Financial Frictions and Export Dynamics in Large Devaluations*

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Abstract

We study the role of financial frictions and balance-sheet effects in accounting for the dynamics of aggregate exports in large devaluations. We investigate a small open economy with heterogeneous firms and endogenous export decisions in which firms face financing constraints and debt can be denominated in foreign units. Despite the negative impact of these channels on capital accumulation and output at the firm-level, we find that they only explain a modest fraction of the gradual increase of exports observed in these episodes. Exports increase since financially-constrained exporters are able to reallocate 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 of aggregate exports, Alessandria et al. (2015) and others show that aggregate exports increase gradually after large devaluations.[1] Figure 1 illustrates this observation for a sample of large devaluations over the period 1980 to 2013.[2]

A potential explanation for the slow response of exports in large devaluations are balance sheet effects due to the prevalence of foreign-denominated debt in emerging economies.[3] Given limited access to finance in these economies, large devaluations increase the domestic value of firms' debt burden, weakening their balance sheets and leading them to decrease investment and output. Moreover, recent studies also document the importance of these channels for the decisions of exporters at the firm-level.[4]

In this paper we investigate the aggregate implications of financial frictions and balance-sheet effects on the dynamics of aggregate exports following large devaluations. To do so, 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 framework to study the transitional dynamics of aggregate exports following a sequence of shocks estimated to resemble the Mexican large devaluation.

We find that financial frictions and balance-sheet effects account for a modest fraction of the dynamics of aggregate exports observed in the data despite their importance for the dynamics of aggregate output and investment. While

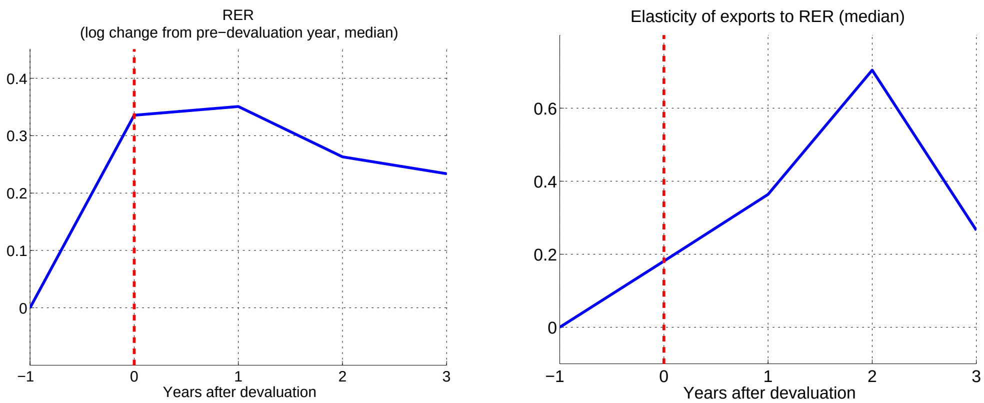
[1]Early references include Magee (1973) and Junz and Rhomberg (1973).

[2]For details of these data see Section 1 of the Online Appendix.

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

[4]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. (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), and Kalemli-Ozcan et al. (2016).

Figure 1: Real exchange rate (RER) and real aggregate export dynamics



Source: Multilateral effective real exchange rate from BIS; real exports data from the World Bank and the International Financial Statistics database published by the IMF. Large devaluations are defined as annual log-changes in the RER greater than 0.20.

financial frictions and balance-sheet effects indeed prevent firms from expanding output and investment, we find that financially-constrained exporters can nevertheless increase exports by reallocating sales across markets. We document evidence consistent with the importance of this channel using plant-level data from the Mexican devaluation in 1994 but we find that our model features too much reallocation relative to the data. In contrast, we show that the model can generate the gradual adjustment of exports observed in the data if we prevent firms from reallocating sales across markets.

