared customs at the Cuidad del Este customs post located at the border between Paraguay, Argentina, and Brazil and known as a smuggling area.

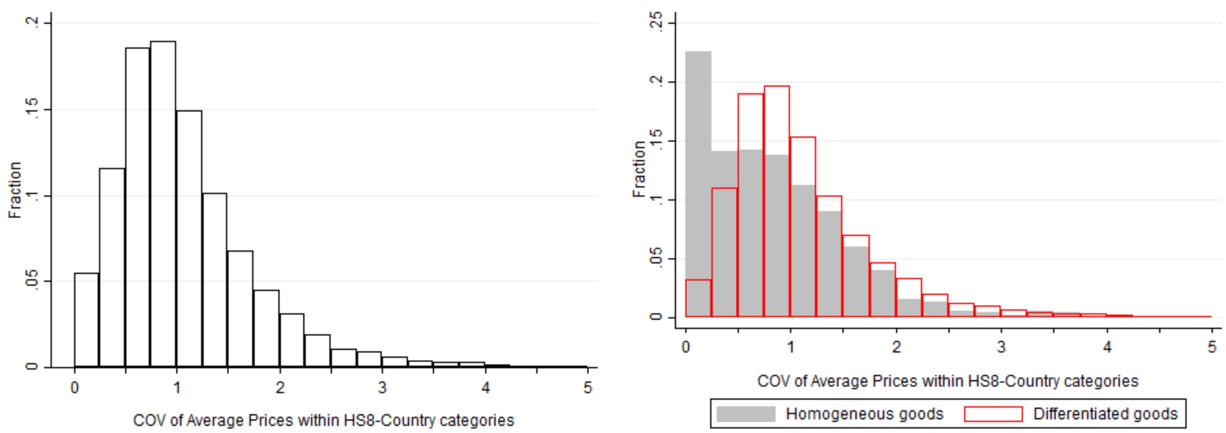
[1] In the data, only 35% of HS8-Country combinations are reported in terms of one unit type

2.2 Stylized Facts

In this subsection, I explore the matched buyer-seller customs data for Paraguayan importers to document the extent and sources of import price variation within a given product category. I also describe several new facts on buyer and seller heterogeneity as well as their relationship, which can help explaining the observed import price variation across buyers.

Fact 1: Average prices of imported goods substantially vary across importers, even within narrowly defined seller-product categories.

To document how prices of imported goods vary across buyers, I first calculate transaction-level unit values as proxies for individual prices and compute an average unit value a buyer in Paraguay pays for a product from a given source country-HS8 product category in a given year. Then, for each source country-HS8 product category, I calculate the coefficient of variation of these average unit values as a measure of price dispersion across buyers. Figure 2 shows the distribution of the coefficient of variation of unit values in the sample of all products, and, separately, in the sub-samples of homogeneous and differentiated goods, as defined in the Rauch classification.



(a) All products (b) By product type

	Mean	95%-CI
All products	0.94	[0.89; 0.98]
Homogeneous	0.68	[0.63; 0.74]
Differentiated	0.98	[0.93; 1.02]

Figure 2: Dispersion of import prices within HS8-Country across buyers, 2013 - 2018.

Notes: Only HS8-Country combinations with more than 5 different importers a year are included in the construction of the distributions. HS8-Country combinations with COV above 5 are assigned a value of 5, for illustrative purposes. Standard errors for 95%-confidence intervals are clustered at the HS8-product level. Products are defined as homogeneous or differentiated based on the Rauch (Rauch (1999)) classification, where homogeneous products include goods traded on organized exchange and reference priced goods.

Across all HS8-Country product categories, the average coefficient of variation of import prices across importers is equal to 94%. Traditionally, this import price variation has been fully attributed to importers purchasing different, more or less expensive, varieties within HS8-Country categories. Figure 2b shows that, indeed, across relatively homogeneous goods, where within HS8-Country product differentiation is a priori limited, import price variation is smaller than across differentiated products, but remains substantial and, on average, is equal to 68%.

To show that the import price dispersion is not entirely driven by "hidden" varieties, I define a product at a more disaggregated HS8-Seller level and compute the coefficient of variation within each HS8-Seller category. At this level of disaggregation, the role of "hidden" varieties is limited as it could only be caused by substantial product differentiation of a given seller of a given HS8 product category. Table 5 presents the mean, 95%-confidence intervals and different percentiles of the coefficient of variation for all products, and separately for homogeneous and differentiated goods. On average, across all products, the within HS8-Seller coefficient of variation of prices is 44%, and it is slightly higher in a subsample of differentiated goods (46%) and lower in a subsample of homogeneous goods (30%).

I calculate that, in cases with more than one seller per HS8-Country category, within-seller variation of average import prices across buyers accounts for about one third of the total import price variation for a given HS8-Country category, with the rest accounted for by between-seller variation of prices. This finding challenges most of the existing theories of importing with firm heterogeneity in two important ways. First, focusing only on the importer heterogeneity, these theories abstract from the seller heterogeneity within a given country. In contrast, the large variation of average prices between sellers suggests that they differ substantially either in their productivity or market power or both. Second, the baseline assumption in the literature on importing is that prices and qualities of goods imported from the same country do not vary across buyers. Yet, the substantial degree of within-seller variation means that sellers vary either quality or quality-adjusted prices across their buyers. Panel B of Table 5 shows that the dispersion of prices across importers is large even in a subsample, in which I can account for differences in detailed product characteristics captured by brand names and product descriptions. The average coefficient of variation of prices across importers is 22%, even within HS8-Seller-Brand-Description cells.[2] It suggests that importer heterogeneity can affect not only the set of countries a firm imports from (extensive margin), but also the prices the firm pays, conditional on quality.

Fact 2. Importer effects account for a large share of the observed variation in transaction-level prices within a given product-seller category.

To isolate the effect of importer heterogeneity on import prices within HS8-seller-year, I first remove the HS8-Country average of each transaction-level price, and estimate:

$$\log \tilde{p}_{bspt} = \delta_{by} + \delta_{spy} + \epsilon_{bpst}, \quad (1)$$

where $\log \tilde{p}_{bspt}$ is the demeaned transaction-level price charged by seller s to buyer b for HS8 product

[2] Notice that because the sample of products used in the COV computation changes, the coefficients in Panel A and Panel B of Table 5 are not directly comparable.

	mean	95%-CI	p10	p25	p50	p75	p90	count
			Panel A: Within HS8-Seller					
All products	0.44	$[0.42, 0.45]$	0.04	0.12	0.32	0.66	1.02	237 683
Differentiated	0.46	$[0.44, 0.47]$	0.05	0.15	0.36	0.68	1.04	202 712
Homogeneous	0.30	$[0.28, 0.33]$	0.01	0.05	0.15	0.44	0.84	34 971
			Panel B: Within HS-Seller-Brand-Description					
All products	0.22	$[0.20, 0.24]$	0	0.02	0.11	0.29	0.61	65 879
Differentiated	0.24	$[0.22, 0.27]$	0.00	0.04	0.13	0.33	0.66	54 521
Homogeneous	0.12	$[0.10, 0.15]$	0	0.00	0.03	0.14	0.33	11 358

Table 5: Coefficient of variation of import prices within HS8-Seller across buyers, 2013-2018.

p at time t; δ_{by} collects buyer-year fixed effects, and δ_{spy} collects seller-HS8-year fixed effects. Notice that the seller-product-year fixed effects can be only estimated for a subsample of sellers that sell the same HS8 product to at least two buyers in a given year. Analogously, buyer fixed effects are estimated based off a subsample of buyers that source at least two different HS8-Seller products a year. These two conditions result in the loss of about a half of observations.

