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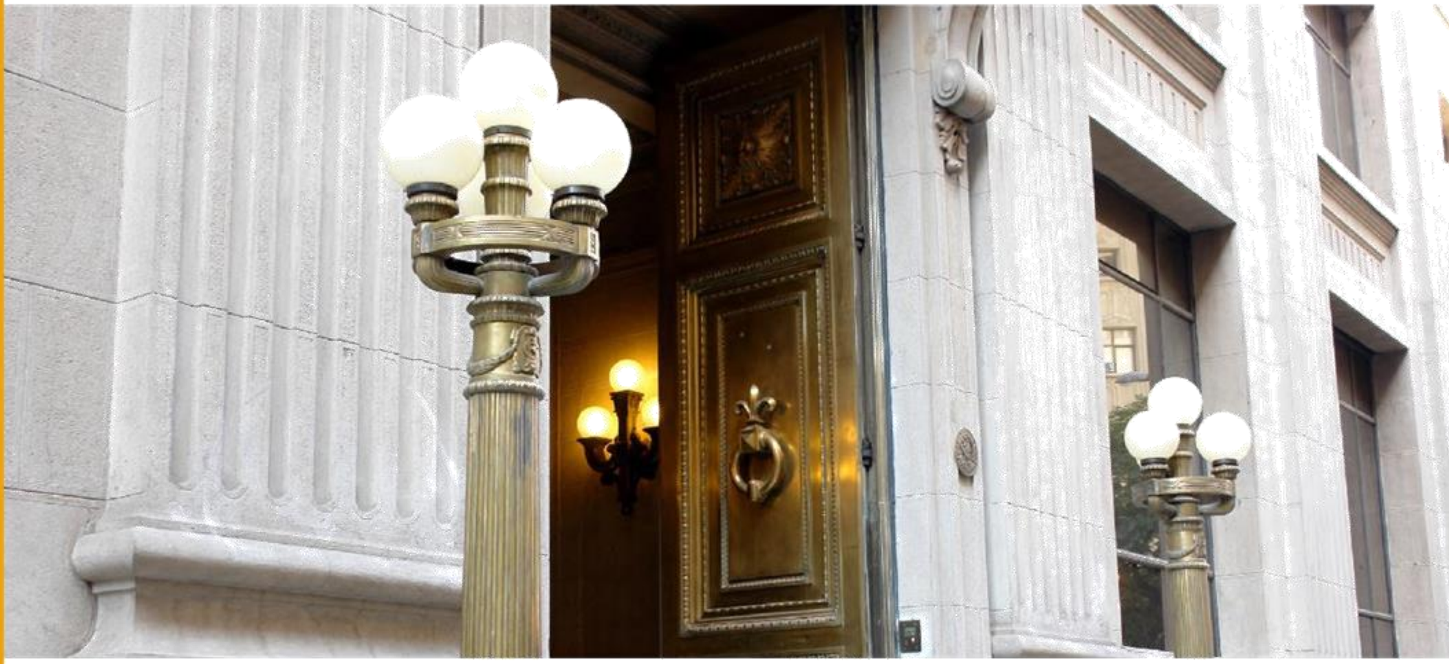

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Firm Export Dynamics and the Exchange Rate: A Quantitative Exploration

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Abstract

This article provides a theoretical model of firm dynamics that replicates the export elasticity values estimated in the empirical literature, and the heterogeneous export response of firms against exchange rate fluctuations. I analyze alternative versions of the model, which allows for a decomposition of the contributions of the different mechanisms (distribution costs, imported intermediate inputs, gradual growth of foreign demand, market access costs in foreign/domestic currency). I evaluate the intensive and extensive margins of exports, and examine the behavior at the aggregate and firm levels. Distribution costs represent the most important factor, but are not sufficient, to replicate elasticity estimations. I show that this mechanism substantially exceeds the relevance of imported intermediate inputs. Distribution costs allow the model to replicate the heterogeneous response of foreign sales to exchange rate movements by decreasing the demand elasticity of more productive firms. I provide a quantitative test using firm-level panels constructed from model simulations and contrast the results with empirical specifications.

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Resumen

En este artículo se presenta un modelo teórico de dinámica de firmas que replica la elasticidad de las exportaciones con respecto a fluctuaciones del tipo de cambio que se documenta en la literatura empírica, así como también la heterogeneidad de esta elasticidad a nivel de las firmas. Se analizan distintas versiones del modelo, lo que permite una descomposición de las contribuciones de diferentes mecanismos (costos de distribución, insumos intermedios importados, crecimiento gradual de la demanda externa, costos de acceso al mercado externo en moneda doméstica/extranjera). Se evalúan los márgenes intensivos y extensivos de las exportaciones, y se analiza el comportamiento a nivel agregado y de las firmas. Los costos de distribución representan el factor de mayor relevancia, pero no son suficientes, para replicar las estimaciones de elasticidades. Se demuestra que este mecanismo es de mayor importancia que el rol de los insumos intermedios importados. Los costos de distribución permiten que el modelo replique la respuesta heterogénea de las exportaciones a movimientos del tipo de cambio, al disminuir la elasticidad de demanda de las firmas más productivas. Se provee una evaluación cuantitativa mediante paneles de firmas construidos a partir de las simulaciones del modelo, lo cual se compara con resultados empíricos.

1 Introduction

Understanding the impact of exchange rate movements on international trade flows is crucial in macroeconomics and for economic policy given their influence on economic activity and the adjustment process of current account balances (see for example, IMF, 2015 Ch. 3). Furthermore, the empirical evidence linking exchange rate depreciations and aggregate exports is often misinterpreted, and researchers frequently caution against instrumenting policies to exploit this relationship as a means of promoting export growth (Auboin and Ruta, 2013; Freund and Pierola, 2012).

The response of exports to movements in real exchange rates has been found to be rather limited in empirical work, with typical elasticities below one. Moreover, it has been documented that high-performance firms are less responsive to exchange rates. This may contribute to explain the weak overall impact of exchange rate movements on aggregate exports, given the predominance of high-productivity firms in international trade. Theoretical work, however, has not established a unified quantitative framework that accounts for these facts. Moreover, a consensus has not been achieved in terms of the main mechanisms that determine aggregate export elasticity or firm export behavior (I review the literature below). This article contributes to the literature and economic policy discussions by providing a theoretical model of firm dynamics that replicates the export elasticity values documented in the empirical literature, and the heterogeneous export response of firms against exchange rate fluctuations.

The model incorporates different features that shape firm-level production and investment decisions, and therefore determine the export supply function. Entry costs and fixed per-period costs of access to the foreign market interact with firm-level heterogeneity to partition firms into exporters and non-exporters (Baldwin and Krugman, 1989; Dixit, 1989). Firms combine imported and domestic intermediate inputs of production and face distribution costs in the domestic and foreign markets.[1] The gradual growth of demand in the foreign market affects entry and exit decisions, as well as the contribution of new exporters to total foreign sales (Ruhl and Willis, 2017). Developing a model that integrates these mechanisms is key to provide a proper assessment of their importance. The analysis of alternative versions of the model allows for a decomposition of the contributions of the different channels, evaluating both the intensive and extensive margins of exports, and understanding the behavior at the aggregate and firm levels.

The quantitative analysis of the model follows a discussion of its parameterization. First, an evaluation of the different versions of the model is carried out by contrasting the behavior of aggregate variables obtained from model simulations against empirical estimations. I compute the elasticity of aggregate exports, as well

[1] A common definition of distribution costs includes: transportation across countries, wholesale and retail services, marketing and advertisement, and local transportation services. Alternative definitions and estimations will be discussed. Distribution services are intensive in local factors and hence non-tradable, thus creating a natural wedge between the prices of tradable goods across countries (Burstein et al., 2003; Corsetti et al., 2008), and moderating the changes in the profitability of exports generated by fluctuations in the exchange rate.

as the responses of foreign market entry and exit rates of firms. These exercises allow me to disentangle the role of alternative mechanisms in determining the reaction of the different margins of total foreign sales. Second, I construct firm-level panels from model simulations and replicate the regression analysis employed in the empirical literature for the different versions of the theoretical framework. This allows me to study both the exchange rate elasticity of exports at the firm-level and their heterogeneous reactions. The latter has been explored theoretically in previous work but has not been quantitatively evaluated. Third, I analyze the dynamic evolution of exports in response to large exchange rate movements. The evidence in this dimension is relatively limited, and exacerbated by confounding factors due to the nature of these events. Nevertheless, I assess the plausibility of the performance of the model in this aspect. Finally, I provide computations of the pass-through of exchange rates to prices.

I find that distribution costs represent the most important factor, but are not sufficient, to replicate elasticity estimations. Imported intermediate inputs are not as relevant as distribution costs for a number of reasons. First, although both imply costs in terms of the foreign currency, imported intermediate inputs can be substituted for the domestic equivalent (to some extent, depending on the elasticity of substitution). Foreign distribution services cannot be substituted. Second, the weight of distribution costs is larger than that of imported intermediate inputs. Third, foreign distribution services are only necessary for exported units, while imported intermediate inputs are necessary for the production of all units. This implies exchange rate fluctuations, through the distribution services channel, directly influences the optimal mix of domestic/foreign sales. In terms of foreign market entry rates, the currency denomination of sunk costs is more important than the gradual growth of exporters, but the effect in terms of aggregate elasticity is similar. This assessment is new in the literature. The dynamic response of total foreign sales to large movements in exchange rates is comparable in terms of magnitude and persistence to what has been documented in previous work. The exchange rate pass-through to prices is within the range of estimations in the literature.[2]

Distribution costs allow the model to replicate the heterogeneous response of foreign sales to exchange rate movements. In line with a series of empirical articles, export volumes of more productive firms react less to exchange rate fluctuations (Li et al., 2015; Berman et al., 2012; and Berthou and Dhyne, 2018). In the model, given the existence of per unit distribution costs in local currency, demand elasticity is decreasing in firm productivity, and with exchange rate depreciations. In front of a depreciation, for example, distribution costs are unchanged in the foreign market and the share in the final consumer price that depends on the export price falls, reducing the elasticity of demand faced by the exporting firm (see Berman et al., 2012). I provide a quantitative test of this mechanism using firm-level panels constructed from model simulations.

[2]The literature on the exchange rate pass-through to prices emphasizes the importance of distribution costs (e.g., Corsetti et al., 2008), with implications for how currency fluctuations affect inflation, and therefore the conduct of monetary policy.

The rest of this article is organized as follows. In Section 2, I provide a review of the related empirical and theoretical literatures. In Section 3, the theoretical framework is described. In Section 4, I discuss different mechanisms that are at work in the model. The parameters and the calibration procedure are discussed in Section 5. Section 6 presents the quantitative analysis and the main results, and Section 7 discusses sensitivity exercises, and the role of certain key parameters. I conclude with some final comments.