To study the quantitative effects of large devaluations on export dynamics, we consider a small open economy populated by a large number of entrepreneurs who produce differentiated goods. Exporting is subject to fixed and variable trade costs, as in Melitz (2003), while entrepreneurs are heterogeneous with respect to productivity and variable trade costs.[5] Finally, following the evidence discussed above, we introduce frictions in financial markets and foreign-denominated debt. In particular, we assume that entrepreneurs can

[5]We introduce heterogeneity in variable trade costs to account for export intensity heterogeneity. As we explain below, this allows us to control the extent to which financially constrained firms can reallocate sales across markets.

borrow in domestic or foreign units up to a fraction of their physical capital stock 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.

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.[6] 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 a modest

[6]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 e.g. Calvo and Mendoza (1996).

share of the dynamics of exports 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 14%. We show that this result is driven by the reallocation channel: While indebted firms invest and produce less than firms with savings, exports increase regardless of firms' 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 sell all of their output internationally, leaving no room for intra-firm reallocation. In this case, exports adjustment is gradual and close to the adjustment observed in the data. Second, we consider an economy in which exporters have homogeneous and low export intensity.[7] 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. These results show that the extent to which firms can reallocate sales across markets plays a key role in accounting for the dynamics of exports in large devaluations and suggest a role for reallocation frictions.

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.

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

1.1 Literature Review

Our model extends the frameworks developed in earlier papers (Kohn et al., 2016, and Leibovici, 2018) 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, 2018), and Leibovici (2018). 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 importance of financial factors in shaping the dynamics of international trade flows in response to aggregate shocks (see, for example Amiti and Weinstein 2011, Paravisini et al. 2015, or Chor and Manova 2012).[8,9] We contribute to this literature by documenting importance of intra-firm sales reallocation in determining the dynamics of aggregate exports in the presence of financial imperfections. In contemporaneous work, Almunia et al. (2018) also find evidence of this reallocation channel in Spain, albeit in response to a different shock (i.e., a domestic demand shock).

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 abstract from sunk entry costs and 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. More broadly, our results can be interpreted as providing

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

[9]Our work also relates to papers examining how the interaction of credit constraints with exchange rate volatility (rather than shocks) affect international trade (e.g. Héricourt and Poncet 2013; Lin et al. 2018).

support for alternative mechanisms such as search frictions, customer capital, or sunk costs as important drivers of export dynamics (see e.g. Arkolakis 2010; Drozd and Nosal 2012; Eaton et al. 2014; Alessandria et al. 2015).

Finally, our paper is also related to a recent literature on the dynamic effects of misallocation on trade flows (Berthou et al. 2018; Brooks and Dovis 2018; Alessandria et al. 2018; Manova 2008). Our paper complements this literature by investigating how financial frictions distort the response of trade flows to devaluations.

2 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: 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. Below, we assume that the numeraire good is the domestic final good and define the real exchange rate as the price of the foreign final good relative to the domestic final good.

2.1 Economic environment

2.1.1 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 $y_t = A_t z_t k_t^{\alpha} n_t^{1-\alpha}$, where A_t 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.[10] 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.

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.[11] Furthermore, exporters are subject to an iceberg trade cost.

In our baseline model, we assume that there are two types of firms: (i) a fraction ζ of firms that are subject to low iceberg export costs, $\tau_L > 1$, resulting in high export intensity, and (ii) a fraction $1-\zeta$ of firms that face high iceberg export costs, $\tau_H > \tau_L$, resulting in low export intensity. This source of heterogeneity allows us to match differences in export intensity observed across firms,[12] and to discipline the extent to which firms reallocate sales across markets in response to a large devaluation.

Financial markets Entrepreneurs have access to financial markets, where they can borrow or save by trading two one-period uncontingent bonds, one

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

[11]Notice that fixed costs are paid every period so the export decision is static. See subsection 5.4 for a discussion of the role of sunk export costs in large devaluations as in Alessandria et al. (2015).