The results of estimation are presented in Table 6, which shows the percentage of the variation in (demeaned) transaction prices accounted for by buyer-year and seller-product-year fixed effects. First, both fixed effects account for a large share of within HS8-Country variation in import prices, as suggested by the adjusted R^2 of 37%, on average across all products. Second, buyer-year fixed effects across all products explain about 20% of the total variation of import prices within HS8-Country categories. This share is larger for homogeneous and consumption goods, where it reaches 55% and 39%, respectively.

	$\frac{Cov(\delta_{by}, \log \tilde{p})}{Var(\log \tilde{p})}$	$\frac{Cov(\delta_{spy}, \log \tilde{p})}{Var(\log \tilde{p})}$	Adj. R^2	N
All products	20.5%	79.5%	0.37	1 193 223
Homogeneous	54.5%	45.5%	0.41	187 834
Differentiated	20%	80%	0.37	945 031
Consumption	38.5%	61.5%	0.37	294 293
Intermediate	26.2%	73.8%	0.37	612 456

Table 6: Variance decomposition of transaction-level prices within HS8-Country, 2013 - 2018

Therefore, in contrast to the existing theories of importing, buyer heterogeneity accounts for a substantial share of import price variation, even conditional on the buyer's sourcing strategy defined at the disaggregated seller-HS8 level. The existing literature has provided only one explanation for this empirical fact: due to complementaries between buyer productivity and seller quality, large, productive firms specialize in importing of higher-quality goods from a given supplier (Blaum et al. (2017)). In the next section, I argue that buyer productivity is systematically correlated with import prices, even conditional on quality of imported goods.

3 Empirical Evidence of Price Discrimination

3.1 Main Results

Here I show that import prices systematically vary across importers of different size, conditional on the quality of imported goods. The main challenge is that neither quality of imported goods, not firm size are directly observed in the data. To overcome this problem, I explore the richness of my customs data and experiment with several different proxies for firm size and quality of imported goods.

First, I consider quantity purchased within a given transaction as a measure of firm size, and investigate how it relates to the price charged by the seller. To capture differences in quality of imported goods across buyers, I experiment with a large set of HS8-seller-year fixed effects and more granular HS8-seller-brand-description fixed effects. Table 7 presents the results, where in all specifications, I additionally include country-quarter fixed effects to absorb the differences in seller's costs across time within a year. Columns (1) to (3) show that buyers purchasing larger volume of a given HS8 product from a given seller pay lower per unit prices. A one percent increase in quantity within a transaction is associated with a 0.25% reduction in price.

If HS8-seller-year fixed effects do not fully absorb differences in quality, and if there are complementaries between importer productivity and quality of imports, then this OLS estimate is expected to be downward biased. To assess if this is true in the data, in column (2) I allow for homogeneous goods, where quality differentiation is a priori limited to have a different slope coefficient, which is expected to be larger in absolute value. The results suggest that buyers of relatively more homogeneous products experience 0.06 percentage points larger reduction in per-unit price with the increase in quantity.

In column (3), I investigate whether the relationship between prices and quantities are different across intermediate goods and final goods (which include consumption goods and capital goods). There could be several reasons for the relationship to be different across product types. First, consumer and capital goods could have more dimensions of product differentiations that are hard to describe, compared to intermediate inputs. Secondly, consumer and capital goods are likely to be traded between wholesalers and retailers, which are usually multi-product firms that can sell very different products even within HS8-seller categories. In contrast, intermediate goods are likely

Dependent Variable:	*logPrice*					
	(1)	(2)	(3)	(4)	(5)	(6)
$\log Quantity$	-0.25***	-0.25***	-0.19***	-0.18***	-0.19***	-0.12***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
$\log Quantity \times Homogeneous$		-0.06***			0.04	
		(0.02)			(0.03)	
$\log Quantity \times Intermediate$			-0.12***			-0.11***
			(0.01)			(0.02)
Constant	3.69***	3.74***	3.64***	3.35***	3.35***	3.29***
	(0.05)	(0.05)	(0.04)	(0.06)	(0.06)	(0.05)
Fixed effects						
HS8×Seller×Year	yes	yes	yes	no	no	no
HS8×Seller×Brand×Description×Year	no	no	no	yes	yes	yes
Country×Quarter	yes	yes	yes	yes	yes	yes
Observations	2905494	2781636	2905494	1309243	1243671	1309243
Adjusted R^2	0.891	0.889	0.892	0.949	0.947	0.949

Standard errors clustered at importer level in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 7: Import prices across buyers of different size

to be traded between manufacturers, that are expected to be more specialized in production of a particular product. Overall, if quality differentiation is a bigger concern in a sub-sample of final goods, the estimated coefficient on quantity is more likely to be biased upwards in this sub-sample. Moreover, since an intermediate good of a given HS8 product category is likely to be purchased by manufacturers competing in the same industry, quantity of inputs purchased can indeed rank their buyers by firm size. The results in column (3) show that that prices of final goods decline with buyer size at a slower rate than prices of intermediate goods, where a one percent increase in quantity results in a -0.3 percent reduction in price.

In columns (4) to (6), I repeat the analysis in a sub-sample of transactions, where I can additionally control for the product's brand and its word description. Comparing prices of the exact same product across buyers, I still find that larger buyers pay substantially lower prices. This persistent finding is consistent with several different pricing rules employed by the seller: quantity discounts (second-degree price discrimination), buyer size discounts (third-degree price discrimination), and cost-based pricing under economies of scale in production or in transportation of goods. I proceed by discussing the role of each pricing scheme in my results in attempt to isolate the overall buyer size effect on import prices.

Under second-degree price discrimination, the seller does not observe each buyer's size and, to maximize profits, designs a non-linear pricing scheme that encourages the buyers to truthfully reveal their type. Such non-linear pricing scheme are associated with quantity discounts: buyer with larger orders are charge smaller per-unit mark-ups. On the other extreme, cost-based pricing under economies of scale implies that sellers experience cost reductions on larger orders and fully pass along their cost savings to the buyers. Both of these pricing schemes imply that large volume buyers pay lower per-unit prices, which could lead to the results reported in Table 7.

Separating these two effects from the buyer size effect, whereby buyers with different intrinsic characteristics pay different prices, is possible in a sub-sample of buyers with multiple orders from the same supplier per year. In Table, I estimate the relationship between per-unit price and total *yearly* quantity of a given product using a sub-sample of buyers with multiple shipments of a given good from a given seller per year. I find that a one percent increase in the overall quantity purchased a year is associated with 0.09% decrease in a transaction-level price. In column (3), I additionally include the quantity purchased at a time to control for second-degree price discrimination and economies of scale, and still find that buyers obtain additional discounts purely due to the size. Columns (4) and (5) show that the buyer-size discounts on top of the quantity discounts are larger in subsamples of homogeneous and intermediate goods. In these sub-samples, for a given volume of a transaction, a one percent increase in the total yearly quantity purchased from the supplier, on average, is associated with 0.11% and 0.06% reduction in prices of homogeneous and intermediate goods, respectively.

