

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, output, and investment in large devaluations. We investigate a small open economy with heterogeneous firms and endogenous export decisions, in which firms face financing constraints and debt can be denominated in foreign units. We find that these channels can explain only a small fraction of the dynamics of exports observed in the data since financially-constrained exporters increase exports by reallocating sales across markets. We show analytically the role of this mechanism on exports adjustment and document its importance using plant-level data.

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

JEL: F1, F4, G32.

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1 Introduction

Understanding the response of exports to aggregate shocks is key for determining the role of trade in driving the recovery from economic downturns. While a large class of open economy models imply that large devaluations are associated with a sharp contemporaneous increase in aggregate exports, this implication is at odds with the dynamics observed in these episodes: Alessandria et al. (2015) and others show that aggregate exports increase gradually after large devaluations.¹

Motivated by the importance of financial constraints and balance-sheet effects for the decisions of exporters at the firm-level (Aguiar, 2005, Berman and Hericourt, 2010, Desai et al., 2008, Kalemli-Ozcan et al., 2016),² in this paper we investigate their role in accounting for the dynamics of aggregate exports, output, and investment following large devaluations using a quantitative general equilibrium model with heterogeneous firms.

We find that financial frictions and balance-sheet effects cannot account for the dynamics of exports at the aggregate-level despite their importance for the dynamics of aggregate output and investment. While financial frictions and balance-sheet effects prevent firms from expanding output and investment, we find that financially-constrained exporters can nevertheless increase exports by reallocating sales across markets. We show analytically and quantitatively that this channel of adjustment is crucial in driving our findings and use plant-level data from the Mexican devaluation in 1994 to document evidence consistent with the importance of this channel.

To investigate these channels, we introduce financial frictions and foreign-denominated debt to a standard general equilibrium model of international trade with heterogeneous firms estimated to match salient features of the Mexican economy before the devaluation experienced in 1994. We use this novel

¹Magee (1973) and Junz and Rhomberg (1973) first documented the slow adjustment of exports to exchange rate movements.

²For 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 et al. (2004), and Krugman (1999). For additional empirical evidence, see Berman and Berthou (2009) and Galindo et al. (2003) and references therein.

framework to study the transitional dynamics of aggregate exports following a sequence of shocks estimated to resemble the Mexican large devaluation. Our findings show that modeling heterogeneity across exporters in a dynamic general equilibrium environment that accounts for transitional dynamics is key for understanding the response of exports to aggregate shocks.

We begin by documenting salient features of large devaluations in emerging economies. First, and consistent with previous studies (Alessandria et al., 2015), we document that the elasticity of exports to real exchange rate changes grows gradually following these episodes. Second, we provide a detailed characterization of the use of foreign-denominated debt and access to credit 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. We also document that financial constraints play an important role, with 53% (60%) of firms pointing to the access to (cost of) financing 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 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 up to a fraction of the value of their 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 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, we show analytically that their effect on the dynamics of exports depends on the degree to which firms can reallocate sales across markets. In response to a real exchange rate change, firms that export a small fraction of their sales can 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 increase exports only 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 deterministic sequence of shocks to aggregate productivity, interest rates, and the price of imported goods. 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 1994.³ 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 and with domestic-denominated debt.

We find that financial frictions and balance-sheet effects explain only a small fraction of the export dynamics observed in the data. In particular, these frictions reduce the average absolute percentage deviation between the exports elasticity implied by the frictionless model and the data by only 21%. We show that this result is driven by the reallocation channel: While indebted firms decrease investment and output, exports increase regardless of firms'

³Mexico 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 e.g. Calvo and Mendoza (1996).

financial position because 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.⁴ 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 in 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 those with high export intensity. 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 in export dynamics. We also show that, as in the model, exports 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.

⁴In this economy, firms export a small fraction of their total sales and thus are able to substantially reallocate sales if needed.

Our model extends the frameworks developed in earlier papers (Kohn et al., 2016, and 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., 2004, Devereux et al., 2006, and Gertler et al., 2007). More broadly, our work contributes to a growing theoretical and quantitative literature that studies the effects of financial frictions on export decisions, such as Chaney (2016), 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.⁵ 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, Chor and Manova (2012) argue that financial factors played an important role in accounting for the collapse of trade in the great recession. 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. (2015) 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 related to Pratap and Urrutia (2004), who investigate the role of credit constraints and international trade in accounting for output and investment dynamics during large devaluations in partial equilibrium.

2 Empirical Evidence

In this section, we document the facts that motivate our subsequent analysis. We first investigate the real exchange rate and aggregate exports dynamics

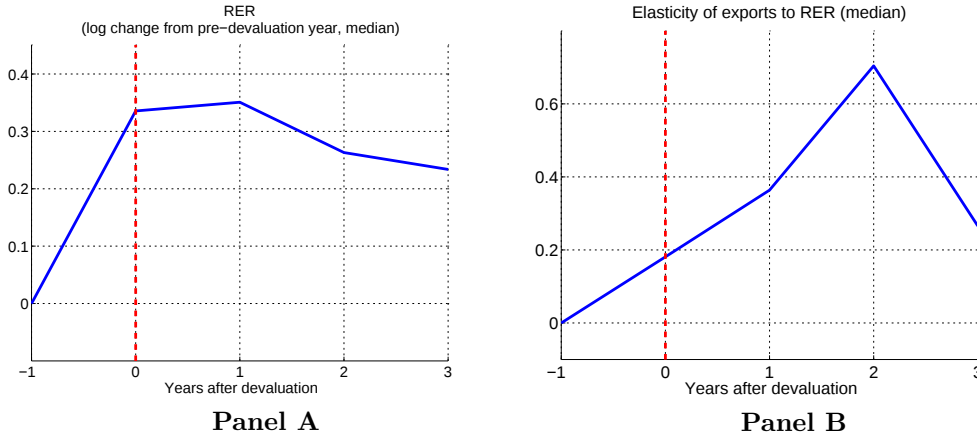
⁵For a detailed review of this literature, see Bems et al. (2013).

in a sample of large devaluations over the past 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%. We restrict our attention to the period between 1980 and 2013. Using this definition, 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).⁶

Figure 1: Aggregate dynamics of the RER and real exports



Source: Multilateral effective real exchange rate (RER) from BIS; real exports data from the World Bank and the International Financial Statistics database published by the IMF.

