Financial Frictions and Export Dynamics in Large Devaluations*

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Abstract

We study the role of financial frictions and balance-sheet effects in accounting for the dynamics of aggregate exports in large devaluations. We investigate a small open economy with heterogeneous firms and idiosyncratic productivity shocks, where firms face financing constraints and debt can be denominated in domestic or foreign units. In our model, a real depreciation affects firms through two channels. On the one hand, it increases the returns to selling internationally, making exporting more profitable. On the other hand, it tightens the borrowing constraint by increasing the value of foreign-denominated debt relative to firms' net worth. We calibrate the model to match key features from plant-level data and use it to quantify the importance of these channels. We find that financial frictions slow down the response of aggregate exports, and foreign-denominated debt amplifies this effect by decreasing firms' net worth on impact. In contrast, without financial frictions and balance-sheet effects, the model counter-factually implies that, following a large devaluation, exports increase immediately to their new steady-state level. We find that accounting for the observed heterogeneity in export intensity across exporters plays a key role for explaining a significant share of the gap between the data and the frictionless model.

JEL: F1, F4, G32.

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1 Introduction

Financial crises typically feature large slowdowns of economic activity and large devaluations of the domestic currency. In particular, these episodes are associated with the decline of key macroeconomic variables such as output, investment, and employment. Yet, by making exports more attractive, large devaluations may also alleviate these effects, providing a way out of the crises.

While a large set of models of international trade imply that large devaluations are associated with sharp contemporaneous increases in aggregate exports,[1] this prediction stands in stark contrast with the dynamics observed in these episodes: for instance, Alessandria et al. (2014) document that aggregate exports increase gradually after large devaluations. This sluggish response of exports may be potentially important to account for the contractionary effects of large devaluations documented by Edwards (1986), Kamin and Klau (1998), and Bebczuk et al. (2006).

A large literature documents the importance of frictions in financial markets and balance-sheet effects for aggregate dynamics in the context of large real exchange rate changes: when firms have foreign-denominated liabilities, a devaluation increases the domestic value of their debt, weakening their balance-sheets, and potentially forcing them to decrease investment and employment.[2] Motivated by these findings, in this paper we investigate the role of financial frictions and the currency denomination of debt in accounting for the slow response of aggregate exports in episodes of large devaluations.

We study a small open economy populated by a large number of entrepreneurs. Entrepreneurs produce differentiated goods by hiring labor to operate previously accumulated physical capital. The productivity of the production process is heterogeneous across entrepreneurs and changes over time following a stochastic process. The first key ingredient of the model is access to international goods markets. We model international trade decisions as in Melitz (2003), where firms are subject to fixed and variable trade costs. Fixed costs are independent of the quantity exported, while variable trade costs not only capture tariffs, but also transportation costs and non-tariff barriers that are increasing in the amount exported.

The second key ingredient of the model is the interaction between frictions in financial markets and debt denominated in domestic and foreign units. We assume that entrepreneurs

[1] This response of exports to changes in the real exchange rate is systematically implied by a large set of models where international trade decisions are static, such as Melitz (2003), Anderson and van Wincoop (2003) or Eaton and Kortum (2002).

[2] In the theoretical literature, this channel is often referred to as the balance-sheet channel (see Aghion et al., 2000, Aghion et al., 2001, Aghion et al., 2004). Aguiar (2005), Desai et al. (2008), Kalemli-Ozcan et al. (2015) provide empirical evidence on the importance of balance-sheet effects in accounting for the dynamics of investment for firms with debt denominated in foreign currency during large devaluations.

have access to two types of bonds that allow them to borrow or save at a given interest rate: one denominated in domestic units and one denominated in foreign units. We make two key assumptions on the nature of their access to financial markets: (i) entrepreneurs face a borrowing constraint which limits the amount that they can borrow; and (ii) a fixed fraction of their net wealth is allocated to bonds denominated in foreign goods.

In our model, an increase in the real exchange rate has offsetting effects on firms' export decisions. The first effect is a standard expansionary effect that makes the domestic good cheaper and increases foreign demand. In response, there is an increase in the number of firms exporting and the amount that they export. The second effect is the effect of financial frictions and balance-sheets. While the expansionary effect may induce firms to increase the amount produce and exported, borrowing-constrained firms may only be able to do so gradually. In addition, an increase in the real exchange rate leads to an increase in the domestic value of debt. As the value of collateral is denominated in domestic units, this tightens the borrowing constraint leading to a decrease in investment and output. To the extent that the latter effects dominate on impact, they may account for the sluggish increase of aggregate exports observed in the data.

In order to quantify the importance of these channels, we calibrate the model to match key cross-sectional moments of Mexican plant-level data for 1994.[3] Consistent with the data, we assume that exporters differ in their export-intensity and consider two types of firms: (i) a fraction that is subject to low export costs and sells most of its output internationally; and (ii) a fraction of firms that is subject to high export costs and sells most of its output domestically. Moreover, in the baseline calibration we assume that low-export-cost firms have all their debt denominated in foreign units while the remaining firms have all their debt denominated in domestic units. This assumption is consistent with the large share of foreign-denominated debt held by exporters that we document below.

We use this economic environment to investigate the extent to which financial frictions and balance-sheet effects can account for the dynamics of exports observed in the data following large real depreciations.[4] In particular, we study the response of the economy to a sudden and unexpected decrease in the real exchange rate caused by a sequence of shocks to the price of imported goods. We consider a situation where the economy is initially in a stationary equilibrium and firms expect that this situation will continue forever. When the price of imported goods decreases, agents learn its deterministic path to the new stationary equilibrium.

[3]Mexico experienced a large devaluation at the end of 1994 when the value of the Mexican peso depreciated roughly 42% between December 1994 and January 1995 (almost 38% in real terms).

[4]We refer to large devaluations and large real depreciations interchangeably.

To understand the role played by financial frictions and foreign-denominated debt, we compare the response of aggregate exports across three different economies: (i) the baseline calibration, with financial frictions and low-export-cost firms subject to foreign-denominated debt; (ii) an economy with financial frictions but without foreign-denominated debt; and (iii) an economy without financial frictions. For each of these economies, we solve the transitional dynamics between the initial and final steady states.

We find that financial frictions slow down the response of aggregate exports. Our results suggest that, without foreign-denominated debt, borrowing constraints imply an elasticity of exports to the real exchange rate that is 23 percent lower than its frictionless counterpart. Moreover, we find that balance-sheet effects further slow down the response of exports: when exporters have foreign-denominated debt, the elasticity of exports to the real exchange rate is 30 percent lower than the frictionless model. In this case, the real depreciation reduces the net worth of firms, amplifying the impact of the borrowing constraints.

We show that these results depend on the extent of export intensity heterogeneity. In a model with financial frictions and foreign-denominated debt where firms are subject to homogeneous export costs, all firms export a low share of their output and aggregate exports adjust immediately to the change in the real exchange rate, as in the frictionless model. With only one type of firms, firms export around one-fourth of their total production and, hence, they are able to increase their exports considerably by decreasing their domestic sales without expanding their total productive capacity. Therefore, the extent to which firms can reallocate sales across markets plays a key role in driving the response of aggregate exports to changes in the real exchange rate.

Finally, we examine the extent to which our model can account for the dynamics of aggregate exports observed in the data when subject to a sequence of shocks that lead to real exchange rate dynamics identical to the median behavior observed in the data across 12 devaluations over 1980-2013. We find that our model can account for a large share of the aggregate export dynamics observed in the data, improving on the implications of its frictionless counterpart: the root-mean-squared error of the exports elasticity between our model and the data is 29 percent lower than implied by the frictionless model.

The remainder of this paper is organized as follows. In the rest of this section, we review the related literature. Section 2 presents evidence on the dynamics of the real exchange rate, aggregate exports, and credit, following episodes of large devaluations. In Section 3, we introduce the model. Section 4 discusses the main mechanism and how real depreciations affect aggregate exports in the model. Section 5 presents the quantitative findings. Section 6 concludes.

Related literature. Our paper is motivated by the evidence documented by Alessandria

et al. (2014), who show that exports tend to grow gradually following large devaluations. This observation stands in stark contrast to a large class of models of international trade with static export decisions, such as Melitz (2003), Anderson and van Wincoop (2004) and Eaton and Kortum (2002), which imply a large immediate response of exports to changes in the real exchange rate.

Our focus on financial frictions and balance-sheet effects is motivated by a large empirical literature that investigates the relationship between credit constraints, firms that hold foreign-denominated debt, and output, in episodes of currency crises. At the aggregate level, Céspedes (2005) and Bebczuk et al. (2006) find that devaluations in countries with a high fraction of foreign-currency-denominated debt have a strong negative impact on GDP growth. At the firm level, Aguiar (2005), Carranza et al. (2003), Galiani et al. (2003), Echeverry et al. (2003), and Benavente et al. (2003), report a negative impact of devaluations on investment in Mexico, Peru, Argentina, Colombia and Chile, respectively. Galindo et al. (2003) provides a summary of the firm-level empirical evidence on the presence of balance-sheet effects in Latin American countries.

In addition, early contributions by Krugman (1999), Aghion et al. (2000), Aghion et al. (2001), Aghion et al. (2004), and Caballero and Krishnamurthy (2003), use stylized models to study the link between balance-sheet effects and the contractionary effects of large devaluations.

Our model builds on the framework that we developed in earlier papers (Kohn et al., 2015, Leibovici, 2015) and is related to quantitative work that explores the connection between exchange rate regimes and financial distress in economies with credit constraints (see Céspedes et al., 2003, Céspedes et al., 2004, Devereux et al., 2006, and Gertler et al., 2007). Pratap and Urrutia (2004) investigate the role of credit constraints and international trade in accounting for output and investment dynamics in a partial equilibrium setup. More broadly, our work contributes to a rapidly growing theoretical and quantitative literature that studies the effects of financial frictions on export decisions, such as Chaney (2013), Caggese and Cunat (2013), Manova (2013), Kohn et al. (2015), and Leibovici (2015).

Finally, the channels that we study complement previous explanations that have been proposed for the gradual response of exports following large devaluations. For instance, Alessandria et al. (2014) study the role of sunk export entry costs and their impact on the extensive margin of exports following large devaluations; in contrast, we analyze the importance of balance-sheet effects and financial frictions. Therefore, throughout our paper, we abstract from sunk export entry costs to restrict attention to our channels of interest.

2 Empirical Evidence

In this section, we document the facts that motivate our subsequent analysis. We start by investigating the dynamics of real exchange rates and aggregate exports in a sample of large devaluations over the last three decades. Next, we present evidence on the currency composition of debt at the aggregate level across countries, and at the plant level across exporters and non-exporters. Finally, we examine the dynamics of aggregate credit during large devaluations.

