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, where firms face financing constraints and debt can be denominated in foreign units. We find that these channels can only explain a small fraction of the dynamics of exports observed in the data. While these frictions distort production and investment decisions, they affect exports significantly less since firms reallocate sales across markets in response to real exchange rate changes. We document the importance of this mechanism using plant-level data.

Keywords: financial frictions, large devaluations, export dynamics, balance-sheet effects

JEL: F1, F4, G32.

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1 Introduction

It is well documented that firms in emerging economies borrow extensively in foreign currency, exposing them to exchange rate fluctuations.[1] Given limited access to finance in these economies, large devaluations increase the domestic value of firms' effective debt burden, weakening their balance-sheets, and leading them to decrease investment and output. These negative effects have been extensively documented following the large devaluations experienced by several emerging economies in the late 1990s and early 2000s.[2]

On the other hand, such exchange rate movements may also have positive effects on the domestic economy: By lowering the relative price of exports, large devaluations increase the foreign demand for domestic goods, potentially boosting exports and offsetting the contractionary impact of these episodes. Indeed, large devaluations have been often suggested as a route to exit recessions and alleviate the impact of negative economic shocks. Therefore, understanding the dynamics of exports in these episodes is key for determining the aggregate effects of large devaluations.

The goal of this paper is to investigate the extent to which financial frictions and balance-sheet effects account for the dynamics of exports in large devaluations. To answer this question, we propose a quantitative general equilibrium model of international trade with heterogeneous firms subject to financial frictions and foreign-denominated debt. Our findings show that, while financial frictions and balance-sheet effects play an important role in accounting for the dynamics of investment and output during large devaluations, these effects do not necessarily account for the dynamics of aggregate exports observed in the data. This result is based on the novel insight that exporters may increase their foreign sales despite being financially constrained by reallocating sales across

[1] See Galindo et al. (2003), Dominguez and Tesar (2006), and Schreger and Du (2016).

[2] For a theoretical discussion of the balance-sheet channel in the context of large devaluations see Aghion et al. (2000, 2001, 2004), Caballero and Krishnamurthy (2003), Céspedes (2005), Céspedes et al. (2003, 2004), and Krugman (1999). For empirical evidence on the importance of balance sheet effects see Aguiar (2005), Berman and Berthou (2009), Berman and Hericourt (2010), Desai et al. (2008), Kalemli-Ozcan et al. (2015), Galindo et al. (2003) and references therein.

markets. Moreover, our findings show that firm-level heterogeneity in export intensity plays a fundamental role in determining the response of aggregate exports.

We begin by documenting salient features of large devaluations in emerging economies. First, and consistent with previous studies (Alessandria et al., 2014), we document that the elasticity of exports to real exchange rate changes grows gradually following these episodes.[3] Second, we show that firms make extensive use of foreign-denominated debt in these economies. In particular, we show that 25% of firms hold foreign-denominated debt — 48% of exporters — and that the share of debt denominated in foreign currency among these firms is 59% on average. Finally, we document that financial constraints play an important role in these economies, with 53% (60%) of firms pointing to the access (cost) to finance as an important obstacle for their operation and growth. Importantly, we find that these constraints are equally important for small and large firms, as well as for exporters and non-exporters.

To study the quantitative effects of large devaluations on export dynamics, we consider a small open economy model that is motivated by this evidence. In our economy, a large number of entrepreneurs produce differentiated goods by hiring labor to operate capital accumulated in previous periods. Productivity is heterogeneous across entrepreneurs and changes over time following a stochastic process. We model international trade decisions as in Melitz (2003), where firms are subject to fixed and variable trade costs. Following the evidence discussed above, we introduce frictions in financial markets and foreign-denominated debt. In particular, we assume that entrepreneurs can borrow in domestic or foreign units subject to a constraint which limits the amount that they can borrow up to a fraction of the value of physical capital at the time of repayment.

In our model, devaluations have opposing effects on firms' export decisions. On the one hand, exporting becomes more attractive, increasing the number of

[3] Interest on the slow adjustment of exports to exchange rate movements has a long tradition starting with Magee (1973) and Junz and Rhomberg (1973) who documented the J-curve response of exports following devaluations. Bahmani-Oskooee and Ratha (2004) provide a detailed survey of this literature.

firms that export and the amount that they sell internationally. On the other hand, the change in the real exchange rate has negative balance-sheet effects on firms as it increases the domestic value of foreign-denominated debt, tightening the borrowing constraint and leading to a decrease in investment and output. Thus, our model captures the main consequences of large devaluations stressed by Frankel (2005) and others in earlier studies.

While credit constraints slow down the adjustment of output and investment, their effect on the dynamics of exports depends on the degree to which firms can reallocate sales across markets. In response to the change in the real exchange rate, firms that export a small fraction of their sales can substantially increase their exports by changing the fraction of goods sold domestically and abroad, without increasing their total sales. In contrast, firms that export most of their output can only increase exports to the extent that they are able to expand total production. In the quantitative analysis, we discipline this channel by considering two types of firms heterogeneous in export intensity.

We calibrate the model to match key moments of Mexican plant-level data for 1994, and use it to study the response to a sudden and unexpected increase of the real exchange rate caused by a sequence of shocks to aggregate productivity, interest rates, and the price of imported goods. The shocks are chosen to match the dynamics of the real exchange rate, investment, and real GDP observed in Mexico following the devaluation at the end of 1994.[4] To determine the role played by financial frictions and foreign-denominated debt, we contrast the response of aggregate exports across two economies: (*i*) our baseline model with financial frictions and foreign-denominated debt; and (*ii*) an economy without financial frictions in which all debt is denominated in domestic units.

We find that financial frictions and balance-sheet effects can only explain a relatively small fraction of the dynamics of exports observed in the data. In particular, these frictions reduce the average absolute percentage deviation

[4]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); see Calvo and Mendoza (1996), Cole and Kehoe (1996) and Sachs et al. (1996).

between the exports elasticity implied by the frictionless model and the data by only 20%. We show that this result is driven by the reallocation channel: while firms with debt decrease investment and output, exports increase regardless of firms' financial position, since firms are able to reallocate sales across markets.

To examine the importance of intra-firm reallocation on aggregate export dynamics, we consider two counter-factual economies with alternative degrees of reallocation. First, we consider an economy in which exporters have homogeneous and low export intensity.[5] In this case, aggregate exports feature a much faster adjustment to changes in the real exchange rate than in our baseline model, and export dynamics look very close to the dynamics implied by its frictionless counterpart. Second, we consider an economy in which exporters sell all of their output internationally, leaving no room for intra-firm reallocation. In this case, exports adjustment is substantially more gradual than in our baseline model. These results further show that 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.

We then investigate the role of foreign-denominated debt on aggregate export dynamics. To do so, we consider counter-factual economies with alternative distributions of foreign-denominated debt. We find that the amount of foreign-denominated debt does not impact export dynamics following devaluations. This finding is driven by the reallocation channel and by general equilibrium effects.

Finally, we provide evidence in support of the role of cross-market reallocation for export dynamics. To do so, we use plant-level data from Mexico's devaluation in 1994. We show that firms with lower initial export-intensity, which are better able to reallocate sales across markets, featured a higher average growth of exports than their high-export-intensity counterparts. This evidence is qualitatively consistent with the implications of our baseline model, suggesting that differences in the degree of intra-firm reallocation play an important role for export dynamics. We also show that, as in the model, exports

[5] In this economy, firms export a small fraction of their total sales and, thus, are able to substantially reallocate sales if needed.

growth in Mexico following the devaluation was largely driven by the intensive margin, which is consistent with the importance of intra-firm reallocation as a key driver of export adjustments.

Our model extends the frameworks developed in earlier papers (Kohn et al., 2016, 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). 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. (2016), and Leibovici (2015). In contrast to previous studies, we study the transitional dynamics of a general equilibrium model with heterogeneous firms subject to credit constraints and balance-sheet effects.

Our paper is also related to a growing literature that studies the dynamics of international trade flows in response to aggregate shocks.[6] In particular, Amiti and Weinstein (2011) and Paravisini et al. (2015) use data at the firm-bank level to investigate the response of exports to aggregate financial shocks. Similarly, while Chor and Manova (2012) argue that financial factors played an important role in accounting for the collapse of trade in the great recession, Behrens et al. (2013) and Bricongne et al. (2012) argue that their role was relatively minor. We contribute to this empirical literature by examining the role of financial factors in response to an aggregate shock using a quantitative general equilibrium model disciplined using plant-level data.

