International Trade, Volatility, and Income Differences

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Abstract I investigate the impact of microeconomic volatility on international trade. The cross-country and micro-level data analysis uncovers a negative link between total exports and microeconomic volatility, challenging the predictions of international trade frameworks with constant elasticity of substitution (CES). Furthermore, analyzing Colombian micro-level data, I find that new exporters expand less over their life cycle when exposed to elevated domestic sales volatility. I construct a novel small open, general equilibrium international trade model incorporating new exporter dynamics and variable markups that also nests models with neither mechanism. I show that the relaxation of the CES assumption is pivotal in generating a negative relationship between international trade and microeconomic volatility, a relationship further magnified by allowing new exporter dynamics. Additionally, the model provides a new rationale for the low engagement of developing economies in international trade, as it generates relationships between trade and the GDP per capita that are consistent with the observed cross-country data. The model results explain almost two-thirds of the variation in the estimated trade frictions along development.

JEL Classifications: F10, F12, F14, F23, F63, O19, O24

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1 Introduction

Living standards vary significantly across the globe, and with them, the patterns of international trade. Countries with a higher level of development have more exporters per capita that are larger and more likely to continue exporting. [1] Consequently, developed countries export more than less developed ones. These facts have been attributed to less developed countries facing relatively high export costs, which have been estimated to have large impacts on the level of development.[2] But how can we unleash the benefits of eliminating these trade costs? To answer this question, we need to understand the source of these relatively high trade costs.

This paper shows that developing countries export less mainly because they are more volatile. Firms' domestic volatility affects their incentives to invest in foreign markets, depressing exporters' growth and total trade. Domestic volatility has a relatively large effect on trade because the costs of investing in foreign market access are relatively high. [3] I show that the interaction between domestic volatility and the trade frictions that affect firm growth in foreign markets explains most of the relationship between development and international trade once we allow for demand to present variable price elasticity in a way that is consistent with the micro-level data.

I start by developing a simplified model to highlight the main mechanism behind the negative relationship between total exports and firm level sales volatility. The model consistent of exporters that invest in shifting the intercept of their demand to grow into foreign markets. Following the literature I refer to the foruce behind this changes in the demand intercept as changes in the firms' customer capital (Fitzgerald et al. (2021), Steinberg (2021)).

Using the model I show two main results. First, that the effects of micro volatility on total exports, hinges on the shape of the firms' revenue function to firms' productivity. Second, that the shape of firms' revenue function to firms' productivity depends on the assumption over how the price elasticity varies with firms' sales. To gain intuition on the first result

[1] See Fernandes et al. (2015) for a study of the relationship between exporter characteristics and development.

[2] See Waugh (2010), Blum et al. (2019), Fieler (2011) and de Sousa et al. (2012).

[3] See Das et al. (2007), Alessandria et al. (2021), Fitzgerald et al. (2021)

note that if the revenue function is convex on firms' productivity, a mean preserving spread over firms' productivity increases total exports, driven by the typical Oi-Hartman-Abel effect. The higher revenues of those firms benefiting of a good productivity draw, more than compensate the revenues drops of the firms receiving a bad shock. The opposite is true when revenues are concave function of firms' productivity.

To understand the second result think about the case where price elasticity decreases with quantities sold. In such instances, as firms' productivity increases, firms' reduce prices but because the price elasticity drops, firms' increase their markup mitigating the shift along the demand curve. Additionally, as firms decrease their prices, quantities become less responsive to price changes, damping the quantities response as firms' productivity increases. Consequently, if price elasticity is sufficiently responsive, revenues will increase with firms' productivity, albeit in a less-than-proportional manner, making revenues a concave function in firms productivity. Importantly, I show that when we have new exporters dynamic, the effects or volatility is amplified, because the investment in customer capital depends on the expected profits of reaching one additional customer.

After presenting the mechanism, I proceeded to document new facts about domestic volatility and trade at the cross-country level. Three salient features stand out in the cross-country data: (1) developing countries have higher microeconomic volatility; (2) more volatile countries export less conditional on the level of development and standard gravity equation variables; and (3) the role of development on trade is substantially reduced after controlling for macro or microeconomic volatility. Indeed, volatility seems to have a much stronger effect on trade than the level of GDP per capita.

I then focus on Colombian the firm-level data to test the existences of the two main mechanism previously discussed: the existence of variable price elasticity and of the new exporter dynamics shaped by customer capital accumulation; and the main micro level mechanism implied by the model. [4] I document three important features of exporters behavior. First, we can't reject the that new exporter growth is driven by increases in the relative market demand, similar to the findings of Fitzgerald et al. (2021) and Steinberg (2021). Second,

[4]A vital advantage of the data is that it allows me to separate domestic from international shocks

exporters more exposed to domestic volatility grow slower rates in their export markets; higher domestic volatility reduces exporters' incentive to invest in foreign markets consistent with the model prediction when price elasticity is variable. Third, larger exporters, with higher market share respond to cost shocks by increasing more markups. I test this last point by using a novel identification strategy that requires minimum assumption over the production function to estimate markup responses.

I then generalize the simplified model to a general equilibrium small open model with firm heterogeneity, firm level persistent productivity shocks, and new exporter dynamics to quantify the role of volatility in trade. The model extends the new exporting dynamic model to allow for a variable price elasticity and, thus, variable markup. The model is such that depending on two parameters, it nests the four possible types of model with either mechanism.

The goal is to test the extent to which the micro-level mechanisms can explain the novel aggregate and micro-level findings regarding exports and volatility. I estimate the model's parameters to match Colombian aggregate average trade openness, the evolution of exporters over their life cycle at the firm-level, and my estimates on heterogeneous markup response to changes in firms' marginal cost, among other standard moments.

The quantitative findings show that the benchmark model can account for the firm-level facts regarding the adverse effects of higher domestic sales volatility on exporters' growth, the cross-country relation between total exports and volatility, and total exports and GDP per capita. Nonetheless, the rest of the models fail to generate quantitative or qualitatively similar predictions to what is observed in the data. These results show the macroeconomic relevance of the micro-level findings documented in the data. Assuming that exporters make a static decision or face demand with constant price elasticity comes at the cost of missing the relationship between aggregate export and the level of volatility.

Furthermore, the quantitative predictions of the model are striking. If we compare the top and bottom 10% countries on the micro-volatility distribution, their difference is consistent with 103% difference in exports. Or for example, the results implies that if Colombia faced the micro-volatility levels of Belgium or Sweden, their export would grow by 55% and 69% higher, respectively.

In addition, the model generates a relationship between total exports and GDP per Capita similar to the one observed in the data. The results also implies that the CES model with new exporter dynamic needs 67% higher icerbeg cots in developing economies than in developed ones to match the relationship between exports and GDP per capita observed in the data. This results explains about two thirds of the estimated trade cost differences across development by de Sousa et al. (2012).

These results highlight the importance of domestic volatility as a determinant of endogenous non-policy trade barriers. And the difficulties that developing countries face in reducing them, as the micro economic volatility is generally quite difficult to reduce. The interaction between domestic volatility and firms' investment cost to grow into foreign markets significantly affects exports once we properly account for their demand characteristics.

Literature. The paper relates to several strands of literature at the intersection of macroeconomics, international trade, and development.

The main contribution of this paper is to understand why developing economies engage in less international trade than developed ones. To the best of my knowledge, this is the first paper showing the relevance of domestic volatility to explain the differences in the estimated export costs in developing economies. The literature goes back to the findings of Rodrik (1998) suggesting the low export performance in Sub-Saharan countries was mainly due to trade costs; Limao et al. (2001) shows the relevance of the lack of infrastructure to explain part of the relatively low levels of trade in these countries. On the other hand, Waugh (2010) shows that to match the data on trade and prices, export costs in developing economies need to be higher than in developed ones, de Sousa et al. (2012) find similar empirical results using the border effects methodology. In contrast, Fieler (2011) argues that non-homothetic preferences in demand for goods are important to understand this relationship. These findings follow models where firms face static decisions; hence, volatility cannot play any role by design. Blum et al. (2019) departs from the static frameworks with the insights of inventory models to understand this relationship. They argue that the shipment data suggest higher per-shipment costs to export in developing economies, explaining part of the export cost. My approach differs from those in the literature in two ways: (1) I rely on the insights of the predictions of dynamics models, and (2) I show that the estimated trade costs are an equilibrium outcome of the interaction between domestic volatility and the dynamic nature of exporter decisions.

This paper is the first one to estimate how domestic sales volatility affects a firm market-specific growth over its life-cycle. There is extensive literature on investment under uncertainty that followed the seminal work of Lucas et al. (1971), Hartman (1972), Andrew (1983) and Pindyck (1982). I focus on a particular type of investment, the market-specific investment that firms make to grow into each market, so far ignored in this literature. [5]

More broadly, the present work proposes a new mechanism through which volatility discourages investment — the existence of variable price elasticity — contributing to the literature on how economic frictions interact with uncertainty affecting firm investment decisions. Until now the literature has focused on the three main frictions: (1) investments frictions that generate the real option effect (e.g. Pindyck (1982), Bloom (2007), Bloom (2009), Novy et al. (2020), Alessandria et al. (2019), Martin et al. (2020),Handley et al. (2017)); (2) financial frictions to explain why uncertainty reduces firms investment (e.g. Arellano et al. (2019) and Merga (2020)); and (3) the existence of sticky prices e.g. (Basu et al. (2017), and Fernández-Villaverde et al. (2015)). My empirical and quantitative findings show the existence and relevance of variable price elasticity and its consequent variable markups as a novel mechanism complementary to the literature.

The third contribution of this paper is to develop a framework that nest the insights Fitzgerald et al. (2021) to explain how exporters grow and how their growth is affected by domestic volatility. By relaxing the assumption of constant price elasticity, the extended model can account for the patterns regarding (1) exporter dynamics over their life cycle, (2) the heterogeneous markup response to exchange rate shocks, and (3) the negative relationship between exporters growth and domestic volatility, I do this within the framework of a

[5] Recent work has found that this investment that works as a demand shifter is essential to explain firms' growth in both their domestic and foreign markets as in Ruhl et al. (2017), Fitzgerald et al. (2021), Steinberg (2021), Alessandria et al. (2021), Fitzgerald et al. (2018), Einav et al. (2021).

general equilibrium small open economy, allowing me to show the aggregate relevance of my micro-level findings to explain the behavior of total exports.

The fourth contribution of this paper is to the literature on the relationship between prices and exchange rates. The literature has struggled to separate the effects of exchange rates on prices as it is unclear whether markup or cost changes drive the price response. I solve this problem by proposing an estimation procedure to compute the pure markup response to exchange rate shocks without estimating the markup level. In this sense, my results complement Berman et al. (2012) finding that larger firms adjust their prices less than smaller ones due to exchange rate changes, and Amiti et al. (2014) finding that larger exporters also import more, showing that consequently, exchange rate changes affect the marginal cost of production. I also propose a new instrumental variable approach to solve the endogeneity problems between exchange rate changes and domestic or foreign shocks affecting the pricing decision of firms.

Layout. The rest of the paper is structured as follows. Section 2 presents a toy model to highlight the main mechanism and the relevance of different assumptions to understand how volatility affects exports. Section 3 presents the data sources. Section 5 presents the estimation strategy and results for the aggregate facts. Section 6 turns to the micro-level facts using administrative firm-level data from Colombia. Section 5 presents the general equilibrium model, and section 7 deals with its estimation and quantitative results. Section 7 concludes.

2 Mechanism in a Simple Example

Prior to delving into the empirical outcomes and the full general equilibrium model, I will establish a simple example to highlight the primary mechanism in its most intuitive form. The goal here is to demonstrate how the assumption of variable or constant price elasticity can reshape the relationship between firms' volatility, total exports, and exporters' growth. This illustration will be conducted within the framework of exporters utilizing a linear production function that expands through an augmentation in customer capital in the market they sell. This serves to underscore the importance of exporters' dynamic decisions in understanding how volatility impacts their choices. In this particular context, our initial focus will be on how the influence of volatility on total exports hinges on the curvature of the revenue function with respect to firms' productivity. Subsequently, I will emphasize the impact of assumptions about price elasticity on this curvature.

Consider a model with a continuum of exporters that solves a two-period problem. These firms initiate their endeavors with a certain amount of customer capital, which we denote as A. The decision of whether or not to engage in exporting is imposed exogenously upon them. Their production process hinges on a linear technology, $q = zl$, and they optimize their value by allocating resources, specifically labor and investments in customer capital. The dynamic problem they face is to determine how much to invest in their customer capital for the upcoming period, all before the idiosyncratic productivity shock z unfolds and before they gain insight into the binary outcome of exporting ($m = 1$) or not ($m = 0$). These productivity shocks are drawn from a continuous distribution, $F(z)$, and exhibit a standard deviation denoted as σ_z. The exporting decision variable,m, follows a Bernoulli distribution (with probability $pr(m = 1) = \iota$). The demand for a firm's product is given by

$$q(A, p) = A^{\alpha}\hat{q}(p)Q^f,$$

A^{α} is the intercept of demand that depends on firms' customer capital, $\hat{q}(p) := q(1, p)$ denotes the static component of demand as a function price, p. The firm's static problem is to choose p to maximize its profits, $\pi(A, z, m)$, after it observed z and m. Firms' optimal profits can be re-written as

$$\pi(A, z, m) = A^{\alpha}\hat{\pi}(z, m),$$

where $\hat{\pi}(z, m) := \pi(1, z, m)$. Because firms use labor to invest in customer capital, which fully depreciates in the next period, their dynamic problem is

$$\max_{A'} A^{\alpha}\hat{\pi}(z, m) - wA' + \beta\mathbb{E}_{F'}\{A'^{\alpha}\hat{\pi}(z', m')|_{z=z}\} \quad (1)$$

s.t.

$$A' \geq 0$$

If firms do not export, $m = 0$, then $\hat{\pi}(z, 0) = 0$, where profits denotes the operational profits firms obtain from engaging in export activities. The optimal condition for customer capital tomorrow is given by

$$A'(z) = \left\{ \frac{\alpha \iota \beta}{w} \mathbb{E}_{F'} \{ \hat{\pi}(z', 1)|_{z=z} \} \right\}^{\frac{1}{1-\alpha}} \tag{2}$$

this optimal investment decision underscores how the curvature of operational profits in relation to firms' productivity plays a pivotal role in determining the impact of higher uncertainty on investment choices. When profits are convex with respect to firms' productivity, greater uncertainty, due to a mean-preserving spread, leads to higher investments by exporters. In contrast, a mean-preserving spread reduces investment if profits exhibit concavity. To comprehend these outcomes, consider the following intuition: heightened uncertainty increases the likelihood of both better and worse productivity outcomes. When profits are convex, the expected profit gains from better outcomes outweigh the profit reductions from worse outcomes, resulting in a higher expected return for acquiring an additional customer. Conversely, the opposite holds when profits exhibit concave behavior in relation to firms' productivity.