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).⁷ We see that, following a

⁶Our results are robust to defining large devaluations based on alternative thresholds as well as to using data at a quarterly frequency.

⁷More precisely, in Panel A 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 Panel B, we plot $\log(X_t/X_{-1})/\log(\xi_t/\xi_{-1})$, where X_t denotes exports at time t . We detrend the log

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 a large devaluation, the median real exchange rate is 23% higher than its pre-devaluation level.

Panel B 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. (2015), 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 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.⁸ The dataset covers six of the nine countries that experienced a large devaluation according to our definition. 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.⁹

We report our results in Table 1. We observe that firms in our sample tend to have a significant amount of debt denominated in foreign currency, and reliance on such debt is substantially higher among exporters compared to non-exporters: 48% and 13%, respectively. 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

growth of exports in each country by subtracting its average log growth over the period.

⁸More details about the WBES data can be found at <http://www.enterprisesurveys.org>.

⁹All surveys were conducted within five years of the devaluation episodes. Results are very similar when computed for all countries for which there are data available on the currency composition of debt.

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

	<i>By export status</i>			<i>By # of workers</i>			
	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: WBES 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.

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 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 debt these firms hold in foreign currency.

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 WBES. 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. 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. 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 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 or cost of finance to be at least a moderate obstacle.

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 (53%) are credit constrained in their access to finance, while an even larger share (60%) find the cost of finance to be a significant constraint. Moreover, we find that this is also the case for both exporters and non-exporters, as reported in the second and third rows of the table: In fact, exporters appear to be more credit constrained than non-exporters.

Table 2: Share of credit-constrained firms

	<i>By export status</i>			<i>By # of workers</i>			
	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: WBES 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 last four 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, they are also likely to be credit constrained in both the access to and cost of finance.¹⁰

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 present when the devaluations took place, potentially affecting the dynamics of exports following these episodes.

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.

¹⁰We also find firms that have debt denominated in foreign currency are slightly less constrained than firms that do not have, both in their access and cost of finance. Results are similar when we compute these statistics for all countries with WBES data available.

There are three types of goods: 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 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.¹¹ 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 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.

¹¹In the description of the model that follows, we use subindex i to identify individual entrepreneurs only when needed for clarification.

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 1 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 iceberg trade cost $\tau > 1$, which requires them to ship τ units for every unit that arrives at its 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 that 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.¹² 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 that limits the amount that they can borrow to a fraction θ of the value of their capital stock at the time the loan is due for repayment. Thus, 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 re-

¹²To model the portfolio choice decision of entrepreneurs across different types of debt, we would need to account for expectations about future real exchange rates and, thus, it would require us to introduce aggregate shocks. In the quantitative analysis, we consider unexpected shocks that affect real exchange rates and we examine the sensitivity of our findings to alternative values of λ .

spective demand schedules. In the domestic market, these 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 quantities and prices of varieties sold in the domestic market by $y_{h,t}$ and $p_{h,t}$, respectively, and those in the foreign market by $y_{f,t}$ and $p_{f,t}$, respectively. The prices of varieties 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, they pay the fixed export costs. They also 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 capital.¹³

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 , export choice, $e_t \in \{0, 1\}$, and prices and quantities $y_{h,t}$, $p_{h,t}$, $y_{f,t}$, and $p_{f,t}$ 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 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 $y_{h,t} + \tau y_{f,t} = Az_t k_t^\alpha n_t^{1-\alpha}$. The 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 this 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

¹³This assumption simplifies the numerical solution of the model by making the capital accumulation decision risk-free; see Midrigan and Xu (2014) and Moll (2014).

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.¹⁴ 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

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

where $Y_{h,t}$ denotes the quantity of the domestic final good produced. The solution 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.

3.1.3 Rest of the world

The rest of the world demands varieties from entrepreneurs and supplies varieties to final good producers. 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 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 both 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 as¹⁵

¹⁴ p_m is denominated in units of the foreign final good.

¹⁵Notice that $a' \geq 0$ does not preclude firms from having positive amounts of debt.

$$v(k, d, z) = \max_{c, a' \geq 0} \frac{c^{1-\gamma}}{1-\gamma} + \beta \mathbb{E}_{z'} [g(a', z')] \\ \text{s.t. } c + a' + d[\lambda + (1-\lambda)\xi/\xi_{-1}] = w + (1-\delta)k + \pi(k, z),$$

$$\text{where } \pi(k, z) = \max_{p_h, y_h, p_f, y_f, n, e \in \{0,1\}} p_h y_h + e \xi p_f y_f - wn - ewF \\ \text{s.t. } y_h + \tau y_f = Azk^\alpha n^{1-\alpha}, \quad y_h = p_h^{-\sigma} Y_h, \quad y_f = p_f^{-\sigma} Y_f$$

$$\text{and } g(a', z') = \max_{k', d'} v(k', d', z') \\ \text{s.t. } k' - \frac{d'}{1+r} = a', \quad d'[\lambda + (1-\lambda)\xi'/\xi] \leq \theta k'.$$

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* 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 $\phi : \mathcal{S} \rightarrow [0, 1]$ 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 goods market clears: $\int_{\mathcal{S}} [c(s) + x(s)] \phi(s) ds = Y_h$; (v) measure ϕ is stationary.

4 Mechanism

In this section, we study analytically the mechanism through which financial frictions and balance-sheet effects affect aggregate exports.¹⁶ First, we examine their effect on aggregate exports in a stationary equilibrium. Then, we investigate their impact on export dynamics following a real devaluation. In doing so, we distinguish the effects in the intensive and extensive margins of trade as well as decompose the impact of real exchange rate changes through

¹⁶See the Online Appendix for derivations of all the results presented in this section.

the standard competitive effect, the balance-sheets effects and the financial frictions. In particular, we isolate the role of export intensity in amplifying the effect of real exchange rate changes in financially-constrained firms.¹⁷

Let $a = k - d/(1 + r)$ denote the entrepreneur's net worth. The solution to the entrepreneur's problem is such that an entrepreneur with net worth a chooses to export if and only if $z > \underline{z}(a)$, where $\underline{z}(a) \in \mathbb{R}$ for every $a > 0$. As shown in the appendix, net worth a and productivity z are the relevant individual state variables for entrepreneurs. Thus, we let $y_f(a, z)$ and $p_f(a, z)$ denote the volume and price of exports, respectively, corresponding to an entrepreneur with state (a, z) who decides to export.

