Export Dynamics in Large Devaluations[1]

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Abstract

We study the source and consequences of sluggish export dynamics in emerging markets following large devaluations. We document two main features of exports that are puzzling for standard trade models. First, given the change in relative prices, exports tend to grow gradually following a devaluation. Second, high interest rates tend to suppress exports. To address these features of export dynamics, we embed a model of endogenous export participation due to sunk and per period export costs into an otherwise standard small open economy. In response to shocks to productivity, the interest rate, and the discount factor, we find the model can capture the salient features of export dynamics documented. At the aggregate level, the features giving rise to sluggish export dynamics lead to more gradual net export dynamics, sharper contractions in output, and endogenous stagnation in labor productivity.
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1. Introduction

It is well-known that following a devaluation of the exchange rate that exports tend to expand gradually. This gradual export growth is often attributed to non-exporters being slow to start exporting and existing exporters being slow to expand the products, markets, or customers to which they sell (see Roberts and Tybout, 97, and Das, Roberts, and Tybout, 2007). The weak export response may also arise in part because of difficulties in financing export expansion since devaluations tend to occur in periods of financial distress. This gradual export expansion is thought to affect the dynamics of net exports and potentially output (Baldwin and Krugman, 89). Here, we reconsider empirically and theoretically the source of sluggish export growth and its consequences. We document the salient micro and macroeconomic features of export dynamics in large devaluations. We then develop a small open economy model in which exports are determined in part by the entry decisions of non-exporters and exit decisions of exporters. We then show the model can capture the observed sluggish growth of exports following a devaluation and that these export dynamics lead net exports to shift more gradually from deficit to surplus. We find that these sluggish export dynamics lead to a sharper contraction in output but shallower depreciations. Additionally, the resources used up in the intangible investment to expand access to export markets leads measured labor productivity to stagnate.

We begin by characterizing the salient features of exports around large devaluations in 11 emerging markets. We focus on these periods of economic turmoil as these are large, easily identified events.[1] First, we confirm that there is a gradual expansion of exports following a devaluation. The elasticity of exports to the real exchange rate is initially low and rises over time, peaking in the third year following the devaluation[2] Second, we find a role for interest rates in dampening export growth. Specifically, we find that in countries with higher interest rates, measured by the J.P. Morgan's EMBI spreads, the elasticity of exports to the real exchange rate is even more sluggish. These two features hold when studying all

[1] More generally, it is well known that trade tends to respond with a lag to real exchange fluctuations.

[2] The export elasticity is measured as the change in exports to foreign expenditures divided by the change in the real exchange rate where the changes have been calculated relative to their pre-devaluation levels. In a standard Armington model, this object is constant. It is a convenient way to compare the export response in countries with different size devaluations.

exports as well as exports to the U.S. Next, we examine the role of the extensive margin in the export dynamics. We analyze the extensive margin with both the product-level data for all the countries' export to the U.S. and the custom trade data for Argentina, Colombia, Mexico, and Uruguay. Using these disaggregate data, we find that the extensive margin of trade (measured as number of products, destinations, and exporters) is important in this sluggishness, and that the level of aggregation is important in measuring the role of extensive margin in export growth.

These features of export dynamics pose a challenge for standard static trade models such as the Armington, Eaton-Kortum, or Melitz[3] models. In these models exports move proportionally to relative prices and there is no direct effect of interest rates on exports.[4] We thus develop a small open economy model that can capture these gradual export dynamics and has a role for the interest rate on exports. We embed a parsimonious model of producers starting and stopping to export into a small open economy that borrows to smooth consumption in response to aggregate shocks to the interest rate, productivity, and the discount factor (impatience). In our model, the amount a country can export depends on the stock of exporters currently actively selling overseas as well as the terms of trade. Over time the stock of exporters can change as a result of investments by non-exporters to access foreign markets and by existing exporters to maintain their presence in foreign markets. Specifically, we follow the literature on export decisions (see Baldwin and Krugman (89), Dixit (89a b), Roberts and Tybout (97), Das, Roberts and Tybout (07), and Alessandria and Choi (07)) and model producer-level decision to export as involving both an up-front, or sunk cost, and ongoing cost. We allow for idiosyncratic shocks to the costs of exporting. Thus, non-exporters will start exporting when the value of exporting exceeds the cost of starting to export. Similarly, exporters will continue to export as long as the value of exporting exceeds the cost of continuing to export. As long as the up-front cost exceeds the continuation cost, the stock of exporters is a durable asset that will adjust gradually to a shock. Profits from exporting

[3]By the Melitz model, we mean the standard version with no plant dynamics and costs of starting to export are the same as the costs of staying in the export market so that the export decision is static.

[4]In these models interest rates can affect trade through general equilibrium factors. In particular, a rise in world interest rates encourages savings which can stimulate exports. This makes the finding of a negative relationship between interest rates and exports even more puzzling.

are thus a return on the foregone resources to build up the stock of exporters. Fluctuations in the interest rate and discount factor thus will potentially affect the incentive to export by altering how the future benefits of exporting are discounted.