2.1 Real exchange rate and export dynamics in large devaluations

We begin by investigating the dynamics of the real exchange rate and real exports following large real devaluations. To identify devaluations, we use data on real effective exchange rates compiled by the Bank for International Settlements (BIS), and define a large real devaluation as an increase in the real effective exchange rate of at least 20% within a year.[5] The data on real exports are based on the export volume indexes from UNCTAD, published by the World Bank, and from the International Financial Statistics (IFS) database published by the International Monetary Fund (IMF). We restrict our attention to the period from 1980 to 2013.[6]

Using our definition above, we identify 14 episodes of large devaluations in our dataset. These include: Argentina (2002), Brazil (1999), Iceland (2008), Japan (2013), South Korean (1998), Malaysia (1998), Mexico (1982, 1986, 1994), Russia (1999) and Venezuela (2002, 2010). In what follows, we drop Japan because, at the time of writing this paper, there are only a couple of observations available after the devaluation; and we drop Russia because of missing export data prior to the devaluation, which results in 12 devaluation episodes.[7]

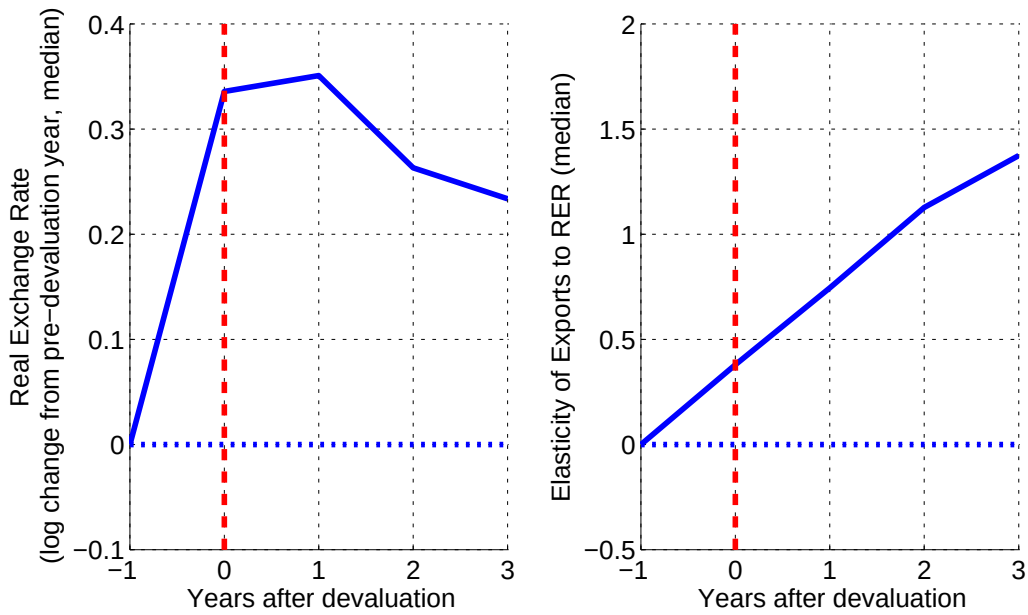
In Figure 1, we plot the median log-change of the real exchange rate relative to the pre-devaluation level (left panel) and the median elasticity of real exports to changes in the real exchange rate (right panel).[8] We see that, following a devaluation, the median exchange

[5] For each country the real effective exchange rate is defined as a weighted average of bilateral exchange rates adjusted with the corresponding relative consumer prices. See Klau and Fung (2006), "The new BIS effective exchange rate indices", BIS Quarterly Review.

[6] Real exchange rates data are reported at a monthly frequency. To aggregate the exchange rate data into yearly frequency, we average across all months within each year. We define the real exchange rate (RER) as the inverse of this yearly average, so that a devaluation consists of an increase in the RER (i.e. an increase in the domestic value of foreign prices relative to domestic prices).

[7] The results presented below are robust to alternative thresholds for the definition of a large devaluation.

[8] More precisely, in the left panel we plot the median value of $\log(\xi_t)/\log(\xi_{-1})$, where ξ_t is the real exchange rate at time t and ξ_{-1} corresponds to the year before the devaluation. In the right panel, we plot $\log(X_t/X_{-1})/\log(\xi_t/\xi_{-1})$ where X_t denotes exports at time t and X_{-1} corresponds to the year before the devaluation.



Source: Exchange rate data from the BIS effective exchange rate dataset, exports data from the World Bank and the International Financial Statistics (IFS) database published by the IMF.

Figure 1: Aggregate Dynamics of RER and Real Exports

rate increases by approximately 34%, slightly increases the following year, before decreasing steadily over the following two years. However, even after four years of the large devaluation, the median exchange rate is 23% higher than its pre-devaluation level.

The right panel of Figure 1 shows that, despite the large change in the real exchange rate, real exports increase gradually following a devaluation. The exports elasticity steadily increase up to a value of 1.4 four years after the devaluation. Moreover, the median export elasticity in the year of the devaluation is only 0.4, less than 30% of its peak value. Thus, Figure 1 shows that real exports respond slowly to sharp and sudden changes in the real exchange rate. This stands in stark contrast to standard trade models (such as Melitz, 2003, or Eaton and Kortum, 2002) which predict a sharp increase in exports following a devaluation: that is, a one-time increase in the export elasticity at the moment of the devaluation.

2.2 Currency composition of liabilities

Currency composition of liabilities across countries In this section, we document the extent to which the countries that experienced large devaluations relied on debt denominated in foreign currency. The data on the currency denomination of debt is scarcely available and, therefore, we rely on the International Currency Exposure (ICE) dataset constructed by Lane

and Shambaugh (2010) and further extended by Bntrix et al. (2015). This dataset covers 117 countries and contains detailed estimates of each country's currency denomination of foreign assets and foreign liabilities for every year between 1990 and 2012. In what follows, we restrict our attention to the countries we considered in Section 2.1 and focus on the currency denomination of their liabilities.[9]

We report the results in Table 1. We observe that, at the time of the devaluation, all the countries in our sample had a significant amount of foreign liabilities denominated in foreign currency relative to their GDP.[10] In particular, the median ratio of foreign liabilities denominated in foreign currency relative to GDP is about 47%, while the average is around 85%. This suggests that a devaluation, by increasing the domestic-currency value of these countries' debt burden, could potentially have negative effects on these economies. Moreover, since the ICE dataset does not include domestically-issued debt denominated in foreign currency, it is likely to underestimate the extent to which these countries relied on foreign-currency-denominated credit at the onset of the devaluation episodes. Finally, note that the high degree of international currency exposure that we document is similar to earlier results reported in the literature that document high levels of currency mismatch in developing economies (e.g., Hausmann and Panizza (2003), Goldstein and Turner (2004)).

Table 1: Currency composition of liabilities across countries

	Liabilities in foreign currency / GDP (%)
Average	86.04
Median	39.21

Source: International Currency Exposure data from Bntrix et al. (2015).

While Table 1 shows that the typical country that experienced a large devaluation in the last three decades had significant international currency exposure, it is silent on the extent to which the exposure was concentrated in the private or public sector of the economy. Thus, in the next section, we investigate whether the same observation holds at the firm level.

[9]Note that two of the devaluations in our sample (Mexico 1982, Mexico 1986) occurred outside of the span covered by the International Currency Exposure dataset. Thus, in this section, we limit our attention to the 10 devaluation episodes covered by the ICE dataset.

[10]Foreign liabilities include portfolio equity, direct investment, portfolio debt, and other debt. The results are virtually unchanged if we restrict our attention to foreign debt since, for the countries in our sample, other types of liabilities represent a small fraction of total liabilities.

Currency composition of debt by export status Given our interest in understanding the dynamics of exports in large devaluations, we now examine the currency composition of debt by export status. We use the World Bank Enterprise Survey (WBES) dataset which contains data on firms' characteristics based on representative surveys of private firms conducted in 135 economies. The World Bank has conducted such surveys since 2002, and they cover a broad range of topics, including firms' financial positions.[11] The dataset covers seven countries that have experienced large devaluations according to our definition (Argentina, Brazil, Indonesia, Malaysia, Mexico, Russia, and Turkey). Out of these seven countries, only the surveys conducted in Brazil, Indonesia, Russia, and Turkey contain information on the share of the firms' debt denominated in foreign and domestic currency. Thus, we limit our study of the currency composition of debt to these four economies.[12]

Table 2: Share of foreign-denominated debt at firm-level by export status

Median	% with foreign-denominated debt	% of foreign-denominated debt
Non-exporters	0.32	0.46
Exporters	0.69	0.55

Source: World Bank Enterprise Survey. Data for Brazil (2003), Indonesia (2003), Russia (2002) and Turkey (2002 and 2005).

We report our results in Table 2. We observe that firms in our sample tend to have a significant amount of their debt denominated in foreign currency and the reliance on such debt is substantially higher among exporters compared to non-exporters. We find that 69% of exporters have some debt denominated in foreign currency compared to 32% of non-exporters. Among the firms that have a positive amount of foreign currency denominated debt, this debt constitutes, on average, 55% of total debt among exporters, while 46% among non-exporters. Thus, not only are exporters substantially more likely to have foreign-denominated debt, but they also tend to issue a higher fraction of their debt in foreign currency.

[11] More details about the WBES data can be found at http://www.enterprisesurveys.org.

[12] Note that these surveys are not conducted annually, and are only available for some years. The years in which the surveys were conducted in Brazil, Indonesia, Russia and Turkey do not correspond to the devaluation years. Nevertheless, all the surveys were conducted within a 5-year window of the devaluation episodes, so we believe that they can be used to infer the importance of foreign-denominated debt also during the devaluations. Moreover, following large and unexpected devaluations, one would expect firms to use less foreign-denominated debt than before; thus, it is likely that the reliance on foreign-denominated debt was even higher at the onset of the devaluation episodes.

These results suggest that foreign-currency denominated debt was not only common in the economies that experienced large devaluations, but also that exporters relied more heavily on such debt.

2.3 Debt dynamics in large devaluations

The evidence presented above shows that countries which experienced large devaluations over the past few decades also had a large share of their total foreign debt denominated in foreign currency. In addition, we documented for some of these economies that firms hold a large share of debt in foreign currency, and that exporters hold a larger share of foreign-denominated debt than non-exporters.

We now conclude this section by investigating the dynamics of aggregate debt during the large devaluation episodes. To do so, we use data on total debt held by the private non-financial sector. This data is collected by the BIS, and is measured in domestic currency. Therefore, to the extent that a large share of debt is denominated in foreign currency, a large devaluation should lead to a significant increase in the amount of debt faced by firms in these economies.[13]

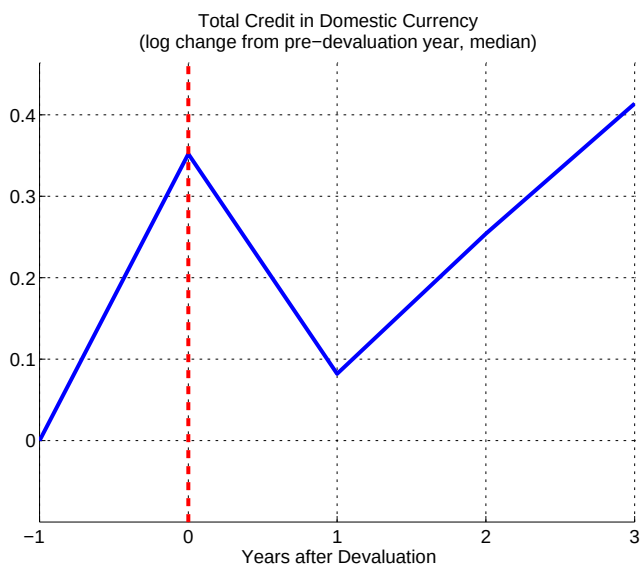


Figure 2: Aggregate debt dynamics

In Figure 2, we plot the median log change of total credit relative to the pre-devaluation level. The figure shows that the median increase in the domestic value of total credit during the year of a large devaluation is higher than 30%. To the extent that this increase in the domestic value of credit results from the currency denomination of debt, we conjecture that

[13] It is not possible in this dataset to classify debt according to their currency denomination.

it could be the driver of the slow response of exports in these episodes. We investigate this conjecture in the following sections. After the devaluation, this value decreases transitorily in the following year, and then continues to increase steadily up to three years after the large change in the real exchange rate.

3 Model

The model consists of an economy populated by a unit measure of entrepreneurs and final good producers who trade with the rest of the world. There are three types of goods in the economy: final goods, domestic intermediates, and foreign intermediates. Final goods are produced by final good producers and used by entrepreneurs for consumption and investment. Domestic intermediates are produced by entrepreneurs and sold to final good producers and the rest of the world. Finally, foreign intermediates are produced by the rest of the world and sold to final good producers. Only intermediate goods can be traded internationally.