2 Relation to the Literature

In this section I present an overview of the literature which, in the interest of clarity, is divided in two parts: empirical evidence and theoretical mechanisms, although some articles provide contributions in both dimensions. A conclusion that can be drawn from the revision of the literature is that there still is a lack of a theoretical benchmark to understand the exchange rate elasticity of exports, as well as of a consensus over the key mechanisms that determine this elasticity.

2.1 Empirical Evidence

A number of articles provide an empirical analysis of the relationship between exchange rates and exports with different types of data. Freund and Pierola (2012) use country-level data to estimate the impact of real exchange rates on exports. They find that depreciations only stimulate exports in developing countries. Their results imply that a 10 percentage point increase in currency competitiveness leads to approximately 3-7 percentage point export growth. Bussière et al. (2016) exploit data on bilateral trade flows, covering 5 thousand products and more than 160 trading partners during 1995-2012. Results depend on the specification, with the median elasticity across economies typically in the range of 0.35-0.50, although these include non-significant coefficients and a wide dispersion in estimates.

The relationship between exchange rates and exports has also been studied with firm-level data. Fitzgerald and Haller (2018) exploit firms and customs microdata for Ireland to estimate how export entry and exit, as well as the export revenue of incumbent exporters respond to changes in tariffs and fluctuations in real exchange rates. In their estimations, although entry into export markets is several times more responsive to tariffs relative to real exchange rates, the absolute level of entry responses to both variables is modest. Furthermore, they do not find statistically significant responses of firm exit from foreign markets to either variable. Their estimates translate into an elasticity of aggregate exports with respect to real exchange rates of 0.50 on impact, and between 0.60 and 0.80 in the long run. These estimates are consistent with the elasticities summarized by Ruhl (2008). Dekle et al. (2010) estimate an elasticity in the range of 0.41 to 0.77, with a preferred estimate of 0.77, using firm-level data from Japan. They reconcile firm-level estimates with an aggregate elasticity of 0.65. Tang and Zhang (2012) and Li et al. (2015), using Chinese data, estimate firm-level elasticities in the range of 0.25 to 0.45. Furthermore, Li et al. (2015) find evidence that distribution costs and the proportion of imported inputs reduce the quantity responsiveness of exports with respect to exchange rate fluctuations. Campa (2004) estimates a firm-level elasticity of approximately 0.70 for Spain, his estimates translate into an aggregate elasticity of 0.80. Fabling and Sanderson (2015) find negligible elasticities at both the extensive and intensive margins in the case of New Zealand.

The role of heterogeneity at the firm-level has also been emphasized. Berman et al. (2012) use firm-level data for France and document that the average exporter increases its export volumes by 4 percent in front of a 10 percent depreciation (the range of estimates for the elasticity is 0.40 to 0.70, with 0.40 being their preferred estimate).[3] They find evidence that higher performance firms tend to absorb exchange rate movements in their markups, reducing the sensitivity in their export volumes. They show that, although this behavior is consistent with different mechanisms, the evidence points in favor of models that emphasize the relevance of distribution costs. Berthou and Dhyne (2018) estimate the exchange rate elasticity using a micro-level dataset for 11 European countries for the period 2001-2011. The benchmark average microeconomic elasticity ranges from 0.50 to 0.80. In line with the results in Berman et al. (2012), the elasticity from the least productive firms is higher than for the most productive firms. These results will be used to evaluate the performance of different versions of the theoretical model.

2.2 Theoretical Mechanisms

The first generation of models that provided microeconomic foundations for trade dynamics at the firm-level formalized the idea that large shocks to the exchange rate could have persistent effects on international trade (Baldwin and Krugman, 1989; Dixit, 1989). These frameworks analyze the decision to export in environments that feature uncertainty in exchange rates, sunk entry costs that must be incurred in order to gain access to the foreign market, and per-period fixed costs to maintain that access.[4] The existence of sunk entry costs implies that the decision to supply the foreign market is forward looking. In these models, *hysteresis* refers to an effect that persists after the cause that brought it about has been removed (Dixit, 1989): a temporary appreciation in the exchange rate, if sufficiently large, induces foreign firms to enter a domestic market. Given that entry costs are sunk, not all of the new entrant firms will leave the market when exchange rates revert to original levels (Baldwin and Krugman, 1989). More recent research provided estimations of these effects (e.g., Roberts and Tybout, 1997; Campa, 2004; Das et al., 2007; Rho and Rodrigue, 2016; Ruhl and Willis, 2017).

To account for the quantitatively different responses of trade flows to changes in tariffs and fluctuations in exchange rates, Fitzgerald and Haller (2018) argue that

[3]In the aggregate, the elasticity of volumes with respect to the exchange rate is 0.95, with 0.08 and 0.87 attributed to the extensive and intensive margins, respectively (their Table XII).

[4]Firms that are not exporting face the costs of establishing distribution channels, learning and complying with bureaucratic procedures, adapting their products and packaging for foreign markets, etc. (see Roberts and Tybout, 1997; Das et al., 2007).

the key feature necessary in standard models of international trade and business cycles is forward-looking investment in customer base. The nature of tariffs makes them more permanent relative to real exchange rates, therefore firms will optimally increase investment in their customer base by a larger extent in response to favorable changes in tariffs than in response to favorable movements in real exchange rates, resulting in export revenue being more responsive to tariffs in line with empirical findings. The mechanisms they propose builds on a growing literature in macroeconomics and international trade on the importance of the customer base of firms. Alessandria et al. (2015) embed a dynamic model of export participation into a small-open-economy framework to account for the gradual expansion of exports in emerging markets following large devaluations (average depreciations of 40-50 percentage points). Their results emphasize the importance of high interest rates and less impatience of the representative household associated with those events. This reduces incentives to invest in expanding exports quickly or strongly, dampening export growth and generating a relatively more gradual net export dynamics.

A series of articles analyze how financial frictions and balance-sheet effects contribute to determine the reaction of exports with respect to exchange rate fluctuations (Pratap and Urrutia, 2004; Chaney, 2016; Kohn et al., 2017; Salomao and Varela, 2018; Alfaro et al., 2018). Similarly, Cooper and Haltiwanger (2006), among others, have already stressed the role of capital adjustment costs for understanding the behavior of investment both at the firm and at the aggregate level: to the extent that firms face costs of adjusting capital, this could represent an obstacle to adjusting the scale of production in response to changes in the profitability of serving the foreign (or domestic) market (see Rho and Rodrigue, 2016; Liu, 2015; Riaño, 2011). Recent work by Lewis (2017) jointly examines three mechanisms: price rigidities, strategic complementarities and intermediate inputs.[5] He concludes that even with significant price frictions, the model is incapable of matching trade-flows responses to exchange rate movements (see also the discussion in Kohn et al., 2017), while imported intermediates are an unlikely source explanation of their dynamics. Similarly, Fitzgerald et al. (2017) conclude that price rigidities and markup adjustments are not sufficient to account for the insensitivity of exports to real exchange rates, and point to the role of the accumulation of customer base in foreign markets.

3 Theoretical Framework

The theoretical framework is a dynamic model of firms that consider the decision to enter a foreign market. Firms are subject to two sources of uncertainty: fluctuations in exchange rates and idiosyncratic productivity shocks. The analysis is at the industry level and thus the process for the exchange rate is taken as exogenous (e.g., Dixit, 1989; Das et al., 2007; Ruhl and Willis, 2017; Lewis, 2017, etc.).[6] It

[5] Greenaway et al. (2010) find evidence of the role of imported intermediate inputs in moderating the impact of exchange rate fluctuations on firm-level exports in the U.K. A strand of the literature has emphasized the role of price rigidities in being conducive to a reduced exchange rate pass-through to consumer prices (e.g., Devereaux and Yetman, 2010).

[6] In the literature, the *exchange rate disconnect puzzle* points to the volatility of exchange rates

abstracts from general equilibrium channels.

To understand firm-level responses it is convenient to think of firms as solving two interrelated problems. The static problem consists of the maximization of profits by the firm in a given period, taking as given its productivity level and stock of capital. Firms combine labor, capital, and imported and domestically sourced intermediate inputs to produce a unique variety of goods. The firm faces two dynamic decisions: accumulation of capital for production and the decision to supply the foreign market. Each of these dynamic decisions faces trade-offs, which are described below.

3.1 Foreign and Domestic Demand

There is a domestic and a foreign market, which are assumed to be segmented so that different prices can be charged by the firm in each market. In the foreign market the firm faces a demand function given by $b \cdot q_x^{\nu-1} = p_x$, where b is a parameter, p_x is the price in foreign currency and q_x is the quantity of the good supplied to the foreign market. Export revenues in domestic currency will be determined according to an exchange rate ε. Similarly, $u \cdot q_d^{\nu-1} = p_d$ is the domestic demand function, with parameter u, domestic price p_d and domestic quantity q_d. This demand function can be derived from a CES utility function where parameter ν determines the elasticity of substitution between the different varieties of goods.[7]

3.2 Production Technology

Firms combine labor, capital and imported and domestically-sourced intermediate inputs to produce a unique variety of goods. Present investment determines capital one period in advance: this results in capital being fixed at the beginning of any given period. In contrast, the levels of labor and intermediate inputs are decided after observing the firm-idiosyncratic productivity shock and the exchange rate at the beginning of each period. The specification for the production function is standard (e.g., Gopinath and Neiman, 2014; Ramanarayanan, 2017), where total output of the firm is determined by:

$$q = e^a \, (k^\alpha \, l^{1-\alpha})^{1-\mu} \, x^\mu$$

where a is a stochastic productivity variable, which will be modelled as an AR(1) process. A CES aggregator x combines a bundle of intermediate inputs produced

and their apparent disconnection from fundamentals. Obstfeld and Rogoff (2001) argue that to understand exchange rate volatility, we need to consider models that account for the high volatility observed in asset markets. Some examples in this direction, giving emphasis to financial factors, are found in Gabaix and Maggiori (2015) and Itskhoki and Mukhin (2017). The latter emphasizes that monetary and productivity shocks cannot be the key drivers of the exchange rate, if a model is to feature the *disconnection* properties. They also argue that their framework can be used as a theoretical foundation for a vast empirical literature that relies on exchange rate variation for identification.

[7] Parameters b and u can be interpreted as the *strength* of demand. With CES utility functions, the strength of demand would be determined by the CES price index and total consumer expenditures.

domestically z and another bundle of imported intermediate inputs m:

$$x = (z^{\rho} + m^{\rho})^{1/\rho}$$

where the elasticity of substitution between the bundles of imported and domestically produced inputs is $1/(1-\rho)$.