Differences in the profit function, arising from variations in the curvature of the revenue function, yield significant implications for how increased uncertainty affects the exporters' growth over time and, consequently, the total exports. To highlight the core mechanism, let's assume that firms' productivity follows an independently and identically distributed (iid) pattern, allowing us to express cumulative exports as

$$Exp = A^{\alpha} \int p(z) \hat{q}(z) dF(z)$$

where $A'(z) = A \; \forall \; z$ since $z \sim iid$. To better understand how the curvature of the revenue function determines volatility effects on total exports, let G represent a second cumulative distribution function derived from F via a mean-preserving spread and denote variables x_G as variable x derived under distribution G. We can right the export differences between a country with low and high uncertainty as,

$$\ln\left(\frac{Exp_G}{Exp}\right) = \underbrace{\ln\left(\frac{A_G^\alpha}{A^\alpha}\right)}_{\text{dynamic response}} + \underbrace{\ln\left(\frac{\int p(z)\hat{q}(z)dG(z)}{\int p(z)\hat{q}(z)dF(z)}\right)}_{\text{static response}} \tag{3}$$

The overall export response to increased volatility depends on the interaction of dynamic and static reactions, as described in the first and second terms of equation 3. The dynamic response deals with how heightened uncertainty impacts firms' expected gains from acquiring more customers, which is closely tied to the curvature of the firm's profit function, as we've previously discussed. Meanwhile, the static response reflects alterations in the distribution of sales. It's worth noting that, conditionally on the firm's productivity, the static sales component - $p\hat{q}$ - remains the same for different distributions. Thus, the static response captures shifts in total sales due to changes in the productivity distribution.

The direction of the dynamic and static responses depends on the curvature of the revenue function. When considering a linear production function, profits will exhibit concavity if a firm's revenue is concave to productivity. This aligns with our previous discussion. When revenues are concave, the expected increase in revenue from more favorable outcomes isn't sufficient to offset the expected revenue decline due to a higher likelihood of unfavorable outcomes. Consequently, total expected revenues decrease, resulting in a negative dynamic response to uncertainty. Similarly, the static response becomes negative when revenues display concavity. In this scenario, the reduction in total sales due to a higher share of less productive firms surpassing the sales increase attributed to a larger share of more productive firms.

Lemma 1. *Under monopolistic competition and linear production function, if the curvature of the revenue function is concave on firms' productivity, then a mean preserving spread reduces total exports. The contrary is true for the conx case.*

Proof: *See appendix C.1*

Neglecting the importance of domestic volatility or inaccuracies in specifying the revenue function can significantly impact the estimation of trade determinants, particularly in estimating trade costs at the origin country. For instance, let's consider a scenario where the data-generating process results in revenue being concave with respect to firm productivity. If we employ a static or dynamic model with a convex revenue function, we will end up estimating higher trade costs for exports to all destinations from the origin country. This is because the model will predict increased exports as firms' volatility rises, whereas, in the actual data-generating process, greater volatility reduces total exports. Similarly, if we accurately account for the curvature of the revenue function but use a static model when the data-generating process is dynamic, we will overlook the dynamic response to volatility. As a consequence, models with incorrectly specified revenue functions and lacking dynamic elements will fail to capture the correct relationships between total trade and volatility, leading to inflated estimates of export costs in the origin country.

Lemma 2. *Under monopolistic competition and linear production function, if the curvature of the revenue function in the model is misspecified, assuming convexity instead of concavity, then the model will estimate higher trade costs when volatility is reduced.*

Proof: *See appendix C.1*

I now turn my attention to exploring how the assumption of variable or constant price elasticity can impact the curvature of revenue and profit functions. I formalize this outcome in lemma 3. However, for the sake of gaining some insight, consider that the transformation of productivity into revenue can be dissected into two primary effects: a direct effect and an indirect effect. The direct effect relates to how changes in marginal costs affect prices, while the indirect effect pertains to how changes in prices impact quantities sold. In the context of constant price elasticity, if firms' productivity increases, they will fully transmit the cost reduction into lower prices, constituting the direct effect. Yet, when price elasticity surpasses two, the price decline is more than offset by the increase in quantities sold - this is the indirect effect. Consequently, revenues rise in a manner that exceeds the proportionality to firms' productivity due to the strong response of quantities to price changes.

This result, however, does not hold true when price elasticity varies in conjunction with quantities sold, resulting in a weakening of both the direct and indirect effects. In such instances, as firms' productivity increases, they reduce prices less compared to the previous scenarios, thereby increasing their markup and mitigating the shift along the demand curve. Additionally, as firms decrease their prices, quantities become less responsive to price changes, damping the indirect effect. Consequently, if price elasticity is sufficiently responsive, revenues will increase with firms' productivity, albeit in a less-than-proportional manner.

Lemma 3 . *Under monopolistic competition and linear production function, if the price elasticity is sensitive enough to firms' prices, then revenues are a concave function of firms' productivity.*

Proof: *See appendix C.1*

3 Data

To document the aggregate facts, I use several data sources: Penn World table database, the Dynamic Exporter Database from World Bank, the Enterprise Survey from the World Bank, and CEPII database. Appendix A.1 contains the details of the cross-country data.

For the micro-level data and model estimation, I use two primary data sources: (1) Administrative data from Colombian customs, (2) Administrative data from "Superintendencia de Sociedades" from Colombia containing the firm's balance sheet information. The first data set reports exports of each firm at the 8-digit product level for each destination and period. The data is monthly and provides information on the quantities shipped and the value of the shipment in Colombian pesos and U.S. dollars over the period 2006-2019. I aggregate export flows for each firm-product-destination yearly to avoid the usual problems with lumpiness in trade.[6]

I merge this data with firm-level data from "Superintendencia de Sociedades" which reports the variables firms declared in their balance sheet information. This dataset provides

[6]See Alessandria et al. (2019) as an example of the lumpiness in trade and its relevance for exporter behavior at high frequency.

information on firms' total income, operational income, operational cost, total costs, profits, and operational profits, among other variables. These variables are in nominal Colombian Pesos, which I deflate with the production price index. The data sets cover a sub-sample of 20,000 firms, the largest firms representing around 90% of total value-added in the country. The sample is skewed towards larger firms, generating a concern due to possible bias for firm-level empirical facts. However since the focus of the paper is on exporters' behavior, this alleviates this concern for two reasons. First, the largest firms in the economy are the ones that are exporters, and second, exports are highly concentrated on larger firms.

4 Cross-country evidence

This section focuses on the cross-country evidence. I document two facts. I start by reexamining the relationship between exports and the level of development. Unconditional on the level of volatility; there exists a positive relationship between aggregate exports and level of development as in Waugh (2010), Fieler (2011), Blum et al. (2019), Fernandes et al. (2015) and de Sousa et al. (2012). Second, I show that conditional on a country's micro volatility, the relationship between aggregate exports and GDP per capita reduces substantially. This result can be explained by the fact that, on average, higher volatility is negatively related to export performance and that developing economies tend to have more micro volatility, as I document in appendix A.2 consistent with the findings of macro volatility as in Ramey et al. (1995),Aghion et al. (2010),Badinger (2010), Imbs (2007), Koren et al. (2007).

Microeconomic volatility measure. To pin down the microeconomic volatility, we would like to rely on pure firms' productivity shocks, but given the data limitations, this is not plausible, so I will focus on changes in domestic sales and treat the model consistently. To rely on a measure that completely purged out the common effects on firms due to aggregate or sectoral changes, compute the firm-level shocks by incorporating country-industry-year fixed (Yeh (2021) and Di Giovanni et al. (2020)). So then we can estimate,

$$\Delta \text{Domestic Sales}_{i,j(i),c,t} = \gamma_{j(i),c,t} + e_{i,j(i),c,t} \tag{4}$$

where ΔDomestic Sales$_{i,j(i),c,t}$ is the percentage change in domestic sales of firm i, belonging to main industry, $j(i)$, in country origin c, in year t. $\gamma_{j(i),c,t}$ denotes country-industry-year fixed effects so that $e_{i,c,t}$ can be interpreted as pure firm-level changes in domestic sales. [7] Once we have the firm-level shock estimates, we can compute the country's microeconomic volatility as the average observed standard deviation across time for each country i as,

$$\sigma_c^{\omega} := \sum_{t=1}^{T} \frac{\sqrt{\sum_{i \in N_{c,t}} \frac{(\hat{e}_{i,c,t})^2}{|N_{i,t}|-1}}}{T}$$

where $|N_{i,t}|$ represents the total number of firms in the country c, and the I already use the mean of the firm-level shocks to be zero.[8]

Exports, volatility, and income differences: Estimation. To empirically understand the relevance of micro volatility on international trade, I estimate a gravity equation expanded with this measure. I decompose the logarithm of country c's exports to destination country d (denoted by $\ln(x_{cdt})$), in an origin country fixed effect (α_c), a destination time fixed effect (γ_{dt}), and a vector of bilateral variables ($\boldsymbol{y}_{cdt}$), and variables for the domestic economy that varies over time, $\boldsymbol{h}_{ct}$ [9],

$$\ln(x_{cdt}) = \alpha_c + \gamma_{dt} + \boldsymbol{\beta} \boldsymbol{y}_{cdt} + \boldsymbol{\beta_2} \boldsymbol{h}_{ct} + \epsilon_{cdt} \tag{5}$$

as in Head et al. (2014) and Eaton et al. (2002) I proceed in a two-step procedure to understand the variables that relate with the origin component of a country, α_c. Once I have estimated the vector $\hat{\alpha_c}$, I project it against a set of variables to understand how they relate to different country characteristics, as follows

$$\hat{\alpha}_c = \beta_0^{\alpha} + \beta_1^{\theta} \ln \sigma_c + \beta_2^{\alpha} \ln \frac{GDP_c}{L_c} + \boldsymbol{\theta_3} \bar{\boldsymbol{y}}_{cj} + \boldsymbol{\theta_4} \bar{\boldsymbol{h}}_c + \boldsymbol{\theta_5} \bar{\boldsymbol{Q}}_c + e_c \tag{6}$$

[7] To avoid these changes being directly related to foreign demand or supply shocks, I restrict the sample to those firms that do not declare any direct or indirect export or import in the database.

[8] I follow the guideline of the World Bank to weight each firm by the weights they provide so that the estimates of using the sample are representative for the economy.

[9] See Head et al. (2014) for a description of gravity models and the two-step procedure.

the two main coefficients of interest are β_1^α and β_2^α, as the former captures the relationship between the average exports of a country and its microeconomic volatility,σ_c, and the latter captures the relationship between the average exports and the average level of GDP per capita of the country,$\frac{GDP_c}{L_c}$. I control for countries' quality institutions, their level of financial development, and direct measures of exporting costs represented by the vector $\bar{\boldsymbol{Q}}_c$, using the three indexes developed by the World Bank that capture the quality of the contract enforcement, the financial development of the country, and the declared export costs that exporters face.[10]. And following Head et al. (2014), I control for the average of bilateral-time variables denoted by $\bar{y}_{cj}$, and origin countries time variables, $\bar{h}_c$, standard gravity equation, and countries terms of trade (TOT) volatility.

Aggregate Fact 1: Positive Relationship between Exports and Income per Capita. Table 1 presents the results for several estimations: the case without controlling by countries' volatility measures and the case when we control by its volatility. Columns (1), (2), and (4) show the estimates (6) without controlling for the volatility measure, where in column (1), I only control for country size, column (2) includes all the gravity controls and the declared export costs as shown by last row of the table, and column (4) adds institutional for contract enforceability , and the financial development index. Both results show significant and relevant relations between the level of development and the average export to each market, even after controlling for country size, the declared cost to export, the country's institutional environment, and financial development (column 4). Consistently with the findings documented by Waugh (2010), Blum et al. (2019), Fernandes et al. (2015) and de Sousa et al. (2012).

Aggregate Fact 2: Negative relationship between microeconomic volatility and exports. Columns (3) and (5) of Table 1 are homologous to columns (2) and column (4), but adding the variable of interest, the microeconomic volatility measures. Two results emerge from its observation. First, the estimated relationship between exports and the level of GDP per capita drops between 20% to 30% after controlling for the level of micro-volatility. Sec-

[10]The inclusion of these three indexes is because they are correlated with the level of development, potentially the volatility of a country, and have been found to be also relevant for international trade Manova (2008), Manova (2013), Kohn et al. (2020), and Blum et al. (2019).

ond, a negative relationship exists between average exports and countries' microeconomic volatility. To put these results in context, the estimates suggest that a country with a standard deviation higher level of micro volatility relative to the mean exports on average between 30% to 34% less. When moving from the first quartile to the last third quartile of the distribution is associated with an increase in total exports between 37% to 42%.

Given the novelty of the aggregate fact 2 to the literature, I perform several robustness checks of this result in appendix A.3. I find that the results are robust to using different measures of microeconomic volatility, and to redoing the exercise only in manufacturing to test the relevance of trade composition.

These aggregate results provide a new potential explanation of why estimated export costs are associated with variations in the level of development even after controlling for the standard determinants of international trade. Volatility does not only predict considerable variations of average exports across countries but also captures a significant share of the variations that had been attributed to the level of development in previous works such as in Waugh (2010), Fieler (2011), and Blum et al. (2019). As discussed in lemmas 1 to 3 of the previous model section, these empirical findings are consistent with the previously discuss model where if price elasticity is responsive enough, and exporters grow slowly over their life cycle, higher volatility decreases exports.