3.1 Economic environment

3.1.1 Entrepreneurs

Preferences Entrepreneurs are risk averse, with preferences over streams of consumption of final goods. Preferences are represented by the expected lifetime discounted sum of a constant relative risk aversion period utility function, $\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \frac{c_t^{1-\gamma}}{1-\gamma}$, where γ denotes the coefficient of relative risk aversion, β is the subjective discount factor, and $\mathbb{E}_0$ denotes the expectation operator taken over the realizations of a productivity shock that is described below, conditional on the information set in period zero.

Technology Entrepreneurs produce differentiated intermediate goods by operating a constant returns to scale production technology $y_t = z_t k_t^{\alpha} n_t^{1-\alpha}$, where z_t denotes an idiosyncratic level of productivity, k_t is the capital stock, n_t is the amount of labor hired, and $\alpha \in (0, 1)$ is the capital share. Labor is hired at a wage rate w_t, denominated in units of final goods. Idiosyncratic productivity z_t follows a time invariant AR(1) process $\ln z_t = (1 - \rho_z)\mu + \rho_z \ln z_{t-1} + \varepsilon_t$, where ε_t is distributed according to a Normal distribution with mean zero and standard deviation σ_ε.

Every period, entrepreneurs are endowed with a unit of labor that is supplied inelastically to other entrepreneurs through a competitive labor market. Capital is accumulated internally by transforming final goods invested in period t into physical capital in period $t+1$. Capital

depreciates at rate δ after being used for production, leading to a law of motion for capital that is given by $k_{t+1} = (1-\delta)k_t + x_t$, where x_t is gross investment.

International trade Entrepreneurs can trade internationally conditional on payment of fixed and variable export trade costs. A firm's export choice at time t is denoted by e_t, and is equal to one if the firm exports in period t and zero otherwise. Firms have to pay a fixed cost F in units of labor every period in which they decide to export. Furthermore, exporters are subject to an ad-valorem trade cost $\tau > 1$, which requires firms to ship τ units for every unit that arrives at destination.

Financial markets Entrepreneurs have access to financial markets, where they can borrow or save by trading two one-period risk-free bonds, one denominated in domestic final goods and the other one denominated in foreign final goods. Financial markets are integrated internationally, and both bonds pay an interest rate r_t in domestic units, in a stationary equilibrium, where the interest rate is taken as given by the small open economy.

We define the real exchange rate ξ as the price of foreign final goods in units of the domestic final good. A firm that chooses to borrow a total amount $\frac{d_{t+1}}{1+r_t}$ (in units of domestic final goods), allocates a fraction $\lambda \in [0,1]$ to debt denominated in domestic final goods, and a fraction $1-\lambda$ to debt denominated in foreign final goods. We assume that λ is a parameter that is taken as given by entrepreneurs. Therefore, in period t, the entrepreneur owes $\lambda\frac{d_{t+1}}{1+r_t}$ units of domestic final goods and $(1-\lambda)\frac{d_{t+1}}{1+r_t}\frac{1}{\xi_t}$ units of foreign final goods. In the following period, the firm repays λd_{t+1} units of domestic final goods for the domestic-denominated debt, and $(1-\lambda)d_{t+1}\frac{\xi_{t+1}}{\xi_t}$ units of domestic final goods for debt denominated in foreign goods.

Entrepreneurs face a borrowing constraint, which limits the amount that they can borrow to a fraction θ of the value of their capital stock at the time that the loan is due for repayment. Thus, while entrepreneurs can trade this bond to save as much as they desire, their borrowing amount d_{t+1} has to satisfy $d_{t+1}\left[\lambda + (1-\lambda)\frac{\xi_{t+1}}{\xi_t}\right] \leq \theta k_{t+1}$ and the natural borrowing limit.

Market structure Entrepreneurs compete with each other under monopolistic competition, and choose the quantities and prices at which to sell in each market subject to their respective demand schedules. In the domestic market, the demand schedule is such that it solves the final good producer's problem, while the demand schedule faced in the international market is given by the rest of the world. Denote the quantities and prices of intermediate goods sold in the domestic market by $y_{h,t}$ and $p_{h,t}$, and those sold in the foreign market by $y_{f,t}$ and $p_{f,t}$. The prices of intermediate goods, $p_{h,t}$ and $p_{f,t}$, are denominated in

units of the domestic and foreign final good, respectively.

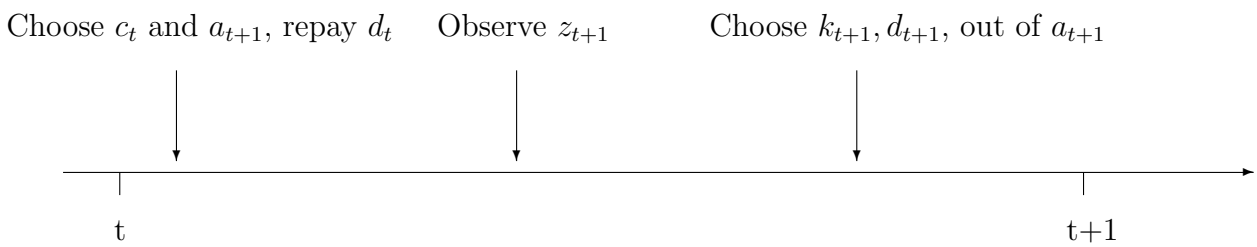


Figure 3: Timing

Timing The timing of entrepreneurs' decisions is as follows. Entrepreneurs begin the period by hiring labor, producing their variety of the intermediate good, and then selling it in each of the markets in which they choose to operate. If they decide to export, $e_t = 1$, then they also pay the fixed export costs. At the same time, they repay their old debt and decide how much net worth, a_{t+1}, to carry over to the following period. At the end of the period, they observe the following period's productivity shock. Then, they simultaneously issue new debt and choose their new level of physical capital. Figure 3 presents the timing of the entrepreneurs' problem.

Entrepreneurs' problem Given this setup, the entrepreneurs' problem at time t consists of choosing sequences of consumption c_t, labor n_t, investment x_t, current period's export status e_t, as well as prices and quantities $y_{h,t}$, $p_{h,t}$, $y_{f,t}$, $p_{f,t}$ at which to sell the intermediate goods in each of the markets, in order to maximize their expected utility. In addition to the borrowing constraint described above and the market-specific demand schedules that are described below, their choices are subject to a sequence of period-by-period budget constraints, law of motion for capital $k_{t+1} = [(1-\delta)k_t + x_t]$, and production technology $y_{h,t} + \tau y_{f,t} = z_t k_t^{\alpha} n_t^{1-\alpha}$. Their budget constraint in period t is given by:

$$c_t + x_t + d_t \left[\lambda + (1-\lambda)\frac{\xi_t}{\xi_{t-1}}\right] + e_t w_t F = w_t + p_{h,t} y_{h,t} + e_t \xi_t p_{f,t} y_{f,t} - w_t n_t + \frac{d_{t+1}}{1+r_t}$$

3.1.2 Final good producers

Final good producers purchase intermediates from entrepreneurs and the rest of the world, and aggregate them to produce a final good. They operate a constant elasticity of substitution (CES) technology with elasticity of substitution $\sigma > 1$. Let the set $[0, 1]$ index the unit measure of entrepreneurs in the economy, and let $\{p_{h,t}(i)\}_{i\in[0,1]}$ and $p_{m,t}$ be the prices of intermediate goods charged by the entrepreneurs and the rest of the world, respectively.[14] Given these prices, final good producers choose the bundle of inputs of domestic and imported intermediates, $\{y_{h,t}(i)\}_{i\in[0,1]}$ and $y_{m,t}$, that maximizes their profits. Then, the problem of final good producers is given by:

$$\max_{y_{h,t}(i),y_{m,t}} Y_{h,t} - \int_0^1 p_{h,t}(i)y_{h,t}(i)di - \xi_t p_{m,t}y_{m,t}$$

subject to

$$Y_{h,t} = \left[\int_0^1 y_{h,t}(i)^{\frac{\sigma-1}{\sigma}} di + y_{m,t}^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}},$$

where $Y_{h,t}$ denotes the quantity of the final good.

The solution to this problem is given by $y_{h,t}(i) = (p_{h,t}(i))^{-\sigma} Y_{h,t}$ and $y_{m,t} = (\xi_t p_{m,t})^{-\sigma} Y_t$, which consist of the demand schedules faced by entrepreneurs and the rest of the world, respectively.

3.1.3 Rest of the world

The rest of the world demands intermediates from entrepreneurs –the domestic economy's exports– and supplies intermediates to final good producers –the domestic economy's imports. The foreign demand for intermediates produced by entrepreneurs is assumed to be given by a downward-sloping demand function with the same constant elasticity of substitution σ as the domestic demand for intermediates, $y_{f,t} = (p_{f,t})^{-\sigma} Y_{f,t}$, where $Y_{f,t}$ denotes the (exogenous) aggregate quantity of foreign final goods of the rest of the world, and $p_{f,t}$ is denominated in units of the foreign final good. The supply of intermediates from the rest of the world, imported by final good producers, is assumed to be perfectly elastic at (exogenous) price $p_{m,t}$.

[14] $p_{m,t}$ is denominated in units of the foreign final good.

3.2 Entrepreneur's problem: Recursive formulation

Let $v(k, d, z)$ be the value function of an entrepreneur with capital k, debt d, and productivity z, who is making consumption and saving decisions, as well as production decisions for the foreign and domestic markets.[15] Let $g(a, z)$ be the value for an entrepreneur with net worth a and productivity z, who decides how much capital k and debt $\frac{d}{1+r}$ carry on to the next period.

Then, the entrepreneur's dynamic problem can be described as

$$\begin{aligned} v(k, d, z) = & \max_{c, a'} \frac{c^{1-\gamma}}{1-\gamma} + \beta \mathbb{E}_{z'} \left[g(a', z') \right] \\ & \text{subject to} \\ & c + a' + d \left[\lambda + (1-\lambda)\xi/\xi_{-1} \right] = w + (1-\delta)k + \pi(k, z) \\ & a' \geq 0 \end{aligned}$$

where

$$\begin{aligned} \pi(k, z) = & \max_{p_h, y_h, p_f, y_f, n, e \in \{0,1\}} p_h y_h + e\, \xi p_f y_f - wn - ewF \\ & \text{subject to} \\ & y_h + \tau y_f = z k^{\alpha} n^{1-\alpha} \\ & y_h = p_h^{-\sigma} Y_h \\ & y_f = p_f^{-\sigma} Y_f \end{aligned}$$

and

$$\begin{aligned} g(a', z') = & \max_{k', d'} v(k', d', z') \\ & \text{subject to} \\ & k' - \frac{d'}{1+r} = a' \\ & d' \left[\lambda + (1-\lambda)\xi'/\xi \right] \leq \theta k' \end{aligned}$$

[15] The value of debt is actually $d \left[\lambda + (1-\lambda) \frac{\xi}{\xi_{-1}} \right]$.

3.3 Competitive equilibrium

Let $\mathcal{S} := \mathcal{K} \times \mathcal{D} \times \mathcal{Z}$ denote the state space of entrepreneurs, where $\mathcal{K} = \mathbb{R}^+$, $\mathcal{D} = \mathbb{R}$, and $\mathcal{Z} = \mathbb{R}^+$ denote the set of possible values of capital, debt, and productivity, respectively. Finally, let $s \in \mathcal{S}$ denote an element of the state space.

For a given value of the interest rate r, a *recursive stationary competitive equilibrium* of this economy consists of prices $\{w, \xi\}$, policy functions$\{d', k', e, c, n, y_h, y_f, p_h, p_f, Y_h, y_m\}$, value functions v and g, and a measure $\phi : \mathcal{S} \to [0, 1]$ such that:

1. Policy and value functions solve the entrepreneurs' problem;
2. Policy functions solve the final good producers' problem;
3. Labor market clears: $\int_{\mathcal{S}} [n(s) + e(s)F]\, \phi(s)ds = 1$;
4. Final good market clears: $\int_{\mathcal{S}} [c(s) + x(s)]\, \phi(s)ds = Y_h$;
5. Measure ϕ is stationary.