Our GE model allows us to identify the shocks that match the dynamics of output, interest rates, and real exchange rates observed in the data and then evaluate the role of trade barriers on export, net export, and output dynamics. We find devaluations, and the associated economic crisis, to be the result of a combination of increased international borrowing costs, less impatience, and a minor increase in observed productivity. In response to these shocks, the country would like to expand its exports by increasing the number of producers that export. However, the sunk aspect of export costs implies that the costs of expanding the stock of exporters are front-loaded while the benefits, measured as future export profits, are backloaded. Thus, to expand the stock of exporters requires the economy initially to devote substantial resources to invest in export capacity which lowers current consumption relative to the future. The desire to smooth consumption thus puts a brake on the speed of export expansion. The intangible investment in export capacity tends to reduce a country's physical output initially and its ability to run a trade surplus and therefore increases its indebtedness. Given that the periods we study are characterized by both high interest rates and more patient consumers, the countries have little incentive to invest in expanding exports too quickly or strongly. Compared to a model without this sunk export cost, this dampens export growth and leads to a more gradual net export dynamics.

Our paper is related to a number of distinct literature on international trade and macroeconomics. First, there is a literature that focuses on understanding why trade responds differently to changes exchange rates or trade costs at different horizons. For instance, Baldwin and Krugman (1989), Dixit (89a), Roberts and Tybout (1997) and Das, Roberts, and Tybout (2007) develop partial equilibrium models of sunk costs and real exchange rate fluctuations. Unlike these models, we develop a GE model which forces us to take a stand on the aggregate shocks but allows us to evaluate the effect of these trade barriers on aggregate fluctuations in output and net exports. Ruhl (2007) and Alessandria and Choi (2011a,b) also develop general equilibrium models of sunk export costs but focus on the dynamics of trade growth in response to change in trade barriers. In terms of business cycles, Alessandria and

Choi (2007) develop a two country GE model with sunk costs and find a minor impact on the dynamics of net exports in response to productivity shocks compared to a model without sunk costs. The larger effects here arise because we consider a different set of shocks (interest rates and impatience) and much larger shocks. Indeed, we find larger differences in how export costs affect aggregate fluctuations in response to interest rates shocks. Additionally, we explicitly consider the aggregate consequences in a particular calibration that generates export sluggishness whereas the earlier Alessandria & Choi model did not generate much sluggishness. Drozd and Nosal (2012) and Engel and Wang (2011) also develop two-country GE models in which trade expands sluggishly over the business cycle. Unlike these models, we measure the sluggishness of exports and evaluate the impact of the model to explain gross and net trade flows. Second, our focus on emerging market business cycles is related to papers by Neumeyer and Perri (2005), Uribe and Yue (2006) and Aguiar and Gopinath (2007). Unlike these papers, we explicitly model gross trade flows and consider their impact on output, net exports, and relative prices. A key feature of our model with relative prices fluctuations is that interest rates are now quite countercyclical as the increases in interest rates generate depreciations that reduce the incentive to produce and consume. Generating countercyclical interest rates is a challenge in standard models, while here the recessionary impact of interest rates is quite strong. Finally, Meza and Quinitin (2007) and Kehoe and Ruhl (2008) have argued that an important puzzle is to explain the large declines in observed productivity in countries with large exchange rate movements. Here we find that overcoming the barriers to exporting lead measured labor productivity to lag TFP by as much as 8 percentage points while exports are expanding.

The paper is organized as follows. The next section documents the dynamics of exports, exchange rates, and interest rates in some emerging markets using aggregate and disaggregate data. Section 3 develops our benchmark model and presents the model calibration. In Section 4 we examine the model's predictions for export dynamics. We conduct the sensitivity analysis in Section 5. Section 6 concludes.

2. Data

We begin by documenting some key relationships between exports, the real exchange rate, and interest rates in a sample of small open economies that experienced a large real exchange rate depreciation in the past two decades.[5] Three salient features stand out. First, the elasticity of exports to the real exchange rate,[6] measured as the change in exports relative to the change in the real exchange rate from prior to the devaluation, is quite low initially and rises over time. Second, high interest rates suppress exports as our export elasticity measure is more sluggish for countries that faced larger increases in international borrowing costs. Third, an important component of the gradual export response is a gradual rise in the extensive margin of trade, where the extensive margin is measured in various ways including by products, product-destinations, and firms. To establish these features we move from the aggregate to disaggregate level.

A. Macro Data

Table 1 lists the eleven countries we consider along with the crisis dates. As mentioned above, the choice of the sample is dictated by two considerations: the countries are small open economies which experienced a recent real exchange rate depreciation, and data is available for at least 24 quarters after the event. The data appendix provides further details on the data sources and construction of all series.

Table 1

Country	Crisis date	Country	Crisis date
Argentina	December 2001	Mexico	December 1993
Brazil	December 1998	Russia	July 1998
Columbia	June 1998	Thailand	June 1997
Indonesia	April 1997	Turkey	January 2001
Korea	October 1997	Uruguay	June 2002
Malaysia	July 1997		

[5] Additional features related to output and net exports are considered when we examine the properties of the model.