Nonetheless, these documented aggregate relationships are not necessarily causal. Because of the cross-country nature of the exercise and despite the efforts to control for the relevant variables, the existence of a potential omitted-variable bias cannot be ruled out. This is why, in the following sections, I will proceed in two ways to provide more evidence in favor of this new explanation. First, I will focus on micro-level data from Colombia. I will test the firm-level assumptions behind lemmas 1 to 3, and their firm-level predictions highlighted in section 2. Second, after showing that neither the main assumptions nor the predictions at the firm level can be rejected, I will estimate a full flesh general equilibrium small open economy, with heterogeneous firms and new exporter dynamics to use it as a laboratory to observe what are the model's predictions regarding higher microeconomic volatility in terms of total exports and GDP per capita.

5 Firm level facts

I turn now to use the micro-level data from Colombia to show three facts supporting the assumptions and predictions of the two main mechanisms highlighted in section 1. In the first part of this section, I focus on how exporters adjust their prices to changes in their marginal cost of production; I document evidence supporting that firms' markups vary with firms' relative productivity, implying by lemma 3, the plausible existence of concave revenue functions. I relegate the most detailed analyses to the appendix because this fact has been shown in Berman et al. (2012) and discussed in Arkolakis et al. (2017).

The stylized model discussed in the second section shows that if exporters grow by expanding the intercept of their demand and if revenue is concave, in this case, microeconomic volatility should discourage new exporter expansion if price elasticity is high enough. I test the first assumptions regarding exporters' growth and its implications in the second part of the section.

Estimating the markup elasticity in the data. The objective is to test if, as firms are more productive, they respond more by changing markups to changes in their marginal cost. To understand how we can estimate the markup responses by observing price changes, let's start with the markup definition.

Markups, μ, are defined as the ratio between the product's price and the product's marginal cost of being sold to the market. Assuming that firms' sales are set ultimately in the currency of the market selling to, prices are given by the following equation

$$p_{i,d,l,t} = \mu_{i,d,l,t} \frac{Mc_{i,d,l,t}}{e_{d,t}}$$

where $\frac{Mc_{i,d,l,t}}{e_{d,t}}$ denotes the marginal cost of production in foreign currency for firm i, product l, destination d, at time t. $e_{d,t}$ is the bilateral exchange rate, $p_{i,d,l,t}$ denotes prices and $\mu_{i,d,l,t}$ represents the markups at time t that firm i set sell to market (d, l). It is important to highlight two consequences that follow this definition for the case of constant markups. First, the exchange rate pass-through to prices should equal minus one. Second, exchange rate pass-through should not vary across destinations. Contrary to the coming findings and the ones in Berman et al. (2012).

Given my data constraint, to test if firms respond more by changing markups to changes in their marginal cost when they are more productive, I use firms' market share in the market they served as a proxy for the ratio of the exporters' relative productivity in the market they served, and exchange rate shocks as changes in the marginal cost in foreign currency [11].

But to estimate the changes in markups due to changes in the exchange rate depending on firms' relative productivity, we need to control the changes that exchange rate movements have on the cost of production. Otherwise, we would obtain biased estimates of markup responses to shocks. [12]

If we assume that the firm's i marginal cost can be decomposed into two components: (1) the marginal cost of production, common to all destinations, denoted as $Mc^a_{i,l,t}$, and (2) the cost of selling the product to a destination d, denoted by $Mc^b_{l,d,t}$, which we generally refer as iceberg cost; then we can control for the changes in the marginal cost of production. By exploiting variation across destinations within firm-product-time and product-time-destination, we can recover the markup changes by observing the price responses to changes in cost. The following equation should clarify this result,

$$\frac{\partial \ln p_{i,d,l,t}}{\partial e_{d,t}} = \frac{\partial \ln \mu_{i,d,l,t}}{\partial e_{d,t}} + \underbrace{\frac{\partial \ln Mc^1_{i,l,t}}{\partial e_{d,t}}}_{\theta_{i,l,t}} \underbrace{-1 + \frac{\partial \ln Mc^2_{l,d,t}}{\partial e_{d,t}}}_{\gamma_{l,d,t}}$$

Suppose now that the markup responses vary across destinations within the exporter, depending on the exporter's relative productivity to that market. In that case, we can use exchange rate shocks interacting with the exporter's market share to recover the differential reaction of firms' markup changes in their marginal cost. To test if markup changes vary

[11] See Arkolakis et al. (2017) for a discussion of models with variable markups and their predictions over heterogeneous exchange rate pass-through

[12] This bias is particularly likely to exist since it has been documented in Amiti et al. (2014) that larger exporters also tend to import more.

with exporters' market share, we can then estimate

$$\varDelta p_{i,d,l,t} = \beta \varDelta e_{i,d,l,t} \times \text{exp. share}_{i,d,l,t-1} + \beta_2 \text{exp. share}_{i,d,l,t-1} + \gamma^1_{i,l,t} + \gamma^2_{i,l,d} + \gamma^3_{l,d,t} + e_{i,d,l,t} \quad (7)$$

where $\varDelta$ denotes log differences of the variables over a year. $\gamma^1_{i,l,t}$ denotes the firm-product-time fixed effects and ,$\gamma^3_{l,d,t}$ denotes the product-destination-fixed effects. Under the previously mentioned assumptions, β captures the differential markup responses to movements in the exchange rate due to firms' differences in their market share. Note that while this estimation producer captures the markup responses to shocks, it cant be used to estimate the level of markups. [13]

A concern of directly estimating 31 is that as exchange rate variation might reflect changes in the destination country, this can bias the estimate. However, we can use an instrumental variable approach to solve this concern. In particular, I instrument the bilateral exchange rate variation intersected with the firm's sales shares with the remittances flows from third countries to Colombia interacted with firms' sales shares. I relegate the detailed presentation on the instrument variable approach and its implementation to the appendix B.1.

Firm-level fact 1: Markup changes increase with market shares. Table 2 presents the estimation results. Panel 1, shows the estimates for the first stage; the F-statistic is on the order of 40, alleviating the concerns of the possibility of weak instruments for all of the cases I presented. Second, as expected, when we compare the OLS results (column 1), with the IV ones (column 2 or 3), we find that our concern about the possible estimation bias triggered by shocks in the destination economy was valid; nonetheless, all estimates are positive and significant. The results show that the markup response to shocks in the marginal cost is increasing in the exporter's market share. Particularly, a firm with a 1 percentage point higher market share will optimally decide to do an exchange rate pass-through that is between 0.71% and 1.20% lower, as shown by columns (2) and (3) of Panel 2, respectively, consistent with the findings by Berman et al. (2012).

[13] I also control for potential trends in prices, as the ones we would expect to be driven by inflation, by adding firm-product-destination fixed effects $\gamma^2_{i,l,d}$. Still, the qualitative results are invariant to adding these fixed effects.

As a validation exercise, panel 3 presents a similar estimate but considers quantities as the dependent variable. The estimation results provide insights into the soundness of the instrument. While the OLS estimate -column 1- predicts a quantity change inconsistent with predicted price changes in panel 2, the IV results -columns 2 and 3- show results consistent with the predicted price changes in panel 1. After using the IV, not only do quantities respond negatively as firms have higher market share, but these results are also consistent with price elasticity higher than 1 as we would expect.

Domestic Volatility and Exporters' Growth. I now turn to test if (1) exporters grow over their life cycle by shifting the intercept of their demand and (2) if higher domestic volatility discourages exporters' growth over their life cycle. This allows me to test the assumption's validity and implication highlighted in section 2 for exporters' growth under higher uncertainty.

Before starting the empirical analyses, it is worth mentioning why I will focus on the evolution of export intensities over exporters' life cycle. To understand this, note that according to the model presented in section 2, exporters' growth over their life cycle in a particular market can be decomposed by two components: (1) the growth driving the demand shifter - the customer capital accumulation A in terms of that model-, and (2) by the differential evolution of prices across markets. [14] This is because of the export intensity - exports from firm i of product l, to destination d, at time t, can be written as,

$$\text{exp int}_{i,l,d,t} = A^{\alpha}_{i,l,d,t} \frac{\hat{q}(p_{i,l,d,t})}{\hat{q}(p_{i,l,\text{dom},t})} \quad ,$$

and consequently, the log difference over time is given by,

$$\Delta \text{exp int}_{i,l,d,t} = \Delta A^{\alpha}_{i,l,d,t} + \Delta \frac{\hat{q}(p_{i,l,d,t})}{\hat{q}(p_{i,l,\text{dom},t})}$$

Now, suppose that price dynamics do not evolve differently over exporters' life cycles in each market, as it will be clear in the coming results. In that case, common shocks to the firm

[14] Note that here I am abstracting from the market aggregate variables changes, as destination time fixed effects can capture them.

will affect similarly the static component across markets -$\hat{q}(.)$-, and hence $\Delta \frac{\hat{q}(p_{i,l,d,t})}{\hat{q}(p_{i,l,\text{dom},t})} \approx 0$. Therefore, $\Delta \exp \text{int}_{i,l,d,t}$ will captures the evolution of the unobservable component $\Delta A^{\alpha}_{i,l,d,t}$.

Firm-level fact 2: New exporters grow by shifting in their demand. Figure 2 presents the estimates of the evolution of exporter intensity -conditional on prices - (panel a) and of prices (panel b) over the exporter life cycle. The details of the estimation procedure regarding exporters' growth are presented in detail in appendix B.2, as results are similar to the ones presented by Fitzgerald et al. (2021) and Steinberg (2021) but applied to the Colombian case. Consistent with their findings, the results show that the differential evolution of exporters' prices across markets is constant over their life cycle. Still, the export intensity grows over the exporters' life cycle, even conditional on exporters' prices. Consequently, exporters grow into markets by shifting their demand conditional on prices.

Firm's Exposure to Volatility and Exporters' Growth. The previous firm-level facts show that we can't reject two key assumptions presented in the simplified model in section 2: the existence of variable markups and exporters that grow by shifting the intercept of their demand. Under these assumptions, one of the model predictions highlighted in section 2 is that if price elasticity is responsive enough, volatility will reduce exporters' growth over their life cycle. I now, proceed to test this implication.

To compute firms' exposure to domestic volatility, I follow a strategy similar to the one in section 4. However, I can exploit a leave-one-out strategy given that I can now exploit firm-level variation. I start by taking out the common shocks for firms in the same industry by regressing the change of the log change of domestic sales against industry-year fixed, as follows

$$\Delta \text{Domestic sales}_{i,j(i),t} = \gamma_{j(i),t} + \Delta \hat{s}^{D}_{i,j(i),t}.$$

where ΔDomestic sales$_{i,t}$ denotes the log difference of domestic sales over time, $\gamma_{j(i),t}$ is the industry-time fixed effects - $j(i)$ is firm's i main industry-, and $\Delta \hat{s}^{D}_{i,t}$ is the residual component that captures the firms level shocks.

Then, we can use the shocks to other firms in the same industry, $j(i)$, to compute firms' exposure to domestic volatility. The focus on shocks to domestic sales to third firms obeys two reasons: first, it allows me to avoid the volatility measure being related to foreign demand shocks, and second, it prevents the measure from being related to shocks to the firm itself. I compute the average cross-sectional standard deviation of firm-level shocks $\Delta\hat{s}^{D}_{i,t}$, at time t, for all the firms besides the firm i, whose main export product, at the sixth digit level is $l^{6d}(i)$ as,

$$\sigma_{i,l^{6d}(i),t} = \sqrt{\frac{\sum_{j\neq i\in N_{l^{6d}(i)}}\left(\Delta\hat{s}^{D}_{j(i),t}\right)^2}{|N_{l^{6d}(i),t}|-1}}$$

where $|N_{l^{6d},t}|$ denotes the number of firms exporting the sixth digit product l^{6d} $\sigma_{i,l,t}$ measures the average volatility of the firm-level domestic shocks to the firms other than i that share its main product of export $l^{6d}(i)$. Then I construct the firms' i exposure to volatility at the four-digit product category $l^{4d}(i)$, as defined as the weighted sum of exports product - at the six-digit - of $\sigma_{i,l^{6d},t}$

$$\sigma_{i,l^{4d}(i),t} = \sum_{l^{6d}(i)\in l^{4d}(i)} \frac{\textit{tot. export}^{l^{6d}(i)}_{t-1}}{\textit{tot. export}^{l^{4d}(i)}_{t-1}}\sigma_{f,t,l^{6d}} \tag{8}$$

I fixed the export shares and the main products of firm i in the previous year to alleviate the concern that future shocks to some particular products may change total exports and, through that, biased the relationship between volatility and exporters' growth. Appendix 3 presents the construction and results using different robustness measures.

Firm-level fact 2: New exporters grow less as they are more exposed to domestic volatility. I estimate the following equation to asses how domestic volatility relates to exporters' dynamics,

$$\begin{aligned}\ln\left(\frac{\text{exp int}_{i,l,d,t+h}}{\text{exp int}_{i,l,d,1}}\right) &= \sum_{j=1}^{6}\beta^1_j \ln\sigma_{i,t}\mathbb{I}_{\{\text{age}=j\}} + \sum_{j=1}^{6}\beta^2_h\mathbb{I}_{\{\text{age}=j\}} \\ &+ \gamma^a_{l,t} + \gamma^b_{d,t} + \gamma^c_{i,t} + controls_{i,l,d,t} + e_{i,m,t}\end{aligned} \tag{9}$$

where $\exp \text{int}_{i,l,d,t}$ denotes the export intensity of product l - at the sixth digit-, that firm i, at time t sells to destination d, defined as the exports divided by the firm's total domestic sales. $\mathbb{I}_{h=j}$ is a dummy variable that is equal to one if the firm's age in that particular market is h. $\gamma^a_{l,t}$ and $\gamma^b_{d,t}$ represent product-time and destination-time fixed effects, capturing those variations in export intensity that are common to the destination or product for each period. γ_i represents the firm-fixed effects to capture the average growth of the export intensity that is common within the firm across different products and destinations. Among controls, I control for the unit values that firms charge when selling to that particular market.