[12]Defever and Riano (2017) use cross-country data to document that export intensity typically features "twin peaks" (bimodal distribution).

denominated in domestic final goods and the other one denominated in foreign final goods. Financial markets are integrated internationally and both bonds are supplied perfectly elastically at a given interest rate r_t by foreign investors.[13]

We denote the real exchange rate by ξ_t (i.e., the price of foreign final goods in units of the domestic final good). A firm that chooses to borrow a total amount $\frac{d_{t+1}}{1+r_t}$ in units of domestic final goods, allocates a fraction $\lambda \in [0,1]$ to debt denominated in domestic final goods and a fraction $1-\lambda$ to debt denominated in foreign final goods. For simplicity, we assume that λ is an exogenous parameter which is identical across entrepreneurs.[14,15] Therefore, in period t, entrepreneurs owe $\lambda \frac{d_{t+1}}{1+r_t}$ units of domestic final goods and $(1-\lambda)\frac{d_{t+1}}{1+r_t}\frac{1}{\xi_t}$ units of foreign final goods. In the following period, 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 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 respective 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. $p_{h,t}$ is denominated

[13] Interest rate parity is satisfied in the stationary equilibrium as the exchange rate is constant. However, in the transition following aggregate shocks, we allow for violations of interest rate parity. Our results are robust to considering a transition in which interest rate parity holds; see Section 5.1 of the Online Appendix.

[14] In Section 5 of the Online Appendix, we investigate the sensitivity of our findings to this assumption. First, we investigate the sensitivity of our results to different values of λ. Second, we allow λ to depend on the type of the firm. Finally, we allow λ to respond during transitional dynamics to deviations from interest rate parity. We find that our results are unchanged in all these extensions.

[15] For a model with endogenous currency composition of debt see Salomao and Varela (2018).

in units of the domestic final good while $p_{f,t}$ is denominated in units of the foreign final good.[16]

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.[17]

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 $y_{h,t} + \tau_i y_{f,t} = A_t z_t k_t^{\alpha} n_t^{1-\alpha}$. The entrepreneur's budget constraint in period t, expressed in units of the domestic final good, is given by $c_t + x_t + d_t \left[\lambda + (1-\lambda)\frac{\xi_t}{\xi_{t-1}}\right] + e_t w_t F = w_t + p_{h,t}y_{h,t} + e_t \xi_t p_{f,t} y_{f,t} - w_t n_t + \frac{d_{t+1}}{1+r_t}$, 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.

2.1.2 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 $p_{m,t}$ be the prices of varieties charged by the entrepreneurs

[16] That is, $\xi_t p_{f,t}$ is the price of a domestic variety sold in the foreign market, expressed in units of the domestic final good.

[17] This assumption simplifies the numerical solution of the model; see Midrigan and Xu (2014) and Buera and Moll (2015).

and the rest of the world, respectively. $p_{m,t}$ is denominated in units of the foreign final good.[18] 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

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

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 $y_{m,t} = (\xi_t p_{m,t})^{-\sigma} Y_{h,t}$, which are the demand schedules faced by entrepreneurs and the rest of the world.

2.1.3 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 (kept constant throughout our analysis) 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 $p_{m,t}$.

2.2 Entrepreneur's problem: Recursive formulation

We assume that A_t, r_t, and $p_{m,t}$ are constant in a stationary equilibrium.[19] Let $v(k, d, z; \tau)$ denote the value function in a stationary equilibrium of an entrepreneur with capital k, debt d, productivity z, and iceberg trade cost $\tau \in \{\tau_L, \tau_H\}$, who makes consumption and saving decisions as well as production decisions for both markets. Let $g(a, z; \tau)$ denote the value function of an entrepreneur with net worth a, productivity z, and trade cost τ at the end of a period, who decides the amount of capital k and debt $\frac{d}{1+r}$ for next period.

[18] $\xi_t p_{m,t}$ is the price of the imported variety expressed in units of the domestic final good.

[19] When we consider transitional dynamics we relax that assumption, but assume that entrepreneurs have perfect foresight over their path.

Then, the entrepreneur's dynamic problem can be represented as[20]

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

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

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

In the quantitative section below, we contrast this model with a frictionless counterpart in which there is no borrowing constraint ($\theta = \infty$) and all debt is denominated in domestic units ($\lambda = 1$). In this case, capital is unconstrained and profits do not depend on the level of net worth.[21]

2.3 Stationary competitive equilibrium

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

Assume that aggregate variables A_t, r_t, and $p_{m,t}$ are constant. 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 $\phi : \mathcal{S} \to [0,1]$ 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 goods market clears: $\int_{\mathcal{S}} [c(s) + x(s)]\,\phi(s)ds = Y_h$; (v) measure ϕ is stationary.