Finally, the channels that we study complement previous explanations 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. Our paper is also closely related to Pratap and Urrutia (2004), who investigate the role of credit constraints and international trade in account-

[6]For a detailed review of this literature, see Bems et al. (2013).

ing for output and investment dynamics during large devaluations in a partial equilibrium setup.

2 Empirical Evidence

In this section, we document the facts that motivate our subsequent analysis. We start by investigating the dynamics of the real exchange rate 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 firm level. Finally, we examine the extent to which firms are credit constrained in these economies.

2.1 Real exchange rate and export dynamics in large devaluations

We define the real exchange rate as the relative value of foreign to domestic prices measured in domestic units, and we define large devaluations as year-to-year increases of the real exchange rate above 20% (in log changes). Data on multilateral effective real exchange rates are compiled by the Bank for International Settlements. Real exports are measured using export volume indexes from UNCTAD, published by the World Bank, and from the International Financial Statistics database published by the International Monetary Fund. We restrict our attention to the period between 1980 and 2013.

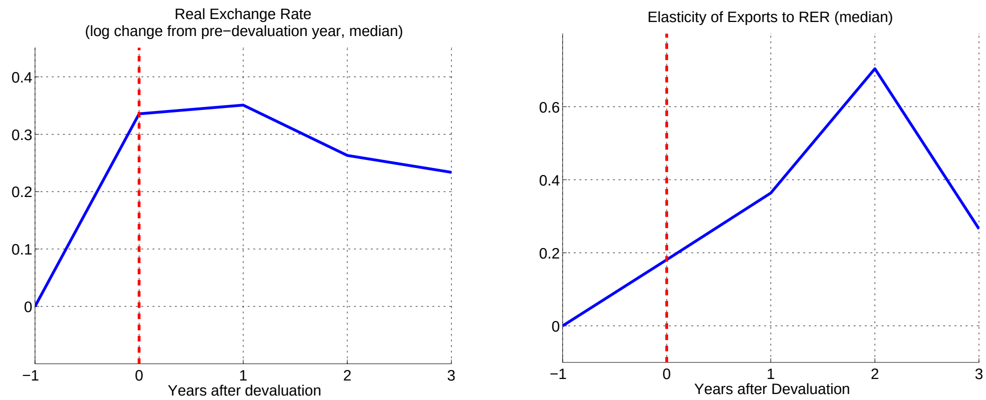
Using our definition above, we identify 12 episodes of large devaluations in our dataset: Argentina (2002), Brazil (1999), Iceland (2008), Indonesia (1998), South Korea (1998), Malaysia (1998), Mexico (1982, 1986, 1994), Turkey (2001), and Venezuela (2002, 2010).[7]

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

[7]We drop Japan (2013) because there are too few observations following the devaluation and Russia (1999) because of missing data on real exports prior to the devaluation. Our results are robust to defining large devaluations based on alternative thresholds as well as to using data at a quarterly frequency.

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

Figure 1: Aggregate Dynamics of RER and Real Exports



Panel A **Panel B**

Source: Real effective exchange rates from the BIS; real exports data from the World Bank and the International Financial Statistics database published by the IMF.

devaluation, the median real exchange rate increases by approximately 34%, and continues to increase slightly the year after before decreasing steadily over the following two years. However, even four years after the large devaluation, the median real 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 increases steadily up to 0.7 three years after the devaluation, before dropping to 0.27. Moreover, the median export elasticity in the year of the devaluation is only 0.18, less than 25% of its peak value. Thus, as in Alessandria et al. (2014), Figure 1 shows that real exports increase slowly after sharp and sudden changes in the real exchange rate.

2.2 Currency composition of liabilities

In this section, we examine the currency composition of debt across manufacturing firms. To do so, we use the World Bank Enterprise Surveys (WBES) dataset which contains data on firms' characteristics based on representative

panel, we plot $\log(X_t/X_{-1})/\log(\xi_t/\xi_{-1})$ where X_t denotes exports at time t. We detrend the log-growth of exports in each country by subtracting its average log-growth over the whole period.

surveys of private firms conducted in 135 economies. Such surveys have been conducted since 2002 and cover a broad range of topics, including firms' financial position.[9] The dataset covers six of the nine countries that experienced a large devaluation according to our definition (Argentina, Brazil, Indonesia, Malaysia, Mexico, and Turkey). Out of these, only the surveys conducted in Brazil, Indonesia, 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 three economies.[10]

Table 1: Share of foreign-denominated debt at firm-level

		By export status		*By # of workers*			
	All firms	Non-exporters	Exporters	[0,25]	[26,100]	[101,250]	250+
Fraction of firms	0.25	0.13	0.48	0.12	0.24	0.38	0.57
Average share	0.59	0.59	0.59	0.45	0.55	0.62	0.62

Source: World Bank Enterprise Surveys. Data for Brazil (2003), Indonesia (2003), and Turkey (2005). We report average values across these countries. The average share of foreign-denominated debt is computed across manufacturing firms with foreign debt.

We report our results in Table 1. 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 48% of exporters have debt denominated in foreign currency compared to 13% of non-exporters. Among firms that have a positive amount of foreign-currency-denominated debt, this debt constitutes, on average, 59% of their total debt stock both for exporters and non-exporters. Thus, while exporters are substantially more likely to have foreign-denominated debt than non-exporters, those that do so tend to issue a similar fraction of their debt in foreign currency. Finally, the last four rows of

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

[10]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, and Turkey do not correspond to the devaluation years. Nevertheless, all the surveys were conducted within 5 years of the devaluation episodes, so we believe that they are also informative about the importance of foreign-denominated debt during the devaluations. The results are very similar when computed, instead, for all countries for which there is data available on the currency composition of debt.

Table 1 present these statistics for firms of different sizes. We see that larger firms are more likely to have foreign-currency-denominated debt, although this relationship is not as stark for the fraction of their debt these firms hold in foreign currency.

These results show that manufacturing firms in the economies that experienced large devaluations had significant shares of debt denominated in foreign currency, and that exporters and larger firms were more likely to rely on such debt.

2.3 Share of credit-constrained firms

Given the prevalence of foreign-denominated debt documented in the previous subsection, large changes in real exchange rates may lead to substantial increases in the domestic value of the total stock of debt. However, to the extent that firms are not credit-constrained, such increases in the debt burden are not likely to affect real outcomes. Thus, we conclude this section by documenting the extent to which firms are credit-constrained in these episodes.

To do so, we restrict attention to manufacturing firms, using firm-level data collected by the World Bank Enterprise Surveys. Out of the devaluation countries identified above, only the surveys conducted in Brazil, Indonesia, Malaysia, and Turkey contain information on the share of credit-constrained firms.[11] We focus on two questions asked by the survey. The first question asks managers to report the extent to which they find access to finance to be an obstacle for their operation and growth. They are given five options: no obstacle, minor obstacle, moderate obstacle, major obstacle, or very severe obstacle. We define firms to be credit constrained if they find access to finance to be at least a moderate obstacle for their operation and growth. The second question asks managers to classify the extent to which they find the cost of finance to be an obstacle for their operation and growth. They are given the same five options as in the first question, and we define firms to be credit constrained analogously.

[11] As described above, the surveys are conducted a few years after the devaluations took place. Nevertheless, we interpret this evidence as informative about the credit environment that may have been faced by firms in these episodes.

Table 2 reports the share of firms that find the access and cost of finance to be at least a moderate obstacle for their growth and operation. We find that a significant share of firms are credit-constrained in their access to finance (53% of them), while an even larger fraction of them finds the cost of finance to be a significant constraint (60% of firms). Moreover, we find that this is also the case for both exporters and non-exporters, as reported in the second and third rows of this table: in fact, exporters appear to be more credit-constrained than non-exporters.