The remaining concern with quantities transacted between a buyer and a supplier is that it may not provide a truthful ranking of firms by their size. Firstly, if buyers of a given product belong to different industries, they might have different production requirements causing quantities of imported goods to vary across buyers, irrespective of their true size. Secondly, if buyers belong to different industries, then differences in the demand for a given imported good can merely reflect differences in the demand of their output rather than firm productivity itself. To address this problem, it is necessary to control for the industry of the buyer, which is unavailable in customs data. However, in a sub-sample of importers that also export their output, I can assign importers to the industry based on the products that they export. Specifically, I consider exporting importers that export products belonging to the only HS2 product category and assign that product category as the importer's main industry.

In Table 9, I repeat the analysis summarized in Tables 7 - 8 in sub-sample of exporting importers that allows me to control for the industry of the buyer. In columns (1) and (2), I use the size of a given shipment as a measure of buyer size and additionally control for the product-industry-year fixed effects in column (2), relative to column (1). The results barely change with the inclusion of industry controls, which is in line with the quantity discounts interpretation of the price-quantity relationship. Under second-degree price discrimination, the seller does not observe buyer's identity or industry the buyer belongs to, and charged the price solely based on the volume of the order.

Dependent Variable:			*logPrice*		
	(1)	(2)	(3)	(4)	(5)
$\log Quantity$	-0.18***		-0.18***	-0.23***	-0.14***
	(0.01)		(0.01)	(0.01)	(0.03)
$\log YearlyQuantity$		-0.09***	-0.03***	-0.11***	-0.06**
		(0.02)	(0.01)	(0.02)	(0.02)
Constant	3.29***	3.05***	3.53***	4.10***	2.57***
	(0.06)	(0.11)	(0.11)	(0.16)	(0.29)
Fixed effects					
HS8×Seller×Brand×Description×Year	yes	yes	yes	yes	yes
Country×Quarter	yes	yes	yes	yes	yes
Homogeneous goods only	no	no	no	yes	no
Intermediate goods only		no	no	no	yes
Observations	1170020	1170020	1170020	573620	196342
Adjusted R^2	0.946	0.941	0.946	0.924	0.969

Standard errors clustered at importer level in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 8: Quantity discounts vs. Buyer size discounts

In contrast, when adding industry controls in column (4) relative to column (3), where buyer size is measures with yearly quantity of the good purchased, buyer-size discounts substantially increase. Columns (5) and (6) show that buyer-size discounts, conditional on the volume in a given transaction, are substantially larger in a sub-sample of exporting importers than in the full sample. Namely, conditional on the size of a given shipment, a one percent increase in the overall yearly quantity purchased from a given seller results in 0.22% reduction in price, which is higher larger than a 0.03% reduction estimated in the full sample of importers. Additionally controlling for the buyer's industry increases the magnitude of the buyer discount to 0.39% and barely changes quantity discounts.

Dependent Variable:	*logPrice*					
	(1)	(2)	(3)	(4)	(5)	(6)
$\log Quantity$	-0.19***	-0.18***			-0.19***	-0.17***
	(0.03)	(0.04)			(0.03)	(0.04)
$\log YearlyQuantity$			-0.33***	-0.53***	-0.22**	-0.39***
			(0.12)	(0.15)	(0.11)	(0.14)
Constant	3.47***	3.40***	4.88***	6.30***	4.98***	6.18***
	(0.16)	(0.18)	(0.86)	(1.08)	(0.75)	(0.96)
Fixed effects						
HS8×Seller×Brand×Description×Year	yes	yes	yes	yes	yes	yes
Country×Quarter	yes	yes	yes	yes	yes	
HS8×Country×Industry× Year	no	yes	no	yes	no	yes
Observations	140056	127106	140056	127106	140056	127106
Adjusted R^2	0.942	0.945	0.936	0.940	0.942	0.945

Standard errors clustered at importer level in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 9: Quantity discounts vs. Buyer size, Exporting Importers

4 Theoretical Framework

In this section, I develop a theoretical framework linking buyer's productivity to the prices of imported inputs she pays. The two main ingredients of this framework are strategic interactions of large intermediate goods producers and the endogenous choice of the extensive margin of sourcing. This framework predicts price discrimination in firm-to-firm transactions with large buyers of inputs obtaining better input prices. I further use the proposed framework to study the implications of price discrimination for consumer and producer gains from trade liberalization.

4.1 Environment

Consider the world consisting of N countries indexed by i and j. Each country i is populated by L_i consumers that inelastically supply one unit of labor each and consume a continuum of final goods varieties. These varieties are produced by heterogeneous final goods producers, which differ in their productivity ϕ. Production of final goods requires intermediate goods, which firms can either produce themselves or purchase from independent input producers upstream. Final goods production technology features increasing returns to scale with fixed costs depending on firm's decision to engage in in-house production of inputs. There is free entry in the final goods market, and the market structure is monopolistic competition.

Fixed number of intermediate goods producers in each country j produce substitutable inputs using labor as the only input in their linear production function. They compete in prices and are large enough relative to the market to internalize the effects of their decisions on aggregate market outcomes. This departure from traditional international trade literature that assume atomistic firms with no market power, brings several new insights. First, it implies that firms charge variable mark-ups of price over marginal costs: input producers with larger market share face lower perceived elasticity of demand and thus can charge higher mark-ups. Second, market power allows same input producers to charge different prices to different buyers for the same good.

For third-degree price discrimination to arise in equilibrium, the following assumptions need to be satisfied. Firstly, intermediate goods producers can observe individual characteristics of their downstream buyers, and, secondly, intermediate goods can only be purchased from their respective producers (in other words, re-selling is not possible).

The sequence of moves in this environment is as follows. First, each potential entrant into the final goods market pay entry costs in terms of labor and learn their productivity. Second, those firms that decide to stay on the market, consider investing additional fixed costs in inputs production technology and exporting. Third, intermediate goods producers decide what prices to charge to their buyers downstream. And in the last stage, final goods producers make their input sourcing and pricing decisions.

In the following sections I describe the details of the model and outline the industry equilibrium.

4.2 Preferences

Consumers in country i have identical preferences represented by the standard CES utility function over a set Ω_i of final goods' varieties ω:

$$U_i = (\int_{\omega \in \Omega_i} q_i(\omega)^{\frac{\sigma-1}{\sigma}} d\omega)^{\frac{\sigma}{\sigma-1}} \tag{2}$$

These utility function gives rise to the following demand system in country i:

$$q_i(\omega) = E_i P_i^{\sigma-1} p_i(\omega)^{-\sigma},$$

where $p_i(\omega)$ is the price of variety ω, $P_i \equiv \left(\int_{\omega \in \Omega_i} p_i(\omega)^{1-\sigma_i} d\omega \right)^{\frac{1}{1-\sigma_i}}$ is the standard CES price index of final goods, and E_i is country i's aggregate spending on manufacturing goods.

4.3 Technology and market structure

In this economy final goods are produced in the downstream sector, which relies on inputs supplied by the upstream sector. Below I describe the market structures in both sectors.

Downstream sector. Each final goods variety is sold by a single firm in a monopolistically competitive environment with free entry. Potential entrant f pays a sunk cost f_e to draw a random productivity ϕ_f and then choose whether to pay per-period fixed costs of production f. In every period, there is an exogenous probability of exit, β.