In models with linear production functions, and therefore constant marginal costs of production, the export decision is separated from the domestic production decision. In the presence of decreasing returns to scale (as is the case here given the fixed level of capital at the beginning of each period), the export and domestic production decisions are interrelated (for more discussion and empirical evidence on capacity constraints see Soderbery, 2014; Vannoorenberghe, 2012; Ahn and McQuoid, 2017).

3.3 Distribution Costs

Supplying a unit of a good requires ϕ_d units of distribution services in terms of domestic labor to reach the final consumer in the domestic market, and ϕ_x units of foreign labor to reach the final consumer in the foreign market. Total distribution costs, in domestic currency, are then given by:

$$h(q_d, q_x, \varepsilon) \; = \; \phi_d \cdot q_d \cdot w + \phi_x \cdot q_x \cdot \varepsilon \cdot w^*$$

where w and w^* are the domestic and foreign wages, respectively. I follow Burstein et al. (2003) and Corsetti et al. (2008) in considering that distribution costs are in terms of the non-tradable services (to be more specific, in terms of local labor in each market).

3.4 Static Problem of the Firm

We have detailed the necessary elements to delineate the static problem of firms. The firm supplying the foreign and domestic markets maximizes profits, taking as given the exchange rate ε, its capital stock k, its idiosyncratic productivity a, and the previously described demand functions:

$$\begin{aligned}\pi_x(a,k,b,\varepsilon) = & \max_{\{z,m,l,q_d,q_x\}} q_d \cdot p_d + \varepsilon \cdot p_x \cdot q_x - w \cdot l - p_m \cdot m \cdot \varepsilon - p_z \cdot z - h(q_d, q_x, \varepsilon) \\ & \text{s.t.} \quad q_d + q_x = e^a \, (k^{\alpha} \, l^{1-\alpha})^{1-\mu} \, x^{\mu}\end{aligned}$$

where p_m and p_z are the prices of the imported and domestic input bundles, respectively (the price of the foreign input basket is in terms of foreign currency). This problem can be re-written using the demand functions for each market:

$$\begin{aligned}\pi_x(a,k,b,\varepsilon) = & \max_{\{z,m,l,h\}} u \cdot q_d^{\nu} + b \cdot \varepsilon \cdot q_x^{\nu} - w \cdot l - p_m \cdot m \cdot \varepsilon - p_z \cdot z - h(q_d, q_x, \varepsilon) \\ & \text{s.t.} \quad q_d + q_x = e^a \, (k^{\alpha} \, l^{1-\alpha})^{1-\mu} \, x^{\mu}\end{aligned}$$

For a firm without access to the foreign market the problem is simply modified by setting q_x equal to zero, these profits will be denoted as $\pi_n(a,k,\varepsilon)$.

3.5 Dynamic Problem: Preliminaries

The exogenous state variables for the firm are $\{a, \varepsilon\}$, the idiosyncratic productivity a follows a stochastic process $\Lambda(a' \mid a)$ and the exchange rate follows a stochastic process $\Gamma(\varepsilon' \mid \varepsilon)$, both with a Markov structure. The endogenous state variables are the stock of capital k and the export status of the firm. The firm supplying only the domestic market faces a sunk entry cost if it wants to enter the foreign market, this implies that the decision to export is dynamic in nature. Additionally, there is a per-period fixed cost of exporting which, depending on the parameterization of the model, generates exit from the foreign market when a firm does not find it optimal to continue to export.

There is a large and exogenously fixed number of (possibly) risk-averse firms (Riaño, 2011; Kohn et al., 2016), where each firm produces a differentiated product as previously described and maximizes expected lifetime utility:[8]

$$\mathbb{E}\left[\sum_{t=0}^{\infty} \beta^t \, u(d_t)\right] \quad \text{with} \quad u(d_t) = \frac{d_t^{1-\psi}}{1-\psi}$$

where $d = \pi(\,\cdot\,) - i - c(i,k)$ are the dividends of the firm and i is investment in capital (profits depend on the export status of the firm), and $c(i,k)$ are capital adjustment costs, these are described next.

3.6 Capital and Adjustment Costs

The stock of capital is decided by the firm one period in advance and evolves according to a standard law of motion:

$$k_{t+1} = (1-\delta)\, k_t + i_t$$

where δ it the rate of depreciation of capital and i_t is investment in period t.

Investment in capital for production is subject to adjustment costs. The baseline specification builds on Cooper and Haltiwanger (2006), which allows us to assess both convex and non-convex adjustment costs, necessary to reproduce relationships between investment and fundamentals that are similar to those documented in the literature. This type of features have been extensively used in different applications including the literature on trade and firm dynamics (e.g., Riaño, 2011; Liu, 2015; Rho and Rodrigue, 2016). As is well understood from this literature, the different types of adjustment costs will allow the model to match a set of moments related to investment: for example, the fraction of observations with negative investment, spike rates of negative and positive investment (i.e., episodes of investment rates in excess of 20 percent), asymmetry in investment rates, etc.[9]

[8] Risk aversion dampens the response of investment to, for example, productivity shocks (Riaño, 2011).

[9] This is not free of empirical challenges. Cooper and Haltiwanger (2006) warn that identifying inaction in investment at the micro-level can be difficult, considering the heterogeneity in capital assets and the associated heterogeneity in adjustment costs.

The irreversibility of investment projects caused by a lack of thick secondary markets for capital goods can act as another form of adjustment cost (Cooper and Haltiwanger, 2006). This problem could be specially acute in developing economies. For example, Riaño (2011) argues that manufacturing firms in Colombia seldom divest capital by selling in secondary markets. Gelos and Isgut (2001) exploit firm-level data for Colombia and Mexico and find that irreversibilities play a more important role than in more advanced economies, while fixed costs of investment do not seem to be important. Irreversibility is incorporated in a simple manner, by considering that the firm is able to sell its capital at a price p_s lower than the price at which it can be purchased.[10] One implication will be that firms will not react as strongly, in terms of investment, to shocks that improve profitability. The specification of adjustment costs is further described in the calibration section.[11]

In theory, capital adjustment costs can be relevant for several reasons (I include in these arguments the fact that capital is chosen one period ahead). First, different studies document that capacity constraints may limit export reactions at the firm level in the short run: firms that face capacity constraints in the short run have a tradeoff between domestic and exports, this is not present in models with constant marginal costs of production. Second, related to the previous point, non-constant marginal costs can affect the pass-through of exchange rates (this is further discussed in Section 6.4). Third, in the presence of capital adjustment costs, long-run responses can differ from short-run responses, firms can adjust capital over time to react to variations in profitability, in particular those generated by exchange rate fluctuations. This is potentially relevant not only for the intensive but also for the extensive margin. Rho and Rodrigue (2016) argue that since capital adjustment frictions slow down the firms' ability to make profits, with mean reverting shocks, they decrease the value of being an exporter.[12]

3.7 New Exporter Dynamics: Gradual Export Growth

In the baseline model the foreign demand parameter b grows over time. This allows the model to replicate the observation that new exporters initially export relatively small amounts and their foreign sale volumes grow gradually (Eaton et al., 2007; Cebreros, 2016; Ruhl and Willis, 2017). This dependence of exports on *foreign-market tenure* can be attributed to different mechanisms. Rauch and Watson (2003) argue that if the foreign market buyer faces uncertainty in terms of the capacity of the supplier to successfully fulfill a large order, then a partnership will start with relatively smaller orders and later graduate to larger ones. They provide supportive empirical evidence, as well as a theoretical model to formalize this idea. Aeberhardt

[10]In addition to specifications considered in the literature it is plausible that the cost of capital in foreign currency, at least in part, could act to some extent as a deterrent of investment in front of a depreciation in domestic currency.

[11]Distribution costs are estimated to be considerably lower for investment goods (see Corsetti et al. 2008), for simplicity I do not incorporate them in the baseline model.

[12]There is a set of papers that document and study these issues along different dimensions (Vannoorenberghe, 2012; Soderbery, 2014; Ahn and McQuoid, 2017; Liu, 2015; Rho and Rodrigue, 2016; Riaño, 2011).

et al. (2014) and Araujo et al. (2016) explore the role of contract enforcement and learning about the reliability of their trade partners. Timoshenko (2015) and Cebreros (2016) attribute the dynamic behavior to a learning process of firms in foreign markets, Arkolakis (2016) emphasizes market penetration costs, while Eaton et al. (2014) study jointly search costs of identifying potential clients and customer learning. Fitzgerald et al. (2017) and Piveteau (2021) propose models where the accumulation of customer base is endogenous, and analyze the role of this mechanism in the determination of the elasticity of exports with respect to the exchange rate. A general result that emerges from these models is that once a gradual dynamic foreign demand process is introduced, the role of sunk costs is reduced significantly.

The specification for this process follows Ruhl and Willis (2017), and consists on the deterministic growth of foreign demand b during access to the export market. With this extension the state variables in the model are $s = \{a, b, k, \varepsilon\}$, and the export status of the firm.

3.8 Dynamic Problem of the Firm

The dynamic problem of the firm can be written in a recursive manner. The export status will be denoted by a subscript in the value function of the firm. State variables are grouped as $s = \{a, b, k, \varepsilon\}$, the value of a non-exporting firm is written as follows:

$$v(s) = \max_{\{k'\}} u(\,\cdot\,) + \beta\,(1-\omega) \sum_{\{\varepsilon',\,a'\}} \Gamma(\varepsilon' \,|\, \varepsilon)\,\Lambda(a' \,|\, a)\ \max\{v(s'), v_{nx}(s')\}$$

where utility values dividend $d(a, k, i, \varepsilon)$ of the non-exporting firm, $v_{nx}(s')$ is the value of a *new exporter*, ω is the exogenous death rate of firms and β is the discount parameter. A firm may enter the foreign market many times during its existence, a firm is labelled as a *new exporter* every time it starts to export.

The dynamic problem of the firm with access to the foreign market is written in the following manner:

$$v_x(s) = \max_{\{k'\}} u(\,\cdot\,) + \beta\,(1-\omega) \sum_{\{\varepsilon',\,a'\}} \Gamma(\varepsilon' \,|\, \varepsilon)\,\Lambda(a' \,|\, a)\ \max\{v(s'), v_x(s')\}$$

where utility values the dividend $d_x(a, k, i, \varepsilon, b) - \varepsilon \cdot c_x$, c_x is the per-period fixed cost of access to the foreign market. The difference between new exporters and incumbents is that the former faces a sunk cost of entry into the foreign market denoted $\varepsilon \cdot c_s$ (otherwise these two problems are equivalent). In the baseline specification per-period fixed costs and the sunk cost of entry into the foreign market are in the foreign currency.