Given the above notation, we express aggregate exports in units of foreign final goods, X , as $X = \int_{a=0}^{\infty} \int_{\underline{z}(a)}^{\infty} p_f(a, z) y_f(a, z) dz da$.

4.1 Aggregate exports in a stationary equilibrium

We first examine how financial frictions distort aggregate exports along the intensive and extensive margins of trade in a stationary equilibrium.

Firm-level exports Along the intensive margin, financial frictions reduce the exports of financially constrained firms since these are forced to operate with a suboptimal amount of physical capital. To see this, consider an entrepreneur with net worth a and productivity z . Conditional on choosing to export, the amount exported in units of foreign final goods is given by

$$\log p_f y_f = \log \Phi + (\sigma - 1) \log \xi - (\sigma - 1) \alpha \log(\tilde{r} + \delta + \mu), \quad (1)$$

where $\tilde{r}$ denotes the effective real interest rate, μ is the Lagrange multiplier on the borrowing constraint, and $\Phi := \left[\frac{\sigma-1}{\sigma} \frac{\alpha^\alpha (1-\alpha)^{1-\alpha}}{w} \frac{Az}{\tau} \right]^{\sigma-1} Y_f$ is a function of structural parameters, the wage rate, and the firm's idiosyncratic productivity level. The effective real interest rate is given by $1 + \tilde{r} =$

¹⁷To keep the analysis analytically tractable, we restrict attention in this section to an economy in partial equilibrium; we abstract from the impact of changes in the real exchange rate on aggregate prices and quantities as well as their impact on firms' net worth accumulation decisions. In the following section, we examine quantitatively the transitional dynamics of aggregate exports following large changes in the real exchange rate allowing for changes in equilibrium prices and the distribution of agents across the state space.

$(1+r)[\lambda + (1-\lambda)\xi/\xi_{-1}]$ and represents the return to saving a unit of domestic goods through financial markets. It follows that as long as $\xi = \xi_{-1}$, the denomination of debt does not affect foreign sales.

The above expression reveals that firm-level exports are positively related to the real exchange rate, through higher foreign demand for firms' goods, and negatively related to the implicit rental cost of capital, $\tilde{r} + \delta + \mu$.¹⁸ Note that financially constrained exporters have higher values of μ and lower exports.

Set of exporters Financial frictions also distort the set of firms that choose to export, reducing the share of firms that find it profitable to do so.

The solution to the entrepreneur's problem is such that if net worth a is above a given level $\bar{a}$, then the export-entry productivity threshold is independent of net worth and firms can operate at their optimal scale. That is, if $a \geq \bar{a}$, then we have that $\underline{z}(a) = \underline{z}^u$, where $\underline{z}^u$ is the optimal export-entry threshold in a frictionless economy, given by

$$\underline{z}^u = \frac{\sigma}{\sigma-1} \left[\left(\frac{w}{1-\alpha} \right)^{(1-\alpha)} \left(\frac{\tilde{r} + \delta}{\alpha} \right)^\alpha \right]^{\sigma-1} \left(\frac{\sigma w F}{Y_f} \right)^{\frac{1}{\sigma-1}} \frac{\tau}{\xi^{\frac{\sigma}{\sigma-1}}} \quad (2)$$

In contrast, entrepreneurs with net worth $a < \bar{a}$ operate at a suboptimal scale if they choose to export. Therefore, for all $a < \bar{a}$ we have $\underline{z}(a) < \underline{z}^u$.¹⁹ It follows that in this economy, the set of firms that choose to export is distorted relative to the frictionless economy, resulting in a lower share of exporters.

As with the intensive margin, foreign-denominated debt does not impact firms' exporting decisions since $\xi = \xi_{-1}$ in a stationary equilibrium.

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 keep the analysis tractable, in this section we consider a small change in the real exchange rate keeping all other aggregate prices and quantities as well as all the structural parameters unchanged. Then, the elasticity of aggregate exports to changes in the real exchange rate is given by:

¹⁸The above equation also shows that firm-level exports depend negatively on the wage rate w , and positively on the idiosyncratic and aggregate productivity levels z and A .

¹⁹For $a < \bar{a}$ the threshold $\underline{z}(a)$ can only be defined implicitly; see the Online Appendix.

$$\frac{\partial \log X}{\partial \log \xi} = \underbrace{\int_{a=0}^{\infty} \int_{\underline{z}(a)}^{\infty} \frac{p_f(a, z) y_f(a, z)}{X} \frac{\partial \log(p_f(a, z) y_f(a, z))}{\partial \log \xi} \phi(a, z) dz da}_{\text{Intensive Margin}} + \underbrace{\int_{a=0}^{\infty} \frac{p_f(a, \underline{z}(a)) y_f(a, \underline{z}(a))}{X} \frac{\partial \underline{z}(a)}{\partial \log \xi} \phi(a, \underline{z}(a)) da}_{\text{Extensive Margin}} \quad (3)$$

which shows that the aggregate exports elasticity is the sum of exports adjustments along the intensive and extensive margins. Below we explore in detail how financial frictions and foreign-denominated debt affect the adjustment along each of these margins.

Intensive Margin The contribution of intensive margin adjustments to the aggregate exports elasticity is given by the exports-weighted average of firm-level export elasticities. Thus, we now examine in turn the firm-level export elasticity of financially unconstrained and constrained firms.