The estimation results are presented in Figure 3. The figure shows the estimated differences in the cumulative change of exports over the exporters' life cycle with a tenure of at least sixth years for each market. It plots the estimated coefficients, β^1_j, and its confidence interval for firms in the manufacturing and retail sector. The estimated coefficients are presented in column (3) of Table 3 of the appendix, several robustness checks are also presented in the appendix B.3, together with the estimations using all the sectors.

6 The Model

We now turn to our general model, a small open general equilibrium economy model incorporating variable markups, extensive and intensive margin decisions into exporting, and persistent firm-level shocks. The economy has a continuum of firms producing intermediate goods, a representative firm producing a domestic bundle, a final good firm producing the consumption good, and a representative household. The household provides labor inelastically and uses labor and profits income to consume a final good. The final consumption goods and the domestic bundle firms are competitive and have a technology that converts domestic intermediate and imported goods into final goods. The intermediate goods firms can sell to the domestic and foreign markets, both of which are monopolistic competitive markets. There are no aggregate shocks.

The timing in the model is as follows. At the end of any given period, firms decide how much to invest in foreign customer capital, allowing exporters to shift their demand's intercept in the foreign market - the intensive margin. At the beginning of the next period, idiosyncratic shocks are realized. Intermediate goods firms decide if they export or not, and firms set their prices for each market they serve, produce, and sell their products to final goods firms or foreign markets in case they face a positive demand. The firm producing the domestic bundle buys the intermediate goods and sells them to the final good firm, which also buys the import bundle to produce the final goods. Households consume and receive payments for their work and their firms' profits. Trade is balanced, so aggregate savings are equal to zero.

Domestic consumers. The representative consumer of this economy owns the firms and holds risk-free bonds in zero net supply. Every period, she observes her bond holdings, b, and the aggregate state of the economy $\mathbb{S}$, decides how much to consume and save, and provides labor inelastically, L^s. Her problem is given by:

$$V^c(b, \mathbb{S}) = \max_{b', C} u(C, L) + \beta \mathbb{E} \left\{ V^c(b', \mathbb{S}') \right\}$$

s.t.

$$P^C C + b' = wL^s + \Pi^{dom} + \Pi^{exp} + r_t b'$$

In equilibrium $b = 0$, implying that total exports are equal to total imports, the net trade balance in this economy is zero, and the interest rate will adjust for this to be the case. The household problem determines the stochastic discount factor for the firm given by $\Lambda = \beta \frac{u_c(C', L')}{u_c(C, L)}$.

Final good production. The final good is producedusing two goods as inputs: a bundle of imported goods, M, and a bundle of domestic goods, D, which are combined in the following way to produce the final good C,

$$\left(M^{\frac{\gamma-1}{\gamma}} \upsilon + (1 - \upsilon) D^{\frac{\gamma-1}{\gamma}} \right)^{\frac{\gamma}{\gamma-1}} \geq C \ , \tag{10}$$

where υ represents the home bias. The price of each of these bundles is given by P^m and P^D, respectively, and P^m are normalized equal to one. The final good firm chooses the amount of domestic and imported consumption bundles to solve

$$\min_{M,D} M + P^D D$$

subject to (10). The solution to this problem yields the following demand for the domestic bundle:

$$D = M \left(\frac{\nu}{1-\nu} \right)^{-\gamma} \left(P^D \right)^{-\gamma} \tag{11}$$

Domestic bundle. The production for the domestic bundle uses intermediate differentiated goods and is given by the following conditions,

$$\int_{\omega \in \Omega^d} \Upsilon \left(\frac{q^d(\omega)}{D} \right) d\omega = 1 \tag{12}$$

where, as in Klenow et al. (2016), $\Upsilon(x)$ is given by

$$\Upsilon(x) = 1 + (\theta - 1) e^{\frac{1}{\eta}} \eta^{\frac{\theta}{\eta}-1} \left(\Gamma(\frac{\theta}{\eta}, \frac{1}{\eta}) - \Gamma(\frac{\theta}{\eta}, \frac{x^{\frac{\eta}{\theta}}}{\eta}) \right), \ \theta > 1; \ \eta > 0 \tag{13}$$

where $\Gamma(a, b)$, represents the incomplete gamma function, I call θ the price elasticity parameter, and η as the super-elasticity parameter. As it will be clear later, conditional on θ, η shapes a firm's markup responses to changes in the intermediate goods prices. The producer of the domestic bundle will observe intermediate good prices $\{p^d(\omega)\}$ and choose the intermediate quantities $q^d(\omega)$ of the variety ω to solve,

$$\min_{q(\omega)} \int_{\omega \in \Omega} p^d(\omega) q^d(\omega) d\omega \tag{14}$$

subject to equations (13), and (12). The solution to this problem yields the following demand for variety ω,

$$\log q(\omega) = \frac{\theta}{\eta} \log \left(-\eta \log \left(\frac{p^d(\omega)}{p_c^d} \right) \right) + \log D \quad \text{if } p^d < p_c^d \tag{15}$$

where p_c^d is the choke price for the domestic varieties in the economy - the maximum price at which the domestic bundle producer will be willing to buy a variety - and is given by

$$p^c = e^{\frac{1}{\eta}} \frac{\theta - 1}{\theta} \frac{P}{\tilde{D}} \tag{16}$$

where P is the price index for the intermediate goods, defined as $P := \int_\Omega \frac{q(\omega)}{D} p(\omega) d\omega$, and $\tilde{D} := \int_\Omega \Upsilon'(\frac{q(\omega)}{D}) \frac{q(\omega)}{D} d\omega$.

Foreign Consumer's Problem Intermediate firms can sell to a foreign importer. The importer takes aggregate demand, Q^*, and foreign prices, P^*, as given [15]. The importer observes the prices of the intermediate goods and solves,

$$\min_{q^*(\omega)} \int_{\omega \in \Omega^*} p^*(\omega) q^*(\omega) d\omega$$

s.t.

$$\int_{\omega \in \Omega^*} A(\omega)^\alpha \Upsilon \left(\frac{q^*(\omega)}{A(\omega)^\alpha Q^*} \right) d\omega = 1 \tag{17}$$

where $\Upsilon(x)$ denotes the indirect utility function of the representative consumer and is given by (13); $A(\omega)$ represents the customer capital that the domestic exporter producing variety ω has when selling to this foreign market, and α is the elasticity of customer capital to demand; this follows from the demand as its given by

$$\log q^*(A, p^*) = \frac{\theta}{\eta} \log \left(-\eta \log \left(\frac{p^*(\omega)}{p^{c*}} \right) \right) + \log A^\alpha + \log Q^* \quad \text{for } p^*(\omega) < p^{c*}, \tag{18}$$

note that $A(\omega)$ ends up being a demand shifter, over which firms can invest and grow into the foreign market as in Fitzgerald et al. (2021). As before, p^{c*} denotes the choke price of the foreign economy, but because the domestic economy is a small open economy, p^{c*} is assumed to be constant, unlike p^c that is an equilibrium object.

Intermediate good firms. As stated before, a continuum of firms with the potential to produce intermediate goods populates the economy. Each potential producer of a variety can

[15] As the domestic economy is small, foreign price and foreign demand are assumed to be invariant to the condition of the domestic market.

produce using a linear production function with time-varying labor productivity. Because the production of each variety, ω, is the same conditional on the firm's i productivity, z_i, and its customer capital, A_i, we can characterize each variety by these two characteristics. Furthermore, the joint distribution of productivity and customer capital will be enough to characterize the distribution of intermediate firms, denoted by $\Psi(z, A)$. Firms' productivity follows a Markov process governed by the transition probability $f(z', z)$.

The timing is as follows. At the beginning of time t, firm i observes its productivity z_i and the level of customer capital A_i and decides if it wants to sell in the domestic and international markets. Contingent on selling to each market, it sets the prices for each market, hires the workers, and produces. At the end of the period, it decides how much to invest in customer capital for the following period to sell in the foreign market. When selling to the domestic market, they can reach all the customers available so there are no gains for investing in domestic customer capital. On top of the investment cost in customer capital, reaching the international market has additional costs. To be able to sell to foreign markets, firms need to pay the fixed cost, f_e, and they also face an iceberg cost, $\tau > 1$. Furthermore, the firms' customer capital depends on firms being present in the market; when a firm stops exporting, it loses the customer capital it accumulated. The firm's problem can be decomposed into a static and a dynamic problem.

Firms' static problem. Now, I characterize the firms' static problem when selling to the international market, but if we set $\alpha = 0$, and $\tau = 1$, the coming equations can also characterize the static problem when selling to the domestic economy. The firms' static problem is consistent in choosing the optimal price such that it maximizes its operational profits, given its production technology, the economy choke price, p^c, wages, and the aggregate quantities, as in

$$\pi(z_i, A_i) = \max_{p_i, l_i} p_i^* q_i^*(A, p_i) - w l_i$$

subject to its production technology, $q_i^* = \frac{l_i \tau}{z_i}$, and equation (18). By choosing the price to maximize their profits, firms implicitly choose their products' price elasticity, conditional on the demand behavior. By staring at equation (18), one can realize the firms price elasticity, ξ is given by,

$$\xi(p) = -\frac{\theta}{\eta \log(\frac{p}{p^{c*}})}$$

the usual maximization argument implies that firms' markups are given by,

$$\mu(p) = \frac{\theta}{\theta + \eta \log(\frac{p}{p^{c*}})} \quad \text{for all } p \leq p^{c*} \tag{19}$$

hence markups are decreasing in the price that firms charge. Put differently, it implies that more productive firms will charge higher markups while less productive firms will charge smaller markups. This result is consistent with the findings by De Loecker et al. (2016), Berman et al. (2012), and the firm-level fact one presented in the previous section. Additionally, the price elasticity equation and the markup equation imply boundaries for the optimal prices such that $\mu(p) \geq 1$, and $\xi(p) \geq 1$

As discussed in Section 2, the behavior of price elasticity and, consequently, the firm's markup are essential to determine the shape of the revenue function in terms of the firms' productivity. In this case, the price elasticity will ultimately depend on two parameters, θ, and η. Depending on their value, the model will generate standard "Oi-Hartman-Abel", under which higher volatility on firms will increase exports, sales, and GDP or shut it down, generating the opposite relationship.

Firm's dynamic problem. In the model, firms make two dynamic decisions directly related to the extensive and intensive margin of the firm. These decisions are the exporting decision, denoted by m, and the investment decision to accumulate more customers, denoted by i_d, which is done using workers. Firms can't sell their customer capital, so they can't make negative investments. To invest i_d in customer capital, the amount of labor required is given by

$$c(i_d, A) = i_d - \frac{\phi}{2}\left(\frac{i_d}{A_i}\right)^{\iota} \tag{20}$$

note that firms' customer capital is given by two-component

$$A_i = k_i + A^{min} \tag{21}$$

a minimum level of customer A^{min}, that is fixed and equal for all firms exporting and paying the exporting fixed cost, and k_i that is where firms can invest and accumulate customer capital, according to the following law of motion,

$$k_i' = m\left(i_d + k_i(1-\delta)\right), \tag{22}$$

when $m = 0$ and firms do not export, they will lose all the accumulated customer capital and only have $A' = A^{min}$, the following period. Denoting with an apostrophe the variables next period, and by , $\mathbb{S}_t$ the vector of aggregate state variables, the firm dynamic problem is to solve

$$\begin{aligned} V(z_i, A_i, \mathbb{S}) = \max_{m\in\{0;1\}; i_d\in[0;\infty)} & \pi^d(z_i, 1) + m(\pi(z_i, A_i) - wf_e) - \\ & - wc(i_d, A_i) + \mathbb{E}\left[\Lambda(S)V(z_i', A_i', \mathbb{S}')\right] \end{aligned} \tag{23}$$

subject to (21) and (22). The decision of exporting or not in this model is a discrete decision given by $m \in \{0; 1\}$. If firms decide to export $m = 1$, they will collect the total profits from exports, given by the operational profits $\pi(z_i, A_i)$ minus the fixed cost of exporting, f_e. When they decide not to export $(m = 0)$, firms will only collect the profits for selling to the domestic market, $\pi^d(z_i, 1)$ for which the domestic customer capital of the economy is normalized to one.

Firm's optimal dynamic behavior. Two main equations characterize the firms' exporter behavior. The optimal capital customer the firm decides to have in the next period is given by,

$$\frac{\partial wc(i_d, A)}{\partial A'} \geq \mathbb{E}_a \left\{ \Lambda \overbrace{(1 - Pr(z_i'^*))}^{\text{export prob.}} \overbrace{\mathbb{E}_{z_i} \left\{ \frac{\partial V(A', z')}{\partial A'} | z_i' > z_i'^* \right\}}^{\text{Expected MR conditional on exp.}} \right\} \tag{24}$$

the condition holds with equality when firms decide to invest in customer capital, $i_d > 0$. In this case, firms decide to equalize the marginal cost of investment, the left-hand side of equation (24), to the expected marginal return on investment, the right-hand side of the same equation, which by the Leibniz rule, is determined by two components. The first is the expected probability that in the next period, the firm will export, z'^* denotes the minimum level of productivity at which the firm will decide to pay the fixed export cost to stay in the export market. The second component denotes the marginal expected return of investment conditional on exporting. Both of these terms are affected by the uncertainty that firms face concerning the realization of future shocks.