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

[21] For the entrepreneur's recursive problem in the frictionless case, see the Online Appendix.

3 Mechanism

In this section, we study analytically the mechanism through which financial frictions and balance-sheet effects affect aggregate exports. First, we examine their effect on aggregate exports in a stationary equilibrium. Then, we investigate their impact on export dynamics following a real devaluation.[22]

3.1 Aggregate exports in a stationary equilibrium

Firm-level exports Financial frictions reduce the exports of financially constrained firms. To see this, consider an exporter with net worth a and productivity z. The amount he exports is given by

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

where $\widetilde{r}$ denotes the effective interest rate, μ is the Lagrange multiplier on the borrowing constraint, and Φ is a function of structural parameters, the wage rate, and the firm's idiosyncratic productivity. The effective interest rate is given by $1+\widetilde{r} = (1+r)\left[\lambda + (1-\lambda)\xi/\xi_{-1}\right]$ and represents the return to saving a unit of domestic final goods through financial markets. Financially constrained exporters have higher values of μ and, thus, lower exports. Moreover, the denomination of debt does not affect foreign sales as long as $\xi = \xi_{-1}$.

Set of exporters In an economy with financial frictions, the export entry decision of firms with sufficiently high net worth is undistorted. On the other hand, entrepreneurs with low net worth operate at a suboptimal scale if they choose to export and they may, thus, not find it profitable to export. Therefore, the share of exporters is lower than in a frictionless economy.

3.2 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, we treat the real exchange rate as an exogenous price and we focus on a small change in ξ ($\xi \searrow \xi_{-1}$).[23]

[22] See the Online Appendix for derivations of all the results presented in this section.

[23] We also abstract from the impact of changes in ξ on other aggregate prices and quantities as well as their impact on firms' net worth accumulation decisions. In Section 4, we examine quantitatively the transitional dynamics of aggregate exports in general equilibrium following shocks to the economy that endogenously generate a large devaluation.

In addition, we assume that all firms in the economy are constrained.[24]

We express aggregate exports in units of foreign final goods as $X = \int\limits_{a=0}^{\infty} \int\limits_{\underline{z}(a)}^{\infty} p_f(a,z) y_f(a,z) \, \mathrm{d}z \, \mathrm{d}a$, where $\underline{z}(a)$ is the productivity export threshold. Then, the elasticity of aggregate exports to (infinitesimal) changes in the real exchange rate is given by:

$$\frac{\partial \log X}{\partial \log \xi} = \underbrace{\int\limits_{a=0}^{\infty} \int\limits_{\underline{z}(a)}^{\infty} \frac{p_f(a,z) y_f(a,z)}{X} \frac{\partial \log(p_f(a,z) y_f(a,z))}{\partial \log \xi} \phi(a,z) \, \mathrm{d}z \, \mathrm{d}a}_{\text{Intensive Margin}} + \underbrace{\int\limits_{a=0}^{\infty} \frac{p_f(a,\underline{z}(a)) y_f(a,\underline{z}(a))}{X} \frac{\partial \underline{z}(a)}{\partial \log \xi} \phi(a,\underline{z}(a)) \mathrm{d}a}_{\text{Extensive Margin}} \quad (2)$$

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. Since a fraction $1-\lambda$ of firms' debt is denominated in foreign currency, the elasticity of their export sales to a change in ξ is

$$\frac{\partial \log p_f y_f}{\partial \log \xi} = (\sigma - 1) \left[1 - \alpha \left(\frac{\theta}{\alpha(\sigma-1)+1} \frac{(1-\lambda)}{(1+r-\theta)} \right) - \alpha \left(\frac{\sigma}{\alpha(\sigma-1)+1} \times \text{Export Intensity} \right) \right] \quad (3)$$

In a frictionless economy, the elasticity of entrepreneurs' export sales to changes in ξ is equal to $\sigma - 1$, the price elasticity of foreign demand. However, foreign debt and financial frictions limit the response of exports to a change in the real exchange rate. An increase in ξ produces negative balance-sheet effects, forcing constrained firms to decrease their scale (second term in the brackets in Equation 3). This effect is larger when θ is high and λ is low; in this case, exporters hold large amounts of foreign-denominated debt.