Table 2: Share of credit-constrained firms

		By export status			*By # of workers*		
	All firms	Non-exporters	Exporters	[0,25]	[26,100]	[101,250]	250+
Access to finance	0.53	0.51	0.56	0.52	0.51	0.54	0.51
Cost of finance	0.60	0.56	0.65	0.55	0.59	0.65	0.63

Source: World Bank Enterprise Surveys. Data for Brazil (2003), Indonesia (2003), Malaysia (2002), and Turkey (2005). We report average values across these four countries. The averages for each country are computed across manufacturing firms.

In the bottom rows of the table, we report the share of credit-constrained firms across the size distribution, as measured by the number of workers. This table shows that the share of constrained firms is approximately constant and independent of firm size. Thus, while larger firms are more likely to hold foreign-currency debt, as shown in the previous subsection, these are also likely to be credit-constrained in both access and cost of finance.[12]

This evidence suggests that credit frictions are important constraints on firms' growth and operation in the devaluation countries. Thus, we conclude that significant credit frictions were likely to be present at the time that the devaluations took place, potentially affecting the dynamics of exports following these episodes. We examine the extent to which this is the case in the following sections.

[12] We also find that firms that have debt denominated in foreign currency are only slightly less constrained than firms that do not have foreign-currency debt, both in their access to finance and their cost. As in the previous subsection, the results are very similar when we compute these statistics for all countries for which there is data available on the WBES.

3 Model

We consider a small open 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 varieties, and foreign varieties. Final goods are produced by final good producers and used by entrepreneurs for consumption and investment. Domestic varieties are produced by entrepreneurs and sold to final good producers and to the rest of the world. Finally, foreign varieties are produced by the rest of the world and sold to domestic final good producers. Only varieties 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 is the coefficient of relative risk aversion, β is the discount factor, and $\mathbb{E}_0$ denotes the expectation operator over the realizations of productivity shocks, conditional on the information set in period zero.

Technology Entrepreneurs produce differentiated varieties by operating a constant returns to scale production technology $y_t = Az_t k_t^{\alpha} n_t^{1-\alpha}$, where A denotes an aggregate level of productivity, 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.[13] 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 $\ln z_t = (1 - \rho_z)\mu_z + \rho_z \ln z_{t-1} + \varepsilon_t$, where ε_t is distributed according to a Normal distribution with zero mean and standard deviation σ_ε.

Every period, entrepreneurs are endowed with a unit of labor that they

[13] In the description of the model that follows, we only use subindex i to identify individual entrepreneurs whenever this is needed for clarification.

supply inelastically to 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 denotes 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 them 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 in a stationary equilibrium, where the interest rate is taken as given.

We define the real exchange rate ξ_t as the price of foreign final goods in units of the domestic final good. A firm that chooses to borrow a total amount $\frac{d_{t+1}}{1+r}$ 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. For simplicity, we assume that λ is a parameter that is taken as given by entrepreneurs. Therefore, in period t, entrepreneurs owe $\lambda\frac{d_{t+1}}{1+r}$ units of domestic final goods and $(1-\lambda)\frac{d_{t+1}}{1+r}\frac{1}{\xi_t}$ units of foreign final goods. In the following period, they repay 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 save as much as they desire, the amount borrowed 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 are monopolistically competitive and choose the quantities and prices at which to sell in each market subject to their respective demand schedules. In the domestic market, demand schedules solve the final good producer's problem, while the demand schedules faced in the international market are given by the rest of the world. We denote the quantities and prices of varieties 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 varieties, $p_{h,t}$ and $p_{f,t}$, are denominated in units of the domestic and foreign final goods, respectively.

Timing Entrepreneurs begin the period by hiring labor, producing their variety, and then selling it in each of the markets in which they choose to operate. If they decide to export 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, issue new debt and choose next period's level of physical capital.[14]

Entrepreneurs' problem Given the setup above, the entrepreneurs' problem at time t consists of choosing sequences of consumption c_t, labor n_t, investment x_t, whether to export or not $e_t \in \{0,1\}$, as well as prices and quantities $y_{h,t}$, $p_{h,t}$, $y_{f,t}$, $p_{f,t}$ at which to sell the varieties in each of the markets, in order to maximize their lifetime expected utility. In addition to the borrowing constraint described above and the market-specific demand schedules that are described below, their choices in every period are subject to a budget constraint, law of motion for capital $k_{t+1}=(1-\delta)k_t+x_t$, and production technology $y_{h,t}+\tau y_{f,t}=Az_t k_t^{\alpha} n_t^{1-\alpha}$. Entrepreneur's budget constraint in period t is given by $c_t+x_t+d_t\left[\lambda+(1-\lambda)\frac{\xi_t}{\xi_{t-1}}\right]+e_t w_t F = w_t+p_{h,t}y_{h,t}+e_t\xi_t p_{f,t}y_{f,t}-w_t n_t+\frac{d_{t+1}}{1+r}$, where the left-hand-side of the above

[14] This assumption simplifies the numerical solution of the model by making the capital accumulation decision risk-free; see Midrigan and Xu (2014) and Moll (2014).

equation captures entrepreneurs' consumption-saving choices while the right-hand-side captures entrepreneurial profits, labor income, and resources available from the issuance of new debt.

3.1.2 Final good producers

Final good producers purchase varieties from entrepreneurs and the rest of the world, and aggregate them to produce a final good. They operate a constant elasticity of substitution 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 be the prices of varieties charged by the entrepreneurs and the rest of the world, respectively.[15] Given these prices, final good producers choose the bundle of inputs of domestic and imported varieties, $\{y_{h,t}(i)\}_{i\in[0,1]}$ and $y_{m,t}$ that maximizes their profits. Thus, the problem of final good producers is given by:

$$\max_{y_{h,t}(i),y_{m,t}} Y_{h,t} - \int_0^1 p_{h,t}(i)y_{h,t}(i)di - \xi_t p_m y_{m,t}$$
$$\text{subject to } Y_{h,t} = \left[\int_0^1 y_{h,t}(i)^{\frac{\sigma-1}{\sigma}}di + y_{m,t}^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}},$$

where $Y_{h,t}$ denotes the quantity of the domestic final good produced. The solution to this problem is given by $y_{h,t}(i) = (p_{h,t}(i))^{-\sigma} Y_{h,t}$ and $y_{m,t} = (\xi_t p_m)^{-\sigma} Y_{h,t}$, which are 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 varieties from entrepreneurs (the domestic economy's exports) and supplies varieties to final good producers (the domestic economy's imports). The foreign demand for varieties 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

[15] p_m is denominated in units of the foreign final good.

for varieties, and is given by $y_{f,t} = (p_{f,t})^{-\sigma} Y_f$. Here, Y_f denotes the exogenous amount of foreign final goods produced in the rest of the world, and $p_{f,t}$ is denominated in units of the foreign final good. The supply of varieties by the rest of the world, imported by final good producers, is assumed to be perfectly elastic at an exogenous price p_m.

3.2 Entrepreneur's problem: Recursive formulation

Let $v(k, d, z)$ denote the value function of an entrepreneur with capital k, debt d, and productivity z, who makes consumption and saving decisions, as well as production decisions for the domestic and foreign markets. Let $g(a, z)$ denote the value function of an entrepreneur with net worth a and productivity z at the end of a period, who decides the amount of capital k and debt $\frac{d}{1+r}$ for next period.

Then, the entrepreneur's dynamic problem can be represented as[16]

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

where,

$$\pi(k, z) = \max_{p_h, y_h, p_f, y_f, n, e \in \{0,1\}} p_h y_h + e\, \xi p_f y_f - wn - ewF$$

$$\text{subject to: } y_h + \tau y_f = Azk^\alpha n^{1-\alpha}$$
$$y_h = p_h^{-\sigma} Y_h, \quad y_f = p_f^{-\sigma} Y_f$$

and,

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

[16]Notice that $a' \geq 0$ does not preclude firms from having positive amounts of debt.

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 $s \in \mathcal{S}$ be an element of the state space.

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

4 Mechanism

In this section, we examine the determinants of aggregate exports in a stationary equilibrium, and investigate the impact of changes in real exchange rates 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 $\int_{s \in \mathcal{S}_x} p_f(s)y_f(s)\varphi(s)ds$, 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 produced by an entrepreneur in state $s \in \mathcal{S}_x$.