As in Melitz (2003), firms will export if productivity is higher than the productivity threshold $z^*(A, \mathbb{S})$. They will decide the contrary when their productivity is below that threshold. The firm productivity threshold is then characterized by the case when the firm is indifferent to export or not, given by

$$\hat{\pi}(z_i^*, A) + \overbrace{\mathbb{E}_F\{\Lambda[V(A', z') - V((A^{min}, z')]\}}^{\text{Option value}} = w(f_e + c(i_d, A)) \tag{25}$$

the marginal firm is indifferent between staying or not in the export market if the operational profits of doing so plus the option value of not losing the customer capital it had accumulated is equal to the investment cost plus the exporting fixed cost. In a static case or in an economy where customer capital is unaffected by the exporter's decision, firms will not face any option value. The existence of the option value generates the well-known effects of hysteresis on international trade, given that firms with higher customer capital, and consequently, that on average spend more time in the export market, will be less likely to drop their export condition. The existence of the option value and hysteresis is an important margin to be present in the model, as its absence will upward bias the effects of uncertainty on total trade. This is because the option value might increase under higher uncertainty, delaying export exits as discussed in Merga (2020)

6.1 Equilibrium

Let's now specify the conditions for an equilibrium for this economy. Market clearing in the labor markets implies that labor inelastically supply, L^s, equals labor demand determined by the sum of labor used for production, investment, and fixed costs,

$$\int l(z, A) d\Psi(z, A) = L^s \quad , \tag{26}$$

total output for the economy is equal to the labor income plus firm profits,

$$Y = wL^s + \int (\pi^d(z_i, 1) + m(\pi(z_i, A_i) - wf_e)) d\Psi(z, A) \quad , \tag{27}$$

and total exports are given by

$$Exp = \int p^*(z, A) q^*(z, A) d\Psi(z, A) \quad , \tag{28}$$

because of the zero net supply of the bond market, trade is balanced, implying that nominal exports and imports are equal, $Exp = Imp$. The demand for the domestic bundle used to produce the final consumption good is given by,

$$D = Imp \left(\frac{\nu}{1 - \nu} \right)^{-\gamma} \left(P^d \right)^{-\gamma}$$

where I make use that nominal imports, Imp, are equal to the imported quantities, M, since $P^m = 1$. The price of the domestic bundle is given by $P^d = \int \frac{q(z,1)}{D} p(z) d\Psi(z, A)$, and the price of the consumption is given by P^C characterized by the usual price index for CES. The supply for the domestic bundle, D is given by the following condition,

$$\int \Upsilon\left(\frac{q(z,1)}{D}\right) d\Psi(z,A) = 1 \tag{29}$$

characterizing the equilibrium domestic choke price, p^c defined in equation (16). The evolution of the firm productivity and customer capital joint distribution, $\Psi(z,A)$, is given by,

$$H(z_t, A_t; \mathbb{S}_t) = \int f(z_t, z_{t-1})\phi(A_t, A_{t-1}, z_{t-1}; \mathbb{S}_{t-1}) d\Psi(z_{t-1}, A_{t-1}) \tag{30}$$

where $H(.)$ is the transition function for the measure of firms, $\Psi_t = H(\mathbb{S}_{t-1})$. Where $f(z_t, z_{t-1})\phi(A_t, A_{t-1}, z_{t-1}; \mathbb{S}_{t-1})$ denotes the measure of firms that will transition from (A_{t-1}, z_{t-1}) to (A_t, z_t), when the aggregate state is given by $\mathbb{S}_t$.

Given the initial measure Φ_0; an equilibrium consists of policy and value functions of intermediate goods firms $\{V(z_t, A_t, \mathbb{S}_t), A'((z_t, A_t, \mathbb{S}_t), q^s(z_t, \mathbb{S}_t), q^{*s}(z_t, A_t, \mathbb{S}_t), m(z_t, A_t, \mathbb{S}_t)\}$; of consumers $\{V^C(b, \mathbb{S}_t)b'(b_t, \mathbb{S}_t), c(b_t, \mathbb{S}_t)\}$; of final good producers $\{M(, \mathbb{S}_t), D(, \mathbb{S}_t)\}$; of domestic bundle producers $\{D(, \mathbb{S}_t), q^d(, \mathbb{S}_t)\}$; the price of the export and domestically sold intermediate goods $\{p^s(z, \mathbb{S}_t), p^{*s}(z, \mathbb{S}_t)\}$; the domestic choke price $\{p^c(, \mathbb{S}_t)\}$; the price of labor units $\{W(, \mathbb{S}_t)\}$; the price of the bonds $\{r(, \mathbb{S}_t)\}$; the price of the consumption good and the domestic bundle, $\{P^c(, \mathbb{S}_t), P^D(, \mathbb{S}_t)\}$; and the evolution of the aggregate states Ψ_t governed by the function $H(, \mathbb{S}_t)$, such that for all time (1) the policy and value function of intermediate good firms satisfy their optimal conditions, (2) domestic consumer decisions are optimal, (3), the final consumption producer and the domestic bundle producer decisions are optimal, (4) the bond market clears and trade is balanced, (5) labor markets clear, (6) the evolution of the measure of firms is consistent with the policy functions of the firms and consumers, and with their shocks.

7 Quantitative Analysis

The objective of the quantitative exercise is to test the model's ability to capture the firm-level facts and to use it to predict the relationship between total exports, a country's microeconomic volatility, and its GDP per capita, and the relevance of each mechanism. For this, I begin with a discussion of the model's parameterization and to perform a moment-matching exercise. Since the model is highly nonlinear, I solved the model using global methods. I explain the algorithm to solve for its equilibrium in appendix D.

I then explore the models' implications at the firm and aggregate level, starting at the firm level. I begin with a study of the models' prediction in terms of exporters' dynamics under different levels of micro-volatility. I illustrate the different predictions of a model with and without variable price elasticity. Finally, I test the four models' predictions for the aggregate relationships of interest.

7.1 Model Calibration

Because the model is highly nonlinear, all parameters affect all the moments, and all are set to match the moments together. Nevertheless, some parameters are more important for certain statistics, as they have a clear empirical moment counterpart based on the model's prediction. There are two parameters that are externally calibrated. These parameters are the consumer's discount rate, β, and the Armington elasticity, γ, set to 0.98, 3.4, and respectively. The home bias, ν is set to match Colombia's trade openness of 0.37. The consumer's utility function is assumed to be given by

$$u(c) = log(c),$$

the firms' productivity follows an AR(1) process,

$$\ln z_{i,t} = \mu + \rho \ln z_{i,t-1} + \epsilon_{i,t}$$

where $\epsilon_{i,t}$ is assume to be normally distributed, with standard deviation σ_z. Both ρ and σ are set to match the estimates of the AR(1) process estimated for the domestic sales in Colombia.

The rest of the parameters governing the firms' decisions are set to match the exporter data from Colombia. The parameters τ, and A^{min}, are set to match the average export intensity of all exporters and of the new exporters', while f^e is set to match the share of exporters over the total active firms. The parameters $\alpha, \iota, \phi, \delta$ are set to match the evolution of the exporters' export intensity evolution over their life cycle.

Finally, the parameters governing the price elasticity, θ, and η, are set to lie within the markup range estimated for Colombia, and the empirical results are presented in Table 2. To match these estimates in the model, I perform the same exercise as in the data, but with two exceptions. First, I can directly observe the markups in the model, so I run the same estimates as in the data but using markups as dependent variables. This prevents me from using the fixed effects used to control for the marginal cost changes. Second, I use wage reductions as the change in the marginal cost of production as in Itshokmarkups ??. Lastly, remember that because I am assuming that the domestic economy is a small open economy, p^{c*}, the international choke price, is assumed to be a parameter consistent with the foreign demand and the estimated parameters for the price elasticity.[16]

All the values of the parameters for each of the possible models are presented in Table 3, while the target moments and the model predictions are presented in Table 4.

7.2 Model Implications

Now, we can test the different models' ability to generate the empirical relations documented in the data section. To achieve this, I simulate four models with or without exporter dynamics and with or without variable markups. For each model, I simulate different economies that vary only in their conditional micro volatility. To achieve this, I need to adjust the mean, μ, and the persistence of the shocks ρ, such that the changes in the volatility of the shocks do not affect the average productivity and the unconditional distribution of firms' productivity.

Without these adjustments, the shocks will generate changes in the average firm productivity, increasing the share of firms on the right tail of the distribution. This would imply countries with higher microeconomics volatility, low exports, and low GDP but with more productive firms on their right tail, contrary to the empirical evidence.

[16] In this case, p^{c*} is assumed to be the choke price that solves the foreign economy the given foreign demand function, assuming that the foreign economy has the same firm distribution and the same price elasticity parameters, θ and η, than the domestic economy.

Quantitative result 1: Higher micro-volatility reduces new exporters growth. I now test the model's ability to replicate the firm-level fact 2, in which those exporters more exposed to domestic volatility grow less over the export markets. To do this, I compare the estimated differential growth due to this higher exposure in the data and in the model. Figure 3 presents the results. The benchmark model can properly predict the qualitative relation regarding the higher domestic volatility and the differential growth of the new exporter. Quantitatively, the model predicts a higher difference relative to the data during the first years of the exporters' lives. These results are successful if we compare them to models without the variable price elasticity, since these other models will predict a null or contrary relationship to the one in the data as shown with the simplified model.

Aggregate predictions: Model vs data. Now, we turn to the models' prediction regarding the aggregate variables. To understand the relevance of volatility and the proposed mechanisms, let's re-write the total exports as in section two, but now without assuming that shocks productivity are iid, in this case, we can re-total exports as

$$Exp_t = \bar{A}\int_{z^*(A)} \frac{A_i^\alpha}{\bar{A}} rev^*(z) d\Psi(z, A)$$

where $rev^*(z) := p^*(z)q^*(z,1)$ is the static component of exports, and $\bar{A} := \int_{z^*(A)} A_i^\alpha d\Psi(z, A)$ denotes the average effective demand shifter over active exporters. Using the covariance definition and the Leibniz rule, we have that the total export response to a marginal change in a generic variable x is given by,

$$\frac{\partial \ln Exp_t}{\partial x} = \underbrace{\frac{\partial \ln \bar{A}}{\partial x}}_{\textit{dynamic margin}} + \frac{1}{\Theta}\ln\left(\overbrace{\partial\frac{\mathbb{E}(rev_i^*(z)|z \geq z^*)}{\partial x}}^{\textit{static margin}} + \overbrace{\partial\frac{\mathbb{C}\mathbf{ov}\left(\frac{A_i^\alpha}{\bar{A}}; rev_i^*(z)|z \geq z^*\right)}{\partial x}}^{\textit{misallocation margin}}\right)$$

$$-\frac{1}{\Theta}\underbrace{\int_A \frac{\partial z^*(A)}{\partial x}\frac{A_i^\alpha}{\bar{A}} rev^*(z^*)\psi_z(z^*, A) d\Psi_A(A)}_{\textit{extensive margin}}$$

where $\Theta := \mathbb{E}(rev_i^*(z)|z \geq z^*) + \mathbb{C}\mathbf{ov}\left(\frac{A_i^\alpha}{A}; rev_i^*(z)|z \geq z^*\right)$, $\psi_z(z^*, A)$ denotes the conditional probability density function of firms productivity, given their value of customer capital, and $d\Psi_A(A)$ is the marginal density function of customer capital.

The previous result shows that in the dynamic model with customer capital, there are, as usual, two main margins of adjustment: an intensive and extensive margin. But in this case, the intensive margin is given by three sub-margins, unlike the case for static models, or new exporters dynamics models with iid shocks. The three sub-margins of the intensive margin are: (i) the dynamic margin, which captures the effect of a change in the average level of customer capital in total exports; (ii) the static margin, which captures the effect of firms' changes in their export static decision - equal to the total intensive margin on static models-; and (iii) the misallocation margin - absent in models with iid shocks-, capturing the changes on the covariance between firms' revenues per customer and firm's relative level of customer capital, a higher covariance increases export as firms that obtain higher revenues per customer reach relative more customer.

Quantitative result 2: Higher micro-volatility reduces total exports. Figure 4 shows the results of this quantitative exercise for the four different models. The models' predictions are striking. Both models with variable markups are qualitative, consistent with the documented empirical relationships between microeconomic volatility and total exports, while the model without variable markups predicts the contrary relationship. Within the models with variable markups, the model with new exporter dynamics generates a quantitative relationship similar to the empirical observed in the data, as it predicts an elasticity between the micro volatility and total exports of around 1.09, which is 76% of the point estimates found in the empirical section - column (3) of Table 1, and which is 60% higher than the model without these dynamics. Abstracting from the existence of variable markups to simplify the analyses comes at the cost of missing the negative relationship between micro-volatility and total trade, consistent with the puzzle discussed in Alessandria et al. (2015). Abstracting from the existence of new exporting dynamics comes at the cost of quantitatively biasing the negative relationship between micro-volatility and international trade downward.

To put this result in context, when we compare the top and bottom 10% countries on the micro-volatility distribution, their difference is consistent with 103% difference in exports. Also, for example, the results imply that if Colombia faced the micro-volatility levels of Belgium or Sweden, their export would grow by 55% and 69% higher, respectively.

Quantitative result 3: Micro-volatility differences generate a positive relationship between exports and GDP per capita. Figure 4 shows the predicted relationship between total trade and GDP per capita that emerges by only changing the micro-volatility for the four models against the data relationship presented in column 1 of Table 1. Not surprisingly, the models with constant elasticity of substitution predicts a negative relationship between total exports and GDP per capita as we vary to microeconomic volaility, consistent with puzzling prediction by standard international trade models discussed in Waugh (2010), Fieler (2011), de Sousa et al. (2012), Alessandria et al. (2015) and Blum et al. (2019); unlike these models, the ones with variable markups predict a positive relationship quantitatively consistent with the data.

These differences in the predictions between models with constant elasticity and variable markups imply that the former models will need higher icebergs to export to match the empirical relationships as micro-volatility increases. But because as micro-volatility decreases, the GDP per capita increases, standard models that can capture this relationship due to their misspecification will predict lower iceberg costs to export with development to match the data. A back-of-the-envelope calculation implies in the new exporter dynamic model with the CES, due to its counterfactual predictions in the relationship between GDP per capita and total trade, driven by the micro-volatility differences, the estimated iceberg export cost should decrease by 0.73% for each percentage point increase in GDP per capita - assuming a trade elasticity of 2.5- so that the model can match the data. My country sample implies that the estimated iceberg cost to export by the CES model will be 67% higher in developing economies than in developed ones. [17] While seemingly a big number, this is in line with the quantitative cost differences found in Waugh (2010), and with the estimates

[17] The result follows by assuming a trade elasticity of 2.5. If we assume a trade elasticity in the range between 2.0 and 3.5, the iceberg cost differences would be between 51% to 91%

by de Sousa et al. (2012), who found that non-tariff barriers up to 90%. [18] Hence, according to our models prediction, cross-country micro-volatility differences can account for around 70% of the higher estimated export iceberg costs that developing economies face.