From Equation (1), we find that the exports elasticity to changes in the real exchange rate for unconstrained continuing exporters is given by

$$\frac{\partial \log p_f y_f}{\partial \log \xi} = (\sigma - 1) \left[1 - \alpha \frac{(1 - \lambda)(1 + r) \frac{\xi}{\xi - 1}}{\tilde{r} + \delta} \right] \quad (4)$$

The first term, $\sigma - 1$, captures the price elasticity of foreign demand. A higher ξ increases demand for domestic goods which makes entrepreneurs expand foreign sales at rate $\sigma - 1$. To increase their foreign sales entrepreneurs accumulate capital and expand total production, leaving domestic sales unchanged. However, devaluations also increase the opportunity cost of holding capital, which decreases firms' optimal scale and hence their optimal level of exports. This effect is captured by the negative sign of the second term above.

Next, we examine the export elasticity of constrained continuing exporters

$$\frac{\partial \log p_f y_f}{\partial \log \xi} = (\sigma - 1) \left\{ 1 - \alpha \left[\frac{\theta}{\alpha(\sigma - 1) + 1} \frac{(1 + r)(1 - \lambda) \frac{\xi}{\xi - 1}}{(1 + \tilde{r})(1 + \tilde{r} - \theta)} \right] - \alpha \left[\frac{\sigma}{\alpha(\sigma - 1) + 1} \times \text{Export Intensity} \right] \right\} \quad (5)$$

where export intensity is given by the ratio of exports to total sales $\frac{\xi p_f y_f}{p_h y_h + \xi p_f y_f}$.

The first term in Equation (5) captures the positive effect of the change in the real exchange rate as in Equation (4). The second term in Equation

(5) captures the negative balance-sheet effect: An increase in ξ tightens the borrowing constraint forcing constrained firms to decrease their scale. Note that balance-sheet effects are the largest for high values of θ and low values of λ ; in this case, exporters hold large amounts of foreign-denominated debt.

Finally, the third term captures the impact of financial frictions and its interaction with export intensity. In contrast to unconstrained exporters, constrained entrepreneurs cannot expand their sales by accumulating more capital and increasing total production. Yet, they have an additional margin to increase exports: constrained exporters increase their foreign sales by *reallocating* sales across markets. That is, they increase foreign sales by decreasing domestic sales. Importantly, firms with low initial export intensity have a larger scope for reallocating sales across markets: a given percentage change in domestic sales leads to a larger percentage exports increase among firms with low export intensity. In the limit, as export intensity approaches zero, this third effect vanishes, as any arbitrary percentage change in exports can be achieved with an infinitesimal change in domestic sales.

We now contrast the above findings with those from a frictionless economy without foreign-denominated debt. In this case, the contribution of the intensive margin to the exports elasticity is simply given by $\sigma - 1$ since none of the negative effects of a devaluation are present in this case.

The above discussion suggests that financial frictions and foreign-denominated debt may substantially reduce the response of exports to changes in the real exchange rate. Moreover, the results above show that the negative effects depend crucially on the fraction of foreign-denominated debt held by firms, λ , the tightness of the borrowing constraint, θ , and the export intensity of exporters that governs the ability of financially constrained exporters to reallocate their sales across markets. In the next section we discipline these three channels in order to quantify the effect of financial frictions and balance-sheet effects on aggregate exports.

Extensive Margin Devaluations can also affect the aggregate elasticity of exports by making the foreign market more attractive and leading non-exporters to begin exporting. From Equation (3), we see that the contribution of this

margin consists of the product between: (i) the size of marginal exporters relative to aggregate exports, $\frac{p_f(a, \underline{z}(a))y_f(a, \underline{z}(a))}{X}$, (ii) the rate at which the export entry threshold changes in response to changes in ξ , $\frac{\partial \underline{z}(a)}{\partial \log \xi}$, and (iii) the mass of marginal exporters, $\phi(a, \underline{z}(a))$.

Consider first the impact of a change in the real exchange rate on the entry decision of unconstrained marginal exporters ($a \geq \bar{a}$). From Equation (2) it follows that $\frac{\partial \underline{z}^u}{\partial \log \xi} = -\underline{z}^u \left[\frac{\sigma}{\sigma-1} - \alpha \frac{(1-\lambda)(1+r)\frac{\xi}{\xi-1}}{\tilde{r}+\delta} \right]$. The first term in this expression captures the positive effect of devaluations on the returns to exporting; thus, the export-entry productivity threshold decreases, leading more firms to export. The second term captures the negative effect of devaluations on the cost of capital in the presence of foreign debt, discouraging entry.

In contrast, firms that start exporting with net worth $a < \bar{a}$, do so while operating at a suboptimal scale; in this case, the export entry threshold $\underline{z}(a)$ is only defined implicitly. It is nevertheless possible to discuss the qualitative impact of devaluations on the export entry decisions of constrained exporters. First, an increase in ξ increases the profits from exporting and hence encourages entry. However, this effect tends to be weaker than for firms with higher net worth since constrained new exporters cannot operate at their optimal scale and take full advantage of the higher demand for their goods. Furthermore, devaluations tighten financial constraints via negative balance sheet effects; thus, as in the case of unconstrained marginal exporters, foreign-denominated debt unambiguously decreases export entry.

Total adjustment Putting together the above discussions, the aggregate elasticity of exports to changes in the real change rate is given by

$$\begin{aligned} \frac{\partial \log X}{\partial \log \xi} = & (\sigma-1) \left\{ 1 - \alpha \left[\frac{(1-\lambda)(1+r)\frac{\xi}{\xi-1}}{\tilde{r}+\delta} \right] \frac{X^u}{X} \right. \\ & \left. - \alpha \left[\frac{\theta}{\alpha(\sigma-1)+1} \frac{(1+r)(1-\lambda)\frac{\xi}{\xi-1}}{(1+\tilde{r})(1+\tilde{r}-\theta)} + \frac{\sigma}{\alpha(\sigma-1)+1} \times \text{Export Intensity} \right] \frac{X^c}{X} \right\} \\ & + \frac{\partial \underline{z}^u}{\partial \log \xi} \frac{p_x(\underline{z}^u)x(\underline{z}^u)}{X} \left[1 - \int_0^{\bar{a}} \phi(a, \underline{z}(a)) da \right] + \int_0^{\bar{a}} \frac{\partial \underline{z}(a)}{\partial \log \xi} \frac{p_x(\underline{z}, a)x(\underline{z}, a)}{X} \phi(a, \underline{z}(a)) da \quad (6) \end{aligned}$$

where X^u and X^c denote the value of exports accounted by unconstrained and constrained exporters. The terms in the first line are the response of aggregate exports due to adjustment by continuing exporters (the intensive margin of trade) and capture the negative effects of devaluations through their impact on the cost of capital (second term), balance sheet effect (the third term) and financial constraints (the fourth term). The terms in the second line capture the effect of devaluations on the export entry decisions of unconstrained exporters (the fifth term) and constrained exporters (the last term) where $1 - \int_0^{\bar{a}} \phi(a, \underline{z}) da$ is the measure of unconstrained marginal exporters.