Firm-level exports Along the intensive margin, financial frictions 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, 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 exported in units of foreign final goods is given by:

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

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 structural parameters. The effective real interest rate $\widetilde{r}$ is given by $1 + \widetilde{r} = (1+r)[\lambda + (1-\lambda)\xi/\xi_{-1}]$, 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 denomination of the debt does not affect foreign sales.

The above equation shows that firm-level exports depend on both aggregate and idiosyncratic variables. First, firm-level exports are increasing in idiosyncratic productivity z since more productive firms find it profitable to export a larger volume of goods. Second, exports are positively related to the real exchange rate since, a higher ξ results in higher foreign demand for firms' goods. Third, foreign sales are increasing in aggregate productivity and inversely related to the wage, as higher wages increase production costs and higher aggregate productivity reduces them. 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 the rental cost of capital among financially unconstrained exporters is given by $\widetilde{r} + \delta$. However, the implicit rental rate of capital among financially constrained exporters is higher than $\widetilde{r} + \delta$ since $\mu > 0$. In this case, the return to investing in physical capital is higher than the borrowing costs, leading firms to borrow as much as allowed by the financial constraint. But these firms cannot borrow enough, forcing them to produce and export less output than in the absence of credit constraints.

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.

In our model, in contrast to a frictionless environment, firms with high productivity might not find it profitable to export. With sufficiently low net worth, firms are forced to choose a suboptimal level of physical capital for the following period. 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.

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

4.2 Real exchange rate changes and aggregate exports

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

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

where $X := \int_{s \in \mathcal{S}_x} p_f(s) y_f(s) \phi(s) ds$ denotes aggregate exports and $M := \int_{s \in \mathcal{S}_x} e(s) \phi(s) ds$ 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, such that given price changes lead to higher changes in sales. The second term captures general equilibrium effects that result from changes in the wage following increases of the real exchange rate: 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, with individual productivities adjusted by the effective interest rate and by the extent to which the financial constraints bind. In particular, increases in the effective interest rate due to a devaluation or a tightening of the borrowing constraints lead to a decrease in aggregate exports.

Consider first an economy without financial frictions. In such economy, a devaluation increases exports through two main channels. First, exports increase along the intensive margin, as firms that were already exporting increase their foreign sales in response to higher foreign demand for domestic varieties (the first term in Equation 1). Second, by making the foreign market more attractive, an increase in the real exchange rate leads some previous non-exporters to begin exporting, raising the share of exporters (as captured by the third term in Equation 1).

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 leads to higher exports through the same channel 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. This slows down the response of exports to a real depreciation (as μ increases, the last term in Equation 1 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, the expansionary effects of real depreciations are smaller under financial frictions.

The negative effects of financial frictions described above are partially offset by intra-firm sales reallocation. Following a devaluation, financially constrained firms increase the proportion of their total production sold abroad at the expense of domestic sales. To the extent that they sell most of their output domestically, financially constrained firms may substantially increase their exports by reallocating sales across markets without adjusting their production scale. On the other hand, if exporters sell most of their output internationally, they may not be able to reallocate output across markets to increase exports as much as desired. It follows that, for firms with relatively low export intensity, the ability to reallocate sales moderates the distortionary effect of financial frictions (a lower increase of μ in the last term of Equation 1).

Finally, consider an economy with financial frictions and debt denominated in foreign goods. The presence of foreign-denominated debt leads to a 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 negatively affects both the intensive and extensive margins, decreasing exports.

Thus, in the model with financial frictions and foreign-denominated debt, the net impact of a devaluation on aggregate exports depends on the share of firms that begin to export, the extent to which continuing exporters increase or reduce their overall scale, and the extent to which these firms reallocate sales between the domestic and foreign markets. While the financial constraints and the balance sheet effects distort the first two margins, the reallocation margin described above partially offsets the distortionary impact of these frictions. Therefore, to determine the contribution of these conflicting forces on 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 and investigate the extent to which financial frictions and balance-sheet effects can account for the slow growth of aggregate exports observed in the data following large real depreciations. We first calibrate the model to match key cross-sectional moments from Mexican plant-level data for year 1994, the 12-month period prior to the large depreciation experienced by the Mexican Peso on December 20$^{\text{th}}$ of that year.[17] Second, we design an experiment to reproduce salient features of the aggregate dynamics of the Mexican economy during and in the aftermath of the devaluation of 1994. In particular, we estimate a sequence of shocks to aggregate productivity, the interest rate, and the price of imports such that the model generates the same dynamics of the real exchange rate, output, and investment as observed in the data. Thus, we ensure that our environment resembles the Mexican economy both along key cross-sectional characteristics as well as in the dynamics of key aggregate variables. Finally, we contrast the implications of the model for the dynamics of aggregate exports with their empirical counterpart.

5.1 Data

We calibrate the model to match salient features of Mexican plant-level data for year 1994 from the Annual Manufacturing Survey (Encuesta Industrial Anual), collected by the National Institute of Statistics and Geography (INEGI). The Annual Manufacturing Survey is an annual survey that collects longitudinal data on a sample of manufacturing plants. We restrict attention to a balanced panel of firms observed between 1994 and 1999. 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 as required to

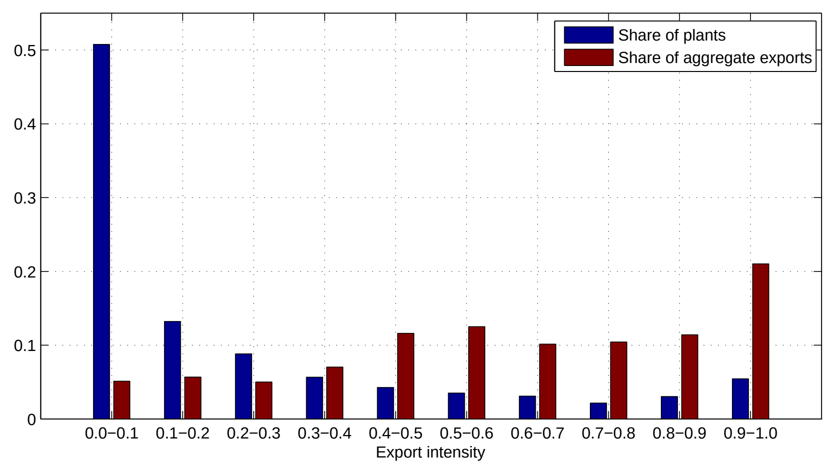
[17] For a detailed account of the Mexican crisis see Calvo and Mendoza (1996), Cole and Kehoe (1996) and Sachs et al. (1996).

account for at least 85% of the total output produced by each 6-digit sector (in decreasing order by size).[18] We supplement this dataset with other data sources described below.

5.2 Export intensity heterogeneity

Heterogeneity in export intensity in the data In section 4, we argued that in the 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; (*ii*) firms that cannot increase their production due to borrowing constraints can increase their exports by reallocating sales from the domestic to foreign markets; and (*iii*) some non-exporters start exporting. We also stressed that the extent to which firms can increase exports by reallocating sales across markets depends on their initial export intensity. Therefore, in order to discipline the importance of this channel, we examine the degree of export intensity heterogeneity observed in the data across firms.

Figure 2: Export intensity distribution



We find that there is substantial heterogeneity in export intensity across firms. Figure 2 shows that, while export intensity is 0.23 on average (i.e. on average, exporters sell 23% of their sales to foreign markets), most exporters feature much lower export intensity and few of them sell most of their production to foreign markets. In particular, for approximately half of all exporters, their foreign sales

[18] For more details, see Iacovone (2008).

constitute only 10% of total production, while almost 17% of exporters sell more than 50% of their output internationally.

Heterogeneity in export intensity in the model. To discipline the extent to which sales reallocation across markets affects aggregate export dynamics, we extend the model to feature differences in export intensity across firms. We assume that there are two types of firms in the model: (*i*) a fraction ζ of firms that are subject to low iceberg export costs, τ_L, leading to high export intensity; and (*ii*) a fraction $1-\zeta$ of firms that face high iceberg export costs, τ_H, leading to low export intensity.