8 Conclusion

This paper studies how micro volatility affects international trade. When price elasticity is high enough, domestic volatility reduces the expected marginal return on investment, and this interacts with the relatively high costs of investments that exporters make to grow in foreign markets, depressing these investments and lowering trade. I show that this explanation is quantitatively consistent with my novel cross-country and firm-level export behavior and volatility evidence. To show the relevance of this explanation, I developed a novel general equilibrium model with new exporter dynamics with variable markup that successfully accounts for the micro and macro-level relationships in the data.

Furthermore, the model nest models with neither mechanism, allowing me to demonstrate that abstracting from the proposed firm-level features would lead one to infer much larger trade friction to match the aggregate trade flows and development data. Indeed, I show that cross-country volatility differences can explain up to two-thirds of unexplained trade differences across development. These trade differences are often attributed to relatively high non-policy trade costs in these countries without a clear understanding of their drivers. This paper proposes a new explanation for these non-policy estimated trade costs. They reflect the highly volatile microeconomic environment in developing economies, and standard models mis-specification, that can't capture the negative relationship between trade and volatility.

The mechanisms and findings of this paper may also contribute to different open questions related to international trade and cross-country development, as the model can be used to study how aggregate variables respond to different sources of risks arising from domestic and foreign sources. For example, on the international front, the model suggests a

[18] In the paper they argue that cost to export from developing economies are around 50% higher, but this is based on a trade elasticity of 8. If we adjust it to 2.5 to be consistent with our exercise, we get 90% additional iceberg costs

stronger role for trade policy uncertainty in dampening trade flows. Additionally, on the domestic side, domestic investment is likely distorted by the emphasized frictions generating differences in firm distribution across the level of development.

Furthermore, the relevance of micro-volatility for trade suggests we should focus on understanding the drivers of micro-volatility. A potential path is to analyze the role of macroeconomic volatility in generating the micro-volatility. In this case, macroeconomic stabilization, including fiscal, monetary, or commercial policy in developing countries, might have an important impact on the level of international trade, pointing toward the need to rethink the sources of gains from trade.

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Figures and Tables

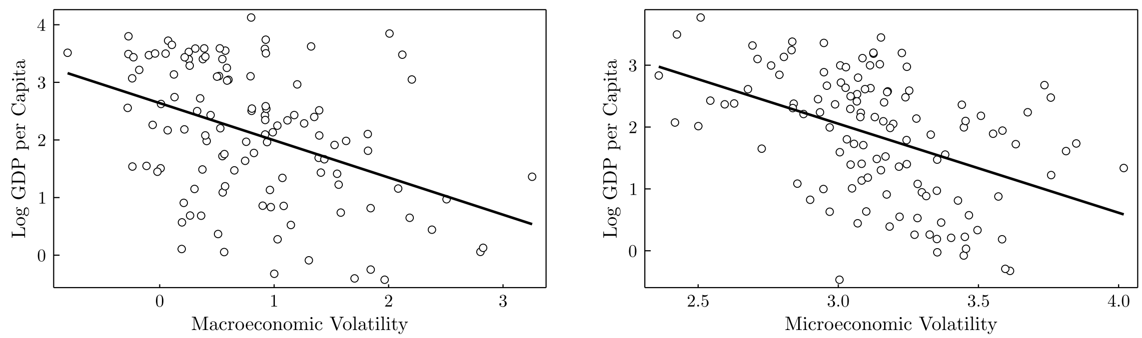
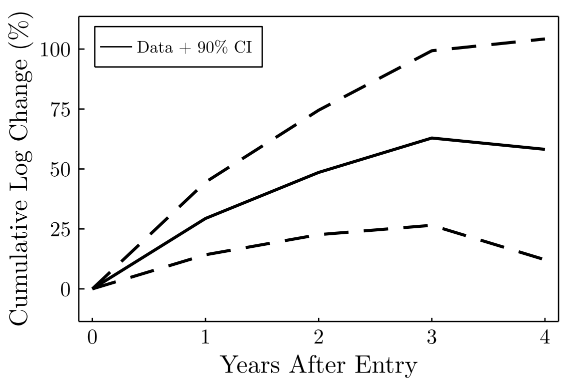
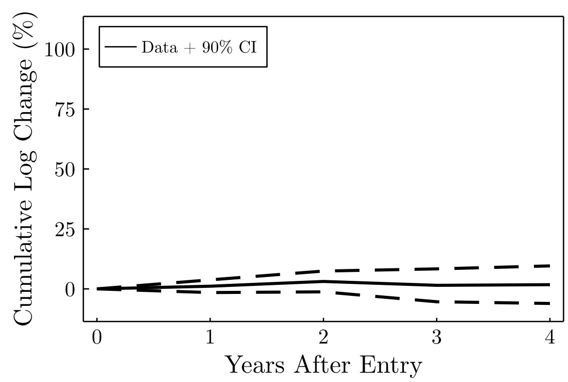


Figure 1: Volatility and GDP per Capita



(a) Quantity Dynamics



(b) Price Dynamics

Figure 2: New Exporter Dynamics

Note: Panel (a) shows the estimated log cumulative change in quantities relative to firms' first year of export to the market. Panel (b) shows the same but for price changes. A market is a six-digit product-destination combination. Both estimates include firm-product-time, product-destination-time, and cohort fixed effects. Firms in the sample are exporters that continuously export to each market, and a new exporter is a firm that exports at a time t, after three years of not exporting to the market. Standard errors in brackets. Error cluster at the firm level.

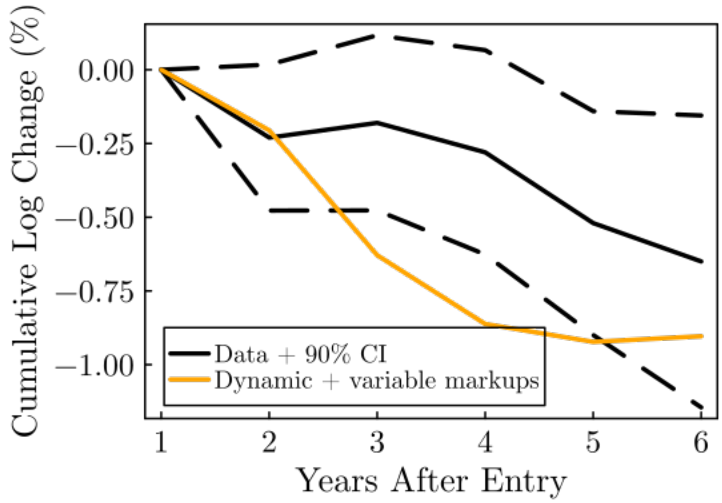
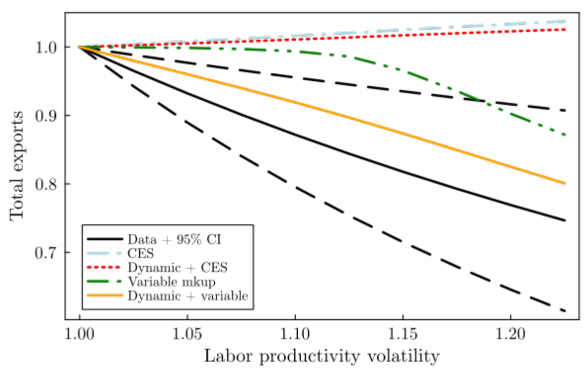
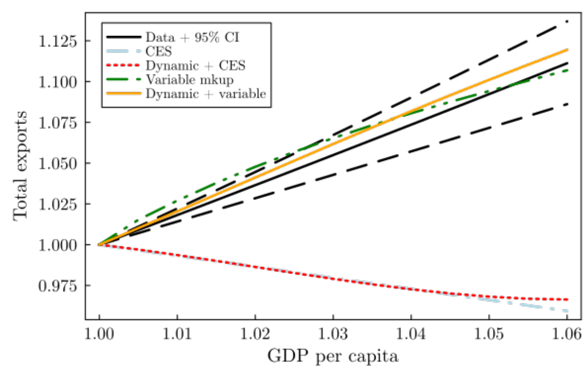


Figure 3: New Exporter Growth and Volatility: Model vs Data

Note: The data results are based on the estimates for Colombian firm level data only focusing on manufacturing. The yellow line shows the cumulative export intensity response elasticity predicted by the model when the micro volatility changes.



(a) Exports and micro volatility



(b) Exports and GDP per capita

Figure 4: Exports, volatility and GDP per capita

Note: The data results are based on Table 1. Micro volatility refers to the standard deviation of firms' changes in labor productivity.

Table 1: Microeconomic Volatility and Average Exports

	(1)	(2)	(3)	(4)	(5)
	Av. Exp	Av. Exp	Av. Exp	Av. Exp	Av. Exp
ln(GDP per capita)	1.81***	1.27***	0.92***	1.23***	0.98***
	[0.20]	[0.15]	[0.16]	[0.16]	[0.15]
ln(Micro Volatility)			-1.44**		-1.62***
			[0.62]		[0.49]
Observations	35211	35211	35211	35211	35211
R^2	0.75	0.85	0.91	0.89	0.93
Number of countries	38	38	38	38	38
Gravity Controls	Only Size	All	All	All	All
Doing Business	-	Exp	Exp	All	All

Note: Av. Exports denote the estimated value for α_i from equation (5). Trade flows are yearly at frequency. First Stage-Observation denotes the amount of observations used to estimate equation (5). The number of countries equals the observations for the second stage. Exp denotes controls for the doing business declared export cost. All add to the declared export costs, the contract enforceability index, and the financial development index. Standard errors in brackets are clustered at the origin country level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 2: Heterogeneous markup responses

Panel 1: First Stage

	(OLS)	(IV)	(IV)
	-	Δex. rate$_{d,t}$ $\times$ $share_{i,l,d,t-1}$	Δex. rate$_{d,t}$ $\times$ $share_{i,l,d,t-1}$
Δremittances$_{\neq d,t}$ $\times$ $share_{i,l,d,t-1}$	-	0.29***	0.41***
	-	[0.04]	[0.05]

Panel 2: Second Stage (Prices)

	$\Delta \log p_{i,l,d,t}$	$\Delta \log p_{i,l,d,t}$	$\Delta \log p_{i,l,d,t}$
Δexchange rate$_{d,t}$ $\times$ $share_{i,l,d,t-1}$	0.15***	0.71**	1.20***
	[0.05]	[0.33]	[0.36]

Panel 3: Second Stage (Quantities)

	$\Delta \log q_{i,l,d,t}$	$\Delta \log q_{i,l,d,t}$	$\Delta \log q_{i,l,d,t}$
Δexchange rate$_{d,t}$ $\times$ $share_{i,l,d,t-1}$	-0.04	-2.51***	-2.96***
	[0.19]	[0.72]	[0.81]
Observations	44,369	44,369	27,257
Firm-product-time FE	✓	✓	✓
Destination-product-time FE	✓	✓	✓
Controls $\times$ $share_{i,l,d,07}$	GDP, TOT	GDP, TOT	GDP, TOT
Exporter Age	≥ 3	≥ 3	≥ 4

Note: Panel (1) shows the first stage results. Panel (2) shows the results using the log difference of unit values over a year. Panel (3) shows the estimated results for quantities exported. Exporter age denotes the minimum age of an exporter in the sample. Controls $\times$ $share_{i,l,d,07}$ denotes the addition of controls by intersecting of firms' sales share to that market intersected with the destination market terms of trade and real GDP. Standard errors in brackets.
Error cluster at the destination country. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 3: Calibrated Parameters

Parameters	Variable markups + Dynamics	CES + Dynamics	Variable markups + Static	CES + Static	Rationale
β	0.96	0.96	0.96	0.96	Yearly frequency discount rate
γ	2.5	2.5	2.5	2.5	Armington elasticity
Parameters estimated within model					
θ	2.90	3.80	2.90	3.80	"Average" price elasticity
η	4.20	-	5.60	-	Super elasticity
σ^{ω}	0.48	0.48	0.48	0.48	Firms' labor productivity s.d.
ρ^{ω}	0.61	0.61	0.61	0.61	Firms' labor productivity persistence
ν	0.71	-	0.71	-	Home bias
f_e	0.08	0.043	1.5	0.10	Exporter fixed costs
α	0.70	0.74	-	-	Customer capital: curvature
ϕ	3.72	14.30	-	-	Investment adjustment cost
δ	0.24	0.42	-	-	Customer capital: depreciation
A^{min}	0.01	0.02	1.00	1.00	Customer capital: Initial value
τ	0.44	0.2	0.38	0.61	Iceberg cost

Table 4: Target Moments

Moment	Data	Variable markups + Dynamics	CES + Dynamics	Variable markups + Static	CES + Static
Average markup	0.45	0.44	0.35	0.45	0.35
Markup sensitivity estimates	0.71	0.63	-	0.66	-
Share of exporters	0.19	0.19	0.2	0.23	0.2
Trade openness	0.37	0.37	-	0.37	-
Av export intensity new exporters	0.40	0.40	0.16	-	-
Av. export intensity	0.45	0.50	0.23	0.46	0.25
S.d. domestic sales shocks	0.36	0.30	0.58	0.30	0.58
Persistence domestic sale shocks	0.47	0.49	0.57	0.46	0.58
Av. growth 2nd year	0.13	0.18	0.18	-	-
Av. growth 3rd year	0.31	0.30	0.31	-	-
Av. growth 4th year	0.40	0.39	0.4	-	-
Av. growth 5th year	0.47	0.45	0.47	-	-
Av. growth 6th year	0.55	0.5	0.52	-	-

Appendix

A Appendix: Cross country Data and Estimation Robustness

Here, I present more details about the data used for the cross-country analyses and the robustness of the cross-country estimates.