[6] We focus on this measure of trade flows since it allows us to compare the export response of devaluations of different sizes and standard theories (Backus, Kehoe, and Kydland, 1994) predict a fairly tight relationship between this variable and the Armington elasticity.

Figure 1 summarizes some salient features in the events we study. The top panel shows the dynamics of the average exchange rate, interest rate, and exports in a 28 quarter window around the devaluations in these 11 emerging market economies. All variables are measured as the change from their levels on the eve of devaluation. The large devaluations are characterized by big real exchange rate depreciations, measured using the local CPI relative to the US CPI and a spike in interest rates, measured as a JP Morgan EMBI spread. On average the real exchange rate depreciates by about 40 to 50 log points initially and the interest rate spread rises about 1800 basis points.[7] These increases exhibit some mean reversion but remain elevated 8 quarters after the devaluation. In contrast, the response of exports, measured in dollars, was muted. Over the first year exports barely change from their pre-crisis level and then only increase gradually when the real exchange rate begins to appreciate. The bottom panel shows that these export and relative price dynamics imply that there is a relatively low elasticity of exports initially and that this export elasticity increases with time. Here we have measured the elasticity of exports in quarter k [8] as

$$(1) \quad \varepsilon_k = \frac{1}{N}\sum_{i=1}^{N} \frac{\left(EX_{it_0+k} - P^M_{t_{0+k}} - D_{t_{0+k}}\right) - \left(EX_{it_0} - P^M_{t_0} - D_{t_0}\right)}{RER_{it_0+k} - RER_{t_0}},$$

where EX is exports, P^M is the US import price deflator, and D is a measure of foreign real expenditure (all measured as logs). This measure isolates how movements in relative prices induce substitution towards the goods from the country with the devaluation. We plot this measure for overall exports and exports to the US, where our measure of real exchange rate and final expenditure are easier to measure and to be consistent with our subsequent analysis of the extensive margin of trade. The export elasticity is quite low initially, averaging about 5 to 10 percent the first year, and then rises steadily over the next 3 to 4 years to about 60 percent.

[7] We also measure interest rates using the financing cost for a median firms based on the World scope data at the annual frequency. For periods after 2003, JP Morgan also provides the Corporate EMBI spreads. The correlation between EMBI and these alternative interest rate measures for the overlapping periods are high and significant.

[8] In an Armington trade model this elasticity is closely related to the elasticity of substitution between imports and domestic goods and is constant.

The large spike in international borrowing costs suggest that the increase in the interest rate may possibly contribute to the slow export growth. To explore how the interest rate influences export growth, we split the 11 emerging economies into two groups based on the cumulative increase in their interest rates 12 quarters following the crisis date.[9] The high interest rate countries are Argentina, Korea, Malaysia, Russia, and Thailand. The low interest rate countries are Brazil, Colombia, Indonesia, Mexico, Turkey, and Uruguay.

Figure 2 depicts the average interest rate and real exchange rate movements along with the median export elasticity to the real exchange rate to the US and overall for the two groups. These figures show that on average, the high interest rate countries experienced a more than 2500 basis point increase in their interest rates, compared to the 1000 basis point increase for the low interest rate countries. At the same time, the real exchange rate depreciation for the high interest rate countries are bigger and a bit more persistent. However, the export elasticity for the high interest rate countries is substantially below the level for the low interest rate countries. For both groups, the trade elasticity increases with time. The short run elasticity is low, and the long run elasticity is much higher.

B. Micro-evidence on Export Dynamics

We now use disaggregated data to study some features of export dynamics following these devaluation episodes. First, we study the movements in the volume and variety of manufactured goods exported to the US. We study exports to the US because we have high-frequency disaggregated data for this market coming from all countries. Also, the US is typically the largest trading partner for these countries and thus exports to the US are likely to be somewhat representative of overall exports. We find two main features: First, the volume of exports grows gradually. Second, the extensive margin grows gradually. Next, we analyze the extensive margin with custom trade data for Argentina, Colombia, Mexico, and Uruguay. The custom trade data for Argentina is at the product and destination level. The custom trade data for the other three countries is at the firm, product, and destination

[9] Specifically, for each country we computed a weighted average of the interest rate over the first twelve quarters. Our weighting scheme weighted earlier periods by more than later periods. Our decomposition into high and low interest rate countries is fairly robust to our weighting scheme, interval considered (i.e. the period the average was computed over), or measure studied (within country spreads or EMBI spreads).

level. Using this extensive dataset, we examine the importance of extensive margin in driving export dynamics for these four countries. The custom-level data shows that the US data tends to understate the role of the extensive margin in export growth.