Firms that stay in the market produce final goods using the following production function:

$$Y_f = \phi_f \left(L_f^{\frac{\zeta-1}{\zeta}} + X_f^{\frac{\zeta-1}{\zeta}} \right)^{\frac{\zeta}{\zeta-1}} \tag{3}$$

$$X_f = \left((\alpha^D X_f^D)^{\frac{\rho-1}{\rho}} + (\alpha^M X_f^M)^{\frac{\rho-1}{\rho}} \right)^{\frac{\rho}{\rho-1}} \tag{4}$$

where Y_f is the output of downstream firm with productivity draw ϕ_f, using labor L_f, the domestic intermediate good X_f^D and the aggregate imported intermediate good X_f^M. Parameters α^D and α^M reflect the quality of domestic and imported inputs, respectively.

The imported composite input X_f^M is a CES aggregate over all foreign input suppliers of firm f. Apart from buying inputs from a common set of independent suppliers Ω, firm f can also pay fixed costs of "backwards integration", f_{BI}, and produce inputs in-house at marginal costs p_{BI}. Therefore, the imported composite input X_f^M can be expressed as:

$$X_f^M = \left(\sum_{n \in \Omega} (\alpha^n x_f^n)^{\frac{\eta-1}{\eta}} + \mathbb{1}_f (\alpha^{BI} x_f^{BI})^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}}, \tag{5}$$

where $\mathbb{1}_f$ is an indicator function, which is equal to one if firm f backwards integrate in the input production.

There are at least two aspects of the downstream technology (3) - (5) worth emphasizing. First, the quality parameters α_n do not vary across buyers of inputs. It means that there are input producers that sell exactly the same products to all downstream firms. Second, the *average* quality of inputs varies across downstream firms only if there is selection into backwards integration. In this model, backwards integration is the only source of heterogeneity in the extensive margin of inputs sourcing across firms. However, the model can be interpreted more broadly to encompass other explanations of the observed differences in the extensive margin of sourcing. If there are search costs of finding a supplier (as in Krolikowski and McCallum (2017), Bernard et al. (2015)) or transaction costs of outsourcing (as in Kikuchi et al. (2012)), the term $\mathbb{1}_f (\alpha^{BI} x_f^{BI})^{\frac{\eta-1}{\eta}}$ will reflect firm f's decision whether to incur those costs or not. Likewise, this term will capture firm's decision to incur relationship-specific investment to obtain a "better" quality (ie tailored) input from any common supplier.

Upstream sector. Unless produced in-house, all imported inputs in this economy can only be purchased from a fixed (exogenous) number of foreign producers, Ω. To produce one unit of an input of quality α_n, input producer n with productivity ψ_n uses labor, L_n, according to the Cobb-Douglas technology:

$$\alpha_n = (L_n \psi_n)^\theta, \tag{6}$$

where $0 < \theta < 1$ reflects diminishing returns to quality.

Input producer n faces iceberg trade costs $\tau_n > 1$ and chooses the free on board (f.o.b) price p_n^k for each buyer k. In doing so, firms supplying the same buyer compete oligopolistically, and internalize the effect of their pricing decisions on buyer's costs of sourcing inputs. Therefore, when quoting a price to its buyer, the firm takes into account the possibility of backwards integration into the input production by the buyer.

After downstream producers pay the fixed costs of entry and learn their productivity, the game proceeds in three stages: first, the upstream firms choose the prices of inputs, p_n^k k, then the downstream firms decide whether to backwards integrate or not, and in the final stage production decisions are made.

In the next subsection, I describe the problems of both upstream and downstream firms and show how oligopolistic competition in the upstream sector combined with the possibility of backwards integration in the downstream sector results in price discrimination in the inputs market.

4.4 Firms' objective functions and equilibrium input prices

In the final stage of the game, each downstream firm f chooses price p_f to maximize its profits:

$$\max_{p_f} \ (p_f - c_f)p_f^{-\sigma} E P^{\sigma-1} - fw - \mathbb{1}_f f_{BI} w, \tag{7}$$

where the marginal costs of the firm c_f is the unit-cost function dual to the production function in (3):

$$c_f \equiv \frac{1}{\phi_f}\left(w^{1-\zeta} + P_f^{1-\zeta}\right)^{\frac{1}{1-\zeta}} \tag{8}$$

Monopolistic competition in the downstream sector implies that the solution to (7) is a constant mark-up over firm $f's$ marginal costs:

$$p_f = \frac{\sigma}{\sigma-1} c_f \tag{9}$$

If firm f stays on the markets, its output, revenue and total profits will be given by:

$$q_f = c_f^{-\sigma} E P^{\sigma-1} m^{-\sigma} \tag{10}$$

$$r_f = c_f^{1-\sigma} E (P/m)^{\sigma-1} \tag{11}$$

$$\pi_f = \frac{r_f}{\sigma} - fw - \mathbb{1}_f f_{BI} w \tag{12}$$

where $m \equiv \frac{\sigma}{\sigma-1}$ denotes a constant mark-up, common across all downstream firms.

In the second stage, the downstream firms must decide whether to backwards integrate into the input production or not, given the prices of independent suppliers. As can be see from (5), backwards integration reduces the costs of sourcing inputs from abroad through the "love-of-variety" effect of the CES production function. Specifically, the unit-cost function dual to (5) is given by:

$$P_f^M = \left(\sum_{n\in\Omega} (p_f^n/\alpha_f^n)^{1-\eta} + \mathbb{1}_f (p_{BI}/\alpha_{BI})^{1-\eta} \right)^{\frac{1}{1-\eta}} \tag{13}$$

On the other hand, it is associated with higher fixed costs of production. Backwards integration occurs when the benefits from backwards integration outweigh the costs. Suppose that the firm's decision represented by $\mathbb{1}_f$ can be approximated with a continuous function Δ. Then taking the derivative of π_f with respect to Δ and letting $\Delta \to 0$ yields:

$$\frac{\partial \pi_f}{\partial \Delta}|_{\Delta\to 0} = \frac{1}{\eta-1} \underbrace{c_f^{-\sigma} E P^{\sigma-1} m^{-\sigma}}_{=q_f} c_f s_{BI} - f_{BI} w = \frac{1}{\eta-1} q_f c_f s_{BI} - f_{BI} w \tag{14}$$

where $s_{BI} \equiv \frac{p_{BI} x_{BI}}{wL + \sum\limits_{n\in\Omega} p_n x_n}$ is a share of the in-house produced input in total production costs when $\Delta \to 0$. This share is large when the quality-adjusted price of the firm's own input is low relative to the average quality-adjusted prices of the inputs the firms buys. From (14), it follows that backwards integration is profitable when

$$\frac{1}{\eta-1} c_f s_{BI} > \frac{f_{BI} w}{q_f}, \tag{15}$$

where the left-hand side represents the per-unit costs savings due to backwards integration, and the right-hand side is the costs of backwards integration per unit of output. Note that when products are perfect substitutes ($\eta \to \infty$), there is no "love-of-variety" effect, which leads to zero costs savings from backwards integration.

Condition (14) also implies that a firm has to be large enough in terms of its output q_f for backwards integration to become profitable. Specifically, there is a productivity cut-off for backwards integration, ϕ_{BI}, such that only firms with productivity draw above it backwards integrate:

$$\phi_{BI} = \left(\frac{f_{BI} w(\eta-1)}{E P^{\sigma-1} m^{-\sigma} s_{BI}} \right)^{\frac{1}{\sigma-1}} \bar{c}, \tag{16}$$

where $\bar{c} \equiv \left(w^{1-\zeta} + P^{1-\zeta}\right)^{\frac{1}{1-\zeta}}$ is a cost index under no backwards integration, common across all downstream firms.