4 Model Mechanics

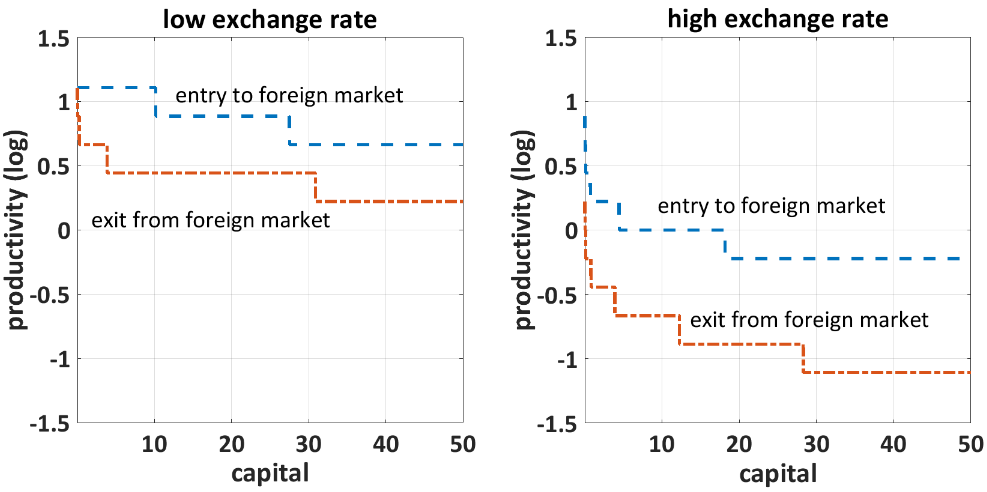
In this section, a description of the *hysteresis* mechanism is presented, which is enhanced in the model by the presence of gradual growth in the export market.

Additionally, I summarize a description of how distribution costs interact with firm productivity, resulting in heterogeneous responses of exports to fluctuations in the exchange rate. This provides a description of key mechanisms of the model, which will contribute to the interpretation of the results in the quantitative analysis.

4.1 Hysteresis Revisited

A property of models with sunk-costs of entry into the foreign market is that firms with a particular productivity level (and in the case of my model, physical capital as well) may be exporters or not depending on the history of their shocks (Dixit, 1989; Baldwin and Krugman, 1989). This result is illustrated in Figure 1. Each panel depicts, for a given level of the exchange rate, the entry and exit decisions as a function of firm productivity (exogenous) and production capital (endogenous but fixed in a given period).

Figure 1. Foreign Market Entry and Exit Decisions.



A firm that is not supplying the foreign market will wait for a sufficiently high level of idiosyncratic productivity to pay the sunk cost necessary to export (the blue line in each panel). However, this is not the productivity level below which producers exit the foreign market. The firm will continue to export until productivity falls below the exit level (the red line in each panel).

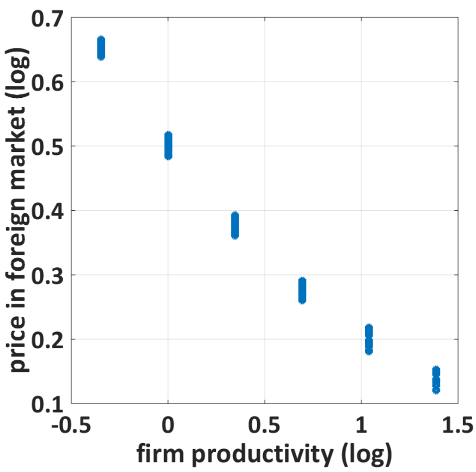
With sunk costs of exporting, the level of productivity that induces a firm to enter the export market is greater than the level that would lead to its exit. This results in an area where the exporter-status of the firm depends on the history of shocks (in the model, both shocks to productivity and exchange rates). The panel on the right in Figure 1 shows that for a higher (more depreciated) exchange rate, the firm will enter the foreign market at a lower level of idiosyncratic productivity, given that higher exchange rates increase the profitability of exporting (although increasing the cost of imported intermediate inputs, the fixed costs in foreign currency and foreign distribution costs). Gradual exporter growth reinforces hysteresis: firms that have remained in the export market for several periods and have increased their foreign demand will be less likely to exit relative to firms that have just entered and face a lower initial demand.

4.2 Productivity and the Exchange Rate Elasticity

In the model, the marginal cost decreases with productivity, and firms with higher productivity have lower export prices (for example, see Figure 2, constructed with model simulations). In contrast, the per-unit costs of distribution in the foreign market, which are denominated in the foreign currency, do not depend on the productivity of the firm. This implies that for more productive firms a larger share of costs are determined by distribution costs in the foreign currency, and a larger share of the price paid by foreign consumers is represented by these distribution costs in the foreign market. To see how this affects elasticity, consider a situation where the exchange rate depreciates, this has a smaller impact on the competitiveness of higher productivity firms (which have a relatively larger proportion of costs determined by foreign distribution costs). The result is that high productivity firms feature a lower elasticity of exports with respect to the exchange rate.[13]

The same reasoning implies that the elasticity decreases for all firms with larger distribution costs in the foreign market. For example, with larger distribution costs denominated in the foreign currency, the share of costs that boosts competitiveness with a depreciation of the exchange rate becomes smaller. Therefore, the elasticity of exports will be lower with larger distribution costs in the foreign market.

Figure 2. Firm Productivity and Export Prices



[13]In the Appendix this mechanism is derived for a simple model. Part of this section builds on the discussion in Berman et al. (2012).

5 Parameters and Calibration

The parameterization follows a standard procedure, a set of conventional parameters is obtained from the literature, and a different set of parameters is calibrated to replicate key empirical moments. In particular, the parameterization of the model benefits from an important amount of work conducted with firm-level data for developing economies.[14] In the case of distribution costs and the parameter that governs the elasticity of demand, given the range of estimates available and their role in the quantitative results, a conservative approach is initially considered as a benchmark. For these, and several other parameters, sensitivity exercises are later provided and discussed, this will also contribute to the understanding of the different mechanisms in the model. For exposition, and in line with the presentation of the theoretical framework, we first present the parameters most directly related to the static problem of the firm, and subsequently the parameters related to the dynamic problem of the firm.

5.1 Baseline Parameters: Static Problem of the Firm

We start with an enumeration of predetermined parameters linked to the static problem of the firm. The share parameter for capital α is set to $1/3$, which is standard. Parameter ρ determines the elasticity of substitution between imported and domestic input baskets. A value of 0.75 is considered by Gopinath and Neiman (2014) for Argentina, this is within the range of estimates by Zhang (2017) and Halpern et al. (2015) for different industries in Colombia and Hungary, respectively, and similar to the range of estimates in Kasahara and Lapham (2013) for Chile. Thus, a value of 0.75 is a sensible point of departure.

The share of intermediate inputs in the production function is determined by μ. A value of $2/3$ is used by Gopinath and Neiman (2014), which is consistent with the input-output table for Argentina. Ramanarayanan (2017) sets the average share of expenditures on intermediate goods as a fraction of gross output equal to 0.525, calculated for Chile. For Colombia, Zhang (2017) provides estimates of the share of inputs in the production function in the range of 0.54-0.65, depending on the industry. I start with a value of $2/3$ for μ, and later provide a sensitivity exercise for this parameter.

[14] For tractability purposes, given the number of model variations and sensitivity exercises, it is convenient to select a manageable number of calibrated parameters.

Table 1. Baseline Parameters: Static Problem of the Firm.

predetermined - ***description of parameter***	***param.***	***value***
share of capital in production	α	1/3
share of intermediate inputs in production	μ	2/3
elasticity of subst. across input baskets	ρ	0.75
elasticity of demand function	ν	0.70
domestic market demand (normalization)	u	1.00
calibration - ***description of parameter***	***param.***	***value***
distribution costs	ϕ	2.30
calibration - ***target moment***	***target***	***model***
mean proportion distribution costs/final price	0.450	0.452

The domestic demand parameter u can be normalized, while the values for b are part of the calibration in the following subsection. The elasticity of the demand function is governed by parameter ν, which is set to 0.70 in accordance with the range of values in the literature. This parameter is important for determining the elasticity of exports with respect to the exchange rate given its influence on profit margins, a sensitivity exercise is provided below.[15]

Distribution costs represent an important proportion of the final price to consumers, this is calibrated in the model (Table 1). Burstein et al. (2003) report the distribution margin for 7 advanced economies: Canada, France, Germany, Italy, Japan, U.K., and the U.S.[16] For consumption goods these values range from 35% in France to 50% in Japan, with an average of 42.8%. The estimate for Argentina is 60%, which could suggest margins are larger for less advanced economies. For a sample of 21 industrialized economies, Goldberg and Campa (2010) document that distribution margins of household consumption goods are in the range of 30-50 percent of the purchase price. Berger et al. (2009) find that overall distribution wedges are around 50-70% for the U.S. during 1994-2007.[17] In the baseline parameterization a conservative approach is taken, distribution costs represent 45 percent of the foreign retail price on average (with the same value of ϕ for both market destinations). This figure is approximately at the mean of estimates in Burstein et al. (2003), similar to the value for all goods computed for the U.S. from the Census of Wholesale and Retail Trade (their Table 5), and close to the mid-range of the estimates of distribution margins provided by Goldberg and Campa (2010). In

[15]For further discussion on this particular parameter see, for example, Alessandria et al. (2015), or the results from stylized models presented in the Appendix.

[16]Their definition of distribution costs includes: transportation across countries, wholesale and retail services, marketing and advertisement and local transportation services.

[17]In Berger et al. (2009) the definition of the *distribution wedge* captures everything that encompasses the gap between the retail price and the price at the dock including both profit margins and local distribution costs. Their regression results using individual item data show a lack of relationship between changes in these wedges and exchange rates. This issue is beyond the scope of this article.

the model this is computed as the average of $\phi_x \, w^*/p_x$ over all exporters and periods.

5.2 Baseline Parameters: Dynamic Problem of the Firm

A period in the model is a year. The exogenous death rate of firms ω is set at 0.025, this is in line with the range of estimates of the death rate for relatively large firms. For example, Ramanarayanan (2017) sets the exogenous exit rate of firms at 0.029. The discount parameter β is set so that the total *effective discount* considering the exogenous death rate $\beta \cdot (1-\omega)$ is 0.94. In models that evaluate financial constraints lower discount parameters are set (e.g., a value of 0.83 in Kohn et al., 2016). The parameter ψ that governs risk aversion is 1.5, within the range of values in the literature (e.g., Kohn et al., 2016; Riaño, 2011).