We map these two types of exporters into the data by classifying them based on their export intensity. In particular, we divide exporters into low-export-intensity and high-export-intensity groups such that each category accounts for approximately half of aggregate exports. As shown in Table 3, the first group contains all firms that export less than 60% of their production, accounting for 47% of aggregate exports. It includes 87% of all exporters and the average export intensity within this group is only 13%. The second group contains all firms with export intensity higher than 0.6 and it accounts for 53% of aggregate exports. Below, we use these moments to calibrate the heterogeneous iceberg costs featured by the model.

Table 3: Heterogeneity in export intensity in Mexico 1994

Export intensity	Share of exports	Share of exporters	Avg. export intensity
0.0 - 0.6	0.47	0.87	0.13
0.6 - 1.0	0.53	0.13	0.84

5.3 Calibration

To calibrate the model, we divide the parameter space into two groups. The parameters in the first group are predetermined, while those in the second group are calibrated simultaneously to match key moments of the data.

The first group of parameters consists of γ, σ, δ, α, r and λ. 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 set the

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

Table 4: Calibration: Mexico 1994

Predetermined		Calibrated		Target Moment	Data	Model
γ	2	F	0.04	Share of exporters	0.32	0.32
σ	4	ζ	0.04	Share of exporters with high X/Y	0.13	0.13
δ	0.06	τ_L	1.76	Avg. export intensity, high X/Y	0.13	0.13
α	0.33	τ_H	5.71	Avg. export intensity, low X/Y	0.84	0.84
r	0.08	ρ_z	0.88	Share of sales accounted by top 25%	0.84	0.82
λ	0.45	σ_ε	0.26	Standard deviation of log sales	1.52	1.55
		β	0.85	Net Exports/GDP	-0.03	-0.03
		θ	0.49	Credit/GDP	0.44	0.44

real interest rate to 0.08, which is the sum of the average EMBI spread on Mexican bonds in 1994 and the average real rate of return on a 1-year US Treasury bond in 1994. Finally, according to the Bank of Mexico, 55% of manufacturing firms' credit by commercial banks was denominated in foreign currency in December of 1994; thus, we set λ to 0.45.

The second group of parameters consists of the share of low-export-cost firms, ζ; the fixed cost of exporting, F; the variable export cost faced by high-export-cost firms, τ_H; the variable export cost faced by firms with low export costs, τ_L; the persistence and the standard deviation of productivity shocks, ρ_z and σ_ε, respectively; the discount rate, β; and the collateral constraint parameter, θ. We choose them to match the following moments: (*i*) the share of exporters with an export intensity higher than 60%, (*ii*) the share of exporters, (*iii*) the average export intensity of firms that export less than 60% of their total sales, (*iv*) the average export intensity of firms that export more than 60% of their total sales, (*v*) the share of sales accounted by the largest 25% of firms, (*vi*) the standard deviation of log sales, (*vii*) the net exports to GDP ratio, and (*viii*) the credit to GDP ratio. We compute target moments (*i*) to (*vi*) using the Mexican plant-level data described above. For (*vii*) we use data reported by the IMF. Finally, for (*viii*), we obtain the ratio of credit to the manufacturing sector by commercial banks to value added in the manufacturing sector from the Bank of Mexico.

Calibration Strategy 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 $(viii)$. We report the calibrated parameters and the target moments in Table 4.[20]

5.4 Large devaluation

We now investigate the extent to which financial frictions and balance-sheet effects can account for the dynamics of aggregate exports observed in the data. Our goal is to examine the dynamics of exports in an economic environment that can capture salient cross-sectional and time-series features of the Mexican devaluation that may affect the response of exports. To the extent that exports may be affected by the dynamics of GDP and investment, we consider it important to account for such dynamics in order to discipline the response of exports implied by the model.

Thus, we consider the economy in a stationary equilibrium, and examine its response to an unexpected change in the path of aggregate productivity A_t, the real interest rate r_t, and import prices $p_{m,t}$. These shocks are realized at the beginning of period 0 when all agents learn their deterministic path from that point onwards. We choose the sequence of $p_{m,t}$, r_t, and A_t for $t = 0, ..., 3$ to match the empirical dynamics of the real exchange rate, the investment-to-GDP ratio, and real GDP over the first four years following the Mexican devaluation in 1994, and we assume that they stay constant for $t \geq 4$.[21,22] We use data on real GDP and investment from the World Bank, and we target the real effective exchange rate from the BIS; real GDP is detrended by subtracting its average growth rate over the whole sample period.

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[20] We study the global solution of the model, solved by value function iteration. We compute the statistics of the model using the stationary distribution of individuals. We solve for the equilibrium transition path from the initial steady-state to the final steady-state by iterating on the sequence of aggregate prices and quantities until all markets clear in all time periods.

[21] Since many shocks might have hit Mexico during its large devaluation in 1994, we consider a broad array of shocks and use the data targets to identify them. This strategy is akin to the one followed by Alessandria et al. (2014). Our results are robust to alternative shocks that can match the dynamics of our target series.

[22] At the time of the devaluation, Mexico also joined the North American Free Trade Agreement (NAFTA). This agreement consisted of a gradual decline in the tariffs that Mexican producers faced to export to the U.S. and Canada; they decreased, on average, from 3.5% in 1994 to 1% in 2001 (Ayhan Kose et al., 2005). On the other hand, average tariffs to the rest of the world increased on average over this period (World Bank). We abstract from these changes throughout our quantitative analysis.

To understand the role played by borrowing constraints and foreign-denominated debt in shaping the response of the economy, we contrast the dynamics implied by our baseline model with the dynamics implied by its frictionless counterpart. That is, we contrast our findings with those from a model without borrowing constraints in which all debt is denominated in domestic units ($\theta = \infty$ and $\lambda = 1$).[23]

5.5 Results

Real exchange rate, real GDP, and investment We first investigate the dynamics of the real exchange rate, real GDP, and investment following changes in the price of imported varieties, interest rate, and aggregate productivity. We contrast their dynamics across the two models described above: (*i*) our baseline model with borrowing constraints and 55% of the total debt denominated in foreign final goods (i.e. $\theta = 0.49$ and $\lambda = 0.45$); and (*ii*) an economy without borrowing constraints and all debt denominated in domestic goods (i.e. $\theta = \infty$ and $\lambda = 1$).

Figure 3, Panel A, plots the percentage deviation of the real exchange rate from its pre-devaluation, steady-state, level for each of these economies and the data. The figure shows that the shocks in both models can be calibrated to closely match the dynamics of the real exchange rate observed in the data, implying a large devaluation followed by a gradual appreciation. Four years after the devaluation, the real exchange rate is still ten percent above its pre-devaluation level.

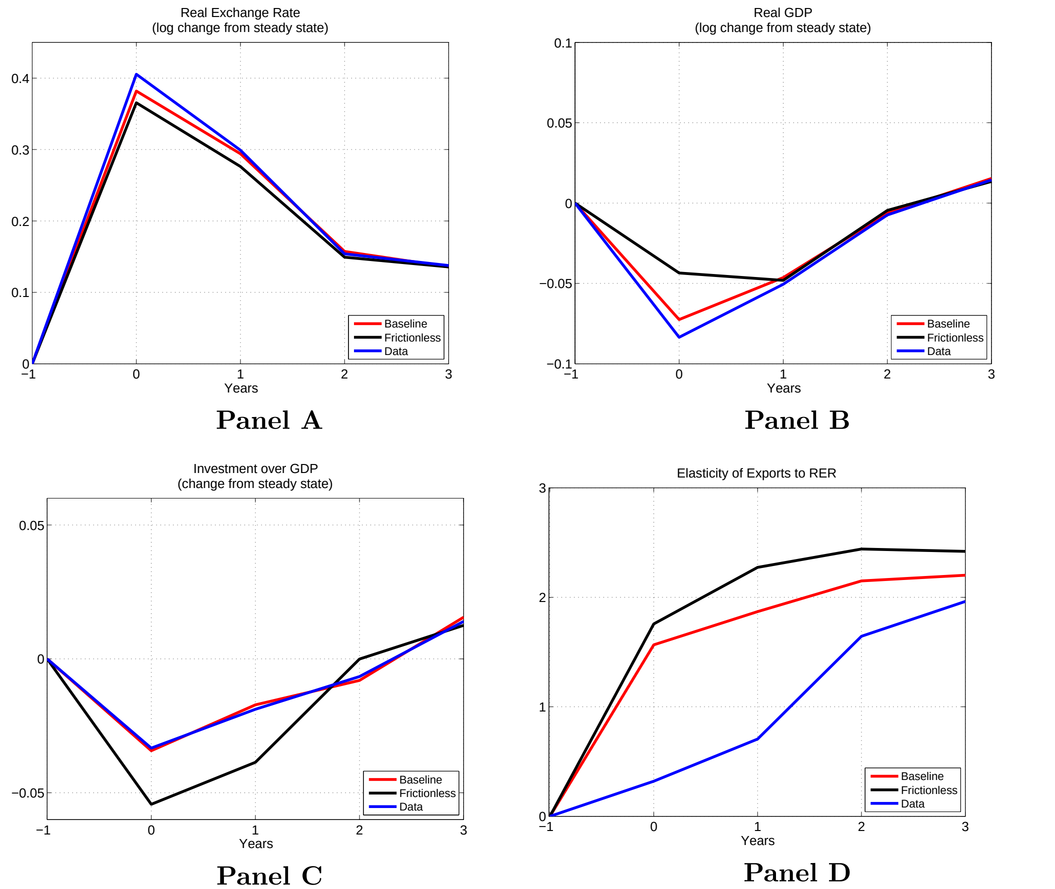
Similarly, Panel B of Figure 3 plots the percentage deviation of real GDP from its pre-devaluation, steady-state, level for each of these economies.[24] In the data, real GDP falls sharply in the period of the devaluation and recovers slowly thereafter, reaching its pre-devaluation level somewhere between the third and fourth year after the devaluation. Real GDP in each of the models matches closely the dynamics observed in the data, except that there is a less dramatic drop in GDP in the frictionless model.