Extensive Margin to US

To get a sense of what drives the gradual response in exports we consider more micro-oriented data on how the number of products and destinations change following a devaluation. We undertake this analysis using highly disaggregated monthly US data on imports (from the Census). An advantage of using this data is that we can also eliminate any concerns from the previous country-level analysis that the gradual increase in exports reflects a gradual increase in global economic activity or a change in the industry composition of exports. Specifically, to control for changes in the economic environment we next consider how a devaluing country's exports to the US gain market share in US imports.[10]

We begin by constructing a trade-weighted measure of each country's market share. That is, we define country i's share of US imports as

$$s_{it}^{\$} = \sum_j \alpha_{ij} \frac{m_{ijt}}{\sum_{i,exChina} m_{ijt}},$$

where m_{ijt} is US imports from country i of HS code j in period t. To control for changes in the industry composition of trade we weigh import shares by each country's trade weights using a 10 year window around the devaluation

$$\alpha_{ij} = \sum_{t=-60}^{60} m_{ijt} / \sum_{t=-60}^{60} \sum_j m_{ijt}$$

To control for the rising share of trade from China, we measure import shares relative to US imports excluding China.

To study the source of the export growth, we construct a measure of the change in the

[10]This does not fully capture the potential changes in exports, since changes in relative prices could also lead to a change in the share of imports in US expenditures. However, this effect is likely to be small since devaluing countries are likely to have a relatively small impact on the relative price of imports to domestic expenditures.

extensive margin. We measure the extensive margin as a count of the distinct number of HS-10 codes shipped to different US customs districts. This is the finest level of disaggregation in the publicly available trade data. Thus we define the extensive margin, p_{it},

$$p_{it} = \sum_p \sum_j I\left(m_{pijt} > 0\right).$$

To account for the growth in trade we also measure this as a share, $s_{it}^{\#}$ where

$$s_{it}^{\#} = \frac{p_{it}}{\sum_{i,exChina} p_{it}}$$

Next, since we are looking at the how a country's share of US imports changes, we construct a measure of its real exchange rate excluding the US and China. Figures 3A and 3B summarize the average dynamics of each of these variables for our panel of 11 countries. The individual country dynamics are plotted in the appendix. To smooth out some of the variation in the data, we present statistics in six month intervals.[11] Figure 3A shows how our share measures vary over time. Figure 3B shows our measures vary when we remove a log-linear trend rather than detrend with the share.

The first panel in each figure shows the dynamics of the trade weighted real exchange rate for each country. In general, the real exchange rate depreciates about 30 to 40 percent over the first year. Over the subsequent 3 years the real exchange rate appreciates slightly, thus changes in relative prices are quite persistent. The second panel shows how our measure of the value of exports evolves. The third panel shows how the extensive margin evolves. The last panel shows how exports evolve with relative prices using a measure of the ratio of mean change in exports to the mean change in the real exchange rate. The elasticity of the export share is close to zero initially and rises to about 50 percent over 36 months. Whether this is persistent beyond three years depends on our detrending method. The elasticity of the extensive margin is considerably larger. Depending on our de-trending it is 1/3 to twice as much over the first three years. In short, the evidence from the US is consistent with our

[11] Our measure of the extensive margin is the average number of HS10-districts per month rather than a count of HS10-districts observed in a six month interval.

finding using the aggregate data of a weak, gradual export response following a devaluation. The US data points to the extensive margin as being important in these export dynamics.

Lastly, we examine the dynamics of exports and extensive margin of exports from the high and low interest rate countries to the U.S. respectively. Figure 4 shows that the high interest rate countries experience a bigger exchange rate devaluation in the first year. Similar to what the aggregate export data suggests, the high interest rate countries experience a slower export growth. The biggest gap in the export growth between the high and low interest rate countries is observed four years after the devaluation. In terms of the extensive margin, the difference between the high and low interest rate increase countries is smaller.[12] The trade elasticities are also bigger for the low interest rate countries than for the high interest rate countries.

Our analysis based on counts provides some sense of the contribution of the extensive margin in export growth following devaluations. However, one might suspect that movements in our measure of the extensive margin might not contribute much to export growth if new exporters are much smaller than existing exporters. To adjust for this possibility, we now examine how important the extensive margin is in export growth. Following Eaton et al (2007), we disaggregate the intensive margin from the exporters' margins of entry and exit as follows:

$$\begin{aligned}
&\frac{X(t)-X(t_0)}{[X(t-1)+X(t)]/2} \\
&= \left(\frac{\sum_{j\in CN^{t0,t}}[x(j,t_0)+x(j,t)]/2}{[X(t_0)+X(t)]/2}\right)\left(\frac{\sum_{j\in CN^{t0,t}}[x(j,t)-x(j,t_0)]}{\sum_{j\in CN^{t_0,t}}[x(j,t_0)+x(j,t)]/2}\right) \\
&\quad+\frac{NEN^{t_0,t}\overline{x}(t_0)}{[X(t-1)+X(t)]/2}+\frac{\sum_{j\in EN_n^{t0,t}}[x(j,t)-\overline{x}(t_0)]}{[X(t0)+X(t)]/2} \\
&\quad-\frac{NEX^{t_0,t}\overline{x}(t_0)}{[X(t_0)+X(t)]/2}-\frac{\sum_{j\in EX^{t0,t}}[x(j,t)-\overline{x}(t_0)]}{[X(t_0)+X(t)]/2}.
\end{aligned}$$

[12] Figure 4 are based on the detrended data where the trade is calculated using the full sample for individual countries. The difference in the extensive margin is more pronouced before detrending or using the pre-devaluation trend.