There are two sources of uncertainty in the model: firm idiosyncratic productivity and the exchange rate. These variables evolve according to independent and discretized AR(1) processes. The autocorrelation parameter and the standard deviation of shocks for firm productivity are 0.70 and 0.35, which are well within the range of values commonly used in the literature on firm dynamics. For the exchange rate process, these parameters are 0.70 and 0.10, respectively. Curran and Velic (2019) conduct a comprehensive global analysis and examine the persistence of real exchange rates for 151 countries, considering both multilateral and bilateral real exchange rates, and find half-lives of less than 1 and 2 years, respectively. The autocorrelation parameter is consistent with the latter.[18]

The model incorporates two types of convex and non-convex capital adjustment costs following Cooper and Haltiwanger (2006), Riaño (2011) and Rho and Rodrigue (2016). Standard investment models assume convex costs of adjustment, a standard quadratic cost specification is employed: $(\gamma/2) \cdot (i/k)^2 \cdot k$. A value of 0.04 is used for γ, which is at the lower bound of the range in Cooper and Haltiwanger (2006).

In the baseline model the non-convex component of adjustment costs consists of transaction costs, which is introduced as a gap between the buying and selling price of capital. This could be attributed to capital specificity and/or a *lemons problem*, or thinness of secondary markets for capital in general. Riaño (2011) makes the extreme assumption that investment is completely irreversible, arguing that secondary markets for capital goods are particularly thin in developing economies. I consider, in the baseline parameterization, a minor level of irreversibility by assuming that the selling price is 90 percent of the price at which capital goods are bought, which is a modest cost (see Liu, 2015). Gelos and Isgut (2001) find evidence that irreversibility plays a more important role in Colombia and Mexico than in advanced economies,

[18] Additionally, for example, I obtain these estimates from the process of the real exchange rate for Mexico for the period 1996-2016 with annual data. Pratap and Urrutia (2004) estimate a higher volatility of 0.145 and a similar persistence parameter for the period 1989-2002 (I obtain similar results for that period). As in their case, I use a CPI-based measure of the real multilateral (111 countries) exchange rate for Mexico, computed by Banco de México.

while fixed costs of investment do not seem to be important.[19] With these parameter values I obtain an *inaction rate of investment* of 0.20, which is common in the literature. The capital depreciation rate is 0.069, which is standard.

Table 2. Dynamic Problem: Baseline Parameters.

predetermined - ***description of parameter***	***param.***	***value***
discount	β	0.964
exogenous firm destruction rate	ω	0.025
risk aversion	ψ	1.500
autocorrelation firm productivity	ρ_a	0.700
volatility firm productivity	σ_a	0.350
autocorrelation exchange rate	ρ_ε	0.700
volatility exchange rate	σ_ε	0.100
capital depreciation rate	δ	0.069
capital convex adjustment cost	γ	0.040
capital irreversibility	p_s	0.900
calibration - ***description of parameter***	***param.***	***value***
sunk cost of entry into foreign market	c_s	0.025
per-period cost of access foreign market	c_x	0.022
foreign market demand, max. level	$\bar{b}$	0.630
foreign market demand, min. level	$\underline{b}$	0.450
calibration - ***target moments***	***target***	***model***
proportion of exporters	0.250	0.249
average exports/total sales (exporters)	0.135	0.137
ratio initial exports/total sales	0.065	0.067
stopper rate (exit rate from foreign market)	0.100	0.091

We next describe the calibration of a set of 4 parameters in this section (Table 2). As is standard, the set of parameters jointly determine the different moments of model-simulated data.[20] The sunk cost of entering the foreign market directly affects the rate at which firms start exporting (sometimes referred to as the *starter rate*), but also has an influence on the rate at which firms stop supplying the foreign market (the *stopper rate*); the reason is that a higher barrier to entry implies that only relatively more productive firms will enter the foreign markets, making them less likely to exit. Therefore, the sunk cost of entry into the foreign market c_s and the fixed per-period cost of exporting c_x contribute to approximate the proportion of firms that export and the rate at which firms stop supplying the foreign market

[19]Interestingly, although they recognize the possibility of financial constraints, they do not find evidence that cash flows affect investment patterns.

[20]While certain moments in the data may be particularly informative about some parameters, it is generally not possible to uniquely identify a parameter from one particular empirical moment.

typically documented (Liu, 2015; Kohn et al., 2016; Kohn et al., 2017; Riaño, 2011; Ruhl and Willis, 2017).[21] These costs are in terms of foreign goods.[22]

The idiosyncratic foreign demand for firms that begin exporting is determined by the lowest level $\underline{b}$, thereafter in every period that the firm continues to export b increases to the next level. A linear grid of 10 values is set for $b \in \{\underline{b}, \bar{b}\}$. With the values shown in Table 2 the ratio of exports to total sales for new exporters is 0.067, and the average ratio for all exporting firms is 0.137, in line with Ruhl and Willis (2017) (and similar to results in Kohn et al., 2016; Riaño, 2011).

6 Quantitative Analysis

I have constructed a theoretical framework that is sufficiently rich to analyze the behavior of aggregate as well as firm-level variables. I simulate the model and estimate the elasticity of aggregate exports with respect to fluctuations in the exchange rate, the impact on entry and exit rates in the foreign market, and domestic prices.[23] Simulated panels are used to contrast the performance of the model at the firm-level with empirical results documented in the literature. In addition to the estimation of elasticity at the firm-level, it provides a validation of the model by replicating the heterogeneous response of firms found in the empirical literature. Together with providing a model that replicates key facts, I contribute to the literature with a quantitative assessment of the underlying mechanisms.

6.1 Aggregate Exports and the Exchange Rate

The main result of interest is the elasticity of aggregate exports with respect to the exchange rate.[24] In the baseline specification of the model the elasticities are 0.574 and 0.754, in terms of their value in foreign currency and quantities, respectively (Table 3). I then show, in each column, the quantitative importance of removing or modifying different components of the model. For each version of the model, I recalibrate the parameters that are part of the calibration in the baseline

[21] There are more complex approaches to specifying these costs. For example, in Ruhl (2008) and Kohn et al. (2016) the entry cost is correlated with firm productivity, in Alessandria et al. (2015) it is random, this allows to reproduce with more precision the size distribution of exporting plants, by generating a number of small exporting firms.

[22] Chaney (2016) discusses the importance of the assumption that the entry cost into the foreign market is denominated in foreign labor. He emphasizes the evidence in Goldberg and Campa (2010), which shows that between 50 to 70 percent of the costs of entering the foreign markets are denominated in foreign currency. Dixit (1989), analyzing the problem of Japanese firms exporting to the U.S. market, assumed that foreign-market entry and exit costs are in dollars (the foreign currency for these firms). The quantitative implications of this assumption are part of the analysis below.

[23] The Appendix describes the solution algorithms for the model as well as the simulation exercises.

[24] All aggregate series are in logarithms and filtered using the HP methodology. Empirical studies find that most of the response of trade to exchange rate movements materialize within the first year (e.g., Leigh et al., 2017; Tang and Zhang, 2012), this is consistent with my simulations.

model following the same approach, while leaving the remaining parameters unmodified. In the second column, a version of the model with no distribution costs is considered, which results in an almost threefold increase in the estimated elasticities. Quantitatively, this is the most important factor in determining the exchange rate elasticity of exports.

Table 3. Regressions on the Exchange Rate: Aggregate Exports.

distribution costs	yes	**no**	yes	yes	yes	yes
dynamic foreign demand	yes	yes	**no**	yes	yes	yes
market costs in for. currency	yes	yes	yes	**no**	yes	yes
imported inputs	yes	yes	yes	yes	**no**	yes
extensive margin	yes	yes	yes	yes	yes	**no**
elasticity of exports: value	0.574	1.620	1.030	1.091	0.924	0.486
elasticity of exports: quantity	0.754	2.223	1.179	1.279	1.199	0.660

Imported intermediate inputs are not as quantitatively relevant as distribution costs for several reasons. First, although both imply expenses in terms of the foreign currency, imported intermediate inputs can be substituted for the domestic equivalent, while foreign distribution services cannot. Second, the weight of distribution of costs is larger than that of imported intermediate inputs. This results from available estimates of distribution costs and a standard calibrated production function. Third, foreign distribution services are required for exported units exclusively, while imported intermediate inputs are necessary for every produced unit. The dynamic foreign demand component, as will be shown, affects entry and exit decisions, as well as the contribution of new exporters to total foreign sales (a decomposition analysis is provided in the Appendix).

The intuition behind the role of the denomination of market access costs is straightforward: if denominated in the foreign currency, the entry of firms to the foreign market when there is a depreciation, for example, will be partially muted as these costs increase in local currency. The last column in the table shows the importance of considering (or removing) the extensive margin in the model. This exercise consists in setting the sunk-cost of entry and the per-period fixed cost to zero (this results in all firms becoming exporters). As documented in the literature, empirically the impact of entry at the aggregate level is modest given that firms that enter the export market are initially relatively small (see Campa, 2004; Eaton et al., 2007; Ruhl, 2008; Berman et al., 2012). The result from the theoretical model is consistent with the empirical literature.

6.2 Simulations and Firm-Level Regressions

The empirical literature has documented the heterogeneous elasticity of exports at the firm-level. One contribution of this article is to provide a quantitative theoretical model that is able to replicate this behavior. I use model-simulated data to account for the response of export quantities at the firm-level, for this I estimate the following regression:

$$\Delta \ln q_{x,it} = \beta_{\varepsilon}\, \Delta \ln \varepsilon_t + \beta_{\varepsilon \times a}\, \Delta \ln \varepsilon_t \times a_{i,t-1} + \beta_a\, \ln a_{i,t-1} + \beta_{\Delta a}\, \Delta \ln a_{it} + \epsilon_{it}$$

where the different variables follow the notation from the theoretical model: $q_{x,it}$ are export quantities of firm i in period t, a is firm productivity, and ε is the exchange rate. The main coefficients of interest are those of the exchange rate, and the one that corresponds to the interaction term of the exchange rate and a lagged measure of productivity, which is in line with specifications exploited in the empirical literature.[25]

Table 4. Firm-Level Simulations and Regressions:
Firm Heterogeneity and Responses to the Exch. Rate - Export Quantities.

distribution costs	yes	**no**	yes	yes	yes	yes
dynamic foreign demand	yes	yes	**no**	yes	yes	yes
market costs in for. currency	yes	yes	yes	**no**	yes	yes
imported inputs	yes	yes	yes	yes	**no**	yes
extensive margin	yes	yes	yes	yes	yes	**no**
Δ exch. rate	0.915	2.023	0.903	0.870	1.349	0.793
Δ exch. rate * firm TFP	-0.378	0.142	-0.285	-0.334	-0.522	-0.462

Notes: variables in logs, all coefficients significant at 1% level,
TFP: firm productivity.

Consistent with the results in Li et al. (2015), Berman et al. (2012) and Berthou and Dhyne (2018), the coefficient on the interaction term is negative and quantitatively significant, indicating that more productive firms have smaller responses (first column in Table 4)[26]. The estimations show that this result depends on the inclusion of distribution costs in the theoretical model. Additionally, in this exercise imported intermediate inputs are important for the elasticity with respect to the exchange rate, given that their inclusion directly influences the intensive margin adjustment of exports in the model.