Finally, Panel C of Figure 3 shows the change in the investment-to-GDP ratio from its pre-devaluation level. In the data, investment drops more than output

[23]This alternative model is calibrated separately using the strategy described in subsection 5.3, except that we do not target the ratio of credit to GDP. Similarly, this model is subject to an alternative sequence of shocks to $p_{m,t}$, r_t, and A_t, chosen to ensure that it also matches the dynamics of the real exchange rate, investment, and real GDP observed in the data.

[24]Consistent with the data, we measure real GDP as a Laspeyres quantity index, keeping prices fixed at their pre-devaluation levels and adjusting quantities over time.

Figure 3: Real exchange rate, real GDP, and investment



in the period of the devaluation, with the ratio between them decreasing by three percentage points on impact, and recovering slowly thereafter. Our baseline model with financial frictions and balance-sheet effects can closely match the dynamics of the investment-to-GDP ratio observed in the data. The frictionless model implies a decline in this ratio that is larger than in the data in the first two periods, but matches it closely in the following periods.

Aggregate exports Next, we examine the response of exports to the shocks described above. We focus on the elasticity of exports to changes in the real exchange rate relative to the initial stationary equilibrium, which we compute as $E_t^{x,rer} = \frac{\ln(X_t)-\ln(X_{-1})}{\ln(RER_t)-\ln(RER_{-1})}$ for $t = 0, 1, 2, ...$, where period -1 is the pre-devaluation period.[25]

Panel D of Figure 3 shows the response of aggregate exports in the baseline and frictionless models. We find that both models imply that exports expand substantially in the period of the devaluation, followed by a further gradual increase over the next few years. The export elasticity in our baseline model with financial frictions and foreign debt is only 7% lower on impact than in the frictionless model, and 16% lower in the long run. Thus, we find that financial frictions slow down the adjustment of exports, but modestly so.[26]

In Panel D of Figure 3, we also contrast the export elasticity implied by the model with its empirical counterpart. We find that the baseline model implies an export elasticity that is considerably higher than in the data. Moreover, the absolute percentage deviation between the exports elasticity implied by our baseline model and the data is only 20% lower than the one implied by the frictionless model. Thus, financial frictions and balance sheet effects modestly improve the fit of the model along this dimension, suggesting that the slow growth of exports following a large devaluation is not significantly accounted by them.

5.6 Impact of financial frictions and balance sheet effects

The discussion above shows that, in an economy with financial frictions and foreign-denominated debt, exports increase almost as fast as in its frictionless counterpart and faster than in the data following a large devaluation. This may suggest that financial frictions are not binding and that balance-sheet effects are weak in our model, resulting in export dynamics similar to a frictionless economy. Below, we argue that this is not the case. In particular, we show that, while balance-sheet effects and financial frictions distort firms' investment and output decisions, they do not lead to slower exports adjustment because firms reallocate their sales between the domestic and foreign markets. Thus, the results below suggest that the reallocation of sales across markets is a key channel behind the dynamics of exports implied by our model.

[25] We measure exports, as in the data, with a Laspeyres quantity index. As in Section 2, we detrend exports growth by substracting its average growth rate over the whole sample.

[26] In both models, changes in aggregate productivity and the fixed nature of physical capital when the devaluation hits lead exports to adjust gradually; we find that financial frictions and balance-sheet effects further slow down such adjustment to a minor degree.

The impact of financial constraints To investigate the extent to which financial frictions bind in our model, we compute the share of financially constrained firms in the steady state before the devaluation takes place. We define a firm to be constrained along the extensive margin if it would export in the absence of financial frictions; and we define a firm to be constrained on the intensive margin if it operates with capital below its optimal unconstrained level given its export decision.[27] Moreover, we measure the extent to which firms are constrained along the intensive margin by computing the ratio between firms' actual capital stock and their unconstrained level of capital. Table 5 reports the results.

Table 5: Share of constrained firms, pre-devaluation

	Extensive margin (%)	Intensive Margin (%)	k/k^*
All firms	10.0%	54.0%	72.1%
Non-exporters	14.7%	46.6%	78.0%
Exporters	—	66.5%	60.2%

Note: k^* is the optimal unconstrained capital level; k/k^* is the average ratio of firms (exporters) capital to the optimal unconstrained capital.

We see that firms are severely constrained along both the extensive and intensive margins. In particular, for given prices, 14.7% of non-exporters would like to export if they could operate at the unconstrained optimal level. Table 5 also indicates that financial frictions strongly limit firms' scale of operation: a large fraction of firms (54%) is constrained along the intensive margin, leading them to operate with a stock of physical capital that is, on average, 28% lower than its optimal unconstrained level. Moreover, exporters in the model are even more affected by financial constraints than non-exporters, with 66.5% of them constrained along the intensive margin (compared to 46.6% of non-exporters), and a stock of physical capital that is, on average, 40% lower than in the absence of financial frictions (compared to 22% lower for non-exporters). Thus, Table 5 shows that financial frictions severely distort firms' decisions limiting their ability to expand their production following a devaluation. Therefore, we conclude that the strong response of exports in the model following a large devaluation is not driven by lax financial constraints; rather,

[27] We compute the firm's unconstrained policy functions while keeping aggregate prices and quantities unchanged at their steady-state levels.

it is driven by the reallocation of sales across markets, as we show below.

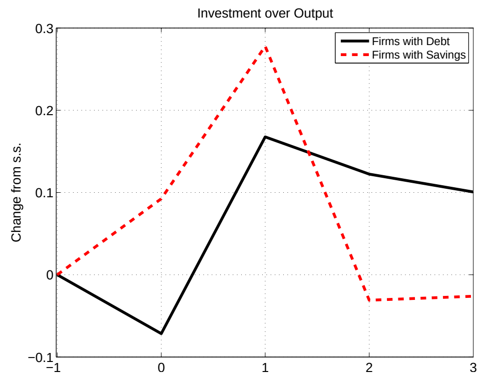
Balance-sheet effects and intra-firm reallocation. To further understand firms' decisions following a large devaluation and the role of financial frictions and balance-sheet effects, we now contrast the dynamics of investment, output, and exports across exporters who differ in their pre-devaluation financial position. In particular, we contrast exporters with debt relative to exporters with savings; the former are negatively affected by balance-sheet effects and are closer to the financial constraint, while the latter benefit from balance-sheet effects and are further away from the constraint. To simplify the comparison, we abstract here from shocks to aggregate productivity and the interest rate, and instead focus on a one-time shock to p_m that generates a permanent devaluation of 40% percent, as in the data. Moreover, since exporters with debt and savings may differ systematically in their idiosyncratic productivity, we restrict attention to exporters with the median productivity level among firms that export in the pre-devaluation period.