Moreover, constrained entrepreneurs cannot expand their exports by increasing total production. Instead, they increase exports by decreasing domestic sales. 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. This is captured by the third term in square brackets in Equation 3.

Extensive Margin The contribution of the extensive margin to the change in aggregate exports depends on: (i) the size of marginal exporters relative

[24] See Section 6 of the Online Appendix for analytical results without this assumption.

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, $\phi(a, \underline{z}(a))$.

An increase in ξ increases the profits from exporting which encourages entry. This effect is weaker for firms with low net worth since they cannot operate at their optimal scale. Furthermore, devaluations tighten financial constraints via negative balance sheet effects; thus, foreign-denominated debt unambiguously decreases export entry.

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

$$\frac{\partial \log X}{\partial \log \xi} = (\sigma - 1) + \underline{z}\frac{\sigma}{\sigma - 1}\int_{a=0}^{\infty} \frac{p_f(a,\underline{z})y_f(a,\underline{z})\phi(a,\underline{z})}{X}\,\mathrm{d}a \tag{4}$$

Summary From the above equations, we see 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.

4 Quantitative Analysis

In this section, we study quantitatively 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 20th 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 aftermath of the devaluation of 1994.[25] Finally, we contrast the implications of the model for the dynamics of aggregate exports with their empirical counterpart.

4.1 Calibration

In this section, 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).[26] We supplement this dataset with other data sources described below.

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 1: 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,

[25] 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.

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

σ, equal to 4.[27] 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 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;[28] (*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

[27]These 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.

[28]We map the two types of exporters in the model by partitioning them in the data into two export intensity groups that account for approximately half of aggregate exports. In particular, firms that export less than 60% of their output account for 47% of aggregate exports. See the Online Appendix for further details.

(i) to ($viii$). We report calibrated parameters and target moments in Table 1.[29]

4.2 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. That is, we study the perfect foresight transition to steady-state. 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 at their $t = 3$ value for all $t \geq 4$.[30,31] 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.

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[29] We study the global solution of the model, solved via 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.

[30] 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 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.

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

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 $\lambda = 1$).[32,33]

4.3 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 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 $\lambda = 1$).

Panel A of Figure 2 plots the percentage deviation of the real exchange rate from its pre-devaluation 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.

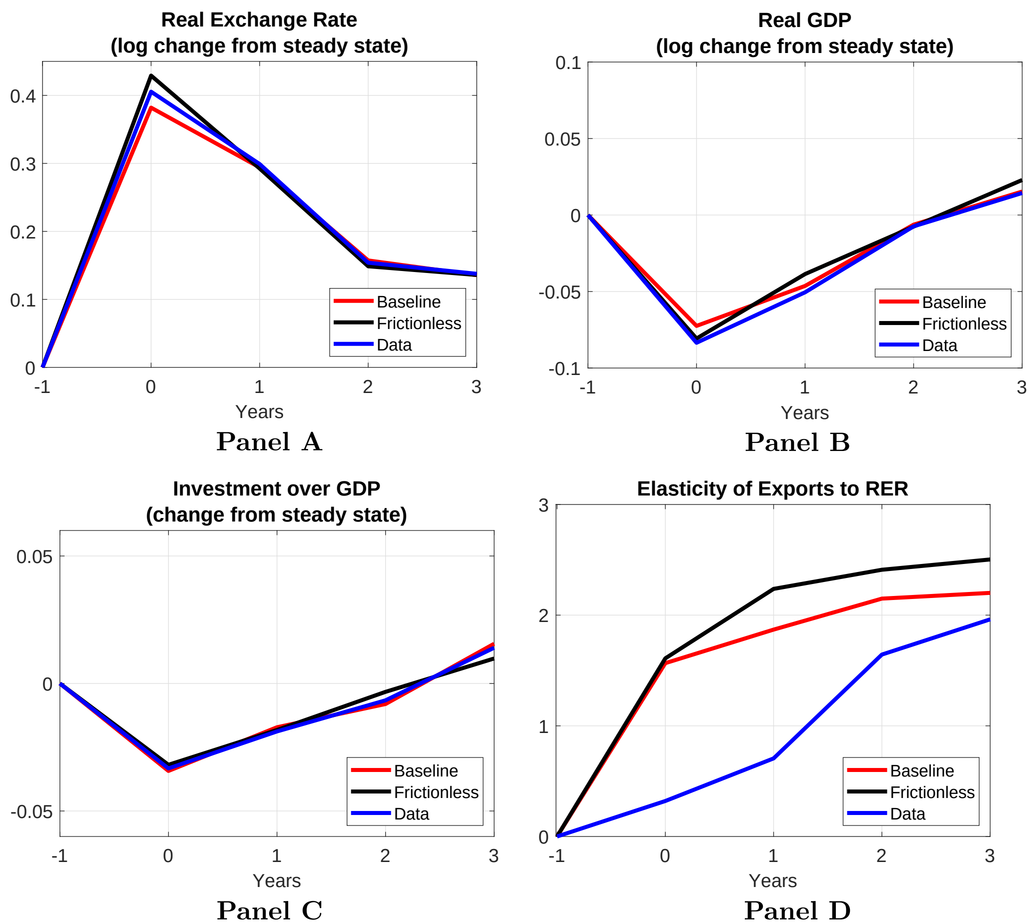
Similarly, Panel B of Figure 2 plots the percentage deviation of real GDP from its pre-devaluation level for each of these economies.[34] In the data, real GDP falls sharply in the period of the devaluation and recovers slowly thereafter, reaching its pre-devaluation level somewhere between the third and