[25] More specifically, the specification is employed by Li et al. (2015), as shown in their equation (3) and the results in their Tables 4-6. Li et al. (2015) introduce the lagged value of productivity to account for the possibility that it may be endogenous to price and quantity variations. Including capital (which I have available from model simulations), and/or firm fixed effects does not result in significant variations in results. In this section the measure of firm productivity is firm TFP, but I also estimate these equations and report the results including output per worker in the Appendix. Berman et al. (2012) conduct estimations with both measures of productivity. The methodology and criteria for this exercise are also described in the Appendix.

[26] The baseline interaction coefficient is approximately in line with empirical results in Li et al. (2015), although larger than those in Berman et al. (2012).

6.3 Foreign-Market Entry and Exit Rates

In this section I study the impact of fluctuations in the exchange rate on foreign market entry and exit rates (Table 5). The results in the baseline model simulations are comparable to the modest impact of the exchange rate on foreign-market entry and exit rates typically estimated in the literature. Berman et al. (2012) find that following a 10 percent depreciation with respect to the currency of a particular country, the probability of exporters to enter this market increases by 2 percentage points. Li et al. (2015), using firm-level data for China, find even more modest effects: they estimate that a 10 percent appreciation reduces the probability of entry by 0.6 percent and the probability of continuing in the export market by 1.1 percent (see Section 2.1, and Tang and Zhang, 2012).

Table 5. Regressions on the Exchange Rate:
Entry and Exit Rates into Foreign Market.

distribution costs	yes	**no**	yes	yes	yes	yes
dynamic foreign demand	yes	yes	**no**	yes	yes	yes
market costs in for. currency	yes	yes	yes	**no**	yes	yes
imported inputs	yes	yes	yes	yes	**no**	yes
extensive margin	yes	yes	yes	yes	yes	**no**
coefficient: entry rate	0.015	0.075	0.093	0.230	0.066	—
coefficient: exit rate	-0.061	-0.098	-0.247	-0.266	-0.124	—

The largest increase in this sensitivity is found when sunk-costs and per-period fixed cost of access to the export market are in domestic currency, which affects both entry and exit rates. The dynamic foreign demand component of the model has an important effect on how entry-exit margins react to exchange rate movements. In absolute terms, the change in the reaction of exit rates is larger than the change estimated for entry rates; the gradual increase in the idiosyncratic demand component makes the exit of firms less sensitive to exchange rate fluctuations by increasing export profitability.[27]

6.4 Exchange Rate Pass-Through to Domestic Prices

The pass-through of exchange rate fluctuations to domestic prices is an additional dimension to evaluate the model. Define the price index of domestic firms (both exporters and non-exporters) in the domestic market in a standard manner:

$$P_d = \left[\int p_d(i)^{\frac{\nu}{\nu-1}} \, di \right]^{\frac{\nu-1}{\nu}}$$

[27] I also estimate linear probability models for entry and exit in the foreign market a the firm-level. The conclusions are similar to those found for aggregate entry and exit rates: the impact of exchange rates is small in the baseline model and they are largest in the version of the model with entry and per-period costs in domestic currency.

The level of pass-through for tradable goods in the baseline calibration is in line with the range of values typically estimated. Goldberg and Campa (2010) estimate the exchange rate pass-through into the total consumer price index (CPI) for 21 OECD economies, with an average of 0.15, although with significant dispersion in estimates across countries (see also Burstein and Gopinath, 2014).[28]

Table 6. Regressions on the Exchange Rate: Pass-Through to Domestic Prices.

distribution costs	yes	**no**	yes	yes	yes	yes
dynamic foreign demand	yes	yes	**no**	yes	yes	yes
market costs in for. currency	yes	yes	yes	**no**	yes	yes
imported inputs	yes	yes	yes	yes	**no**	yes
extensive margin	yes	yes	yes	yes	yes	**no**
pass-t.: domestic index	0.125	0.274	0.133	0.130	0.002	0.111
pass-t.: avg. dom. price	0.146	0.266	0.154	0.151	0.002	0.131

When removing imported intermediate inputs the pass-through is almost eliminated (Table 6). In this case, for non-exporters the exchange rate is not relevant in their price decisions. For exporters their price in the domestic market can be affected by export quantities, given that capital is fixed for that period and the marginal cost is not constant. For example, a depreciation that incentivizes firms to increase exports affects marginal costs and therefore domestic prices (for further discussion on this mechanism see Soderbery, 2014). However, quantitatively the effect of this channel is small, in part due to the relatively small weight of capital in the production function. Finally, local distribution costs have an important role in reducing the pass-through of the exchange rate to domestic prices of domestic firms by increasing the share of costs in domestic currency.

7 Sensitivity Analysis and Intertemporal Responses

In this section, I discuss how the main results are sensitive to different key parameter values. This contributes to further shed light on the different mechanisms underlying the results of the quantitative analysis. Additionally, I document the dynamic response of aggregate exports in the case of large exchange rate depreciations for the baseline specification, and for variations of the model that center on the role of capital.[29]

[28]The exercise presented in this section refers to the pass-through of the exchange rate to consumer prices of domestically produced tradable products. In the Appendix, model estimations of the pass-through to foreign prices are provided. Additional articles analyzing the role of distribution costs and imported intermediate inputs are Corsetti et al. (2008) and Amiti et al. (2014).

[29]Although not the focus of the paper, this exercise addresses the possibility that capital has important effects on export dynamics, as discussed in Section 3.6.

7.1 Sensitivity Analysis

Table 7. Sensitivity Exercises
Regressions on the Exchange Rate: Aggregate Exports.

model/modification	**base**	$\nu = 0.60$	$\alpha = 1/6$	$\mu = 0.55$	$\rho = 0.65$
elasticity of exports: value	0.574	0.353	0.563	0.694	0.565
elasticity of exports: quantity	0.754	0.533	0.731	0.907	0.742

Export profit margins are a central determinant of the incentives to export.[30] These margins are governed by the parameter ν that sets the elasticity of the demand function. Reducing its value to 0.60 from 0.70 of the baseline specification has a significant impact on the aggregate elasticity of exports (Table 7). In contrast, changes in parameters ρ and α have negligible effects in the quantitative results. Parameter ρ determines the elasticity of substitution between domestic and foreign input baskets. A more inflexible production function would be expected to increase the elasticity of exports, since this reduces the capacity of firms to adjust the basket of intermediate inputs of production against changes in relative prices. A smaller α implies a smaller weight for capital, the input of production that is fixed within a period, and a larger weight for inputs that can be adjusted within a period.[31] Finally, parameter μ sets the share of intermediate inputs in the production function. In particular, a smaller value for this parameter reduces the importance of the basket of imported intermediate inputs relative to inputs in domestic prices, which increases the elasticity of exports.

7.2 Dynamic Responses of Aggregate Exports

In this section I document the dynamic response of aggregate exports for large depreciations in the baseline model, and in additional selected variations. This exercise provides an additional description of the workings of the baseline model, and allows for a comparison of previously reported elasticities with results in the context of large shocks, addressing potential questions regarding non-linear behavior in the model.[32] Additionally, this section complements the discussion regarding the role of capital in the model. In this dimension, I show results for two variations of the baseline model: more stringent capital adjustment costs ($\gamma = 0.06$ and $p_s = 0.30$), and a reduced value for parameter α of 1/6 (in line with the previous section). Finally, the version of the model with no distribution costs is included for compar-

[30] The Appendix provides analytical results in a stylized model.

[31] Similarly, in the case where capital is completely fixed, there is a negligible modification in the synchronous response of exports.

[32] Although this is not the focus of my analysis, large depreciations are an important subject of study on their own, and have received much attention in the literature (e.g., Alessandria et al., 2015; Kohn et al., 2017; Blaum, 2019). In Alessandria et al. (2015), for example, the authors consider the additional role of interest rates and the discount factor in determining the dynamics of exports, in episodes where devaluations are relatively more permanent in nature.

ison, this is the most important element of the model in terms of quantitative effects.

Figure 3. Impulse Response Functions: Exchange Rate Shock and Aggregate Exports

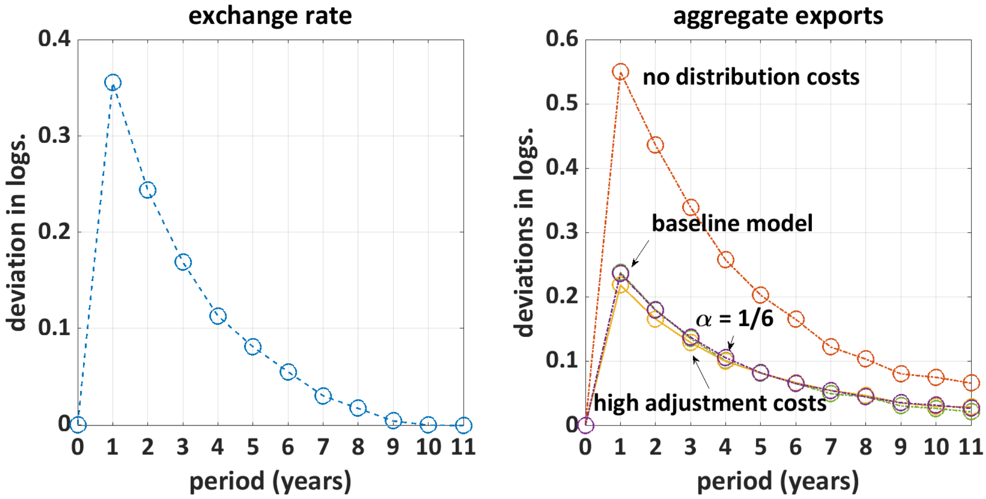


Figure 3 exhibits the impulse response functions for shocks to the exchange rate of 35%.[33] The model does not exhibit non-linear behavior relative to previously reported estimations of elasticity, and this includes the version of the model with no distribution costs. In the two variations of the model that modify the role of capital, changes in the intertemporal responses are modest relative to the baseline specification, although they are perceptibly smaller in the case of more stringent capital adjustment costs. Finally, the effects on aggregate exports are more persistent than the shock on the exchange rate, this is due to the effects on the entry margin of firms.

8 Conclusions

In this article I develop a theoretical model of firm dynamics to provide a quantitative analysis of the determinants of the elasticity of exports with respect to the exchange rate. I find that distribution costs are essential, but not sufficient, to replicate estimations from the empirical literature, both at the aggregate and the microeconomic levels. Furthermore, distribution costs are crucial to reproduce the heterogeneous response of firms: export volumes of more productive firms react less to exchange rate fluctuations. Together with providing a model that replicates key

[33]The methodology is described in the Appendix. Exchange rate fluctuations of the magnitude considered for the impulse response functions have a low probability given the exchange rate process. Nevertheless, they are comparable to those analyzed in the literature and provide an additional assessment of the model. For example, Kohn et al. (2017) consider a devaluation of approximately 40% to replicate the episode of Mexico in 1994 and, similar to the evolution of the exchange rate considered here, four years after the devaluation the real exchange rate is 10% above its pre-devaluation level.

facts, I present a quantitative assessment of the underlying mechanisms that determine the exchange rate elasticity of exports.