Proposition 1. There exist a productivity cut-off, ϕ_{BI}, such that only downstream firms with productivity draws above the cut-off, backwards integrate into the production of inputs. This productivity cut-off is determined in expression (16).

Proof follows from the profit maximizing condition with respect to backwards integration in (14).

In the first stage, the input producers upstream choose input prices for the downstream firms to maximize profits. Since there are two types of input buyers - those that backwards integrate and those that do not - price discrimination is profit maximizing. Thus, upstream producer n may choose different prices to different buyers as a solution to the following profit maximization problem:

$$\max_{p_f^n} \quad \left(p_f^n - \frac{w_n\left(\alpha_n\right)^{1/\theta}\tau_n}{\psi_n}\right)\underbrace{{\alpha^M}^{\rho-1}{\alpha_n}^{\eta-1}\left(\frac{p_f^n}{P_f^M}\right)^{-\eta}\left(\frac{P_f^M}{P_f}\right)^{-\rho} X_f}_{\text{=demand for input } x_f^n} \tag{17}$$

As a solution to this profit maximization problem, the upstream producer will choose price p_f^n, according to the Lerner index:

$$\frac{p_f^n - \frac{1}{\psi_n} w_n\left(\alpha_n\right)^{1/\theta}\tau_n}{p_f^n} = \frac{1}{\varepsilon_f^n} \tag{18}$$

where the left-hand side is a mark-up over the upstream producer's costs and the right-hand side is the inverse of demand elasticity of the downstream buyer of input n. This elasticity can be expressed as a function of supplier n in firm f's expenditures on imported inputs, s_f^n:

$$\varepsilon_f^n \equiv -\frac{\partial x_f^n}{\partial p_f^n}\frac{p_f^n}{x_f^n} = \eta - (\eta - \rho)s_f^n, \tag{19}$$

where $s_f^n \equiv \frac{\left(p_f^n/\alpha_n\right)^{1-\eta}}{(P_f^M)^{1-\eta}}$ is the share of input n in firm f's expenditures on imported inputs.

The downstream firms that can backwards integrate (those with ϕ_f exceeding ϕ_{BI}) spend a smaller share of their expenditures on each common across firms producer n. It means that due to backwards integration, larger downstream firms have larger demand elasticity for any input they purchase.

The profit maximizing condition in (18) suggests that the input price can be decomposed into a cost and a mark-ups components as follows:

$$p_f^n = \underbrace{\frac{\varepsilon_f^n}{\varepsilon_f^n - 1}}_{\text{mark-up}}\underbrace{\frac{1}{\psi_n} w_n\left(\alpha_n\right)^{1/\theta}\tau_n}_{\text{marginal costs}} \tag{20}$$

The input producers selling higher quality inputs charge higher prices to *all* their buyers, because they have both higher marginal costs of production and higher mark-ups. When comparing two downstream buyers of one seller of the exact *same* quality input, larger buyers that backwards integrate into the input production obtain more favorable input prices because of the lower mark-ups. I summarize these results in the following proposition.

Proposition 2. Oligopolistic input producers producing higher quality inputs charge higher mark-ups. For an input of the same quality, an oligopolistic input producer charges a higher mark-up to a buyer that does not backwards integrate and a lower mark-up to a buyer of the same quality input that does backwards integrate.

Proof follows from expressions in (18) - (20).

Propositions 1 and 2 together suggest that the oligopolistic input producers engage in price discrimination, such that, compared to their less productive rivals, more productive firms downstream obtain better input prices for the exact same goods. In the next subsection, I explore what the deviation from the Law of One Price implies for the industry equilibrium in the downstream sector.

4.5 The effect of price discrimination on the industry equilibrium

In the zero stage of the game, downstream firms decide whether they should stay on the market or not after learning their productivity. The firm entry/exit decision pins down the industry equilibrium outcomes such as the number of active firms on the market, their average profits and the consumer price index. In this subsection, I show that by improving intra-industry resource reallocation, price discrimination in the inputs markets benefits final goods consumers through lower prices.

Free entry requires that the sunk entry cost $f_e w$ equals the present value of expected profits:

$$f_e w = (1 - G(\phi_*)) \frac{1}{\beta} \bar{\pi}, \tag{21}$$

where ϕ_* is the exit productivity cut-off, $1 - G(\phi_*)$ is the share of potential entrants that stay active on the market after learning their productivity, $\bar{\pi}$ is the expected per-period profits of active firms, and β is an exogenous probability of exit.

The least productive firm that stays on the market after learning its productivity earns zero profits. Assuming that this firm can not backwards integrate into the production of inputs, its productivity, ϕ_*, is determined from the zero-profit condition:

$$\phi_* = \left(\frac{fw(\sigma - 1)}{EP^{\sigma-1} m^{-\sigma}} \right)^{\frac{1}{\sigma}} \bar{c} \tag{22}$$

The expected per-period profits of active firms can be calculated as the profit of the firm with average productivity, $\tilde{c}$:

$$\bar{\pi} = \frac{1}{\sigma} \tilde{c}^{1-\sigma} E(P/m)^{\sigma-1} - fw - \frac{1 - G(\phi_{BI})}{1 - G(\phi_*)} f_{BI} w \tag{23}$$

where $\frac{1-G(\phi_{BI})}{1-G(\phi_*)}$ is the probability of backwards integration.

For the ease of derivations, I will further rely on the assumption that firm productivity in the downstream sector, $G(\phi)$ has a Pareto distribution with the shape parameter κ: $G(\phi) = 1 - \phi^{-\kappa}$. Then using the expressions for productivity cut-offs (16) and (22) in (23), one can find the equilibrium average profits:

$$\bar{\pi} = \frac{\sigma - 1}{\kappa - \sigma + 1} f w \Lambda, \tag{24}$$

where $\Lambda \equiv 1 + \left(\frac{f_{BI}}{f}\right)^{\frac{\sigma-\kappa-1}{\sigma-1}} (\gamma - 1)^{\frac{\kappa}{\sigma-1}}$ is increasing in the extend of price discrimination γ. Note that the Law of One Price implies that $\gamma = 1$ and thus underestimates the average profits in the downstream sector. In contrast, the larger is the extend of price discrimination, the higher per-period average profits.

Since in equilibrium more productive firms downstream obtain better input prices, price discrimination improves the intra-industry allocation of resources, leading to higher average profits. The reallocation of resources from less to more productive firms, however, comes at the cost of higher exit rates under price discrimination. Using the expression for the expected profits in the free entry condition (21), one can find that the exit productivity cut-off increases in the extend of price discrimination:

$$\phi_* = \left(\frac{\sigma - 1}{\kappa - \sigma + 1} \frac{f}{f_e \beta} \Lambda\right)^{\frac{1}{\kappa}} \tag{25}$$

As a result, price discrimination in the inputs markets implies higher market concentration in the downstream sector. In equilibrium, the number of active firms downstream is given by

$$M = 1 - G(\phi_*) = \frac{\kappa - \sigma + 1}{\sigma - 1} \frac{\beta f_e}{\Lambda f} \tag{26}$$

Since price discrimination results in higher average productivity and does not change firms' market power (mark-ups are constant with the CES preferences), it is expected to increase consumer welfare through lower prices. To derive this result formally, I use the zero-profit condition for the least productive active firm, ϕ_* to derive the price index faced by final consumers:

$$P = \left(\frac{\sigma - 1}{\kappa - \sigma + 1} \frac{f}{\beta f_e} \Lambda\right)^{-\frac{1}{\kappa}} \left(\frac{f \sigma}{E}\right)^{\frac{1}{\sigma-1}} m \bar{c} \tag{27}$$

It is easy to see that the extend of price discrimination reduces the final goods price index, thus benefiting the consumers. In the next proposition I summarize the effects of price discrimination in the inputs market on the industry equilibrium.