[32] This alternative model is calibrated separately using the strategy described in Subsection 4.1, 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.

[33] While interest rate parity is violated in the transition, in the appendix we recompute the experiment such that interest rate parity holds every period after the initial unexpected shock. Our results are robust under either assumption.

[34] Consistent 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.

Figure 2: RER, real GDP, investment, and elasticity of exports



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 of GDP in the frictionless model.

Finally, Panel C of Figure 2 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.[35]

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.[36]

Panel D of Figure 2 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. In particular, we find that financial frictions slow down the adjustment of exports, but modestly so.[37]

In this panel 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 14% 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 Financial Frictions, Balance-Sheet Effects, and Reallocation

Our results in the previous section show that financial frictions and balance sheet effects have a modest impact on the dynamics of aggregate exports. We now investigate why is the quantitative impact so limited.

We first study the impact of balance-sheet effects and financial frictions at the firm-level, and show that even though investment and output decisions are affected at the firm-level, these effects do not lead to slower exports growth

[35] In 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.

[36] We detrend exports growth in the data by subtracting its average growth rate over the whole sample.

[37] 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 but modestly so.

since firms reallocate sales across markets. Then, we examine how alternative degrees of reallocation would affect aggregate export dynamics, and show that the effects would be much larger in an economy in which firms cannot reallocate sales across markets. We then contrast these findings with evidence from data on Mexico's 1994 devaluation. We find that the elasticity of exports is higher across firms with low export-intensity both in the data and in the model, suggesting that sales reallocation was an important driver of exports dynamics in the Mexican devaluation. We conclude by discussing alternative channels complementary to our mechanism.

5.1 Financial frictions and balance sheet effects at the firm-level

The impact of financial constraints We first investigate the extent to which financial frictions bind in our model. To do so, 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.[38] 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 2 reports the results.

Table 2: Share of constrained firms, pre-devaluation

	Extensive margin (%)	Intensive margin (%)	k/k^*
All firms	10.0%	53.4%	72.1%
Non-exporters	14.7%	46.6%	78.0%
Exporters	—	65.5%	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: Given prices, 14.7% of non-exporters would like to export if

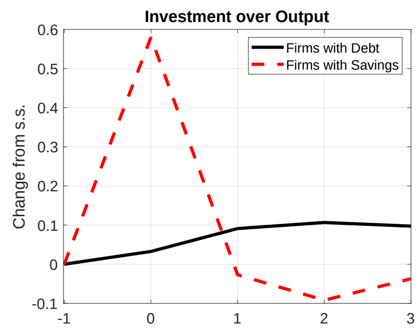
[38] We compute the firm's unconstrained policy functions while keeping aggregate prices and quantities unchanged at their steady-state levels.

they could operate at the unconstrained optimal level. Table 2 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 2 shows that financial frictions severely distort firms' decisions, limiting their ability to expand their production following a devaluation.