A.1 Cross country Data

Penn World Tables. This data covers 183 countries between 1950 and 2019. I use this data for the country's total factor productivity and other aggregate variables such as GDP, and export and import prices. [19]

Dynamic Exporter Database. This data source provides data on the number of exporters, average exports per exporter, entry and exit rates, and new exporter growth. The data is at the origin-destination-year level. This new data has been used by Fernandes et al. (2019) and Fernandes et al. (2015). It provides data to compute the relevance of the intensive and extensive margin of trade to account for the relationship between total exports and volatility. Its disadvantage is the limited coverage of countries. It covers 70 countries from 1990 to 2012, but for most countries only covers from 2005 to 2012.

CEPII. I use two datasets from the CEPII foundation, the "Gravity" data set and the "TradeProd" data set. [20] The first data provides information on variables relevant to explain bilateral trade across countries, such as the existence of trade agreements, geographical characteristics, variables measuring cultural proximity, and the existence of a common currency. The data set covers the years 1948 to 2019.

The "TradeProd" data set provides information on bilateral trade, production, and protection in compatible industry classifications for developed and developing countries. This data runs from 1980 to 2006 for 26 industrial sectors within manufacturing—this data set yields bilateral product level exports across countries. The advantage of this data source over the Dynamic exporter database is the extended period and the number of countries. The disadvantage is the lack of data on the margins of trade for different exporters. The data

[19] See Feenstra et al. (2015) for more details.

[20] See Head et al. (2010) and De Sousa et al. (2012) at CEPII foundation webpage for more detailed about these data sets

on manufacturers serves as a robustness check to show that the results are not driven by differences in sectoral composition across development levels.

Enterprise Survey from the World Bank. This data set provides comparable data across countries on sales, labor, and capital for firms in each country. I use labor and labor productivity changes to construct comparable measures of the microeconomic volatility in each country.

A.2 Relationship Between GDP per Capita and Volatility.

Figure 1 shows a negative relationship between the average level of GDP per Capita (Y-axis) and each measure of volatility (X-axis). Each variable is presented in logs, and the standard deviations for each measure are in percentage points. When I compare the average level of microeconomic volatility, I find that developing countries are 59% more volatile than developed countries for the sub-sample of countries I have data. When I focus on the macroeconomic volatility, developing countries are on average 74% more volatile than developed ones. [21]

A.3 Cross-Country Estimation

Measurement of microeconomic volatility. There are some potential concerns about using the cross-sectional standard deviation of the changes in firm-level domestic sales to measure volatility. To test for different measures, I use three measures and present the results in Table 3. Ont measures is construct using the firm-level labor productivity for those that do not export or import denoted as *Micro Volatility*$^{tfp}_{NonExpo}$, the other is using the labor productivity but for all firms, denoted as *Micro Volatility*$^{tfp}_{All}$. The final is measure, denoted by *Micro Volatility*^{Coomon}, is using the common component of the three measures constructed using the principal component method.

A.4 Volatility and The Margins of Export

I examine how the different margins of trade react to these differences in levels of volatility. Table 2 shows the result when I use the microeconomic volatility measure, with 68% of the reduction in exports due to the intensive margin, 55% because of the extensive margin, and

[21] I define developed economies as those with a GDP per capita (PPP at 2011 us dollar) above 30,000.

-23% associated with the compositional margin. This finding suggests that volatility generates higher sorting into the export market and that the uncertainty channel is big enough to counteract the possible positive effect of higher volatility through the distributional margin.

B Appendix: Firm-level Estimation

B.1 Estimation of Markup response: Instrumental variable approach

In this appendix section I present more details of the estimation procedure to estimate how markups response to exchange rate changes depending on their firms sale shares.

To test if markup changes vary with exporters' market share, we can then estimate

$$\Delta p_{i,d,l,t} = \beta \Delta e_{i,d,l,t} \times \text{exp. share}_{i,d,l,t-1} + \beta_2 \text{exp. share}_{i,d,l,t-1} + \gamma^1_{i,l,t} + \gamma^2_{i,l,d} + \gamma^3_{l,d,t} + e_{i,d,l,t} \quad (31)$$

where Δ denotes log differences of the variables over a year. $\gamma^1_{i,l,t}$ denotes the firm-product-time fixed effects and ,$\gamma^3_{l,d,t}$ denotes the product-destination-fixed effects. Under the previously mentioned assumptions, β captures the differential markup responses to movements in the exchange rate due to firms' differences in their market share. Note that while this estimation producer captures the markup responses to shocks, it cant be used to estimate the level of markups. [22]

To estimate β without bias we need to abstract from the exchange rate variation that might reflect changes in the average productivity of the destination country, as this can bias the estimate. However,I use an instrumental variable approach that solve this concern. I instrument the bilateral exchange rate variation intersected with the firm's sales shares with the remittances flows from third countries to Colombia interacted with firms' sales shares to that destination. The first stage is then given by

$$\begin{aligned} \Delta e_{i,d,l,t-1} \times \text{exp. share}_{i,d,l,t-1} = {} & \Delta remittances_{d,t} \times \text{exp. share}_{i,d,l,t-1} + \\ & + \text{exp. share}_{i,d,l,t-1} \times crtl_{d,t} + \theta_{i,l,t} + \gamma_{l,d,t} + e_{i,d,l,t} \end{aligned}$$

Two assumptions are needed to validate this procedure. First, the remittance flows to Colombia affect the exchange rate of Colombia with the rest of the countries; this seems natural as the average net remittances to Colombia represent, on average, 10% of the total

[22] I also control for potential trends in prices, as the ones we would expect to be driven by inflation, by adding firm-product-destination fixed effects $\gamma^2_{i,l,d}$. Still, the qualitative results are invariant to adding these fixed effects.

export flow. Also, it has been documented that the remittances are unlikely to vary due to exchange rate variation. [23]

The second assumption is that shocks affecting the remittances to Colombia from a third country do not generate differential price changes for a product sold in several destinations after controlling for the common shocks that may hit all the destination countries. Conditional on global, destination market shocks, and common firm's marginal cost, the changes in remittances from a third country cannot be generated by shocks affecting the relative differences in firms the export share from the Colombian firm.

For example, imagine we have Colombia and three other countries: the USA, Argentina, and Brazil. To violate this exclusion restriction, we would need the shock that changes the remittance flows from the USA to Colombia to affect the Colombian firm's relative price changes between Brazil and Argentina, conditional on the aggregate shocks affecting each country.

B.2 New exporter dynamics

I revisit the facts documented in Fitzgerald et al. (2021) and Steinberg (2021) to understand how Colombian exporters grow over their life cycle. I find that while, on average, exporters increase the number of exports over their life cycle, this is not true for observed prices. Exporters grow into foreign markets by shifting their demand, conditional on prices. The evolution of quantities in a particular market, defined as a six-digit product and destination pair, by estimating:

$$\ln \text{export}_{i,d,l,t} = \sum_{h=0}^{5} \beta_h \mathbb{I}^h_{\{age=h\}} + \ln p_{i,d,l,t} + \gamma^a_{i,l,t} + \gamma^b_{d,l,t}\gamma^c_{p\text{cohorts}} + \epsilon_{i,d,l,t}$$

where $\text{export}_{i,d,l,t}$ represents the total export value that firm i is selling of product l to destination d in year t. I project total markets against a dummy variable $\mathbb{I}^h_{\{age=h\}}$ that equals one when the exporters spent h years continuously selling product l to destination d. I control for the prices of the product, $p_{i,d,l,t}$, and I include firm-product-time fixed effects,

[23] See Mandelman (2013) and Lartey et al. (2012) for a discussion on the effect and relevance of remittances on the exchange rate, and Mandelman et al. (2020) for the small response of remittances to exchange rates

$\gamma^a_{i,l,t}$, and product-destination-time fixed effects $\gamma^b_{d,l,t}$. Adding these fixed effects allows me to purge out the common variation in sales for firm i of product l at time t; the second set of fixed effects allows me to purge out the common variation across exporters within a destination product time. To understand the price dynamics over the exporter's life cycle, I estimate the same equation but without controlling for prices:

$$\ln p_{i,d,l,t} = \sum_{h=0}^{5} \beta^p_h \mathbb{I}^h_{\{age=h\}} + \gamma^a_p{}_{i,l,t} + \gamma^b_p{}_{d,l,t} + \gamma^c_p{}_{\text{cohorts}} + \epsilon_{i,d,l,t}$$

in this case, β^p_h captures the differential changes in prices over the life cycle of the exporter relative to the common variation in prices for that product l at time t.

By construction β^p_0 and β_0 are set to zero so that each estimate of $\{\beta_h\}^H_{h=1}$ or $\{\beta^p_h\}^H_{h=1}$ captures the cumulative change of the dependent variable to the exporter entry value. New exporters, the ones with age equal to zero, are defined as those exporters that did not export any positive amount to that product-destination market in the last three years[24].

B.3 Volatility and Sales Dynamics Over Exporter Life Cycle

Table 3 presents the estimation of equation (9). Column 1 to column 3 presents the results using the measure of domestic sales volatility as described in (8). Column (1) includes firm fixed effects for those exporters with 2 years or more continuously exporting to the market (product-destination), column (2) includes firm-year fixed effects, and column (3) presents the same estimation of column (2) for those exporters that exported 5 years to each market. Column (4) and (5) presents the estimation results of running the same estimation as in column (2) but using two different measures as described below.

The measure of volatility use in Column (4) is constructed as follows:

1. Compute the log difference on one year of the real domestic sales of each firm i, defined as Δdom. sales

[24] This implies that I lost the first three years of my sample since I cannot observe if the exporters did any export before.

2. Compute the cross-section standard deviation of Δdom. sales, for each year t of those firms with main products of export in the sixth digit belong to the product category J. And take the average over time, for each 6 digit product j. Denote this measure by sd_J^{hs6}
3. Compute the weighted mean by the total of exports of each 6-digit product J on the 4 digit product category K of sd_J^{hs6}. Denoted as sd^{hs4}, which contains a vector for each of 4 digit products of exports.
4. Take the lof of sd^{hs4}

The measure of volatility use in Column (5) is constructed as follows:

1. Restrict the sample to those exporters with at least 2 products and two countries of destination.
2. First compute the common changes in the exports of a firm to all of the products $\gamma_{i,t}$, by estimating:

$$\Delta exp_{i,l,d,t} = \gamma_{i,t} + \theta_{d,l,t} \tag{32}$$

3. Compute the cross-section standard deviation of $\gamma_{i,t}$, for each year t, of those firms other than i with main products of export in the sixth digit belong to the product category J. And take the average over time, for each 6 digit product j. Denote this measure by $sd_J^{hs6,Cexp}$

The similar patterns documented in columns (1) and (3), and in columns (4) and (5), suggest that the possible selection because of entry and exit, which may bias the result, are not enough to change the patterns. Column (4) shows that if we also use the domestic changes in sales for firm i to compute the volatility measures, the patterns observed between the exposure to domestic volatility and their relative growth still hold. Lastly, column (6) use a measure of the variations in sales that are common across the markets exporters served to construct the volatility measure. This measure captures shocks common to the firm across the markets it serves, alleviating the concerns that these results may drive demand shocks. The similarity in the estimates and patterns suggests that the changes in demand shocks in the domestic market, the foreign market, or the entry or exit of exporters are not behind the patterns observed in the data.

C Model

C.1 Proofs

Lemma 1. Under monopolistic competition and linear production function, if the curvature of the revenue function is concave on firms' productivity, then a mean preserving spread reduces total exports. The contrary is true for the convex case.

Proof. Total exports can be written as:

$$Exp = A^{\alpha} \int p(z)\hat{q}(z)dF(z)$$

Is enough to prove that both $p(z)\hat{q}(z)$, and A^{α} are decreasing in volatility. So let's start by the last term of the equation, where the argument follows by Jensen's' inequality. Note that is revenues are concave on firm's productivity, then $p(z)\hat{q}(z)$ is concave as A is given at any point in time. Define $g(z) := p(z)\hat{q}(z)$, then $\mathbb{E}_z[g(z)] = (\int p(z)\hat{q}(z)dz)$. Assume that Y is a random variable with mean zero, and independent on X. We can then define $X = Z + Y$, so that X is a mean preserving spread over Z. Now note that

$$\mathbb{E}_X[g(X)] = \mathbb{E}_Z[\mathbb{E}_Y[g(Z+Y)|_Z]] \leq \mathbb{E}_Z[g(Z + \mathbb{E}_Y[Y|_Z)]] = \mathbb{E}_Z[g(Z)]]$$

Where the inequality is followed by Jensen's inequality. Now, I will show that A is decreasing in volatility if revenues are concave. Note that because production is linear in labor, and revenues concave, profits are concave in productivity too. Note that by equation (2), are proportional to $\left\{\mathbb{E}_{F'}\left\{\hat{\pi}(z',1)|_{z=z}\right\}\right\}^{\frac{1}{1-\alpha}}$. By the argument above, $\mathbb{E}_{F'}\left\{\hat{\pi}(z',1)|_{z=z}\right\}$, will be decreased under a mean preserving spread.

Lemma 2. Under monopolistic competition and linear production function, with continuous revenue function in firms' productivity, if the curvature of the revenue function in the model is miss-specified - assuming convexity instead of concavity with respective to firms productivity- the model will estimate higher firm-level iceberg costs when volatility is reduced.

Proof. Let Exp^{e1} denote the total export from the data-generating process from Economy 1, and Exp^{e2} the data on total exports for Economy 2. For simplicity, assume the structural parameters of these economies are the same, except that for Economy 2, firms face a higher conditional volatility than Economy 1. By lemma 1, then we have that $Exp^{e1} > Exp^{e2}$.

Denote the log differences between these economies by $\Delta Exp = \ln Exp^{e1} - Exp^{e2}$. By lemma 1, this implies that in the true data generating process $\Delta Exp > 0$.

Now, let's denote the predicted export change of the model with convex revenue function when we have a mean preserving spread over firms productivity as $\Delta Exp^{\text{convex model}}$. By lemma 1, a model with convex revenue function predicts $\Delta Exp^{\text{convex model}} < 0$; as a mean, preserving spread in these models will increase exports.