There are additional channels that potentially contribute to determine the reaction of exports against movements in the exchange rate. First, there is evidence that product quality, in addition to firm productivity, is an important factor influencing firm-export behavior. Given that improving product quality implies a costly investment, this may act as an impediment to a rapid increase in exports in front of an exchange rate depreciation (for discussions and related references see Brooks, 2006; Crino and Epifani, 2012). Second, alternative non-CES demand specifications can generate variable markups, which could complement the role of distribution costs, and influence the heterogeneous elasticity of firms. This channel has gained attention in the literature.[34] Third, a series of articles endogenize, for different purposes, the intensive and extensive margins in the utilization of imported intermediate inputs.[35] A stylized fact of this literature is that the largest exporters are the largest importers, this could further affect how aggregate exports react to exchange rates.

Fourth, as countries become more integrated in the global production process, a currency depreciation improves the competitiveness of a decreasing fraction of domestic value added embodied in the value of exports, and raises the cost of imported inputs that is increasing its weight. Ahmed et al. (2015) exploit a panel data-set covering 46 countries over the period 1996-2012 and find suggestive evidence that the elasticity of manufacturing exports to the real effective exchange rate has decreased over time. Their findings also indicate that participation in global value chains may have contributed to reduce this elasticity. However, they report that the results are sensitive to the methodology as well as the sample size and composition, as well as the period of observation (their findings are challenged by Leigh et al., 2017).

Finally, the complementarity of tradable goods with services and goods with a large non-tradable component may have a quantitatively important role in determining the elasticity of interest. For example, the American Automobile Association provides annual reports of operating and ownership costs for different types of vehicles. In one year these costs exceed 1/4 of the total price of a new unit.[36] A similar case could be made for other durable goods, such as personal computers. These issues could be interesting topics for further research.

[34]The Appendix provides a simple numerical example. Additionally, oligopolistic competition frameworks provide alternative setups that deliver variable markups (see Atkeson and Burstein, 2008; Amiti et al., 2019). These channels can be interpreted as complementary to the role of distribution costs.

[35]This literature includes, for example, Kasahara and Lapham (2013), Amiti et al. (2014), Gopinath and Neiman, (2014), Halpern et al. (2015), Ramanarayanan (2017), Blaum (2019).

[36]These costs include maintenance, insurance, financial charges, depreciation, etc.

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A Mechanisms in Stylized Models

I describe several versions of a stylized problem of a firm that supplies the foreign market. This section serves several purposes. First, simply a presentation issue, it shows that the solution is invariant to whether distribution costs are paid by the firm, or separately by the final consumer. The former is the one employed in this article (with slightly more parsimonious notation; the same price is paid by the final consumer and received by the firm). Second, it supports the discussion of the results regarding the heterogeneous response of exports to exchange rate movements. Third, it illustrates the role of key parameters in a simple setting. Finally, we provide a comparison with a non-CES demand function specification.

A.1 Stylized Model with Distribution Costs

A model with constant marginal costs provides the simplest structure for these purposes, and it allows to independently analyze the decision of the firm satisfying the foreign market. We consider a firm with a productivity parameter φ that determines its marginal cost. The foreign quantity demanded of the variety provided by the firm is $q_x(\varphi) = a \cdot (p^c(\varphi))^{-\sigma}$, where a is a constant incorporating aggregate income y^* and the price index p^* of the foreign country (which are fixed throughout and hence irrelevant for the conclusions), parameter σ governs the elasticity of demand. The price, in foreign currency, paid by the consumer is $p^c(\varphi) \equiv p(\varphi)/\varepsilon + \phi_x\, w^*$, where $p(\varphi)$ is exporter price expressed in home currency, ε is the nominal exchange rate, w^* is the wage rate in the foreign country, and ϕ_x are the units of labor in the foreign country required for distribution per unit sold. The wage in the domestic country is w.

The profits of the firm can be written as follows:

$$\pi(\varphi) = \left[p(\varphi) - \frac{w}{\varphi}\right] q_x(\varphi) = \left[p(\varphi) - \frac{w}{\varphi}\right] a \left[\frac{p(\varphi)}{\varepsilon} + \phi_x\, w^*\right]^{-\sigma}$$

Defining as $r \equiv \varepsilon\, w^*/w$ the real exchange rate of the home country with the foreign country, the following expressions for the optimal prices are derived:

$$p(\varphi) = \frac{\sigma}{\sigma-1}\frac{w}{\varphi}\left[1 + \frac{r\,\phi_x\,\varphi}{\sigma}\right] \quad \text{and} \quad p^c(\varphi) = \frac{\sigma}{\sigma-1} w^* \left[\frac{1}{\varphi\, r} + \phi_x\right]$$

and the solution for the quantity exported is:

$$q_x(\varphi) = a\left[\frac{\sigma-1}{\sigma}\right]^{\sigma} (w^*)^{-\sigma}\left[\frac{1}{\varphi\, r} + \phi_x\right]^{-\sigma}$$

Alternatively, the costs of distribution can be paid by the firm. In this case, the consumer price of a variety exported from the home country is $p^c(\varphi) \equiv p(\varphi)/\varepsilon$, where $p(\varphi)$ is the exporter price expressed in home currency. The function for demand remains $q_x(\varphi) = a \cdot (p^c(\varphi))^{-\sigma}$. Profits for the firm are written as:

$$\pi(\varphi) = \left[p(\varphi) - \frac{w}{\varphi} - \phi_x\, \varepsilon\, w^*\right] q_x(\varphi) = \left[p(\varphi) - \frac{w}{\varphi} - \phi_x\, \varepsilon\, w^*\right] a \left[\frac{p(\varphi)}{\varepsilon}\right]^{-\sigma}$$

The following optimal prices are derived:

$$p(\varphi) = \frac{\sigma}{\sigma-1}\left[\frac{w}{\varphi} + \phi_x\, \varepsilon\, w^*\right] \quad \text{and} \quad p^c(\varphi) = \frac{\sigma}{\sigma-1}\left[\frac{w}{\varphi\, \varepsilon} + \phi_x\, w^*\right]$$

and the solution for the quantity exported is unmodified from the previous solution:

$$q_x(\varphi) = a \left[\frac{\sigma-1}{\sigma}\right]^{\sigma} (w^*)^{-\sigma} \left[\frac{1}{\varphi\, r} + \phi_x\right]^{-\sigma}$$

The firm-specific elasticity of the volume of exports with respect to the exchange rate is given by the following expression:

$$\frac{\partial q_x(\varphi)}{\partial r} \cdot \frac{r}{q_x(\varphi)} = \frac{\sigma}{1 + \phi_x\, \varphi\, r}$$

This result implies that high productivity firms feature lower elasticity. More productive firms have lower export prices, and a larger share of the price paid by consumers is represented by distribution costs in the foreign market (this can be seen in the expression for $p^c(\varphi)$). Under the same logic, the elasticity decreases with local distribution costs in the foreign market; higher distribution costs denominated in the foreign currency imply that the share of costs that becomes more competitive, for example, with a depreciation of the exchange rate is smaller. Additionally, parameter σ affects the elasticity of exports given its influence on profit margins and incentives to export.

Similarly, the firm-specific price elasticity is given by:

$$\frac{\partial p(\varphi)}{\partial r} \cdot \frac{r}{p(\varphi)} = \frac{\phi_x\, \varphi\, r}{\sigma + \phi_x\, \varphi\, r}$$

which increases with distribution costs ϕ_x and firm productivity φ.

For a numeric example, we can take a value of 3.33 for σ (equivalent to the baseline calibration), and 1 for firm productivity φ and the real exchange rate r. The quantity elasticity shifts from 3.33 with no distribution costs, to approximately 1 when ϕ_x is equal to 2.3 (in this simple model this implies that distribution costs represent 49 percent of the final price to the consumer), the price elasticity shifts from 0 to 0.41.

A.2 Stylized Model with Non-CES Demand Specification

We consider an alternative model of variable markups with non-CES demand.

We follow Amiti et al. (2019) with the following specification from Klenow and Willis (2016):

$$q_x(\varphi) = \psi\left(\frac{p^c(\varphi)}{p^*}\right) q^* \quad \text{where} \quad \psi(x) = \left[1 - \hat{\varepsilon}\log\left(\frac{\sigma}{\sigma-1}\,x\right)\right]^{\sigma/\hat{\varepsilon}}$$

Under this specification, σ controls the elasticity while the new parameter $\hat{\varepsilon}$ controls the super-elasticity of demand (the elasticity of the elasticity). The profits of the firm are expressed as follows:[37]

$$\pi(\varphi) = \left[p(\varphi) - \frac{w}{\varphi} - \phi_x\,\varepsilon\,w^*\right]\left[1 - \hat{\varepsilon}\log\left(\frac{\sigma}{\sigma-1}\cdot p(\varphi)/\varepsilon\right)\right]^{\sigma/\hat{\varepsilon}}$$

The first order condition from this problem is given by:

$$p(\varphi) - p(\varphi)\,\hat{\varepsilon}\,\log\left(\frac{\sigma}{\sigma-1}\cdot p(\varphi)/\varepsilon\right) = \left[p(\varphi) - \frac{w}{\varphi} - \phi_x\,\varepsilon\,w^*\right]\sigma$$

which is equivalent to the previous solution when $\hat{\varepsilon}$ is zero. To provide a numerical example, we take values of σ of 3.33 as in our baseline calibration and $\hat{\varepsilon}$ equal to 1.6 from Amiti et al. (2019), with productivity and real exchange rate levels of 1, ϕ_x of 2.30 and a wage level of 0.25. The quantity elasticity with CES demand (i.e., $\hat{\varepsilon}$ of zero) is approximately 1, and approximately 1.3 with the non-CES demand function.

B Description of Solution and Simulation Algorithms

The theoretical model is solved via value function and policy function iteration (the combination of these algorithms increases the speed of convergence, as is well known). The state space is discretized. The AR(1) processes for the exchange rate and the idiosyncratic firm productivity shocks are discretized and the Markov transition matrices $\Gamma(\varepsilon' \,|\, \varepsilon)$ and $\Lambda(a' \,|\, a)$ are constructed following the method described in Tauchen (1986). A linear grid with 10 values is specified for the foreign demand value b, while for production capital k I specify a grid with 500 points.