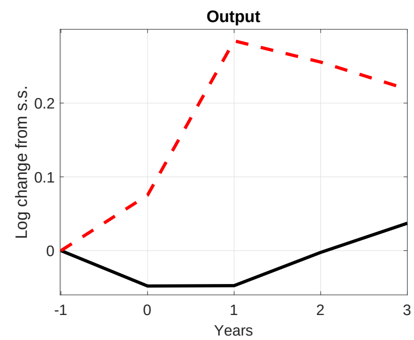
Balance-sheet effects and intra-firm reallocation We then contrast the dynamics of investment, output, and exports across exporters who differ in their pre-devaluation financial position. In particular, we compare exporters with debt relative to exporters with savings; the former are negatively affected 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 3 presents the results. Panel A shows that firms with debt (black solid line) increase the investment-to-output ratio gradually relative to its steady state level, as the devaluation damages their balance sheets. On the other hand, exporters with savings (red dashed line) increase the investment-to-output ratio sharply in response to the devaluation, 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.

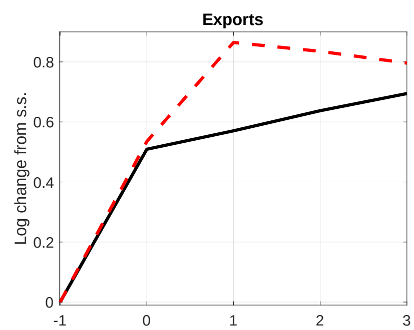
Figure 3: Micro-level evidence on financial frictions



Panel A



Panel B



Panel C

Next, Panel B shows the dynamics of output following a large devaluation. We find that exporters with savings expand their scale of operation by hiring labor and accumulating capital 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 are not able to increase their capital stock and total sales on impact. Moreover, given their lower investment following the initial shock, the total production increases gradually a few years after the devaluation. 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.

5.2 Export intensity, reallocation, and aggregate export dynamics

Given the role of sales reallocation at the firm-level, we now examine the effect of intra-firm reallocation across markets on aggregate export dynamics. To do so, we 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 4 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%).[39] To quantify the extent to which limited reallocation across markets may account for the dynamics of aggregate exports observed in the data, we re-estimate the sequence of shocks to aggregate productivity, the real interest rate, and import prices, for the economies examined in this section following the approach discussed in Section 5.4.

Figure 4 shows the export elasticity implied by each of these models as a percentage of their final-steady-state value.[40] We find that, even though model (*ii*) is a standard trade model with financial frictions, it 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. 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

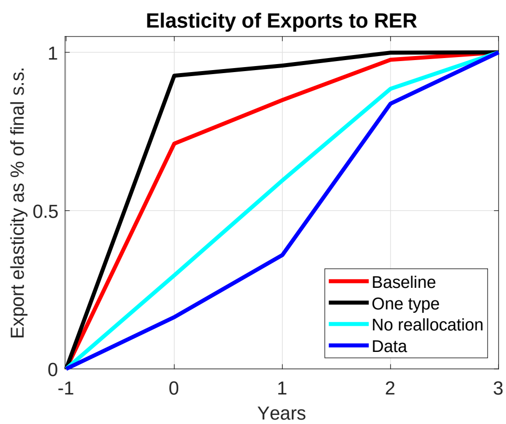
[39] Models (*ii*) and (*iii*) are calibrated using the strategy described in Subsection 4.1, with the exception that we choose the variable trade cost to match the aggregate ratio of exports to total sales instead of average firm-type-specific export intensities. In our calibration of Model (*ii*), firms that export sell 24.5% of their output internationally.

[40] See the Online Appendix for more details about this exercise.

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.[41] Thus, this case features substantially slower dynamics of exports than the baseline model and very close to the data. 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.

Figure 4: Exports elasticity and export intensity heterogeneity



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.