Proposition 3. Deviation from the Law of One Price in the form of price discrimination in the inputs markets implies higher average profits, higher market concentration, and lower final goods prices.

Proof follows from the expressions in (23), (26), (27) and the fact that Λ increases in the extend of price discrimination.

5 Price Discrimination and the Gains from Trade

5.1 Input trade liberalization

I use the framework introduced above to understand the *mechanisms* through which trade reforms affect firm performance and social welfare. Since firms participate in international markets as both buyers of inputs and sellers of final goods, they are affected by both input and output trade liberalization reforms. In this paper, I explore how the deviation from the Law of One Price affects welfare gains from both types of reforms. In this subsection, I focus on the effect of price discrimination on welfare gains from *input* trade liberalization.

The proposed theoretical framework allows for three mechanisms through which a reduction in input tariffs can affect firm performance in the downstream sector: the intensive and the extensive margins of trade in inputs and the intra-industry reallocation of activities across downstream firms. In what follows, I study each mechanism separately.

As it was derived above, in equilibrium, the price of input n faced by firm f can be written as a firm-specific mark-up times marginal costs:

$$p_f^n = \mu_f^n(p_f^n)c_n, \tag{28}$$

where $\mu_f^n(p_f^n) \equiv \frac{\varepsilon_f^n(p_f^n)}{\varepsilon_f^n(p_f^n)-1}$ is a function of the input demand elasticity, which depends on input n's share in firm f's expenditures. Since this share itself depends on the price of the input, it follows that both the input demand elasticity and the mark-up can be written as function of p_f^n.

Now consider a reduction in tariffs faced by input producer n, equivalent to the reduction in iceberg trade costs τ_n. To understand the cost-shock pass-through into the input price, rewrite equation (28) in logs:

$$logp_f^n = log\mu_f^n(p_f^n) + logc_n \tag{29}$$

Denoting the mark-up elasticity with respect to price with $\Gamma_f^n = -\dfrac{dlog\mu_f^n(p_f^n)}{dlogp_f^n}$ and taking first differences of (29) yields:

$$dlogp_f^n = -\Gamma_f^n dlogp_f^n + dlog\tau_n \tag{30}$$

From here it follows that the change in the input price due to the input trade liberalization is determined by the mark-up elasticity with respect to price:

$$\frac{dlogp_f^n}{d\tau_n} = \frac{1}{1+\Gamma_f^n} \tag{31}$$

Note that if Γ_f^n is positive, then the pass-through is *incomplete*, and it decreases with Γ_f^n. Intuitively, a reduction in tariffs leads to an increase in firm's market share, which induces the firms to increase the mark-ups. As a result, the buyers of inputs benefit through a less than complete pass-through of the full cost reduction.

Given the input demand elasticity in (**??**), the mark-up elasticity with respect to price becomes

$$\Gamma_f^n = \frac{(\eta-\rho)(\eta-1)s_f^n\left(1-s_f^n\right)}{\varepsilon_f^n\left(\varepsilon_f^n-1\right)} > 0 \tag{32}$$

It is positive and increases in the input's expenditure share for inputs with less than 50% share in firms' total expenditures. Hence, larger downstream buyers that backwards integrate enjoy larger cost-shock pass-through. In other words, larger buyers downstream gain more from input trade liberalization than smaller ones. The same result holds if the cost shock originates from the exchange rate volatility.

Importantly, the cost-shock pass-through is incomplete and decreases in the buyer's size solely due to the mark-ups being variable across the buyers of inputs. If sellers of inputs charged the same mark-up to all their buyers, the cost-shock pass-through would be the same across the buyers. Therefore, if, given the same cost shock, larger buyers experience larger price changes in the data, it in itself proves the existence of price discrimination. This result is summarized in the following proposition.

Proposition 4. If input producers compete oligopolistically and can price discriminate, the cost-shock pass-through is incomplete and heterogeneous across input buyers. Specifically, the cost-shock pass-through (weakly) decreases in the buyer's size.

Proof. The incompleteness of the cost-shock pass-through follows from (31). To see, how the pass-through relates to the buyer's size, consider the expression for mark-up elasticity in (32). If $s_f^n \in [0, 1/2]$, it increases in input n's share s_f^n. Since larger buyers of inputs can backwards integrate, s_f^n weakly decreases in buyer's size. Hence, larger buyers of inputs experience larger cost-shock pass-through.

5.2 Trade Liberalization Downstream

Now I relax the assumption that only intermediate goods are traded internationally and allow for exports of final goods. I introduce the following notation: subscript d denotes domestic economy, while subscript i denotes any foreign country.

Exporting final goods to any foreign country i requires investing f_x fixed costs. Then, downstream firms decide whether to export and backwards integrate by comparing the total profits of the *four* possible options, described below.

Profits if only serving the domestic market and outsourcing all inputs:

$$\pi_d^O = \frac{1}{\sigma} E_d (P_d/m)^{\sigma-1} \left(C^O\right)^{1-\sigma} \phi^{\sigma-1} - f \tag{33}$$

Profits if only serving the domestic market with in-house production of inputs:

$$\pi_d^{BI} = \frac{1}{\sigma} E_d (P_d/m)^{\sigma-1} \left(C^{BI}\right)^{1-\sigma} \phi^{\sigma-1} - nf \tag{34}$$

Profits if exporting to country i and outsourcing all inputs:

$$\pi_x^O = \frac{1}{\sigma} \left(C^O\right)^{1-\sigma} \phi^{\sigma-1} \left(E_d (P_d/m)^{\sigma-1} + \tau_{di}^{1-\sigma} E_i (P_i/m)^{\sigma-1}\right) - f - f_x \tag{35}$$

Profits if exporting to country i with in-house production of inputs:

$$\pi_x^{BI} = \frac{1}{\sigma} \left(C^{BI}\right)^{1-\sigma} \phi^{\sigma-1} \left(E_d (P_d/m)^{\sigma-1} + \tau_{di}^{1-\sigma} E_i (P_i/m)^{\sigma-1}\right) - nf - f_x \tag{36}$$

Exporting decision as well as the choice of a sourcing strategy $S = \{BI, O\}$ are illustrated in Figure 3, where the four profit functions are plotted against firm productivity ϕ.

In equilibrium depicted in Figure 3, downstream firms self-select into four groups: the least productive firms ($\phi^{\sigma-1} < \phi_*^{\sigma-1}$) exit the market, the low productivity firms ($\phi_*^{\sigma-1} \leq \phi^{\sigma-1} \leq \phi_x^{\sigma-1}$) outsource all their inputs and only serve the domestic final goods consumers, the medium productivity firms ($\phi_x^{\sigma-1} \leq \phi^{\sigma-1} \leq \phi_I^{\sigma-1}$) still outsource all their inputs but also export their final goods, and finally, the most productive firms ($\phi^{\sigma-1} > \phi_I^{\sigma-1}$) both export and produce some of their inputs in-house.