4 Mechanism

In this section, we study the mechanism through which changes in the real exchange rate affect aggregate exports in our model. To do so, we first examine the determinants of aggregate exports in a stationary equilibrium, focusing on the impact of financial frictions and foreign-denominated debt. We then investigate the channels through which a large devaluation affects aggregate exports and examine their net impact on aggregate export dynamics.

4.1 Aggregate exports in a stationary equilibrium

In a stationary equilibrium, aggregate exports in units of foreign final goods are given by:

$$\text{Exports} = \int_{s \in \mathcal{S}_x} p_f(s) y_f(s) \varphi(s) ds,$$

where $\mathcal{S}_x := \{s \in \mathcal{S} | e(s) = 1\}$ denotes the set of firms that choose to export, and $p_f(s)y_f(s)$ denotes the value of exports in units of foreign final goods produced by an entrepreneur in state $s \in \mathcal{S}_x$.

Firm-level exports Along the intensive margin, financial frictions and foreign denominated debt reduce the volume of goods exported by firms with a binding borrowing constraint. To the extent that some firms cannot borrow as much as desired, they are forced to operate with a sub-optimal amount of physical capital, which leads them to produce a sub-optimal amount of goods, reducing their level of exports.

To see this, consider an entrepreneur with capital stock k, debt level d, and productivity z. Conditional on choosing to export, the amount that such entrepreneur exports, in units of foreign final goods, is given by:

$$\log(p_f y_f) = \log \Phi + (\sigma - 1) \log z + (\sigma - 1) \left[\log \xi - (1 - \alpha) \log w - \alpha \log \left(\widetilde{r} + \delta + \mu(1 + \widetilde{r} - \theta)\right)\right], \tag{1}$$

where $\widetilde{r}$ denotes the effective real interest rate, μ is the Lagrange multiplier on the entrepreneurs' borrowing constraint, and $\Phi := \left[\frac{\sigma}{\sigma-1} \frac{\tau}{\alpha^\alpha (1-\alpha)^{1-\alpha}}\right]^{1-\sigma} Y_f$ is a constant that is a function of parameters. The effective real interest rate $\widetilde{r}$, denominated in units of domestic goods, is given by $1 + \widetilde{r} = (1 + r) \left[\lambda + (1 - \lambda)\xi/\xi_{-1}\right]$, and represents the return to saving a unit of domestic goods through financial markets. As long as $\xi = \xi_{-1}$, which is the case in the stationary equilibrium, the above expression implies that the units in which debt is denominated does not affect foreign sales.

Equation 1 shows that firm-level exports depend on both aggregate and idiosyncratic variables. First, as in standard models of international trade, firm-level exports are increasing in idiosyncratic productivity z; given the downward-sloping demand faced by exporters in the foreign market, more productive firms find it profitable to export a larger volume of goods. Second, exports are positively related to the real exchange rate since, holding everything else equal, a higher ξ reduces the foreign value of the domestic economy's exports, resulting in higher foreign demand for firm's goods and higher exports. Third, foreign sales are inversely related to the wage, as higher wages increase production costs. Finally, exports sales are also decreasing in the cost of capital as captured by $\widetilde{r} + \delta + \mu(1 + \widetilde{r} - \theta)$, which can be interpreted as the implicit rental cost of capital.

Note that, among financially unconstrained exporters, we have that $\mu = 0$ and the capital rental cost is simply given by $\widetilde{r} + \delta$. Among financially constrained exporters, however, $\mu > 0$, and the implicit rental rate of capital is higher than $\widetilde{r} + \delta$. In this case, the return to investing in physical capital is higher than the borrowing costs, pushing firms to borrow as much as possible given the financial constraint. Now, these firms cannot borrow enough to increase the stock of physical capital up to the point where its implicit rental rate equals the borrowing costs. The lower level of capital held by firms in the economy with financial frictions implies

that firms produce and export less output than in its frictionless counterpart.[16]

Set of exporters Along the extensive margin, financial frictions distort the set of firms that choose to export, reducing the share of firms that find it profitable to do so.

To understand why this is the case, consider first an economy without financial frictions ($\theta = \infty$). Given that entrepreneurs observe next period's productivity when making the investment decision, it follows that in the frictionless economy firms always operate with the optimal level of capital. Therefore, as in standard models of international trade with endogenous export entry decisions, firms choose to export to the extent that their productivity is sufficiently high to make it profitable to pay the fixed export costs; otherwise, they choose to sell only in the domestic market.

In contrast, with financial frictions, firms with high productivity but a low level of net worth might not find it profitable to export. With sufficiently low net worth, firms have insufficient access to internal and external funds, which forces them to choose a suboptimal level of physical capital for the following period. Even though it would be profitable for these firms to pay the fixed export cost in the absence of financial frictions, they choose not to export since they cannot achieve a sufficiently high scale of production to make exporting profitable. Therefore, in this economy the set of firms that choose to export is distorted relative to the frictionless economy, featuring a lower share of exporters. Figure 4 illustrates this effect on firms optimal exporting policies.

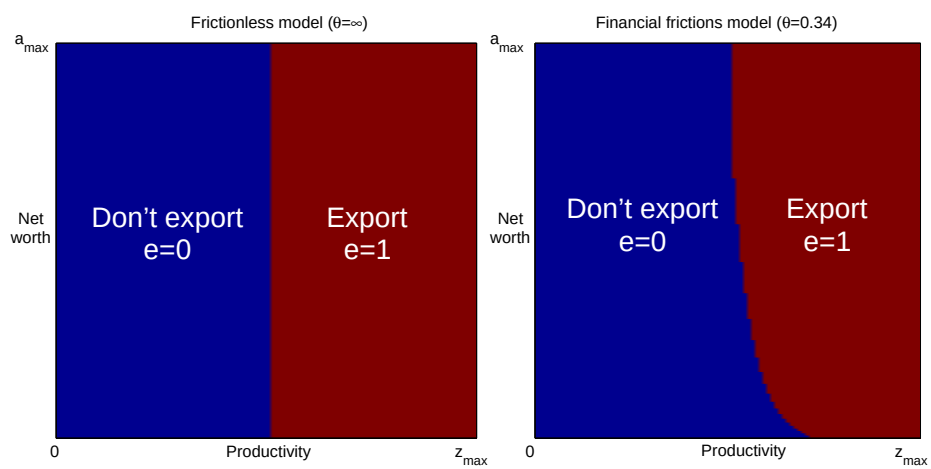


Figure 4: Export entry policy

[16]Note that, as shown by Leibovici (2015), financial frictions also affect firm-level exports through their effect on the equilibrium wage. While the quantitative analysis below takes into account these effects, we abstract from them in this section to ease the exposition.

Note that, as with the intensive margin, given that $\xi = \xi_{-1}$ in a stationary equilibrium, the foreign-denomination of debt does not impact firms' export entry decisions in this case.

4.2 Large devaluation and aggregate exports

We now investigate the impact of a large unexpected increase in the real exchange rate ξ, a large devaluation, on aggregate exports. To do so, we focus on the elasticity of aggregate exports to changes in the real exchange rate:

$$\frac{\partial \log X}{\partial \log \xi} = (\sigma - 1) - (\sigma - 1)\frac{\partial \log w}{\partial \log \xi} + \frac{\partial \log M(\mathcal{S}_x)}{\partial \log \xi} + \frac{\partial \log \left[\frac{1}{M(\mathcal{S}_x)} \int_{s \in \mathcal{S}_x} \left(\frac{z}{[\tilde{r}+\delta+\mu(1+\tilde{r}-\theta)]^{\alpha}} \right)^{\sigma-1} \phi(s) ds \right]}{\partial \log \xi} \quad (2)$$

where $X := \int_{s \in \mathcal{S}_x} p_f(s) y_f(s) \phi(s) ds$ denotes aggregate exports and $M(\mathcal{S}_x) := \int_{s \in \mathcal{S}} e(s)\phi(s)ds$ denotes the measure of exporters.

We observe that the elasticity of aggregate exports is equal to the sum of four terms. The first term, $\sigma - 1$, captures the price elasticity of foreign demand. Higher values of $\sigma - 1$ imply a more elastic foreign demand, where small price changes lead to higher changes in sales. The second term captures general equilibrium effects that result from changes in the wage following a large devaluation: to the extent that the wage increases, the aggregate exports elasticity decreases. The third term is the elasticity of the share of exporters with respect to changes in the real exchange rate. Finally, the last term captures the impact of changes in the real exchange rate on the average productivity of exporters, weighted by the effective interest rate and by the extent to which their financial constraints bind. In particular, increases in the effective interest rate due to a large devaluation or a tightening of the borrowing constraints lead to a decrease in the productivity weight and, thus, to a decrease in this measure of productivity and aggregate exports.

To better understand the response of exports to changes in the real exchange rate, we now analyze how exports respond in the frictionless model, in the model with financial frictions and no foreign-denominated debt, and in an economy with financial frictions and foreign-denominated debt.

Consider first an economy without financial frictions ($\theta = \infty$). In this economy, a devaluation increases exports through two channels. First, it increases exports through the intensive margin of trade, as firms that were already exporting increase their foreign sales in response to higher foreign demand for domestic intermediate goods (the last term in Equation 2). Second, by making the foreign market more attractive, an increase in the real exchange rate leads some previous non-exporters to begin exporting increasing the share of exporters (as captured by the third term in Equation 2). Finally, as exporters expand their

foreign sales, demand for labor increases which results in a higher wage. This dampens the increase of exports following a devaluation (the second term in Equation Equation 2).

Consider next the response of exports in an economy with financial frictions and all debt denominated in domestic final goods. In this economy, a devaluation has the same expansionary effect as in the case above, but the increase of exports is smaller. To the extent that exporters are financially constrained, they cannot immediately adjust their overall scale of production, since they first need to increase their net worth to expand their stock of physical capital. This slows down the response of exports to a real depreciation (as μ increases, the last term in Equation 2 decreases). Moreover, while devaluations induce some non-exporters to start exporting, there is less entry into the foreign market than in the frictionless economy, since financial frictions prevent firms from operating at their optimal scale. Therefore, while real depreciations have expansionary effects on aggregate exports in a model with financial frictions, these effects are smaller than in its frictionless counterpart.

The negative effects of financial frictions described above are partially offset by a reallocation channel that is absent in the frictionless economy: for a given level of total sales, devaluations increase the marginal revenue from exporting relative to the marginal revenue from domestic sales. Therefore, following a devaluation, financially constrained firms choose to increase the proportion of their total production sold abroad at the expense of domestic sales. To the extent that firms sell most of their output domestically, firms may be able to substantially increase their exports by reallocating sales across markets. However, to the extent that firms sell most of their output internationally, they may not be able to reallocate output across markets to increase exports as much as desired. Firms with higher margin to reallocate sales across markets experience lower increases of μ and, therefore, lower decreases in the last term of Equation 2.

Finally, consider the economy with financial frictions and debt denominated in foreign goods. The presence of foreign-denominated debt leads to an additional contractionary force: balance-sheet effects. The increase in the real exchange rate increases firms' debt burden in terms of domestic goods, tightening the borrowing constraint of those firms that were already financially constrained, and forcing some previously unconstrained firms to become constrained. This affects negatively both the intensive and extensive export margins and tends to decrease exports.

Thus, in the model with financial frictions and foreign-denominated debt, the net impact of a large devaluation on aggregate exports depends on the extent to which firms increase or reduce their overall scale, the extent to which these firms decide to reallocate between the domestic and foreign markets, and the share of firms that begin to export. Therefore, to determine the contribution of these conflicting forces to the observed dynamics of aggregate

exports in episodes of large devaluations, we quantify their relative importance in the next section.

5 Quantitative Analysis

In this section, we study the quantitative implications of our model. We calibrate the model to match key cross-sectional moments of plant-level data and investigate the extent to which financial frictions and balance-sheet effects can account for the dynamics of aggregate exports observed in the data following large real depreciations.