5.3 Evidence of the mechanism: Mexico 1994

In this section, we examine the extent to which export dynamics in the data depend on the degree of reallocation. To do so, we use plant-level data from Mexico's 1994 devaluation.[42]

[41] 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 5.3.2, we do not expect this assumption to significantly affect our findings.

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

5.3.1 Reallocation across markets

Our findings above show that the strength of the reallocation channel depends crucially on firms' export intensity at the time of the devaluation. Thus, 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. 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 Mexican plant-level data:[43]

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

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.

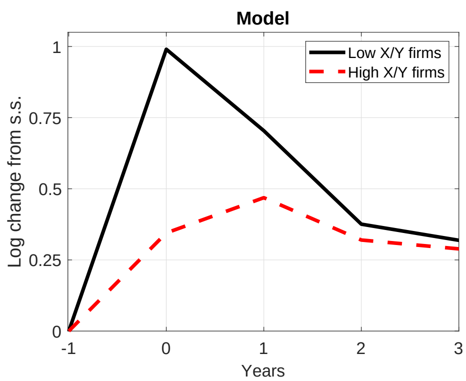
To estimate this specification in the data, we also add industry fixed effects and control for three plant-level variables that may impact exports adjustment but which we do not model explicitly in our quantitative analysis: (*i*) the ratio of firms' final good inventories to total sales, (*ii*) the 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 5 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

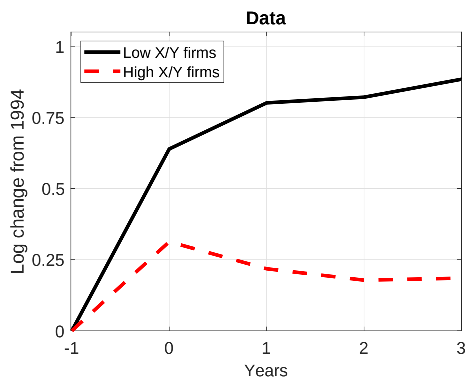
[43] In the model, we simulate a panel of one million firms and examine their dynamics in response to the experiment conducted in Section 4.2.

red line). 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 exports 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.

Figure 5: Firm-level exports growth by export intensity



Panel A



Panel B

Panel B of Figure 5 shows the average growth of exports relative to the pre-devaluation year for firms with low and high initial export intensity in the data.[44] 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.[45]

5.3.2 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 for by the intensive margin.

[44] We evaluate the estimated regression at the average industry fixed effect and at the average value of each of the control variables across all plants in 1994. Given that NAFTA is contemporaneous to the 1994 devaluation, industry fixed effects allow us to control for differential changes in tariffs before vs. after NAFTA across industries.

[45] In contemporaneous work, Almunia et al. (2018) also find evidence of reallocation across markets in Spain following a burst of the 2009 housing bubble. Similarly to us (see Section 5.3.2), they find that reallocation was driven mostly 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 3: 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	0.09	0.91	0.27	0.73
1998	0.06	0.94	0.29	0.71

In Table 3, we report the share of the cumulative growth of exports in the model and the data explained by the extensive and intensive margins.[46] 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.[47]

5.4 Discussion

Our analysis shows 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

[46] 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.

[47] These findings are consistent with the role of the extensive and intensive margins documented by Kehoe and Ruhl (2013).

the potential impact of financial frictions and balance-sheet effects relative to a standard frictionless model of international trade.

Imported Intermediates Large devaluations make exporting more attractive but they also make importing more costly. 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. While 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. In Section 4.1 of the Online Appendix, we further evaluate empirically the importance of this mechanism, extending the analysis that we conduct in Section 5.3.1. Our findings suggest that the prevalence of imported intermediates among exporters are unlikely to have significantly slowed down the response of exports after the devaluation.

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. 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 devaluations is the gradual process through which firms in international trade find 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.

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 abroad. 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.

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.

6 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.

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. In our model, financial frictions and balance-sheet effects slow down aggregate export dynamics following large real depreciations. However, when calibrated to match salient features of the data, we find that exports in the model increase 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 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.

These findings suggest that frictions to the reallocation of sales across markets might play an important role in accounting for the dynamics of exports in large devaluations.

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