Note that in Figure 3, the parameters are such that the strategy of serving only domestic consumers and producing some inputs in-house is always dominated by other strategies.It implies that there are no firms that invest in in-house production of inputs and do not export, which reflects the complementarity between exporting and in-house production.

In equilibrium, the demand for input k by downstream firms that outsource their inputs and by those that backwards integrate is, respectively:

$$\begin{aligned} x_k^O &= \left(\frac{p_k^O/\delta_k}{P_f^O}\right)^{-\eta} \left(\frac{P_f^O/\alpha_f}{P_x^O}\right)^{-\rho} \left(C^O\right)^{-\sigma} (\phi/m)^{\sigma} \left(E_d P_d^{\sigma-1} + \mathbb{1}_x \tau_{di}^{-\sigma} E_i P_i^{\sigma-1}\right) \\ x_k^{BI} &= \left(\frac{p_k^{BI}/\delta_k}{P_f^{BI}}\right)^{-\eta} \left(\frac{P_f^{BI}/\alpha_f}{P_x^{BI}}\right)^{-\rho} \left(C^{BI}\right)^{-\sigma} (\phi/m)^{\sigma} \left(E_d P_d^{\sigma-1} + \tau_{di}^{-\sigma} E_i P_i^{\sigma-1}\right), \end{aligned} \tag{37}$$

where $\mathbb{1}_x$ is an indicator function, which is equal to one if the firm is an exporter and zero otherwise.

To study how trade liberalization (i.e. reduction in bilateral iceberg trade costs τ_{di}) affects firms' incentives to backwards integrate and export, it is useful to write down the cut-off productivities, ϕ_*, ϕ_x and ϕ_I.

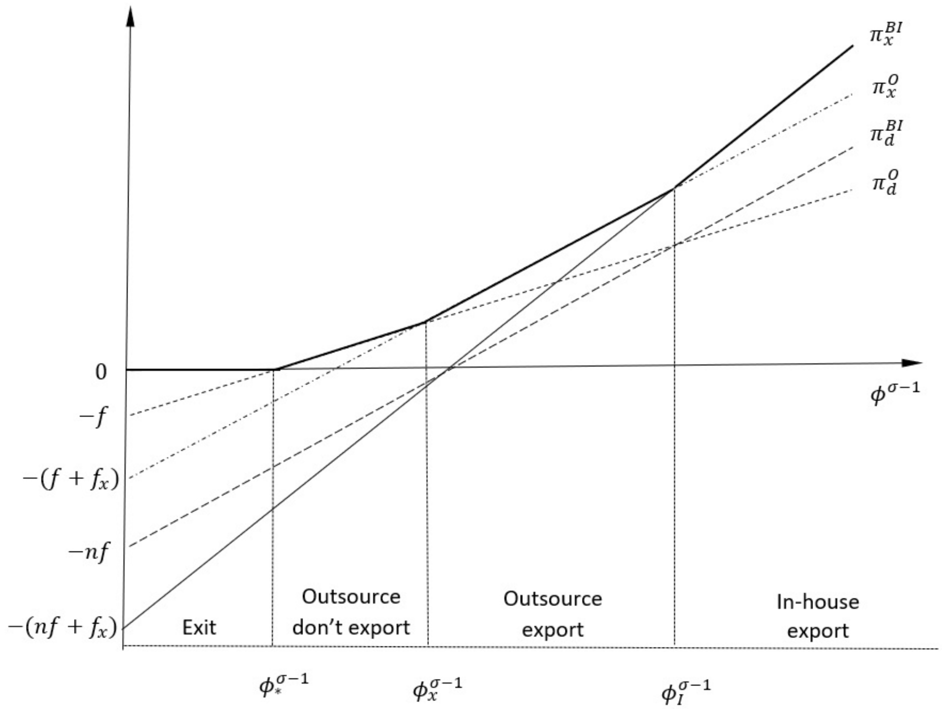


Figure 3: Exporting and Input sourcing modes

The exit productivity cut-off ϕ_* is determined from the zero-profit condition:

$$\pi_d^O(\phi_*) = 0 \quad \Leftrightarrow \quad \frac{1}{\sigma} E_d (P_d/m)^{\sigma-1} \left(C^O\right)^{1-\sigma} \phi_*^{\sigma-1} - f = 0 \tag{38}$$

Since the marginal exporter from d to i outsources all its inputs, the exporting productivity cut-off ϕ_x can be expressed as a function of ϕ_* using $\pi_d^O(\phi_x) = \pi_x^O(\phi_x)$ as:

$$\phi_x = \phi_* \left(\frac{f_x/(E_i P_i^{\sigma-1})}{f/(E_d P_d^{\sigma-1})} \right)^{\frac{1}{\sigma-1}} \tau_{di} \tag{39}$$

Hence, as long as $\frac{f_x/(E_i P_i^{\sigma-1})}{f/(E_d P_d^{\sigma-1})} > 1$, $\phi_x > \phi_*$, as illustrated in Figure 3.

Finally, the least productive firm that can produce inputs in-house is an exporter. The productivity of this firm, ϕ_I, is found from $\pi_x^{BI}(\phi_I) = \pi_x^O(\phi_I)$ as:

$$\phi_I = \phi_* \left(\frac{n-1}{\gamma-1} \frac{E_d P_d^{\sigma-1}}{E_d P_d^{\sigma-1} + \tau_{di}^{1-\sigma} E_i P_i^{\sigma-1}} \right)^{\frac{1}{\sigma-1}} \tag{40}$$

From the expressions (39) - (40) it follows that both exporting and backward integration productivity cut-offs are increasing in iceberg trade costs τ_{di}. In other words, the reduction in trade costs due to trade liberalization with country i allows firms that previously did not export to start exporting. Moreover, some firms that found it profitable to export even before trade liberalization, now find it also profitable to invest in the upstream technology. This is because trade liberalization works as a (arguably exogenous) shock to the demand for goods produced by exporters, which makes backward integration more profitable.

The described effects of trade liberalization in the downstream sector are illustrated in Figure 4.

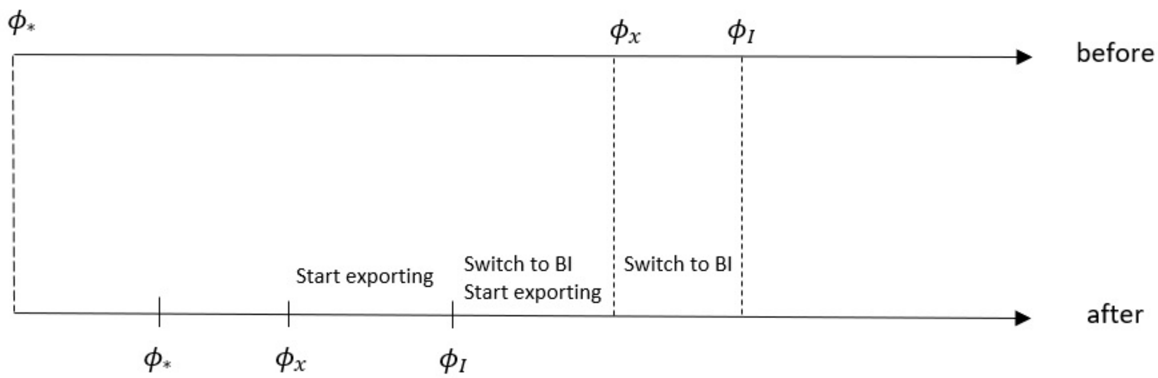


Figure 4: The effects of trade liberalization

Figure 4 makes it clear that gains from trade liberalization are heterogeneous across different downstream firms. For example, firms that were large exporters of final goods even before trade liberalization are not expected to gain through lower input prices, as they already obtain low input prices due to their size. On the other hand, very small domestic producers of final goods still can not export even after the decrease in transportation costs. It is only the more productive new exporters and less productive old exporters that are predicted to gain through lower input prices. After the reduction in trade costs, those firms experience a positive demand shock, which makes in-house production of inputs more profitable and allows them to obtain lower input prices from the upstream producers.