To quantify these channels, we study the response of the economy to a sudden and unexpected increase in the real exchange rate caused by a sequence of shocks to the price of imported varieties, $p_{m,t}$. Moreover, to understand the role played by financial frictions and foreign-denominated debt, we compare the implications of our baseline model with those of a version of the model in which all debt is denominated in domestic unit, as well as another version without financial frictions ($\theta = \infty$).

5.1 Data

We calibrate our model to match salient features of Mexican plant-level data in 1994, covering the twelve months leading to the large devaluation that took place on December 20th, 1994. Specifically, we use the Annual Manufacturing Survey (Encuesta Industrial Anual), collected by the National Institute of Statistics and Geography (INEGI), which we supplement with other data sources specified below. The Annual Manufacturing Survey is an annual survey that collects longitudinal data on a sample of manufacturing plants. The dataset excludes plants in export processing zones ("maquiladoras," which are subject to tax and tariff incentives) and contains all plants with more than 100 workers, and as many smaller plants (in decreasing order by size) as are required to account for at least 85% of the total output produced by each sector; for more details see Iacovone (2008).[17]

5.2 Exporters heterogeneity

Heterogeneity in export intensity. In our model, firms respond to changes in the real exchange rate by adjusting exports through three channels: (i) exporters expand their foreign sales by increasing their scale, either by accumulating capital or by hiring labor; (ii) firms that cannot increase their production due to borrowing constraints can increase their foreign

[17] Our findings are robust to calibrating our model to salient features from the Chilean Annual Manufacturing Survey (ENIA), which covers all plants with at least 10 workers in an alternative emerging economy.

sales by reallocating sales from the domestic to foreign markets; and (iii) some non-exporters start exporting. The extent to which firms can reallocate their sales across markets depends on their initial export intensity (that is, the share of sales accounted by exports): firms with higher export intensity have less scope for reallocation. Therefore, in order to discipline the importance of this channel, we examine the extent of heterogeneity in export intensity across firms.

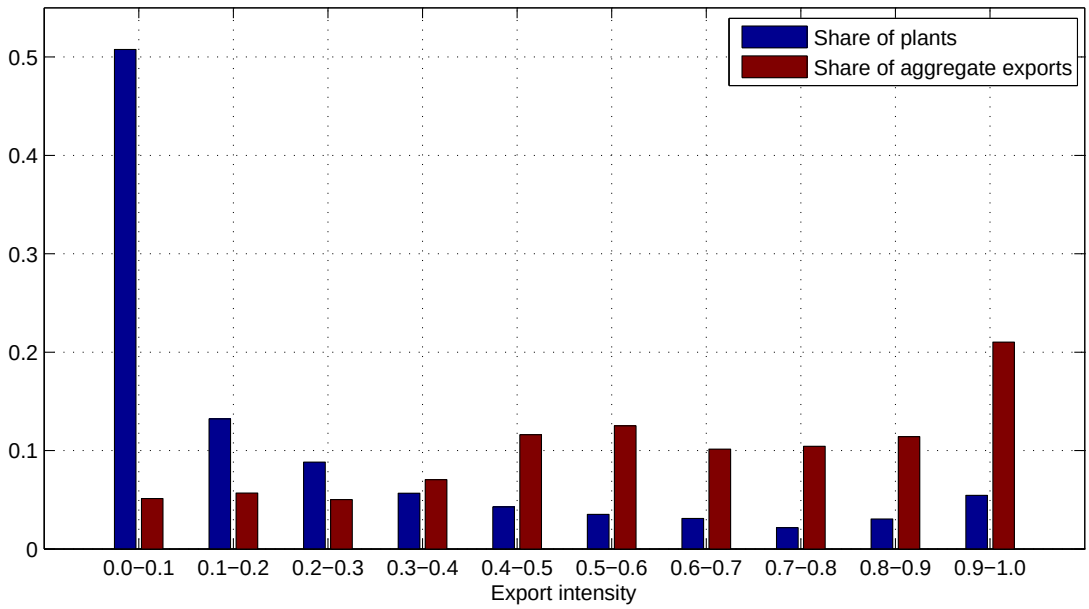


Figure 5: Export intensity distribution

We find that there is indeed substantial heterogeneity in export intensity across firms. Figure 5 shows that, while the average export intensity is 0.23 (i.e. on average, firms export 23% of the total sales), most exporters feature much lower export intensities and others sell most of their production to foreign markets. In particular, approximately half of the plants sell less than 10% of their total sales to foreign markets (but more than 0%), while more than 17% of the plants sell more than 50% of their output internationally. This large degree of export intensity heterogeneity suggests that firms may be able to reallocate their sales across markets in response to a real exchange rate to very different degrees.[18]

To examine the extent to which firms with low and high export intensity may matter

[18]It is also worth noting that, despite their small numbers, exporters with high export intensity account for the majority of exports. In particular, the 5% of firms that have export intensity of 0.9 or higher accounts for more than 20% of exports while the exporters with export intensity of less than 0.1 account for only 5% of exports (though more than 50% of exporters fall into this category. We found similar heterogeneity among manufacturing firms in Chile.)

in the aggregate, we divide them into two groups based on their contribution to aggregate exports. Firms with export intensity below 0.6 account for almost 50% of aggregate exports and constitute 86% of all exporters. Firms with export intensity higher than 0.6 account for almost 50% of aggregate exports and constitute 14% of all exporting firms. Note that the latter group doesn't simply consist of firms that are also larger domestically: these firms account for less than 2% of aggregate domestic sales. We report the results in Table 3.

Table 3: Heterogeneity in export intensity among exporters

Export intensity	Share of exports	Share of exporters	Avg. export intensity
0.0 - 0.6	0.47	0.86	0.13
0.6 - 1.0	0.53	0.14	0.84

Heterogeneity in the currency composition of debt. As argued in the empirical section, there is substantial evidence that exporters have a significantly larger share of their liabilities denominated in foreign currency compared to non-exporters. Using balance-sheet data on firms from different Latin-American countries, Martınez and Werner (2002), Benavente et al. (2003), Galiani et al. (2003), Pratap et al. (2003), Carranza et al. (2003), Aguiar (2005), Bleakley and Cowan (2008), find evidence that exporters tend to have more debt denominated in foreign currency than non-exporters. We find a similar pattern among firms in Brazil, Indonesia, Russia and Turkey using WBES dataset (Table 2).

Assumptions. Above we showed that there is substantial heterogeneity in export intensity across firms and that exporters tend to hold more foreign-denominated debt than non-exporters.

Motivated by this evidence, in the quantitative analysis below, we consider two types of firms: (i) a fraction ζ of firms that is subject to low export costs, leading to high export intensity; and (ii) a fraction $1-\zeta$ that face high export costs, leading to low export intensity. We refer to the first group of firms as "low-export-cost" firms and to the second group of firms as "high-export-cost" firms. High-export-cost firms are subject to fixed costs F and variable trade costs τ; low-export-cost firms face no fixed costs and are subject to a variable trade cost $\tau_X < \tau$.

Since exporters tend to hold more foreign-denominated debt than firms that produce for the domestic market, we assume that firms in the first group have all their debt denominated

in foreign units while the rest have all their debt denominated in domestic units. That is, we set λ_X, the fraction of debt denominated in domestic final goods among low-export-cost firms, to 0, and λ, the fraction of debt denominated in domestic final goods among the remaining firms, to 1. All other parameters are the same across the two groups.

While we conduct the main quantitative analysis under the assumptions above, we also study the sensitivity of our results to these assumptions. We find that the impact of financial frictions and balance-sheet effects on aggregate exports during a large devaluation crucially depends on the distribution of export intensity and debt across firms.

5.3 Calibration

In this subsection, we describe our calibration strategy. We divide the parameters space in two groups. The parameters in the first group are predetermined, while those in the second group are calibrated to match key moments of the data.

Table 4: Parameterization

Predetermined		Calibrated	
γ	2	ζ	0.04
σ	4	F	0.04
δ	0.06	τ	6.33
α	0.33	τ_X	1.96
β	0.8	σ_ε	0.25
ρ_z	0.9	θ	0.34
r	0.06		

The first group of parameters consists of γ, σ, δ, α, ρ_z, β, and r. We set the risk aversion parameter, γ, to 2 and the elasticity of substitution across varieties, σ, equal to 4. These values fall well within the values used in previous studies.[19] We follow Kohn et al. (2015) and set $\beta = 0.8$, $\rho_z = 0.9$, $\delta = 0.06$, and $\alpha = 0.33$. Finally, we set the real interest rate to 0.06.[20]

The second group of parameters consists of the fixed cost of exporting, F; the variable export cost faced by high-export-cost firms, τ; the variable export cost faced by firms with low

[19] See Guvenen (2006), Blundell et al. (1993) for the intertemporal elasticity of substitution, and Ruhl (2008) for the elasticity of substitution across varieties σ.

[20] In addition, we normalize the exogenous variables by setting $p_m = 1$ and $Y_f = 10$.

export costs, τ_X; the standard deviation of productivity shocks, σ_ε; the collateral constraint parameter, θ; and the share of low-export-cost firms ζ. We choose them to match the following moments: (i) the share of exporters, (ii) the average export intensity of firms that export less than 60% of their total sales, (iii) the average export intensity of firms that export more than 60% of their total sales, (iv) the standard deviation of log sales, (v) the share of all plants that feature an export intensity higher than 60% in the Mexican data, and (vi) the credit-to-GDP ratio. We compute target moments (i) to (v) using the Mexican plant-level data described above. For (vi), we obtain the ratio of private credit to GDP from the World Bank.

Calibration Strategy. The parameters that we use in our calibration are presented in Table 4, while the target moments and their model counterparts are presented in Table 5. To calibrate the model, we follow a Simulated Method of Moments approach. We choose the parameters to minimize the objective function MWM', where M is a row vector that consists of the log-difference between each target moment and its model counterpart. W is a weighting matrix that allocates the same weight to each of the cross-sectional moments (i) to (v). Table 5 shows that the model is able to match the target moments almost exactly.

Table 5: Target moments

	Data	Model
Share of exporters	0.29	0.29
Share of firms with low export costs	0.04	0.04
Avg. export intensity of high-cost-exporters	0.13	0.13
Avg. export intensity of low-cost-exporters	0.84	0.84
Standard deviation of log sales	1.58	1.58
Credit/GDP	0.31	0.31

5.4 Large devaluation

In this section, we investigate the response of the economy to an unexpected increase in the real exchange rate — a real depreciation — caused by a decrease in the price of imported intermediates, p_m. A decrease in p_m increases the real exchange rate since it reduces the cost of producing a unit of the domestic final good, thus increasing the relative price of the foreign

final good.[21] We consider an economy in a stationary equilibrium. The experiment, then, consists of *unexpectedly* changing the price of imported intermediates p_m, and investigating the dynamic response of the economy to this shock.

To approximate the behavior of the median change of the real exchange rate in devaluation episodes (as documented in section 2), we assume that the price of imported intermediates decreases gradually.[22] In particular, we study an unexpected decrease of p_m from 1 to 0.71 in period 2, and an additional decrease from 0.71 to 0.55, its final value, in period 3. As a result of these shocks, the real exchange rate increases by approximately 35%, a value close to the one observed in the data.

To understand the role played by foreign-denominated debt and borrowing constraints in shaping the response of the economy to a change in the real exchange rate, we compare the dynamics implied by our baseline model with the dynamics implied by two alternative versions of our model. First, we examine the role of balance-sheet effects by contrasting our findings with those from a model with financial frictions and debt denominated in domestic units ($\theta = 0.34$ and $\lambda = \lambda_X = 1$). Then, we examine the role of financial frictions by contrasting our findings with those from a model without borrowing constraints and debt denominated in domestic units ($\theta = \infty$ and $\lambda = \lambda_X = 1$).[23]

Timing of the shock. The shock to the price of imported intermediates occurs in period 2 after entrepreneurs hire labor and make their production decisions (i.e. after they choose n and produce their domestic and foreign output, y_h and y_f), but before final goods are produced and entrepreneurs' consumption-saving decisions take place. We present the exact timing in Figure 6 and explain it in more details below.