In the absence of financial frictions and foreign-denominated debt, the above elasticity simplifies to

$$\frac{\partial \log X}{\partial \log \xi} = (\sigma - 1) + \underline{z}^u \frac{\sigma}{\sigma - 1} \int_{a=0}^{\infty} \frac{p_f(a, \underline{z}^u) y_f(a, \underline{z}^u) \phi(a, \underline{z}^u)}{X} da \quad (7)$$

Comparing Equations (6) with Equation (7) suggests that financial frictions and foreign-denominated debt may substantially depress the elasticity of aggregate exports if firms hold large amounts of foreign-denominated debt (λ is high), firms are financially constrained (high μ), and have high export intensity. In the next section, we evaluate the importance of these distortions quantitatively, accounting for general equilibrium effects as well as firms' dynamic asset-accumulation decisions.

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 the year 1994, the 12-month period prior to the large depreciation experienced by the Mexican Peso on December 20 of that year. Second, 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 Mexican economy during and in the aftermath of the devaluation of 1994.²⁰ 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 the 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 account for at least 85% of the total output produced by each 6-digit sector (in decreasing order by size). For more details, see Iacovone (2008). We supplement this dataset with other data sources described below.

5.2 Export intensity heterogeneity

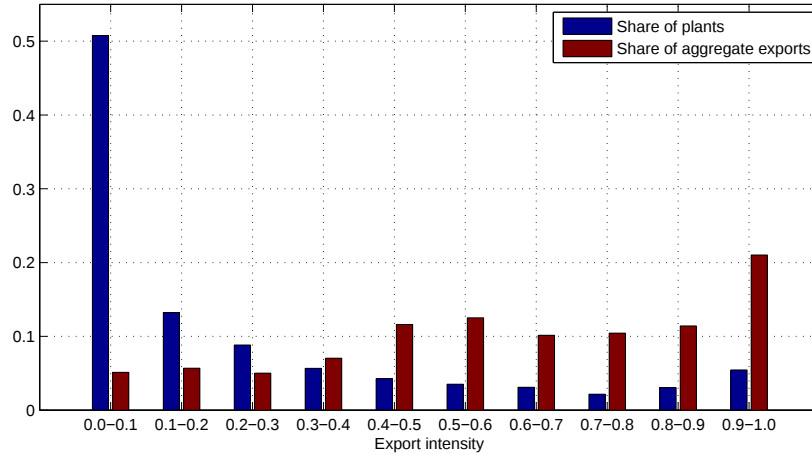
In Section 4, we showed that the extent to which firms can increase exports by reallocating sales across markets depends on their initial export intensity. Therefore, in order to discipline the importance of this channel, we examine the degree of export intensity heterogeneity observed in the data across firms.

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

To discipline the extent to which sales reallocation across markets affects

²⁰Thus, 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.

Figure 2: Export-intensity distribution in Mexico, 1994



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.

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

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 60% of their production, accounting for 53% of aggregate exports.²¹

²¹Defever et al. (2017) use cross-country data to document that export intensity typically

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.

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

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 4.²² We set the real interest rate to 0.08, which is the sum of the average Emerging Market Bond Index (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 with 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 costs faced by high-export-cost firms, τ_H ; the variable export costs faced by low-export-cost firms, τ_L ; the persistence and the standard deviation of productivity shocks, ρ_z and σ_ε ; the discount rate, β ; and the collateral constraint parameter, θ . We choose them to match the following moments: (i) the share of exporters

features "twin peaks," with some firms exporting a lot of their output and others a little.

²²These values fall well within the values used in previous studies. See Blundell et al. (1993) for the intertemporal elasticity of substitution and Broda and Weinstein (2006) for the elasticity of substitution across varieties, σ .

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 moments (i) to (vi) using Mexican plant-level data. For (vii), we use data from 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 calibrated parameters and target moments in Table 4.²³

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

²³We 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 periods. See the Online Appendix for details of our numerical solution algorithm.

that point onwards. We choose the sequence of $p_{m,t}$, r_t , and A_t for $t = 0, \dots, 3$ 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 $t \geq 4$.^{24,25} We use real GDP and investment data from the World Bank, and real effective exchange rate data from the Bank for International Settlements; real GDP is detrended by subtracting its average growth rate over the sample period.

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 $\lambda = 1$).²⁶

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 rates, 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 $\lambda = 1$).

²⁴Since 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 as in Alessandria et al. (2015). In the Online Appendix, we report the sequence of shocks that we estimate and show the role of each shock in accounting for the three aggregate target series.

²⁵At the time of the devaluation, Mexico also joined the North American Free Trade Agreement (NAFTA); however, tariffs to the U.S. and Canada decreased gradually from 3.5% in 1994 to 1% in 2001 (Ayhan Kose et al., 2005). We abstract from these changes.

²⁶This 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. In the Online Appendix, we show that the implications of the frictionless model are similar if, instead, we use the same sequence of shocks as in the baseline model.