Now, let's define $\ln \hat{\tau}$ as the difference between the prediction of the convex model and the true data-generating process where profits are concave. Hence we have that

$$\ln \hat{\tau} := \Delta Exp - \Delta Exp^{\text{convex model}} > 0$$

By definition, then, we have

$$\ln \hat{\tau} = \ln(\frac{Exp^{e1}}{Exp^{e2}}) - \ln(\frac{Exp^{\text{convex model},e1}}{Exp^{\text{convex model},e2}}) > 0$$

So we get that,

$$\ln(\frac{Exp^{e1}}{Exp^{e2}}) = \ln(\frac{Exp^{convex,e1}}{Exp^{convex,e2}}) + \ln \hat{\tau}$$

Such that

$$\frac{Exp^{e1}}{Exp^{e2}} = \frac{Exp^{convex,e1}}{Exp^{convex,e2} \ \hat{\tau}^{-1}}$$

This implies that if the model revenue function is miss specified, using convex revenue functions, when the data generating process is concave, we will need the predicted exports by the convex model to be reduced by $\hat{\tau} > 1$, when we increase firms' productivity volatility to match the total export variation observed in the data. The adjustment must compensate for the predicted model increase in ΔExp^{convex} due to the revenue miss-specification.

Now, I show that conditional on all the structural parameters of the economy, except for those shaping the mean preserving spread, exists a marginal cost $\hat{mgc}$ that is higher than the actual marginal cost of production denoted by mgc for all firms, such that

$$\int rev(\hat{mgc})dF = Exp^{\text{convex model},e2}\ \hat{\tau}^{-1}$$

Hence is sufficient to show that there exists an $\hat{mgc}$, such that,

$$rev(\hat{mgc}) = \frac{rev(mgc)}{\hat{\tau}}$$

where mgc, is such that,

$$\int rev(mgc)dF = Exp^{\text{e2}}$$

It is sufficient to show that there exists an $\hat{mgc}$, such that,

$$rev(\hat{mgc}) = \frac{rev(mgc)}{\hat{\tau}}$$

To prove it, assume the contrary. We have two cases. The first case is $\hat{mgc} \leq mgc$ for some firms, and the previous equalities hold. Let's start with the case of equality for all firms since $\tau > 1$; this is a contradiction by lemma 1.

Now assume for some firms $\hat{mgc} < mgc$, and for the rest, it holds with equality. Since $\hat{\tau} > 1$, this implies that revenues are increasing in the marginal cost- a contradiction.

The second case is that for every possible marginal cost higher than the benchmark one, we have that $\int rev(\hat{mgc})dF > Exp^{convex,e2}\ \hat{\tau}^{-1}$This implies that the revenue function is bounded below and above zero, as $\infty > \tau > 1$, and $Exp^{convex,e2} > Exp^{convex,e1} > 0$ by Lemma 1.

But by firms' problem if $\hat{mgc} \to \infty$ it implies that $p \to \infty$. Now we have two options. The first option is that as prices converge to infinity, revenues converge to infinity, but this implies revenues increase with the marginal cost of production, a contradiction. The second one is that revenues converge to zero as prices converge to infinity. This latter case implies that $Exp^{convex,e2}\ \hat{\tau}^{-1} < 0$— another contradiction by Lemma 1. Now that we know that $\hat{mgc} > mgc$, such that $\int rev(\hat{mgc})dF(z) = Exp^{convex,e2}\ \hat{\tau}^{-1}$, we can define the firm-level iceberg costs

$$\tau := \frac{\hat{mgc}}{mgc} > 1$$

which is the common firm-level iceberg cost needed by the convex revenue model such that it match the data after a mean preserving spread.

Lemma 3. Under monopolistic competition and linear production function, if the price elasticity is decreasing and sensitive enough to firms' prices, then revenues are a concave function of firms' productivity.

Proof. without loss of generality abstract from customer capital to facilitate the notation. Hence, revenues will be written as $rev(z) = p(z)q(p(z))$. We need to show that if price elasticity is sensitive enough, then we can have that, $\frac{\partial^2 rev(z)}{\partial^2 z} \leq 0$ Let's start by writing the revenue change relative to the firm's productivity as follows

$$\frac{drev(z)}{dz} = \frac{dp}{dz}\left[q + p\frac{\partial q}{\partial p}\right]$$

Now take the second difference,

$$\frac{d^2rev(z)}{dz^2} = \frac{d^2p}{dz^2}\left[q + p\frac{\partial q(p)}{\partial p}\frac{\partial p}{\partial z}\right] + \frac{dp}{dz}\left[2\frac{\partial q(p)}{\partial p}\frac{dp}{dz} + p\frac{\partial^2 q(p)}{\partial p^2}\frac{dp}{dz}\right]$$

Which we can group as

$$\frac{d^2rev(z)}{dz^2} = \frac{d^2p}{dz^2}\left[q + p\frac{\partial q(p)}{\partial p}\right] + \left(\frac{dp}{dz}\right)^2\left[2\frac{\partial q(p)}{\partial p} + p\frac{\partial q(p)}{\partial p} + p\frac{\partial^2 q(p)}{\partial p^2}\right]$$

Now, we know that $\frac{d^2p}{dz^2} \geq 0$, as we assume the price elasticity decreases with firms' productivity, in constant with the; we also know that price elasticity is negative $\frac{\partial q}{\partial p} < 0$. Note that $\frac{\partial q}{\partial p} = \theta\frac{q}{p}$, where $\theta < -1$. Now let's denote the elasticity of the price elasticity with respect to the firm's price as $\eta_{-\theta,p}$, and note that the second derivative of quantities with respect to prices is,

$$\frac{\partial^2 q}{\partial p^2} = [\eta_{-\theta,p} - 1 + \theta]\,\frac{\theta q}{p^2}$$

Then, we can rewrite the second derivative of the revenue function as

$$\frac{d^2 rev(z)}{dz^2} = \underbrace{\frac{d^2 p}{dz^2}\,[q(1+\theta)]}_{<0} + \left(\frac{dp}{dz}\right)^2 \left[2\frac{\theta q}{p} + [\eta_{-\theta,p} - 1 + \theta]\,p\frac{\theta q}{p^2}\right]$$

So we have that,

$$\frac{d^2 rev(z)}{dz^2} = \underbrace{\frac{d^2 p}{dz^2}\,[q(1+\theta)]}_{<0} + \left(\frac{dp}{dz}\right)^2 \frac{\theta q}{p}\,[1 + \eta_{-\theta,p} + \theta]$$

Note that in the case of constant price elasticity, we have $\eta_{-\theta,p} = 0$, and hence the second term is positive. But, when the price elasticity is not constant $\eta_{-\theta,p} > 0$. Furthermore, if $\eta_{-\theta,p} > -\theta - 1 > 0 \forall z$, then the second term is negative, and we have that $\frac{d^2 rev(z)}{dz^2} < 0$.

D Algorithm

The model only needs to solve for the steady state of the economy given different parameters for σ, and its counterpart adjustment in μ, and ρ, such that we only do a mean preserving spread over the conditional volatility of firms productivity.

I solve the model using global methods, given the highly non-linearities of the firm's problem. Note first that the firms' domestic decision is a static one, and we only need to solve for the optimal prices. To solve for the export decision, firms need to know their customer capital level A, their productivity z_i, and domestic wages, w, with which they need to make a proper forecast for z_i', and w'. In principle, firms need to know the firm's distribution to solve for w and w'. But because I will solve for the steady distribution, instead of using the firms' distribution as a state variable, which is infeasible, or using the Krussel Smith method, I will use wage prices as a state variable, which is sufficient to characterize the firm's decision, given the assumption of the small open economy.

To solve for the aggregate equilibrium of the economy, I process the following. When calibrating the model, I set the wage equal to one. This allows me to set wages equal to one in the baseline economy without any shocks. For each change in the volatility parameters, I solve for the whole value function, policy functions, and aggregate economy again.

For each parameter value, the solution is computed as follows:

1. Fix the parameter values of the problem. and pre-set ϵ to small value.
2. Set a grid space of the size $(20X85X10)$ for firms' productivity, customer capital, and wages. Solve for the optimal value function and optimal policy function using global methods.
3. Pre-set wages to w^n
4. Use the obtained optimal policy function to expand the grid space to $(100X120)$ possible grid points for state variable. Compute a Markov transition matrix for the firms' measure for state variable, $H(.)$ conditional on wages w^n
5. Pre-set a non-degenerate aggregate distribution Ψ^j, conditional on wage w^n
6. Update Ψ using the Markov transition matrix until $|\Psi^{j+1} - \Psi^j| \leq \epsilon$
7. Using Ψ, compute the aggregate variable and the domestic choke price p_d^c
8. Compute the excess labor demand $\Delta L = L^d - L^s$.
9. If the labor excess demand $|\Delta L| > \epsilon$, update $w^n = w^{n+1}$ and start from 3 again.

I fix a wage level, and using the expanded space, I compute the Markov transition matrix for each firm state based on the firms' optimal decision, conditional on the pre-set wage. Using the transition matrix, I can update the aggregate distribution until it converges given a wage. Then I can construct a labor demand and supply after solving for all the equilibrium objects, and check if the labor market clear. If it does not, I adjust wages and start the process again.

E Appendix - Figures and Tables

Table 1: Robustness Measures Microeconomic Volatility and Exports

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Av. Exp	Av. Exp	Av. Exp	Av. Exp	Av. Exp	Av. Exp	Av. Exp	Av. Exp
ln(GDP per capita)	1.81***	1.27***	0.92***	1.23***	0.98***	0.92***	0.94***	0.93***
	[0.20]	[0.15]	[0.16]	[0.16]	[0.15]	[0.17]	[0.16]	[0.16]
ln(Micro Volatility)			-1.44**		-1.62***			
			[0.62]		[0.49]			
$ln(\text{Micro Volatility}^{tfp}_{NonExpo})$						-0.96**		
						[0.46]		
$ln(\text{Micro Volatility}^{\text{tfp}}_{All})$							-0.84*	
							[0.46]	
$ln(\text{Micro Volatility}^{\text{Common}})$								-0.14**
								[0.07]
Observations	35211	35211	35211	35211	35211	35211	35211	35211
R^2	0.75	0.85	0.91	0.89	0.93	0.93	0.92	0.93
Number of countries	38	38	38	38	38	38	38	38
Gravity Controls	Size	All	All	All	All	All	All	All
Doing Business	-	Exp	Exp	All	All	All	All	All

Note: The table replicates the results of Table 1 using different way of computing aggregate volatility. Standard errors in brackets. Error cluster at origin country. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 2: Microeconomic Volatility and Average Export

	Total exports	Total exports	Exporters	$\text{Exports}_{\text{Inc. firm}}$
$\frac{\text{GDP}}{\text{L}}$	0.74***	0.53**	0.96***	-0.39*
	[0.20]	[0.24]	[0.14]	[0.20]
ln Micro-Volatility$_i$		-1.42**	-0.78**	-0.97**
		[0.61]	[0.38]	[0.43]
First-stage Observations	36229	36229	36229	36229
R^2	0.85	0.87	0.94	0.86
Numb. Countries	38	38	38	38
Year $\times$ Destination $\times$ Product FE	✓	✓	✓	✓
Gravity Controls	✓	✓	✓	✓
Doing Business	All	All	All	All

Standard errors in brackets. Error cluster at country level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 3: Volatility, Sales Dynamics and Exporter Life Cycle.

	(1)	(2)	(3)	(4)	(5)
	$\Delta\frac{\text{exp}_{ildt}}{\text{tot. sales}}$	$\Delta\frac{\text{exp}_{ildt}}{\text{tot. sales}}$	$\Delta\frac{\text{exp}_{ildt}}{\text{tot. sales}}$	$\Delta\frac{\text{exp}_{ildt}}{\text{tot. sales}}$	$\Delta\frac{\text{exp}_{ildt}}{\text{tot. sales}}$
$\ln \text{Volatility}_{it}$	0.00	-	-	0.01	-
	[0.02]	-	-	[0.03]	-
$\mathbb{I}_{\{age_{ildt}=2\}} \times \ln \text{Volatility}_{it}$	-0.01	0.00	0.01	-0.01	0.04
	[0.03]	[0.04]	[0.05]	[0.02]	[0.08]
$\mathbb{I}_{\{age_{ildt}=3\}} \times \ln \text{Volatility}_{it}$	-0.00	-0.01	-0.04	-0.00	0.02
	[0.04]	[0.05]	[0.07]	[0.02]	[0.12]
$\mathbb{I}_{\{age_{ildt}=4\}} \times \ln \text{Volatility}_{it}$	-0.08	-0.10	-0.17	-0.06*	-0.15
	[0.05]	[0.07]	[0.10]	[0.03]	[0.16]
$\mathbb{I}_{\{age_{ildt}=5\}} \times \ln \text{Volatility}_{it}$	-0.22***	-0.26***	-0.41***	-0.13***	-0.62***
	[0.08]	[0.10]	[0.15]	[0.04]	[0.23]
$\mathbb{I}_{\{age_{ildt}=6\}} \times \ln \text{Volatility}_{it}$	-0.48***	-0.57***	-0.71***	-0.17**	-0.78**
	[0.14]	[0.17]	[0.24]	[0.07]	[0.39]
Observations	23,710	23,121	14,956	23,197	21,174
R-squared	0.26	0.30	0.36	0.29	0.23
Firm FE	✓	-	-	-	-
Firm-year FE	-	✓	✓	✓	✓
Product-year FE	✓	✓	✓	✓	✓
Destination-year FE	✓	✓	✓	✓	✓
First month-year	✓	✓	✓	✓	✓
Age exporting	≥ 2	≥ 2	$= 5$	≥ 2	≥ 2
Volatility measure	Benchmark	Benchmark	Benchmark	No leave out	Common effect

Note: The table presents the estimation of equation (9). Column (1) use the benchmark measures of domestic exposure to volatility. Column (4) and Column (5) use other two measures of volatility described in B.3. Age exporting denotes the minimum years that exporters continuously export to each market in the sample. Error cluster at the firm level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$