As shown in Figure 6, at the beginning of period 2 entrepreneurs make their hiring and production decisions expecting the real exchange rate to stay at its steady state level, ξ. In particular, they decide how much of their output to sell domestically and how much of it to export. After entrepreneurs' production takes place, the shock to the price of the imported intermediate occurs. At the time of the shock, all agents learn that the price of the imported intermediate decreases from 1 to 0.71 in period 2 and that it will decrease further from 0.71 to 0.55 in period 3, staying at its new level thereafter. Thus, at the time of the shock all agents learn the deterministic path of p_m from that point onwards. Given rational expectations and the absence of aggregate uncertainty, they also update the expected deterministic path of

[21] While there are alternative ways to induce a real exchange rate depreciation in our model, we found that the main results are robust to alternatives that generate devaluations of a similar magnitude.

[22] The gradual decrease of the imports price allows us to generate a persistent real exchange rate depreciation. The results with a one-time decrease in the price of imports are reported in section 5.6.

[23] These alternative models are calibrated separately using the strategy described in subsection 5.3, with the exception that we don't target the ratio of credit to GDP in the frictionless model.

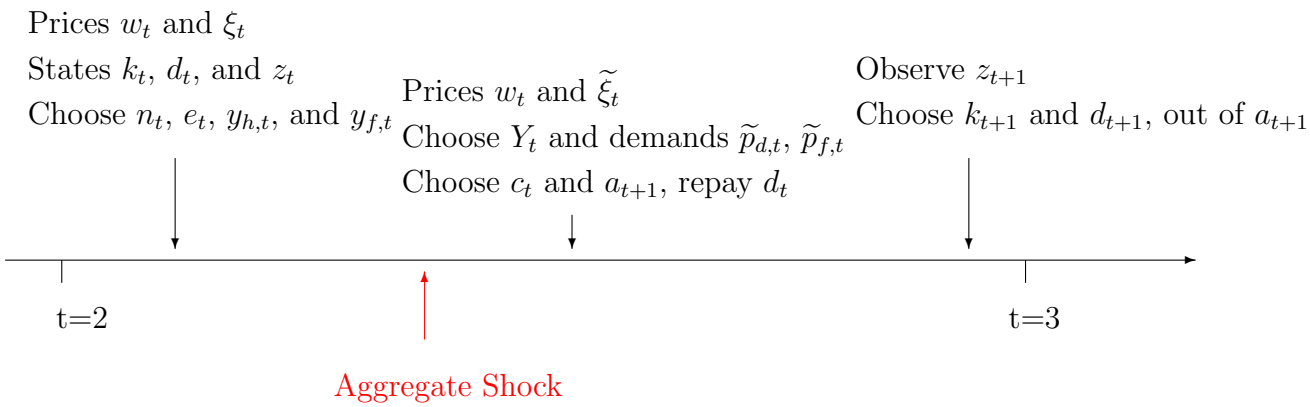


Figure 6: Timing of devaluation

all other aggregate variables of the economy.

After the decrease in p_m, final good producers decide how much of the final good to produce. They also decide how many domestic and imported intermediates to purchase, leading to an adjustment of prices and profits obtained by entrepreneurs from the production of intermediates, according to the updated demand for these from final good producers. In response to the choices of final good producers, the price of the intermediate goods, and the exchange rate adjust to their new levels, $\widetilde{p}_{d,t}$, $\widetilde{p}_{f,t}$, and $\widetilde{\xi}_t$, respectively.

Once the production of final goods takes place, entrepreneurs collect their profits, choose their consumption and net worth, repay their old debt under the new real exchange rate, and, if they choose to export, they also pay the fixed costs of exporting, resulting in the following budget constraint:

$$c + a' + d\left[\lambda + (1-\lambda)\frac{\xi}{\xi_{-1}}\right] - (1-\delta)k = w + p_h y_h + e\xi p_f y_f - wn - ewF$$

At the end of the period, firms observe next period's idiosyncratic productivity, z', and choose how much capital and debt to carry on to the following period, out of the net worth a'.

5.5 Results

RER and aggregate exports. We first investigate the behavior of the real exchange rate following a decrease in the price of imported intermediates and compare its dynamics across the three models mentioned above: (i) our baseline model with borrowing constraints, debt denominated in foreign final goods among low-export-cost firms, and debt denominated in domestic final goods for the remaining firms (i.e. $\theta = 0.34, \lambda = 1, \lambda_X = 0$); (ii) an economy with borrowing constraints and debt denominated in domestic goods for all firms (i.e. $\theta = 0.34, \lambda = 1, \lambda_X = 1$); and (iii) an economy without borrowing constraints and debt denominated in domestic goods (i.e. $\theta = \infty, \lambda = 1, \lambda_X = 1$).

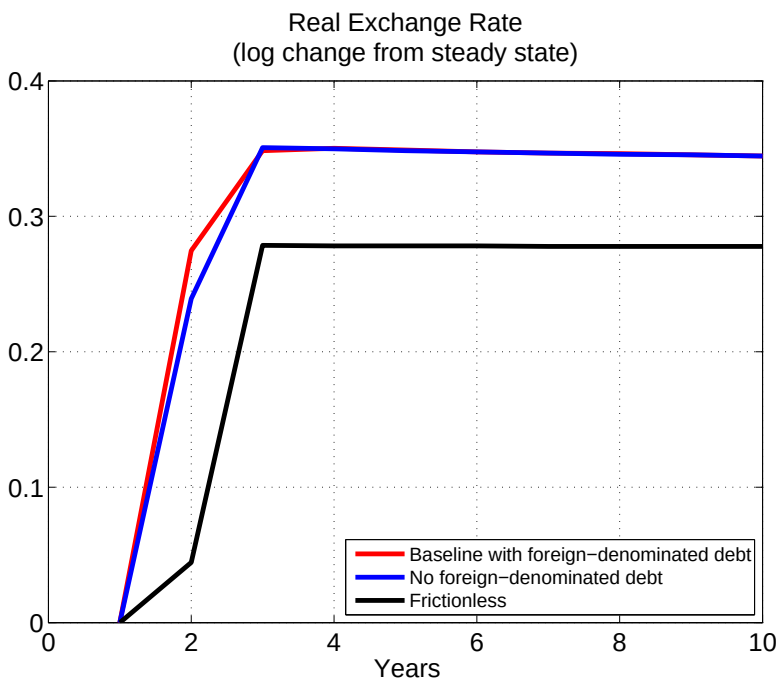


Figure 7: Real Exchange Rate

Figure 7 plots the percentage deviation of the real exchange rate from its steady state for each of the economies, following the shock to the price of imported intermediates. We observe that, in the baseline model, the real exchange rate increases on impact by around 28%, followed by an additional 8% increase in period three, and stays relatively constant afterwards. The real exchange rate follows a similar pattern in the model with financial frictions and no foreign-denominated debt, except that its initial response is smaller (it increases on impact by 24%). In the frictionless model, the real exchange rate only increases by 6% in period 2, before reaching its new steady state level in period 3, 29% above its initial level. Thus, the same shock generates a smaller real exchange rate increase in the economy

without financial frictions compared to the economies with borrowing constraints.

Next, we examine the response of exports to these changes in the real exchange rate. Since the same shock generates different responses of the real exchange rate across the three models, we focus on the elasticity of exports to changes in the real exchange rate relative to the initial stationary equilibrium.[24] This not only allows us to compare the response of exports across the models but also to compare them with the data.

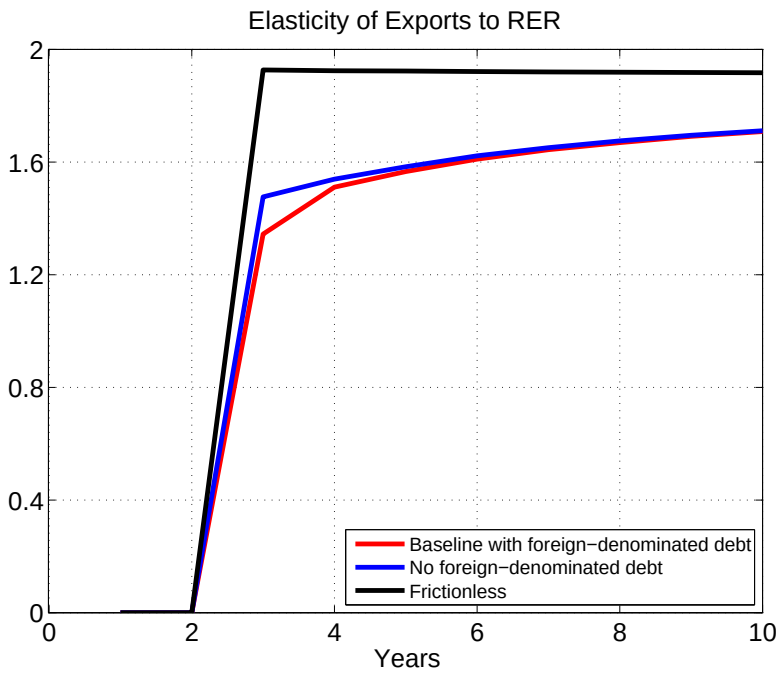


Figure 8: Elasticity of Exports to Real Exchange Rate Changes

Figure 8 plots the response of aggregate exports in the three models described above. First, note that, in the economy without financial frictions, aggregate exports adjust to their new stationary equilibrium level as soon as firms are able to adjust their exports in period 3. Thus, a standard model of international trade with fixed export costs but no borrowing constraints implies that exports adjust immediately to the change in the real exchange rate. This stands in stark contrast to the gradual increase observed in the data, as observed in Figure 1.

With financial frictions and only debt denominated in domestic units, not only is the exports elasticity significantly lower than in the frictionless economy in period 3, but it also grows slowly towards its long-run equilibrium value, thus generating a pattern of gradual

[24] Specifically, the elasticity of exports to the real exchange rate is computed as $E_{x,rer} = \frac{\ln(X_{1+k})-\ln(X_1)}{\ln(RER_{1+k})-\ln(RER_1)}$ for $k = 1, 2, ...$, where period 1 is the pre-devaluation period. This is the same object examined in the empirical section (Figure 1).

adjustment closer to the one observed in the data. In particular, for each one-percent increase in the real exchange rate, aggregate exports increase by 1.48% in period 3, a value 23% lower than its frictionless counterpart, 1.93%, and substantially closer to the empirical elasticity. Thereafter, the elasticity of exports to real exchange rate changes increases slowly to its final value of 1.78. This result suggests that financial frictions significantly slow down the aggregate exports adjustment to its new steady state value.

Finally, we examine our baseline model, where low-export-cost firms have all of their debt denominated in foreign units and, hence, the value of their net worth is affected when the real exchange rate increases. We observe that, in this case, the export elasticity is only 1.34 in period 3, 9% lower than in the economy with no foreign-denominated debt and 30% lower than in the model without financial frictions. Thereafter, the export elasticity increases slowly to its new long-run value of 1.78, the same long-run level as in the model with financial frictions and only domestic debt. Throughout this adjustment, however, the model with balance-sheet effects implies a lower export elasticity than the model with no foreign-denominated debt. Therefore, we conclude that the model with financial frictions and balance-sheet effects, our baseline model, implies an aggregate export adjustment that is closer to the dynamics of exports observed in the data than the other versions of the model.

Other aggregate variables. Given the findings above, we conclude that financial frictions slow down the adjustment of aggregate exports, and that foreign-denominated debt amplifies this effect. We now describe the effects of the real depreciation on other aggregate variables such as credit and the expenditure-related components of GDP.