where t_0 is the period of devaluation, $X(t)$ denotes the total exports to destination n in year t, $x(j,t)$ is exports by firm j to destination n in period t. The term $CN^{t_0,t}$, $EN^{t_0,t}$, and $EX^{t_0,t}$ represents the set of firms that exported in t_0 and t, that exported in t but not t_0, and that exported in t_0 and not t, respectively. We refer to these sets of firms as pairwise continuing, pairwise entering, and pairwise exiting. $NEN^{t_0,t}$ and $NEX^{t_0,t}$ represent the number of firms in the $EN^{t_0,t}$ and $EX^{t_0,t}$ sets, respectively. The term $\overline{x}(t_0)$ represents average exports of a firm in period t_0. The first line on the right hand side is the intensive margin and captures the change in imports from continuing exporters. The second and third line on the right hand side are the extensive margin and captures the volume of exports from new exporters net of the volume lost from those that stopped exporting in period t.

Because we are interested in the dynamics of intensive and extensive margins following devaluations, we decompose the cumulative growth of exports relative to the period of devaluations. Therefore, the intensive and extensive margins are the cumulative margins following devaluations. An alternative decomposition is to define continuers, entrants, and exiters period by period and calculation the intensive and extensive margin, as in Eaton et al (2007).

Figure 5 shows the decomposition of cumulative export growth for the high and low interest rate increase countries in our sample. The black solid lines are for the percent change in exports. Consistent with Figure 4, the high interest rate countries experience smaller export growth. For both groups, the intensive margins play a bigger role in contributing to the export growth compared to the extensive margin due to entry and exit. Yet the cumulative effect of extensive margin is also not negligible, especially for the low interest rate countries as shown by the blue dashed lines in the lower panel. The finding that the extensive margin is more important for the low interest rate increase countries suggests that interest rate movements depress export growth and a potential channel is the extensive margin due to the entry and exit.

Customs data for four countries

We now show that the US data may understate the importance of the extensive margin since product-level data may hide changes in the number of firms or producers exporting a given product. We can get a sense of the bias by looking at the transaction level data. Our detailed trade data are the customs data on import and export shipments. The data vary somewhat in coverage over time, but give detailed information for each trade shipment, generally including the name of the importer or exporter, the date of declaration, the source or destination country, the quantity, weight, price, and value of the good, along with detailed information at disaggregation levels as the 6-digit HTS classification for Mexico, or 10-digit for Colombia and Uruguay, or 11-digit HTS classification for Argentina. We obtained most of our data from Penta-Transaction, a private provider of trade statistics that receives the shipment data from the customs authorities. We restrict our data to manufactured goods.

Figure 6 shows the breakdown of the aggregate movements in trade to all destination by two measures of the extensive margin for each of the four countries. For each country, we decompose the extensive margin (using the Eaton method) at the most disaggregate product-destination level we have. For Colombia, Mexico, and Uruguay we then measure the contribution of the extensive margin by the firm-product-destination level. For Argentina, since we lack firm-level data we go from 6-digit to 10-digit data. Not surprisingly, all of the data show a stronger extensive margin response at the more disaggregate level. For Mexico at the six digit level, studying firms nearly triples the contribution of the extensive margin response. For Colombia and Uruguay the increase in the contribution is a bit smaller but still quite large. For Argentina, going to a lower level of aggregation nearly doubles the role of the extensive margin. Thus, it appears the extensive margin is an important driver of the export response following devaluations.

3. Model

We extend the basic model of a small open economy that borrows and lends to smooth consumption to include endogenous entry and exit from exporting. As is standard, the economy is subject to exogneous shocks to the world interest rate, R^w, productivity, z, and discount factor, β.[13] These shocks lead to endogenous fluctuations in the output, exporters,

[13] Discount factor shocks are common in macroeconomic modelling (see Eggertson and Woodford, 2003, Smets and Wouters, 2007, Guerron, 2010, Christiano, Eichenbaum, and Rebelo, 2011). An increase in β will generate a sudden stop in that it will lead to a large increase in the current account and a large depreciation. In this respect it is similar to a shock that tightens a borrowing constraint (Mendoza, 2010).

and the real exchange rate.[14]

The economy produces two types of good. There is a homogeneous domestic non-tradable, D, produced using labor, $D = zl_0$. There is an export sector with a unit mass of imperfectly substitutable intermediate goods that can potentially be exported. Each variety is produced with diminishing returns,[15] $y_1 = (zl_x)^\alpha$. Each producer has a different fixed cost of exporting so that in any period only a subset, N, of the producers export.

Specifically, we assume that cost of exporting depends on the producer's export status in the previous period and an idiosyncratic component. That is non-exporters draw their cost from a distribution $F_0(\kappa)$ and exporters draw their cost from a different distribution $F_1(\kappa)$ with $F_0(\kappa) \leq F_1(\kappa)$. These costs are valued in efficiency units of labor and also scaled by aggregate productivity z. These costs can not be recovered when a product is no longer exported. When the cost of entering the export market exceeds the cost of continuing in the market place, i.e. $F_0(\kappa) < F_1(\kappa)$, exporting is a dynamic decision. We also assume that there is a one period lag in changing export status so that the current measure of exporters is pre-determined.