Being positively correlated with firm sales, reductions in tariffs on final goods can be used as an instrumental variable for firm size when studying its effect on input prices faced by final goods producers.

In what follows I explore the implications of third-degree price discrimination in inputs markets for the downstream industry equilibrium.

5.3 Industry Equilibrium

Downstream industry equilibrium in country d consists of the price of final goods (P_d), (endogenous) number of firms (M_d) and the average profits of active firms.

Free entry to the downstream sector requires that the sunk entry cost f_e equals the present value of expected profits:

$$f_e = (1 - G(\phi_*))\,\frac{1}{\beta}\bar{\pi}, \tag{41}$$

where $1 - G(\phi_*)$ is the share of potential entrant that stay active after learning their productivity, and $\bar{\pi}$ is an expected per-period profits of active firms. The expected per-period profits can be expressed as the sum of expected profits from domestic sales and expected profits from exporting:

$$\bar{\pi} = \bar{\pi}_d + p_x \bar{\pi}_x, \tag{42}$$

where $p_x = \frac{1-G(\phi_x)}{1-G(\phi_*)}$ is the share of exporting firms in the downstream sector. For the ease of derivations, I will further assume that $G(\phi)$ is a Pareto cummulative distribution function with the shape parameter κ[3]:

$$G(\phi) = 1 - \phi^{-\kappa}$$

Under this distributional assumption, the expected profits become[4]:

$$\bar{\pi} = \frac{\sigma - 1}{\kappa - \sigma + 1} f\Delta \tag{43}$$

$$\Delta = 1 + \left(\frac{f_x}{f}\right)^{\frac{-\kappa+\sigma-1}{\sigma-1}} \left(\frac{A_d}{A_i}\right)^{-\frac{\kappa}{\sigma-1}} \tau^{-\kappa} + (\gamma-1)^{\frac{\kappa}{\sigma-1}} (n-1)^{\frac{\sigma-\kappa-1}{\sigma-1}} \left(\frac{A_d}{A_d + \tau_{di}^{1-\sigma} A_i}\right)^{\frac{-\kappa-\sigma-1}{\sigma-1}} \left(1 + \frac{\kappa}{\sigma-1}\frac{A_i \tau^{-\kappa}}{f_x A_d}\right),$$

where $A_j = E_j(P_j/m)^{\sigma-1}$.

As Δ is increasing in the marginal cost advantage of in-house production γ, so is the average profits in the downstream sector.

Using the solution for expected profits (43) in the free entry condition (41), one can find the exit productivity cut-off as a function of parameters, including Δ:

$$\phi_* = \left(\frac{\sigma - 1}{\kappa - \sigma + 1}\frac{f}{\beta f_e}\Delta\right)^{\frac{1}{\kappa}} \tag{44}$$

This cut-off allows to solve for the number of active firms in the downstream sector of country d:

$$M_d = 1 - G(\phi_*) = \frac{\kappa - \sigma + 1}{\sigma - 1}\frac{\beta f_e}{\Delta f} \tag{45}$$

Therefore, larger cost reductions due to in-house production implies fewer firms in the downstream sector in equilibrium. This is because price discrimination in inputs markets leads to higher expected profits in the downstream sector. Under free entry and constant mark-ups, higher expected profits can only be sustained with fewer firms on the market, hence - smaller M_d.

[3]Standard assumption that found empirical support in international trade literature

[4]For expected profits to be positive, the following restriction on the parameters should be satisfied: $\kappa > \sigma - 1$

Two other important productivity cut-offs, ϕ_x and ϕ_I can be easily obtained from (39) and (40):

$$\phi_x = \left(\frac{\sigma - 1}{\kappa - \sigma + 1}\frac{f}{\beta f_e}\Delta\right)^{\frac{1}{\kappa}} \left(\frac{f_x/\tau_{di}^{1-\sigma}A_i}{f/A_d}\right)^{\frac{1}{\sigma-1}} \tau_{di} \tag{46}$$

$$\phi_I = \left(\frac{\sigma - 1}{\kappa - \sigma + 1}\frac{f}{\beta f_e}\Delta\right)^{\frac{1}{\kappa}} \left(\frac{n-1}{\gamma-1}\frac{A_d}{A_d + \tau_{di}^{1-\sigma}A_i}\right)^{\frac{1}{\sigma-1}} \tag{47}$$

Finally, the price index in the downstream sector can be solved for using the solution for ϕ_* and the zero-profit condition for the least productive active firm on the market (38):

$$P_d = \left(\frac{\sigma - 1}{\kappa - \sigma + 1}\frac{f}{\beta f_e}\Delta\right)^{-\frac{1}{\kappa}} \left(\frac{f\sigma}{E_d}\right)^{\frac{1}{\sigma-1}} m P_x^O \tag{48}$$

Thus, final goods consumers gain from price discrimination, as it reduces the price of the consumer goods: as γ increases, the final goods price index P_d falls.

6 Conclusion

The existence of price discrimination has been long documented and studied in industrial organization, yet the international trade literature neglects the possibility of different firms getting different price for exact same product. I this paper, using firm-level Customs data, I showed that the assumption of common prices does not seem to hold in the data. When purchasing the same input, buyers with larger quantities obtain lower input prices. To rationalize this observation, I build a model of trade in intermediate goods, in which there are differences in endogenous demand elasticity across buyers of inputs. In this model, heterogeneous downstream firms can decide to produce inputs in-house and export their goods. Both exporting and in-house production are associated with larger fixed costs. As a result, only initially more productive firms sort into in-house production of inputs and exporting. As more productive firms can substitute inputs produced in-house for the one they buy from upstream suppliers, their demand on inputs is more elastic. Since input prices are inversely proportional to the demand elasticity, upstream suppliers charge lower prices to larger (more productive) downstream firms.

Incorporating price discrimination into the general equilibrium trade model allows to study its implications for market aggregates. For instance, wider possibility for price discrimination in the upstream sector increases the expected profit of the downstream sectors and reduces the number of active firms in that sector. This, in turn, implies that consumers benefit from price discrimination through lower production costs of the final goods producers as well as the selection of more productive firms.

This paper also showed that firms decisions to export and engage in in-house production of inputs are complementary. On the one hand, by reducing firm's production costs and thus increasing operational profits, in-house production of inputs allows firms to overcome the fixed costs of exporting. On the other hand, by offering larger economies of scale, exporting itself encourages firms to set-up the production of inputs. Thus, instances of trade liberalization in the downstream sectors can be used as exogenous shocks to identify the causal effect of firm's productivity of the prices of inputs it faces.

The proposed framework with price discrimination in the inputs markets can be further used to empirically study the role of imported intermediates in firms productivity. When firms face different prices on same inputs, it results in heterogeneity in productivity gains from trade liberalization in the upstream sectors.

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