As we discuss in the mechanism section, while real exchange rate depreciations lead to an increase in exports by increasing the domestic value of firms' export profits, they also have a contractionary effect on exports. First, they reduce firms' net worth, tightening the borrowing constraint exactly when firms want to expand their capital and production. Second, if the shock creates a persistent devaluation so that further devaluations are expected in the near future, it increases the opportunity cost of capital for firms borrowing in foreign goods.

Figure 9 shows the dynamics of the total domestic value of credit of low-export-cost firms in our baseline model and in the model with financial frictions but only domestic-denominated debt. We observe that, in the baseline model, the real depreciation causes a reduction in net worth that leads to an increase in credit in period 2 due to the higher domestic value of credit. In period 3, credit decreases sharply due to the contraction of investment that results from the tightening of the borrowing constraint. Credit increases gradually thereafter, following the increase of capital and production. In contrast, in the

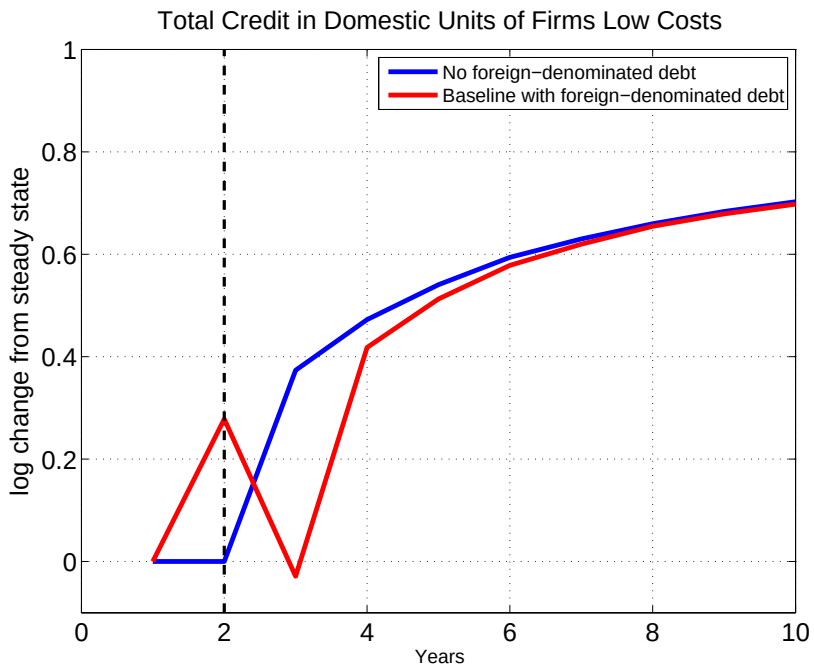


Figure 9: Total Domestic Value of Credit of Low-Export-Cost Firms

economy with only domestic-denominated debt, credit increases monotonically to its new steady state, following the increase in production.

Next, we examine the effect of the real exchange rate change on GDP, consumption, investment, and the ratio of net exports to GDP. Figure 10 shows that, following a reduction in the price of imported goods, GDP and consumption increase gradually in our baseline model and in the model with only domestic-denominated debt.

In contrast, investment and the ratio of net exports to GDP differ substantially across the two economies. Following the aggregate shock, there is a sharp increase of investment and a worsening of the trade balance in the model with only domestic-denominated debt. In contrast, in the presence of foreign-denominated debt, investment and net exports do not respond on impact, adjusting from period 3 onwards. In particular, in our baseline model, investment increases slightly in period 2 before featuring a sharp increase in period 3, while net exports relative to GDP stays flat in period 2 before falling in period 3. Investment does not increase on impact as a result of the lower net worth of constrained firms and the higher opportunity cost of capital due to the expected further real exchange rate depreciation between periods 2 and 3. The low response of net exports to GDP in the model with foreign-denominated debt is driven by the lower aggregate demand due to balance-sheet effects that prevail in period 2, offsetting the increased demand for imports in response to the shock in their price. In contrast, net exports to GDP fall sharply in period 2 in the model with no

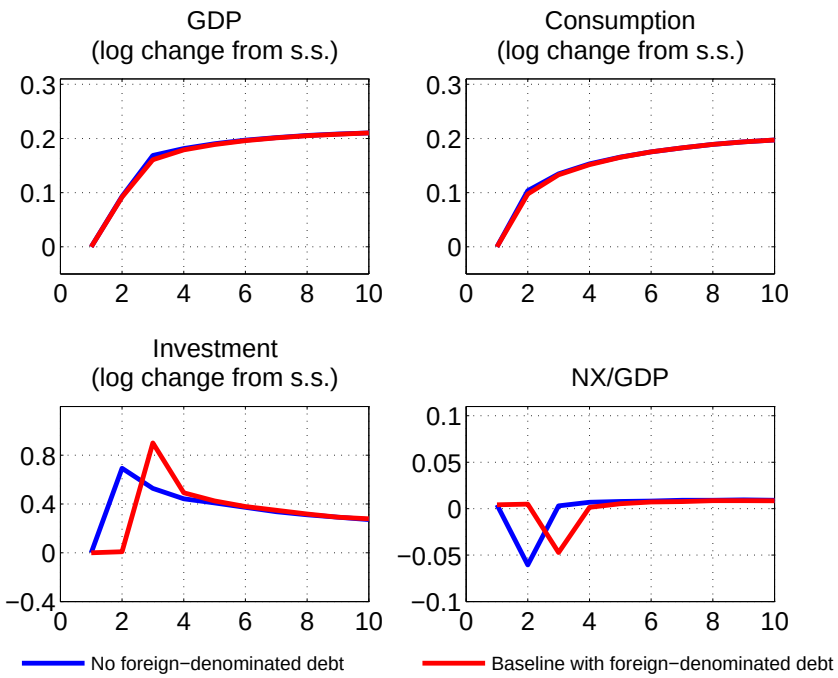


Figure 10: Expenditure-Related Components of GDP

foreign-denominated debt, as is the case in period 3 for the baseline model.

5.6 Sensitivity analysis

In our baseline calibration above, we make two stark assumptions: (i) we assume that there is a fraction of firms that face lower export costs than the rest, and (ii) we assume that low-export-cost firms are the only ones with foreign-denominated debt. While both of these assumptions are motivated by our plant-level evidence and by earlier empirical findings in the literature, we now investigate the extent to which our results hinge on them. In addition, we examine the behavior of the real exchange rate and aggregate exports to a one-time shock in the price of imported intermediates, instead of the gradual shock that we considered above.

All debt denominated in foreign units. We first analyze the effect of a real exchange rate depreciation on aggregate exports when all firms have only foreign-denominated debt. In Figure 11, we present the elasticity of exports to changes in the real exchange rate and compare it with our baseline model and the version of the model in which all debt is denominated in domestic units.

Surprisingly, we find that the elasticity of aggregate exports in the case of only foreign denominated debt is higher than the elasticity implied by the model in which only a fraction

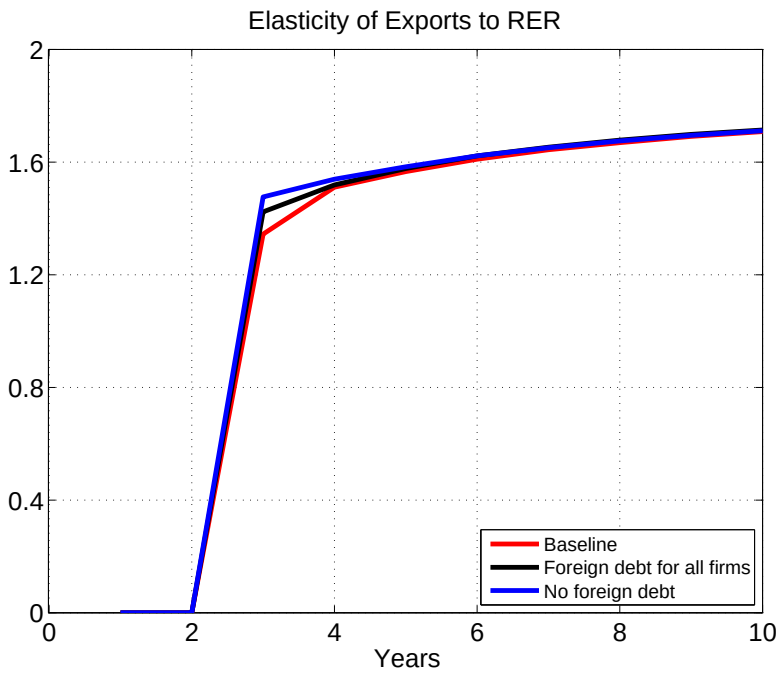


Figure 11: Elasticity of Exports to RER: All Foreign-Denominated Debt

ζ of firms holds foreign-denominated debt, and close to the elasticity implied by the model with only domestic-denominated debt.

When all firms hold foreign-denominated debt, the devaluation has a negative effect on domestic producers with high export costs by increasing the domestic value of their liabilities. Many of these producers do not export, neither before nor after the devaluation, and therefore do not benefit from the increased foreign demand for domestic goods. Consequently, these firms are negatively hit by the devaluation and decrease their labor demand, leading to a lower increase in the wage than in the other cases as shown in figure 12. Exporters benefit from the relatively lower prevailing wage, and hire more labor, increasing their total production and exports by more than in the baseline model, where the devaluation does not adversely affect high-export-cost firms. This translates into a higher export elasticity compared to our baseline model.

Export intensity and the extent of reallocation. Throughout our analysis above, we assume that there are two types of firms that differ with respect to their export intensity: (i) firms subject to low export costs which have high export intensity, and (ii) firms subject to high exports costs which have low export intensity. We now analyze the extent to which alternative assumptions on the distribution of export intensity, and the resulting potential to reallocate sales across markets, affect our findings.

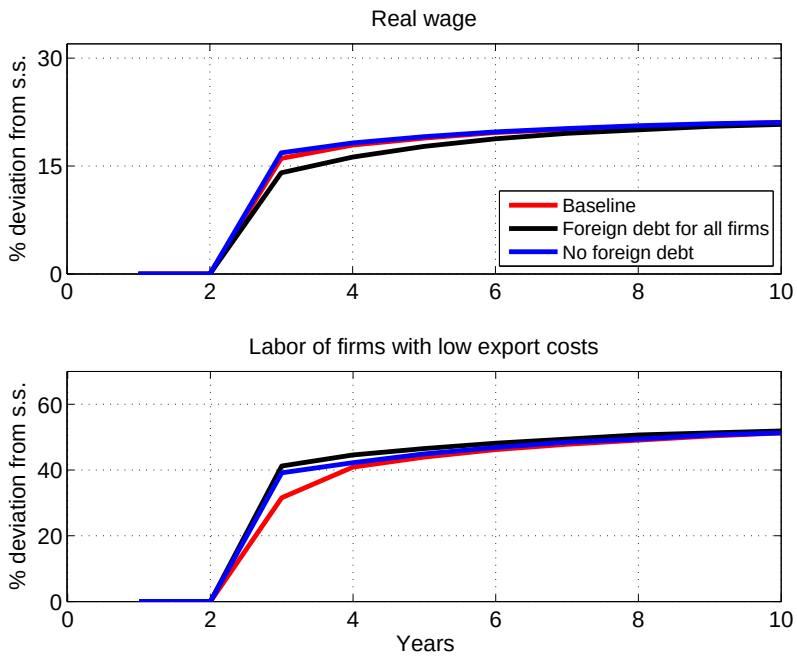


Figure 12: Elasticity of Exports to RER: All Foreign-Denominated Debt

Figure 13 below compares the export elasticity implied by a model with financial frictions and all debt denominated in foreign units across three alternative assumptions about the distribution of export intensity: (i) the baseline model; (ii) an economy with only one type of firms where all firms are subject to the same fixed and variable trade costs, implying that every firm has the same export intensity; and (iii) an economy with two types of firms where firms of one type export but cannot sell domestically and firms of the second type sell domestically but cannot export.[25] Figure 13 shows export elasticity for each model as a percentage of its final steady state value.