Given these fixed export costs, it is well known that there will be a threshold for non-exporters to start to export, $\kappa_0(S)$, and a threshold for exporters to continue exporting, $\kappa_1(S)$. These thresholds will then determine the fraction of non-exporters who start exporting $F_0(\kappa_0)$ and the fraction of exporters who continue exporting, $F_1(\kappa_1)$. Given these decisions the law of motion for the stock of exporters is

$$(2) \quad N' = F_1(\kappa_1)N + F_0(\kappa_0)(1 - N).$$

Consumers consume a composite non-traded good made by combining the domestic good and foreign goods imported from abroad. Imports, M are acquired using the revenue from exporting and the net financing from international borrowing and lending with a one-period discount bonds. The asset position is denoted by B. The bonds are assumed to be

[14] We focus on thses shocks rather than shocks to foreign demand or the exogenous price of exports since those shocks will reduce exports.

[15] This is a parsimonious way of modelling the differences in tradables and non-tradables as well as allowing the model to generate fluctuations in producer and consumer prices.

denominated in foreign goods. To keep the model stationary we allow for the country to pay a premium above the world rate that is increasing in its debt $R(B, R^w)$.[16] The aggregate state of the economy is thus (z, β, R^w, B, N).

We consider the problem of consumers, final good aggregators, and then exporters. We then sketch out the equilibrium conditions.

A. Consumer's problem

Consumers start out the period with a stock of debt, B. They also receive labor income, wl, and profits from owning the exporters, Π. They are subject to shocks to how they discount future utility (i.e. β changes over time). They chose how much to consume of a final good and how much to borrow at rate, R. The Bellman equation is

$$\begin{aligned} V(z, \beta, R^w, B, N) &= \max_{\{C, l, B'\}} u(C, l) + \beta E V\left(z', \beta', R^{w'}, B', N'\right) \\ \text{subject to} &: \quad PC = wl + \Pi - B + \frac{B'}{1 + R(B, R^w)} \end{aligned}$$

The first order conditions are:

$$\begin{aligned} \frac{u_c}{P} &= \frac{u_l}{w} \\ u_c/P &= \beta E (1 + R(B, R^w)) u_{c'}/P' \end{aligned}$$

B. Final good market

The final consumption good is produced by a competitive final good sector that combines domestic and foreign inputs and sells them at P. The aggregator's problem is

$$\begin{aligned} P &= \min p_d D + p_m M \\ G(D, M) &= \left(D^{\frac{\gamma-1}{\gamma}} + \omega^{\frac{1}{\gamma}} M^{\frac{\gamma-1}{\gamma}}\right)^{\frac{\gamma}{\gamma-1}} \geq 1, \end{aligned}$$

where ω is the Armington weight on the imported good and γ is the elasticity of substitution between home and foreign goods. For simplicity we assume that domestic goods are produced in a perfectly competitive sector ($p_d = w/z$). Given the Armington structure the price of the

[16] Any other way of making the economy stationary is fine too. See Schmitt-Grohe and Uribe (2003) for alternative methods to close the small open economy models.

final good and allocations are:

$$P = \left(p_d^{1-\gamma} + \omega p_m^{1-\gamma}\right)^{\frac{1}{1-\gamma}}$$
$$p_m/p_d = \omega^{\frac{1}{\gamma}} (M/D)^{-\frac{1}{\gamma}}$$

C. Export sector.

Potential producers in the export sector are characterized by their pre-determined export status, $m \in \{0,1\}$ and their current idiosyncratic cost of exporting, $\kappa \in F_m(\kappa)$, where the distribution of entry costs depends on current export status. Fixed export costs are iid. Paying the cost to export allows the producer to export in the following period. Exporters hire labor and face a downward sloping demand curve: $EX(p,S) = \overline{EX}(S)\, p^{-\theta}$, where $\overline{EX}(S)$ is a demand shifter that depends on the state of the economy. We first consider the export decision taking the intratemporal pricing decision as given and then study the pricing decision.[17]

The Bellman equation of a producer with export status $m \in \{0,1\}$ and fixed export cost κ in aggregate state S is:

$$V_m(\kappa, S) = \max\left\{m\pi(S) - \frac{w}{z}\kappa + Eq' V_1(\kappa', S'),\, m\pi + Eq(S') V_0(\kappa', S')\right\}$$

where $\pi(S)$ denotes the profits from exporting and the cost of exporting depends on the cost draw κ and aggregate productivity. Producers discount the future with the stochastic discount factor $q(S')$. This problem implies that only producers with low fixed costs of exporting will export. The export cost of the marginal exporter equals the difference in the expected value of a potential exporter from being an exporter or a non-exporter

$$\frac{w\kappa_m(S)}{z} = Eq'\left[V_1(S') - V_0(S')\right] = \frac{w\kappa^*(S)}{z}.$$

With iid entry shocks the gain in export value is independent of the current export status