Figure 4 contrasts the dynamics of investment, output, and exports across exporters who arrive to a devaluation with debt (black solid line) relative to savings (red dashed line). Panel A shows that firms with debt cut the investment to output ratio relative to its steady state level as the devaluation damages their balance sheets. On the other hand, exporters with savings increase the investment to output ratio, as they expand their scale to take advantage of the higher foreign demand for their goods. Notice that exporters with debt invest less than exporters with savings over the first two years after the devaluation, as it takes time for these firms to rebuild their balance sheets.

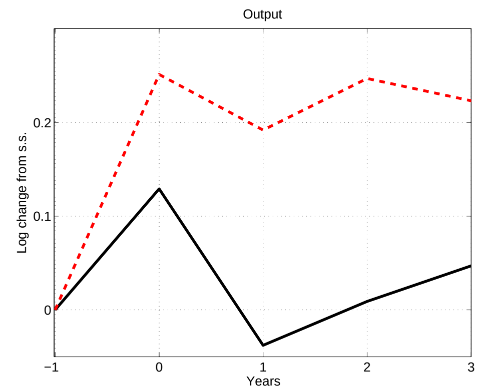
Next, Panel B shows the dynamics of output following the large devaluation. We find that exporters expand their scale of operation by hiring labor in order to immediately take advantage of higher foreign demand for their goods. However, since exporters with debt are more likely to be financially constrained, they operate with a lower capital stock and expand their sales by a lower amount on impact. Moreover, given their lower investment following the devaluation, the total production of exporters with debt decreases in the following period and increases slowly thereafter. This slow increase is driven by the financial constraints, which limit the scale and investment rates of these exporters.

Interestingly, despite these large differences in investment and output dynamics across exporters with debt or savings, Panel C shows that these firms feature very

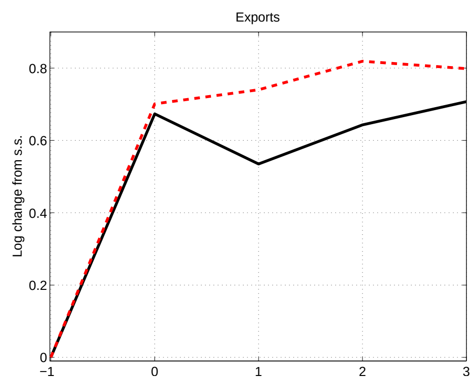
Figure 4: Micro-level evidence on financial frictions



Panel A



Panel B



Panel C

similar export dynamics. In particular, exporters with debt substantially increase their foreign sales despite their lower output and investment: they do so by reallocating domestic sales to the foreign market. Therefore, we find that, despite the impact of financial frictions and balance-sheet effects on output and investment, export dynamics are not affected due to the reallocation of sales across markets.

6 Reallocation and Debt Distribution

The quantitative analysis from the previous section shows that financial frictions and balance-sheet effects do not significantly slow down the dynamics of aggregate exports since firms reallocate sales across markets. In this section, we investigate the extent to which alternative assumptions on the degree of intra-firm reallocation and distribution of foreign-denominated debt affect these findings. To do so, we study the response of the economy to a one-time permanent decrease in the price of imported varieties $p_{m,t}$ from 1 to 0.55.[28]

Export intensity and the extent of reallocation We first examine the role of intra-firm reallocation across markets on aggregate export dynamics. Throughout our analysis above, we assume that there are two types of firms that differ in 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, may affect our findings.

Figure 5 contrasts the implied export elasticity dynamics under 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 and, thus, feature the same export intensity; and (*iii*) an economy with two types of firms, where firms of one type export but cannot sell domestically (export intensity = 100%), and firms of the other type sell domestically but cannot export (export intensity = 0%).[29]

Figure 5: Exports Elasticity: Export Intensity Heterogeneity

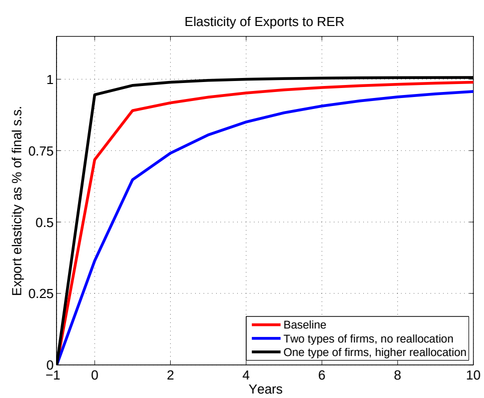


Figure 5 shows the export elasticity implied by each these models as a percentage

[28]In the baseline model, this shock leads to a 40% persistent increase in the real exchange rate; a value close to the one observed in the data.

[29]Models (*ii*) and (*iii*) are calibrated using the strategy described in subsection 5.3, with the exception that we choose the variable trade cost to match the aggregate ratio of exports to total sales instead of average firm-type-specific export intensities. In our calibration of Model (*ii*), firms that export sell 24.45% of their output internationally.

of their final-steady-state value. We find that, even though model (*ii*) is a standard trade model with financial frictions, its implied export elasticity behaves almost as in its frictionless counterpart. As discussed in the previous section, even though these firms are subject to financial constraints and balance-sheet effects, their low export intensity allows them to substantially increase their exports by reallocating sales across markets. This effect largely offsets any impact of borrowing constraints and balance-sheet effects on aggregate export dynamics.

In contrast, firms that export in model (*iii*) have no domestic sales to reallocate to the foreign market.[30] Thus, in this case the export elasticity is significantly lower than in models (*i*) and (*ii*). The only way in which firms can increase their exports is by hiring labor and by expanding their physical capital stock. However, as investment declines following the decrease in net worth due to balance-sheet effects, the export elasticity is significantly lower on impact than in the final steady state.

Given the sharp differences across these models, we conclude that the export intensity distribution and the implied degree of reallocation play a key role in driving their implications for aggregate exports during episodes of large devaluations.

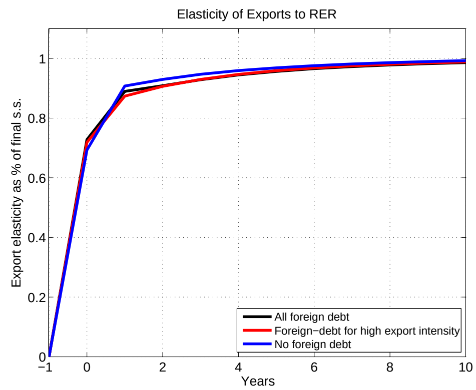
Alternative distribution of foreign debt. We now investigate the extent to which alternative assumptions on the distribution of foreign-denominated debt may affect the model's implications for the dynamics of aggregate exports in large devaluations. We consider three alternative distributions of foreign-denominated debt: (*i*) an economy in which low-export-cost firms have more foreign-denominated debt (100% of the debt denominated in foreign units) than high-export-cost firms (50% of the debt denominated in foreign units);[31] (*ii*) an economy in which all debt is denominated in domestic units; and (*iii*) an economy in which all debt is denominated in foreign units. The implications of these alternative distributions of foreign-denominated debt for the export elasticity are presented in Figure 6.

We find that the dynamics of the export elasticity is largely identical across the alternative debt distributions that we consider, suggesting that balance-sheet effects do not play a significant role in driving aggregate export dynamics. This finding is

[30] To simplify the solution, we solve model (*iii*) assuming that there is a fixed share of firms that export; given the small role played by the extensive margin on exports growth, as described in Section 7, we do not expect this assumption to significantly affect our findings.

[31] These values are calibrated based on the joint distribution of the share of foreign-denominated debt in total debt and the share of firms with high export intensity across Mexican industries in 1994.

Figure 6: Alternative Distributions of Foreign Debt



driven by the reallocation channel and by general equilibrium effects that operate through the labor market.[32]

7 Evidence of the Mechanism: Mexico 1994

The analysis above shows that the dynamics of aggregate exports implied by the model in episodes of large devaluations depend on the degree to which financially constrained exporters are able to reallocate sales across markets. In this section, we examine the extent to which export dynamics depend on this channel using plant-level data from Mexico's devaluation in 1994.