Figure 3: RER, real GDP, investment, and elasticity of exports

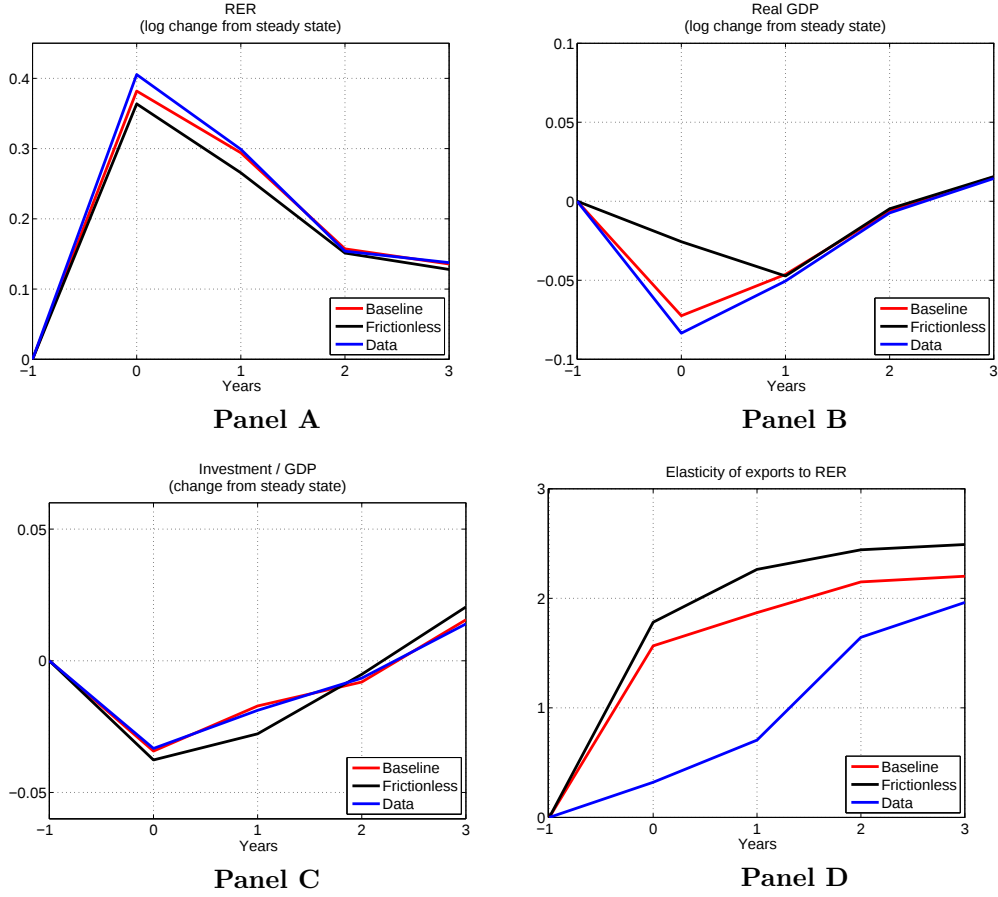


Figure 3, Panel A, plots the percentage deviation of the real exchange rate from its pre-devaluation, steady-state level for each of these economies and the data. The figure shows that shocks in both models can be calibrated to closely match the dynamics of the real exchange rate observed in the data, implying a large devaluation followed by a gradual appreciation. Four years after the devaluation, the real exchange rate is still 10% 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.²⁷ In

²⁷Consistent with the data, we measure real GDP and real exports as Laspeyres quantity indexes, keeping prices fixed at pre-devaluation levels and adjusting quantities over time.

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 in the period of the devaluation, with the ratio between them decreasing by 3 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.²⁸

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 $E_t^{x, rer} = \frac{\ln(X_t) - \ln(X_{-1})}{\ln(RER_t) - \ln(RER_{-1})}$, where period -1 is the pre-devaluation period.²⁹

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.³⁰

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,

²⁸In the Online Appendix, we show that our model matches salient qualitative features of the dynamics of the trade balance not targeted in our estimation approach.

²⁹We detrend exports growth by subtracting its average growth rate over the whole sample.

³⁰In 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 absolute percentage deviation between the exports elasticity implied by our baseline model and the data is only 21% lower than 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

In this section, 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. These results suggest that the reallocation of sales across markets is a key channel behind the dynamics of exports implied by our model.

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 to be constrained on the intensive margin if it operates with capital below its optimal unconstrained level given its export decision.³¹ 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: For given prices, 14.7% of non-exporters would like to export

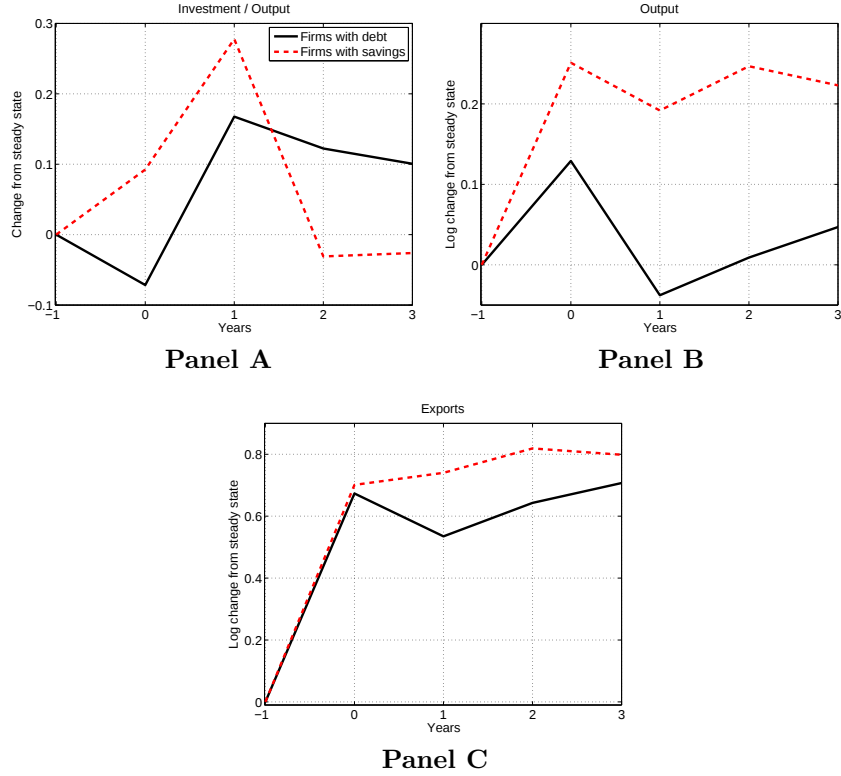
³¹We compute the firm's unconstrained policy functions while keeping aggregate prices and quantities unchanged at their steady-state levels.