[17] We focus on a model with no dispersion in exports among exporters. We have also developed a model in which new exporters start exporting a small amount and expand exports gradually over time. This richer model generates nearly identical aggregate response to the shocks considered and so we focus on this more parsimonious model.

and therefore the threshold for starting and continuing to export is identical ($\kappa_0 = \kappa_1 = \kappa^*$). Integrating over the distribution of entry costs, we can define the expected values of starting as a non-exporter and an exporter as

$$\begin{aligned} EV_0(S) &= -\frac{w}{z}\int_0^{\kappa^*(S)} \kappa dF_0(\kappa) + q' \left[F_0(\kappa^*) EV_1(S') + (1 - F_0(\kappa^*)) EV_0(S')\right], \\ EV_1(S) &= \pi - \frac{w}{z}\int_0^{\kappa^*(S)} \kappa dF_1(\kappa) + q' \left[F_1(\kappa^*) EV_1(S') + (1 - F_1(\kappa^*)) EV_0(S')\right]. \end{aligned}$$

Defining the difference in the expected value of exporting as

$$\Delta V(S) = EV_1(S) - EV_0(S),$$

yields a straightforward relationship between the current gain in the value of exporting and profits, export costs, and the future gain from exporting,

$$\Delta V(S) = \pi - \frac{w}{z}\int_0^{\kappa^*(S)} \kappa \left(dF_1(\kappa) - dF_0(\kappa)\right) + q' \left(F_1(\kappa^*) - F_0(\kappa^*)\right) E\Delta V(S')$$

Focusing on the steady state $\left(q = \frac{1}{1+r}\right)$ we get an intuitive expression for the marginal exporter

$$\frac{w\kappa^*}{z} = \frac{\pi + \int_0^{\kappa^*} \left(F_1(\kappa) - F_0(\kappa)\right) d\kappa}{1+r}.$$

The marginal entry cost is equal to the discounted expected profits from exporting plus the savings in future costs of exporting. When $F_1(\kappa) = F_0(\kappa)$ there is no dynamic element to exporting.

The pricing decision is straightforward. The firm faces a downward sloping demand curve $\overline{EX}_t p_x^{-\theta}$ and cost of labor of w. The final producer solves the following problem:

$$\begin{aligned} \pi &= \max_{p_x} p_x EX(p_x) - w l_x \\ EX(p_x) &= (z l_x)^\alpha = \overline{EX}_t p_x^{-\theta} \end{aligned}$$

The optimal price is a markup over marginal cost

$$p = \frac{\theta}{\theta - 1} mc = \frac{\theta}{\theta - 1} \frac{w}{\alpha z} y^{\frac{1}{\alpha} - 1}$$

D. External Demand

To close the model, we assume that if N exporters each cahrge p_x that aggregate export revenue equals

$$(3) \quad EXR = N^{\frac{\gamma - 1}{\theta - 1}} p_x^{1-\gamma} Y_t,$$

where θ denotes the elasticity of substitution between varieties and γ the elasticity of substitution between exports and domestic goods in the ROW. In the appendix we show this equation can be derived from the optimization problem of a representative agent in the ROW. This implies that as the number of exporters expands they cannibalize some of the exports of existing exportings. By varying γ and θ we can change the relationship between the export price, exporters, and aggregate exporters. The number of exporters, or the extensive margin of exports, affects exports. For example, if $\gamma = 1.3$ and $\theta = 3$ then doubling the number of exporters increase export revenues by 15 percent holding the export price constant. If $\gamma = \theta$ then doubling exporters doubles exports.

E. Equilibrium

We first describe the steady state equilibrium. We will calibrate and solve the model numerically in the subsequent subsection. We assume consumers have GHH preferences $u(C, L) = \frac{(C - \lambda L^\eta)^{1-\sigma}}{1-\sigma}$, where σ is the risk aversion coefficient, η governs the labor supply elasticity, and λ is a scale parameter for the aggregate labor supply. GHH preferences are widely used to study the business cycles for small open economies as it eliminates the wealth effect from the labor supply.

The states of the economy are (N, B) and shocks (z, R_t^w, β). We normalize $p_m = 1$. The endogenous variables are $\{C_t, L_t\}$ the prices are $\{p_d, p_x, w, P, R\}$ and the firm decisions are $\{l_x, l, \kappa^*\}$. Collecting the equations we have