7.1 Reallocation Across Markets

In section 6, we saw that the strength of the reallocation channel depends crucially on firms' export intensity at the time of the devaluation. In particular, a key testable prediction of our model is that foreign sales of firms with high export intensity grow less than those of firms with high export intensity. Thus, below we compare the growth of exports across firms with different export intensity in the model and in the data.

To compute the differential growth of exports across firms with heterogeneous export intensity, we estimate the following specification in the model and the Mex-

[32] In economies with a high share of foreign-denominated debt, devaluations lead to stronger negative balance-sheet effects, affecting non-exporters more than exporters. Therefore, non-exporters decrease labor demand relative to exporters, benefiting the latter via general equilibrium effects and offsetting the impact of foreign-denominated debt on exports.

ican plant-level data:[33]

$$\ln \frac{X_{i,t}}{X_{i,-1}} = \sum_{j=0}^{3} \left[\beta_j + \gamma_j \text{High initial export intensity}_{i,t}\right] \mathbb{I}_{\{t=j\}} + \varepsilon_{i,t}$$

where $t = -1$ is the pre-devaluation period, $X_{i,t}$ denotes the value of firm i's exports in period t at constant prices, $\mathbb{I}_{\{t=j\}}$ denotes an indicator function that is equal to one in year j and is zero otherwise, and High initial export intensity$_{i,t}$ is an indicator function that is equal to one if firm i's export intensity is above 0.60 in the pre-devaluation year and is zero otherwise. Therefore, γ_j denotes the difference in growth rates between firms with high and low initial export intensity in period j relative to the pre-devaluation year.

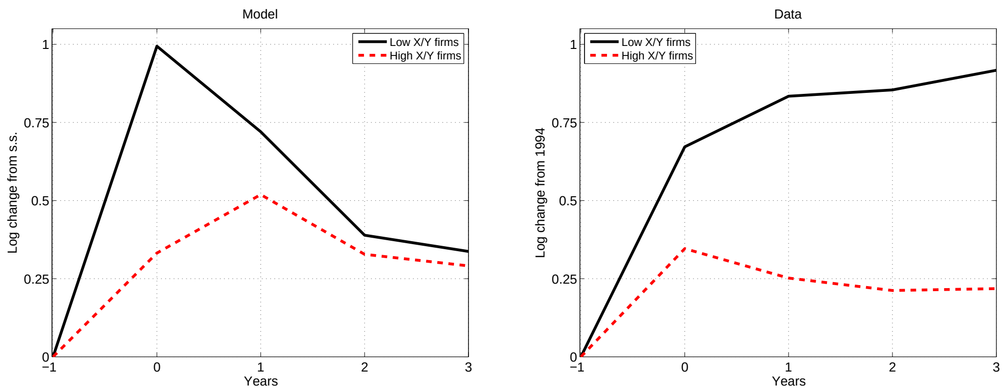
To estimate this specification in the data, we also add industry fixed effects and control for three plant-level variables that may impact exports adjustment but which we do not model explicitly in our quantitative analysis: (*i*) the ratio of firms' final good inventories to total sales, (*ii*) the ratio of firms' intermediate input inventories to total intermediates, and (*iii*) the ratio of imported intermediates to the total wage bill.

Panel A of Figure 7 depicts the average growth of exports relative to the pre-devaluation year for firms with low and high export intensity in the model. We observe that low-export-intensity exporters (solid black line) feature a higher growth of exports than their high-export-intensity counterparts (dashed red line). On impact, the response of low-export intensity firms is much higher because when shocks hit firms cannot immediately adjust capital and can only respond by hiring more labor or reallocating sales from the domestic to the foreign markets. Since firms with lower export-intensity have a higher potential for reallocation they can increase their foreign sales relatively more. While this difference declines in the following years it does not disappear, as financially constrained firms cannot increase their scale as much as they would want to. However, constrained firms with low export-intensity can expand their exports significantly by reallocating sales from the domestic to the foreign market.

Panel B of Figure 7 shows the average growth of exports relative to the pre-

[33] In the model, we simulate a panel of one million firms and examine their dynamics in response to the experiment conducted in subsection 5.4.

Figure 7: Firm-Level Exports Growth by Export Intensity



Panel A **Panel B**

devaluation year for firms with low and high initial export intensity in the data.[34] As implied by the model, we find that average exports growth is higher among firms with low initial export intensity. However, the magnitudes implied by the model are substantially different from those observed in the data. We interpret these findings as evidence in support of the relationship between the degree of intra-firm sales reallocation and export intensity implied by our model.

7.2 Exports Growth: Extensive vs. Intensive Margins

To the extent that the reallocation channel is strong in our model, a significant share of exports growth should accounted by the intensive margin. To test this prediction, we now contrast the contribution of the intensive and extensive margins to exports growth between the model and the data.

Table 6: Exports' growth: Extensive vs. intensive margin

	Model		Data	
	Extensive margin	Intensive margin	Extensive margin	Intensive margin
1995	0.06	0.94	0.05	0.95
1996	0.08	0.92	0.22	0.78
1997	0.05	0.95	0.27	0.73
1998	0.06	0.94	0.29	0.71

[34] We evaluate the estimated regression at the average industry level ($\overline{\alpha}_k$), and at the average value of each of the control variables.

In Table 6, we report the share of the cumulative growth of exports in the model and the data explained by the extensive and intensive margins.[35] The intensive margin accounts for the majority of exports growth in both the model and the data. In particular, in the year of the devaluation, the intensive margin contributes over 90% of the expansion of exports. In the years following the devaluation, the contribution of the intensive margin decreases to about 75% while in the model it stays at around 94%. Thus, while the model underestimates the importance of the extensive margin, both the model and the data imply that exports growth is predominantly driven by the intensive margin which is consistent with reallocation being important channel of export growth.

8 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 use the model to investigate the response of aggregate exports to a large real depreciation.

In our model, financial frictions and balance sheet effects slow down aggregate exports following large real depreciations. On the one hand, financial frictions prevent firms from exporting at their optimal scale in response to changes in the real exchange rate, also reducing the rate of entry of firms to the export market. On the other hand, foreign-denominated debt amplifies these effects by reducing the net-worth of firms when they need it the most to increase their scale.

To quantify the importance of these channels, we calibrate the model to match cross-sectional moments of Mexican plant-level data, and study the dynamics of aggregate exports in response to a series of shocks designed to replicate key features of the Mexican devaluation at the end of 1994. We find that exports increase much faster than in the data and close to a frictionless benchmark. Thus, our results

[35] Specifically, we examine the contribution of the extensive and intensive margins to aggregate exports growth relative to the pre-devaluation period according to $\frac{X_t - X_{-1}}{X_{-1}} = \frac{\sum_{i \in S_t^X \setminus S_{-1}^X} X_{i,t} - \sum_{i \in S_{-1}^X \setminus S_t^X} X_{i,-1}}{X_{-1}} + \frac{\sum_{i \in S_t^X \cap S_{-1}^X} (X_{i,t} - X_{i,-1})}{X_{-1}}$, where S_k^X denotes the set of firms that export in period k and period -1 denotes the pre-devaluation period. The first term measures the contribution of the extensive margin, while the second one captures the role of intensive margin adjustments to exports growth.

suggest that financial frictions and the balance sheet effects are not important drivers of aggregate export dynamics.

Earlier empirical and quantitative studies in the trade literature identify financial frictions a key driver of export dynamics at the firm-level (see Kohn et al., 2016, Manova, 2013 or Minetti and Zhu, 2011 and references therein). Yet, in our model, financial frictions and balance sheet effects have a relatively modest effect on the behavior of aggregate exports. While these frictions distort production, investment and export decisions, their overall effect on aggregate exports crucially depends on firms' ability to reallocate their sales from domestic to foreign markets. This channel allows firms to expand their exports even if their output declines.

Thus, a key contribution of our paper is to highlight a novel channel through which firms expand foreign sales in response to a large real exchange rate increase: the reallocation of sales between markets. This mechanism moderates the effect of financial frictions and balance-sheet effects. Nonetheless, to discipline the interaction between these forces, we emphasize the need of a model with heterogeneous firms, such as the one we set up in this paper, that can account for the joint distribution of export-intensity, financial frictions, and foreign debt.

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