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.

Balance-sheet effects and intra-firm reallocation Next, we contrast the dynamics of investment, output, and exports across exporters who differ in their pre-devaluation financial position. In particular, we compare 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%, 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.

Figure 4: Micro-level evidence on financial frictions



Next, Panel B shows the dynamics of output following a large devaluation. We find that exporters expand their scale of operation by hiring labor in order to 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.

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

6 Reallocation and Debt Distribution

We now investigate the extent to which alternative assumptions on the degree of intra-firm reallocation and distribution of foreign-denominated debt affect our findings. To do so, we study the response of the economy to a one-time permanent decrease in the price of imported varieties from 1 to 0.55.³²

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 (high export intensity); and (*ii*) firms subject to high exports costs (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.

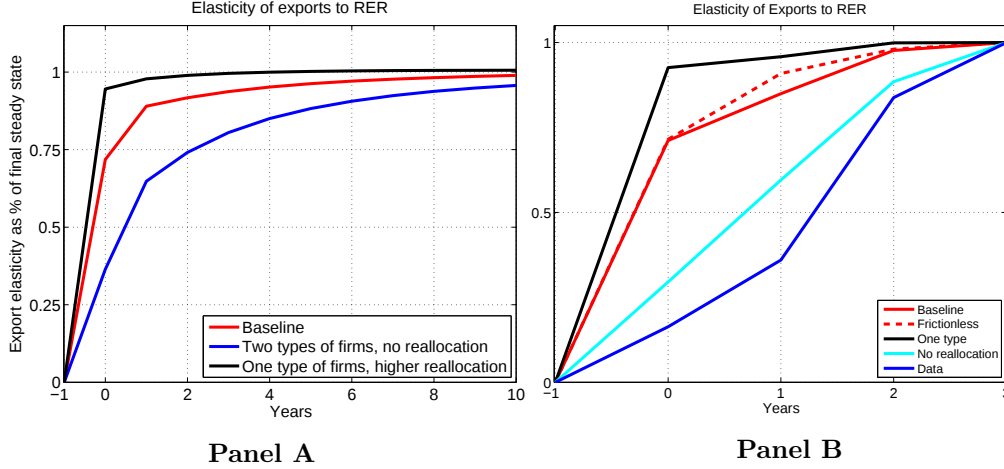
Panel A of Figure 5 contrasts the implied export elasticity dynamics under alternative assumptions about the export intensity distribution: (*i*) the baseline model; (*ii*) an economy with only one type of firms, where all are subject to the same fixed and variable trade costs and feature the same export 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%).³³

Panel A of Figure 5 shows the export elasticity implied by each of these models as a percentage 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. 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

³²In 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.

³³Models (*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.

Figure 5: Exports elasticity and export intensity heterogeneity



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.³⁴ 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.

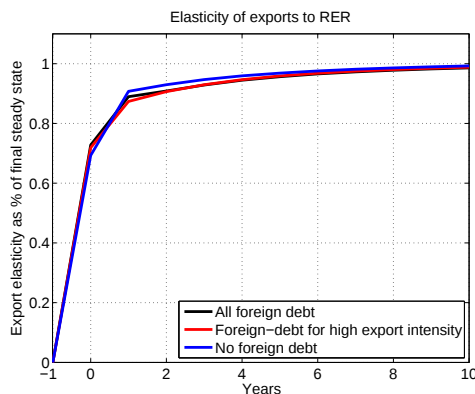
The sharp differences across these models suggest that the export intensity distribution and the implied degree of reallocation play a key role in driving the implications of financial frictions and foreign-denominated debt for aggregate exports during episodes of large devaluations. Therefore, we conclude this discussion by quantifying the extent to which limited reallocation across markets may account for the dynamics of aggregate exports observed in the data. To do so, we re-estimate the sequence of shocks to aggregate productivity, the real interest rate, and import prices, for the two economies examined in this section following the approach discussed in Section 5.4.

³⁴To 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.

Panel B of Figure 5 reports the implied export elasticities relative to the final steady-state.³⁵ First, we find that the baseline model and its frictionless counterpart feature export elasticity dynamics that are very close to each other, as discussed in the previous section. Second, we find that the economy with no reallocation features substantially slower dynamics of exports than the baseline model and very close to the data. Finally, we find that the model with one type of firms (and, thus, with a high degree of reallocation) features an export elasticity on impact that is very close to its final-steady-state value despite the impact of financial frictions and balance-sheet effects.

We interpret these findings as evidence that frictions affecting the degree to which firms may reallocate sales across markets might play an important role for the dynamics of aggregate exports in episodes of large devaluations.

Figure 6: Alternative distributions of foreign debt



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);³⁶

³⁵See the Online Appendix for more details about this exercise.

³⁶These 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.

(*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 driven by the reallocation channel and by general equilibrium effects that operate through the labor market.³⁷

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 1994.³⁸ We conclude by discussing alternative channels complementary to our mechanism.

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 low 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

³⁷In 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.

³⁸In the Online Appendix, we contrast the dynamics of exports across industries with differential degrees of dependence on external finance.