To compute aggregate moments and regressions with aggregate series, the model is simulated 50 times, each with 100 thousand firms and 300 periods (a period represents a year). The first 100 periods of the series are discarded and thus not considered in the computation of statistics, to avoid dependence on initial conditions. Aggregate series for exports and prices are in logarithms, and the Hodrick-Prescott filter is applied to all aggregate series.

To compute the impulse response functions I simulate the model 100 times, each with 100 thousand firms and 300 periods (again the first 100 periods are discarded). When the exchange rate is at its long-run average (i.e., equal to 1), in the

[37] I omit demand shifters for simplicity, which in Amiti et al. (2019) summarize different variables that influence demanded quantities for a given price. I also omit aggregate variables since we are focusing on a partial equilibrium problem of the firm.

next period a shock is introduced. This means I select the level of the exchange rate as either a large depreciation or a large appreciation, depending on the *event* I want to analyze, to a specific point on its grid starting from a particular level of the exchange rate. After this shock I let the exchange rate evolve stochastically according to its Markov transition matrix. A condition is specified so that at least 50 periods have to pass before I consider a new event (the amount of periods between events is, therefore, random). Each simulation may provide, at most, 4 events. Endogenous variables evolve according to their respective policy functions. For the impulse response functions more simulations are needed relative to the aggregate moments and regressions, since I need a sufficiently large number of *events* to compute the average impulse response function. This average impulse response function is what I report for each variable (see for example the average evolution of the exchange rate in Figure 3). The number of periods shown in the Figures of the main text is selected as those that are enough for the exchange rate to return to its long-run average.

For the firm-level regressions using model simulations I simulate 8,000 firms for 300 periods. I then construct a panel using 51 years (Table 6 and App.-3).

C Decomposition of Export Growth

Following Eaton et al. (2007) I compute period by period how changes in total exports reflect the contributions of incumbent firms, entrants, and exiters. I start from the change in total exports in any given period:

$$\frac{X_t - X_{t-1}}{(X_t + X_{t-1})/2}$$

where X_t denotes total exports in period t. Growth can be decomposed into three parts, the first part is the contribution of continuing firms:

$$\left[\frac{\sum_{j\in C_t}(x_{j,t} + x_{j,t-1})/2}{(X_t + X_{t-1})/2}\right]\left[\frac{\sum_{j\in C_t}(x_{j,t} - x_{j,t-1})}{\sum_{j\in C_t}(x_{j,t} + x_{j,t-1})/2}\right]$$

where $x_{j,t}$ are exports by firm j in period t. The term C_t represents the set of continuing firms (the firms that exported in periods t and in the previous period $t-1$). The contribution of incumbents equals the share of exports of continuing firms over the two periods, multiplied by the growth in their export revenues.

In the baseline model the share of exports of continuing firms has an average over time of 0.935, while the average of the second term, representing their growth in their export revenues is 0.011. When I remove the dynamic foreign demand component from the model, the value of 0.011 turns to -0.065 (Table App.-1): in this version firms enter the foreign market when they benefit from a positive productivity shock, but these shocks exhibit mean reversion.

The second part represents the contribution of entrants to export growth:

$$\frac{NEN_t \cdot \bar{x}_{t-1}}{(X_t + X_{t-1})/2} + \frac{\sum_{j \in EN_t}(x_{j,t} - \bar{x}_{t-1})}{(X_t + X_{t-1})/2}$$

where EN_t represents the set of firms that exported in period t but not in period $t-1$ and NEN_t represents the number of entrants. The contribution of entry is expressed as the sum of two terms: the growth of exports implied by the increase in the number of exporter if new firms had the same average foreign sales as those of the average firm in the previous period, and the difference between exports of entrants and those of the average firm in the previous period. The means of these two terms in the baseline model are 0.088 and -0.031, respectively. Again there is a notable difference in the version of the model where the dynamic foreign demand component is removed: the value of -0.031 turns to 0.035: in the model with growing foreign demand, new exporters start exporting relatively small amounts, explaining the lower (and negative) term in the baseline specification.

The last term is the contribution by exiting firms:

$$-\frac{NEX_t \cdot \bar{x}_{t-1}}{(X_t + X_{t-1})/2} - \frac{\sum_{j \in EX_t}(x_{j,t-1} - \bar{x}_{t-1})}{(X_t + X_{t-1})/2}$$

where EX_t represents the set of firms that exported in period $t-1$ and not in period t, while NEX_t is the number of exiting firms. As in the case of entry, the contribution of exit is itself decomposed into two terms: the sum of the reduction that would have occurred if exiting firms had the export revenues of the average exporter in the previous period, and a term that considers the relative size of exiting firms (exiting firms are relatively small).

In the baseline model, the means of these two terms are 0.086 and -0.024, respectively. This first component, with an average contribution of 0.086, implies there is a loss of exports from the exiting firms, the second component reflects the fact that on average the foreign sales of exiting firms is smaller than the average exports of firms.

Table App.-1. Decomposition of Export Growth.						
distribution costs	yes	**no**	yes	yes	yes	yes
dynamic foreign demand	yes	yes	**no**	yes	yes	yes
market costs in for. currency	yes	yes	yes	**no**	yes	yes
imported inputs	yes	yes	yes	yes	**no**	yes
extensive margin	yes	yes	yes	yes	yes	**no**
continuing firms: share	0.935	0.948	0.915	0.915	0.929	1.000
continuing firms: growth	0.011	-0.012	-0.065	0.014	0.013	0.000
entering firms: fixed average	0.088	0.088	0.111	0.114	0.095	—
entering firms: *relative term*	-0.031	-0.012	0.035	-0.040	-0.033	—
exiting firms: fixed average	0.086	0.089	0.109	0.110	0.094	—
exiting firms: *relative term*	-0.024	-0.038	-0.028	-0.029	-0.025	—

In the model there is no long-run growth in total exports, so that the average growth rate of exports is expected to be zero.

D Simulations and Firm-Level Regressions

In Table App.-2 I repeat the estimations of Table 4, replacing TFP with revenues per worker. Qualitatively the conclusions are unchanged.

Table App.-2. Firm-Level Simulations and Regressions: Firm Heterogeneity and Responses to the Exch. Rate: Export Quantities.						
distribution costs	yes	**no**	yes	yes	yes	yes
dynamic foreign demand	yes	yes	**no**	yes	yes	yes
market costs in for. currency	yes	yes	yes	**no**	yes	yes
imported inputs	yes	yes	yes	yes	**no**	yes
extensive margin	yes	yes	yes	yes	yes	**no**
Δ exch. rate	1.122	2.044	0.855	0.661	1.527	1.136
Δ exch. rate $*$ firm RpW	-0.225	0.082	-0.082	-0.032	-0.318	-0.319

Notes: variables in logs, coefficients significant at 1% level.
RpW: revenues per worker.

E Simulations and Firm-Level Regressions: Mexico

I exploit firm level data from Mexico to provide an additional assessment of the theoretical framework with an alternative specification. I use the Annual Industrial Survey (*Encuesta Anual de la Industria Manufacturera*, in Spanish) produced by the national statistics institute INEGI, for the period 2009-2015 (for a detailed description of this database see Iacovone, 2008). The data-set does not include *maquiladoras*. In this Appendix, I explore an alternative specification relative to the one in the main text. Export revenues and physical capital are deflated using the industrial price index, similar to Rho and Rodrigue (2016). An important restriction of this dataset is that it does not include export prices or quantities.

In the spirit of Berman et al. (2012), Li et al. (2015), and Berthou and Dhyne (2018), I include an interaction term of the real exchange rate with (deflated) revenues per worker. In the data regression I include controls for the industrial sector at the 3 digit level. Additionally I include the volatility of the real exchange rate and the EMBI sovereign interest rate spread, both with negative signs and statistically significant at the 10% level (all results and alternative specifications explored are available upon request). All regressions include a constant term.

The simulation procedure was described in this Appendix. Note, in particular, that the last version of the theoretical model has almost 400 thousand firms since this version does not include an extensive margin (and it takes one period for new firms to start exporting). In the regressions with simulated data there are no significant changes when considering firm fixed effects. The R-squared is particularly high in the version of the model with no dynamic foreign demand: in this version of the model there is one less state variable that determines the export supply function, while remaining state variables are included in the regression. In the model version in the second column there is no variation in the variable revenues per worker.

I have also estimated logit models with the firm-level data to evaluate the impact of the exchange rate on the extensive margin: there was no statistically significant role or entry or exit (results are available upon request). The level of capital and the ratio of imported inputs of production had statistically significant, robust, and positive effect on entry, and statistically significant, robust, and negative effect on exit (results are available upon request). As has been previously discussed, the literature finds a small or no role for the exchange rate in determining entry and exit into foreign markets, which is consistent with the baseline theoretical model.

Table App.-3. Firm-Level Simulations and Regressions:
Firm Heterogeneity and Responses to the Exchange Rate: Export Revenues.

	theoretical model						**data**
distribution costs	yes	**no**	yes	yes	yes	yes	–
dynamic foreign demand	yes	yes	**no**	yes	yes	yes	–
market costs in for. curr.	yes	yes	yes	**no**	yes	yes	–
imported inputs	yes	yes	yes	yes	**no**	yes	–
extensive margin	yes	yes	yes	yes	yes	**no**	–
exchange rate	0.93	4.42	1.52	0.76	1.31	1.68	1.11*
exch. rate ∗ rev. per worker	-0.46	-0.95	-0.03	-0.25	-0.01†	0.00†	-0.40*
physical capital	3.11	0.57	-0.07	2.99	2.89	1.84	0.56***
revenues per worker	0.51	—	0.92	0.55	0.52	1.15	2.05**
R-squared (overall)	0.66	0.44	0.97	0.59	0.66	0.80	0.47
N. observations	102,459	111,594	130,681	91,863	145,791	397,694	16,492

Notes: variables in logs, all theoretical model coefficients significant at 1% level, except † (not significant).

F Exchange Rate Pass-Through to Foreign Prices

I present a complementary exercise to the exchange rate pass through to domestic prices presented in Table 5. I compute the elasticity of the price index and the average price of exported goods (in foreign currency), in the foreign market (Table App.-4).

Table App.-4. Regressions on the Exchange Rate: Pass-Through to Foreign Prices.

distribution costs	yes	**no**	yes	yes	yes	yes
dynamic foreign demand	yes	yes	**no**	yes	yes	yes
market costs in for. currency	yes	yes	yes	**no**	yes	yes
imported inputs	yes	yes	yes	yes	**no**	yes
extensive margin	yes	yes	yes	yes	yes	**no**
pass-t.: export price index	-0.195	-0.612	-0.153	-0.220	-0.301	-0.208
pass-t.: avg. export price	-0.217	-0.596	-0.150	-0.233	-0.334	-0.252

As in the case of domestic prices, distribution costs and imported intermediate inputs have a significant role in determining the exchange rate pass-through.

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