Even though model (ii) is a standard trade model with financial frictions, we find that the export elasticity is almost as high as in the frictionless model. This result is driven by the high reallocation of production towards foreign sales by continuing exporters. Since firms only use a small share of their resources (capital and labor) to produce for the foreign market, they are able to reallocate their production from the domestic to the foreign market even holding their total output unchanged (i.e. even in the case in which they have a binding borrowing constraint).[26] That is, even though these firms are subject to financial

[25] Models (ii) and (iii) are calibrated separately using the strategy described in subsection 5.3, with the exception that we choose variable trade costs to match the aggregate ratio of exports to total sales instead of average export intensities.

[26] See the mechanism section for the connection between firm-level export intensity and the strength of the reallocation channel.

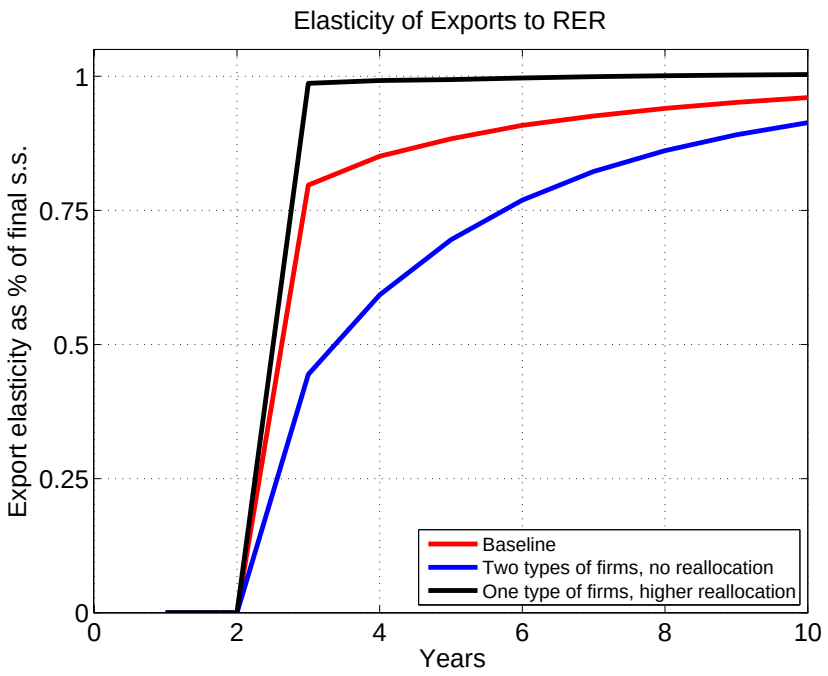


Figure 13: Elasticity of Exports to RER: Export Intensity Heterogeneity

constraints, which are binding for many of them, to the extent that their export intensity is sufficiently low, they can reallocate sales across markets. This effect largely offsets any impact of borrowing constraints and balance-sheet effects on aggregate export dynamics.

We contrast these findings with those implied by model (iii) above: an economy in which a fraction of firms only exports and the rest only produce for the domestic market. In this model, exporters have no margin to reallocate domestic sales to be sold internationally. Thus, in this case, the export elasticity in period 3 is significantly lower than in models (i) and (ii).[27] Therefore, the only way in which firms can increase their exports is by hiring labor and by expanding their physical capital. However, as their physical capital declines following the decrease in net worth due to the devaluation, this adjustment is severely suppressed and the resulting export elasticity is significantly lower than its final steady state value.

Given the sharp differences across models (i) to (iii), we conclude that the distribution of export intensities and the implied degree of reallocation play a crucial role in driving the response of aggregate exports during episodes of large devaluations. This is why, in our baseline model, we discipline the extent of reallocation available to firms by calibrating it to capture salient features of the export intensity distribution in the data (see Table 3).

[27] In addition, there is no entry into exporting in this case (i.e. no adjustment along the extensive margin), which further mutes the response of aggregate exports. However, in the baseline model, the increase in export intensity of continuing exporters accounts for more than 80% of the increase in exports.

One-time shock. Finally, we consider a one-time decrease in the price of imported goods, instead of the gradual decrease considered above. Figure 14 contrasts the behavior of the real exchange rate and the exports elasticity implied by our baseline model under these two alternative experiments.

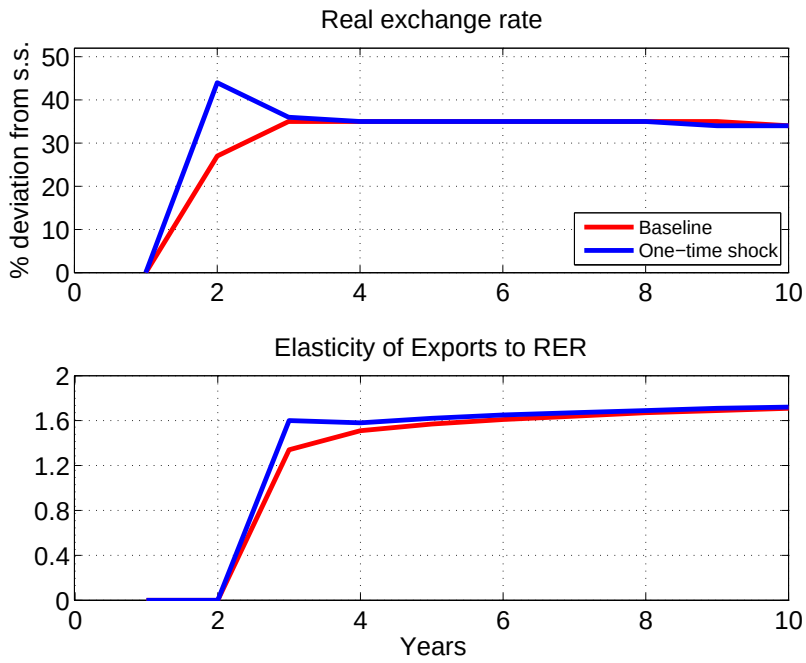


Figure 14: Elasticity of Exports to RER: One-Time Shock

As discussed above, the gradual shock generates a real exchange rate depreciation in periods 2 and 3, with a persistent but modest appreciation thereafter. In contrast, in the case of a one-time shock, the real exchange rate depreciates sharply in period 2, but it sharply appreciates between periods 2 and 3, after which the two models imply very similar paths for the exchange rate.

Consequently, with a one-time shock the exports elasticity is higher in period 3 than in the gradual-shock case. From period 4 onwards the evolution of the exports elasticity in both cases in very similar. The larger increase in the exports elasticity on impact is due to the effect of a lower opportunity cost of capital in period 2, as firms expect an appreciation that decreases the effective rate of return they have to pay on their foreign-denominated debt. All other results presented above remain unchanged under this one-time shock.

5.7 Export dynamics in large devaluations: Model vs. Data

The experiment above is designed to contrast alternative models subject to a common and parsimonious sequence of shocks that, in the baseline model, can match the median real exchange rate change *on impact* across the 12 devaluations considered in section 2. We now examine the extent to which our baseline model with financial frictions and foreign-denominated debt can account for the dynamics of aggregate exports when facing real exchange rate *dynamics* identical to those observed in the data, as reported in section 2. To do so, we choose the sequence of import price shocks to match the median real exchange rate change relative to the pre-devaluation year over a period of four years after the devaluation.

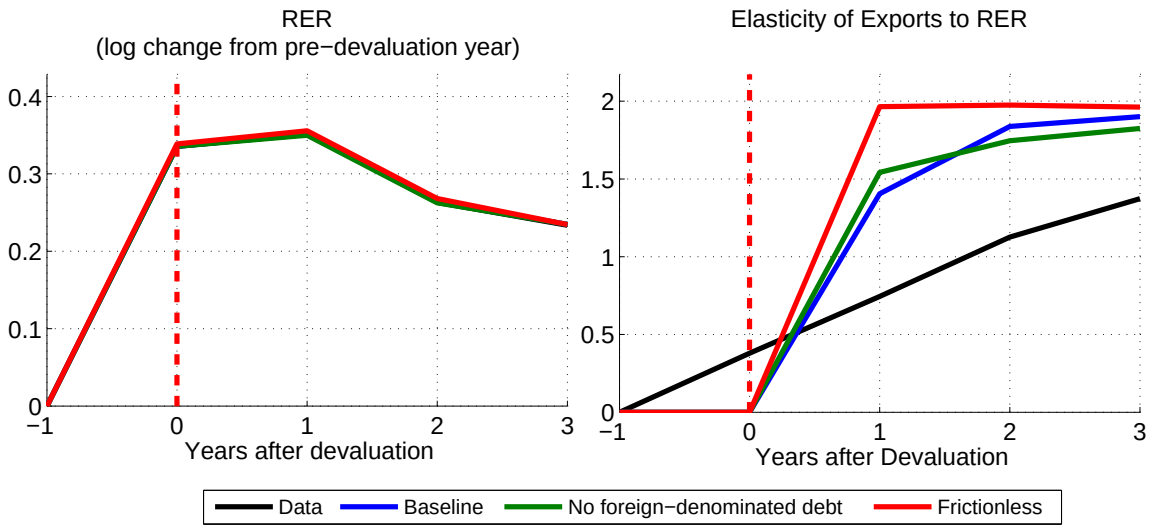


Figure 15: Export Dynamics in Large Devaluations: Model vs. Data

The left panel of figure 15 plots the real exchange rate dynamics implied by the model, as well as those observed in the data. We find that the sequence of import price shocks can be chosen to exactly match the dynamics of the real exchange rate observed in the data. Specifically, there is a sharp increase of the real exchange rate that lasts for two years, including the devaluation year; afterwards, the real exchange rate appreciates gradually for two years.

The right panel of figure 15 plots the export elasticity implied by the model, and contrasts it with the median exports elasticity observed in the data across the 12 devaluations considered in section 2. We find that the model can successfully account for the qualitative pattern observed in the data: the export elasticity is very low in the period of the devaluation, and increases gradually thereafter. Quantitatively, the model implies an export elasticity that is uniformly higher than observed in the data after the period of the devaluation.

We also contrast the export elasticity implied by our baseline model with its counterpart without foreign-denominated debt, as well as with the frictionless model. We find that balance-sheet effects lead to a lower exports elasticity on impact, which is compensated with higher exports in subsequent periods. Therefore, we find that the root-mean-squared error between each of these models and the data is practically identical. Both of these models, however, imply an exports elasticity that is uniformly lower than the exports elasticity implied by the frictionless model. Quantitatively, we find that the root-mean-squared error between our baseline model and the data is 29% lower than for its frictionless counterpart.

6 Conclusion

In this paper, we ask: to what extent do financial frictions and balance-sheet effects can account for export dynamics in large devaluations? To answer this question, we set up a standard trade model à la Melitz (2003), introduce financial frictions and foreign-denominated debt, and investigate the response of aggregate exports to a large real depreciation.

Our results suggest that financial frictions slow down aggregate exports following large real depreciations. Financial frictions prevent firms from exporting at their optimal scale in response to changes in the real exchange rate, thereby also reducing the rate of entry of new firms to the export market. Foreign-denominated debt amplifies these effects by reducing the net-worth of firms when firms need it the most to increase their scale. We find that these effects are quantitatively significant: a model with financial frictions and debt denominated in foreign units can explain up to 47 percent of the gap in the response of exports, on impact, between the data and a frictionless version of the model.

The strength of these effects hinges on the distribution of export intensity implied by the model. Without export intensity heterogeneity, standard calibrations imply no effects of financial frictions and foreign-denominated debt on exports. In this case, firms export a small share of their total sales and, thus, are able to reallocate production from domestic to foreign sales, even without expanding their overall scale.

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