and the Mexican plant-level data:³⁹

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

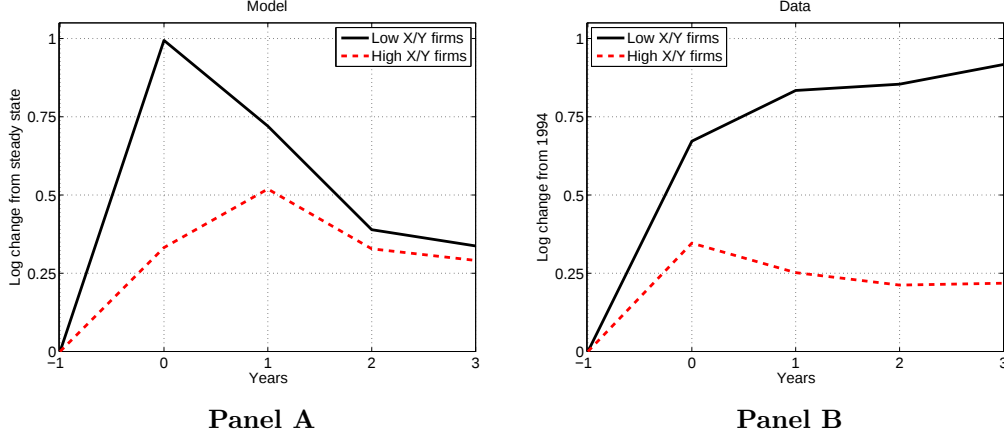
where $t = -1$ is the pre-devaluation period, $X_{i,t}$ denotes the value of firm i 's exports in period t at constant prices, $\mathbb{I}_{\{t=j\}}$ denotes an indicator function that is equal to one in year j and is zero otherwise, and $\text{High initial export intensity}_{i,t}$ is an indicator function 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.

³⁹In the model, we simulate a panel of one million firms and examine their dynamics in response to the experiment conducted in Section 5.4.

Figure 7: Firm-level exports growth by export intensity



Panel B of Figure 7 shows the average growth of exports relative to the pre-devaluation year for firms with low and high initial export intensity in the data.⁴⁰ As implied by the model, we find that average exports growth is higher among firms with low initial export intensity. However, the magnitudes are substantially different from those observed in the data. We interpret these findings as evidence 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 be 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.

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.⁴¹

⁴⁰We evaluate the estimated regression at the average industry level ($\bar{\alpha}_k$) and at the average value of each of the control variables.

⁴¹Specifically, 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.

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

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, both the model and the data imply that exports growth is mainly driven by the intensive margin, consistent with reallocation being an important channel of export growth.

7.3 Discussion

Our findings suggest that financial frictions and balance-sheet effects cannot account for the gradual adjustment of exports observed in episodes of large devaluations. We now briefly survey alternative mechanisms that might be driving the slow response of aggregate exports in these episodes; in the quantitative analysis we purposefully abstract from these alternatives to quantify the potential impact of financial frictions and balance-sheet effects relative to a standard frictionless model of international trade.

Imported Intermediates While large devaluations make exporting more attractive, they also make importing more costly. Thus, to the extent that exporters import a non-trivial fraction of their intermediate inputs (Bernard et al. 2007; Kugler and Verhoogen 2009), the higher cost of imports may slow down the adjustment of exports in these episodes. Even though we abstract from this potential channel in the quantitative analysis, we control for the use of imported intermediate inputs in the empirical analysis when we contrast the implications of the model with evidence from the data.

Invoice Currency and Pass-Through While prices in our economy are fully flexible, economies with sticky prices and local currency pricing may feature gradual dynamics of exports after large devaluations. With sticky prices *à la* Calvo (1983), a very small fraction of exporters would adjust prices when the devaluation takes place, increasing the quantity exported; all other exporters would keep their prices fixed and the quantity exported would also remain unchanged due to local currency pricing. Over time, exporters would continue to adjust their prices in response to changes in the real exchange rate and aggregate exports would increase gradually.

However, it is worth noting that this mechanism might not be economically plausible for two reasons. First, prices would need to be extremely sticky to account for the gradual increase in aggregate exports observed over the first four years following a large devaluation, a much longer time span of price-stickiness than usually assumed in models with sticky prices. Second, it might not be realistic to assume that prices are sticky in response to such large changes in the economic environment; menu-cost models would certainly imply substantial price adjustments on impact under local currency pricing, undermining the potential of this channel to account for gradual exports adjustment.

Customer Capital Another complementary channel that may account for the sluggish adjustment of exports in large devaluation is the gradual process through which firms in international trade accumulate customers. Previous studies suggest that finding new customers takes time and effort, particularly in international trade (Arkolakis 2010, Drozd and Nosal 2012; Eaton et al. 2014). Thus, one way to interpret our findings is as evidence that forces other than financial frictions and balance-sheet effects, such as the slow growth of demand, may be driving the dynamics of exports in large devaluations.

Notice, however, that the evidence presented in this section is consistent with a supply-driven explanation for the slow increase in exports. In particular, we show that firms with low export-intensity tend to increase exports more than high-export-intensity firms during large devaluations, as they might be reallocating domestic output towards the foreign market, more so in the presence of financial frictions as discussed in the mechanism section.

Sunk Export Costs Another complementary channel that can slow down the dynamics of exports in episodes of large devaluations are sunk export entry costs, as shown by Alessandria et al. 2015 in an economy without frictions in financial markets. To the extent that interest rates increase in large devaluations, the lifetime expected returns from exporting may decrease, leading non-exporters to postpone their decision to start selling in foreign markets.

Our quantitative analysis abstracts from this channel in order to isolate the role of financial frictions and balance-sheet effects from this alternative channel. Sunk export entry costs might amplify the impact of financial frictions, by further distorting firms' export participation decisions. Notice, however, that these amplification effects are not likely to be quantitatively significant given the relatively small impact of the extensive margin on the adjustment of exports in these episodes, as documented in this section. Additionally, sunk export costs are a reduced-form way of capturing non-tariff trade barriers. Thus, given that financial frictions can act as sunk costs, as described in Kohn et al. 2016, our analysis captures at least part of the sunk costs faced by firms.

Banks balance-sheets Finally, our analysis abstracts from balance-sheet effects that affect the banking sector, which may amplify the impact on aggregate exports and economic activity. In the Online Appendix, we show the results of an alternative exercise where we consider shocks to the fraction of collateralizable assets, θ (we interpret these as shocks to banking sector balance-sheets, i.e. a financial crisis), and find similar results as in our main exercise.

8 Conclusion

In this paper, we investigate the role of financial frictions and balance-sheet effects in accounting for export dynamics in large devaluations. To do so, 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. However, when calibrated to match salient features of the data, we find that exports in the model increase

much faster than in the data and close to a frictionless benchmark. Thus, our results suggest that financial frictions and balance-sheet effects are not important drivers of aggregate export dynamics. 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.

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 that can account for the joint distribution of export intensity, financial frictions, and foreign debt.

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