$$\begin{aligned}
u_c/P &= u_l/w \\
u_c &= \beta E\left(1+R\right)u_{c'} \\
P &= \left(p_x^{1-\gamma}+\omega\right)^{\frac{1}{1-\gamma}} \\
1/p_d &= \omega^{\frac{1}{\gamma}}\left(M/D\right)^{-\frac{1}{\gamma}} \\
p_d &= w/z \\
p_x &= \frac{\theta}{\theta-1}\frac{w}{\alpha z}\left(\left(zl_x\right)^{\alpha}\right)^{\frac{1}{\alpha}-1} \\
\left(zl_x\right)^{\alpha} &= N^{\frac{\gamma-\theta}{\theta-1}}p_x^{-\gamma}Y_t \\
L &= \frac{D}{z}+Nl_x+N\frac{\int_0^{\kappa^*}kdF_1\left(\kappa\right)}{z}+\left(1-N\right)\frac{\int_0^{\kappa^*}kdF_0\left(\kappa\right)}{z} \\
\Pi &= N\pi-N\frac{w}{z}\int_0^{\kappa^*}dF_1\left(\kappa\right)+\left(1-N\right)w\int_0^{\kappa^*}dF_0\left(\kappa\right) \\
\pi &= \frac{1}{\theta-1}\frac{w}{\alpha z}\left(\left(zl_x\right)^{\alpha}\right)^{\frac{1}{\alpha}-1} \\
N' &= NF_1\left(\kappa^*\right)+\left(1-N\right)F_0\left(\kappa^*\right) \\
R &= R_t^w+e^{\psi\left(B'-\bar{B}\right)} \\
\Delta V &= \pi-\frac{w}{z}\int_0^{\kappa^*}\kappa\left(dF_{1,t}\left(\kappa\right)-dF_{0,t}\left(\kappa\right)\right)+Eq\left(F_1\left(\kappa^*\right)-F_0\left(\kappa^*\right)\right)\Delta V' \\
\frac{w\kappa^*}{z} &= q\Delta V' \\
M+(1+R)B' &= EXR+B
\end{aligned}$$

Given the curvature in the production of exported goods, it is useful to define the real exchange rate as the relative price of domestic consumed to imported goods or

$$RER = G_x/G_m.$$

We also define real output as

$$Y = D+\frac{\theta}{\theta-1}\frac{\overline{p_x}}{\overline{p_d}}EX,$$

where the term $\frac{\theta}{\theta-1}$ adjusts for the lack of markup on domestic goods and bars denotes steady state prices. Finally, we measure net exports scaled by gross trade flows

$$NX = \frac{EXR - M}{EXR + M} \approx \ln \frac{EXR}{M}$$

F. Calibration

This subsection describes how we set the parameters in the model. Some parameters are based on standard values. Some parameters are chosen so that the steady state equilibrium can match certain empirical moments. Finally, some other parameters are chosen to match the observed sluggish export dynamics.

First, we set the time discount factor β, the risk aversion σ, and labor supply parameter η to the standard values. The elasticity of labor supply parameter η is taken from Mendoza (1991). The weight on labor in the utility function, λ, is chosen so labor is one third of the time endowment. The interest elasticity parameter is chosen to make the model stationary.

Entry and continuation costs are assumed to be exponentially distributed,

$$F_i(k) = \left(\frac{k}{f_i v_i}\right)^{\frac{1}{v_i - 1}} \text{ for k} \in [0, f_i v_i].$$

The mass of exporters and persistence of exporting are primarily determined by f_0 and f_1 while the dynamic response of the extensive margin is primarily determined by the dispersion of the costs. Note that as v_i converges to 1 the distribution of costs becomes degenerate at f_i. For simplicity we set $v_1 = v_0 = v$ and then choose v to get the response of the extensive margin in these devaluation episodes.

Consistent with evidence in Das, Roberts and Tybout (2007), we assume that exporting is a very persistent activity. Empirical evidence for the US is that about 10 to 12 percent of existing exporters exit per year. Evidence for Colombia and Chile shows even less exit from exporting. However, many of exiting exporters are relatively small, thus the share of trade accounted for exiting exporters is less than the amount of exit. Since we have no heterogeneity in production in the model, we target an exit rate of 1.5 percent so that $n_1 = 0.985$ and $n_0 = \frac{1-n_1}{1-N} N$. The ratio of entry to continuation cost (f_0/f_1) determines the exit rate while f_0 determines the fraction of plants that export. We set this so 25 percent of plants export.

The elasticity of substitution, γ, curvature in production, α and elasticity of substitution, θ, will determine the dynamics of the volume and variety of exports. Since part of our goal is to evaluate the contribution of this sluggishness on aggregate outcomes, we choose parameters so that the model can come close to match these export dynamics. We choose the curvature in the production function, α, so that the export price relative to the non-traded locally produced goods price (i.e. $\mathrm{P}_x/(w/z)$) moves about as much as the ratio of the producer price based real exchange rate to the consumer price based real exchange rate. We set $\theta = 3$ so that exporter's price over average costs (including fixed costs) is 12 percent. We set $\gamma = 1.3$ to come close to the average export elasticity following these devaluations. This is well within the range of typical values used in quantitative studies.

We assume the shocks each follow an AR1 process of

$$\begin{aligned} \log z_t &= \rho_z \log z_{t-1} + \varepsilon_t^z, \\ R_t^w - \overline{r} &= \rho_r \left(R_{t-1}^w - \overline{r} \right) + \varepsilon_t^r, \\ \beta_t &= \rho_\beta \beta_{t-1} + \varepsilon_t^\beta \end{aligned}$$

where $\rho_z = \rho_\beta = \rho_r = 0.95$. We then choose the sequence of shocks to (z_t, R_t^w, β_t) so that the model can match the observed typical dynamics of industrial production, the EMBI rate, and the real exchange rate in our 11 devaluation episodes. Our focus will be on matching the dynamics of these economies around devaluations and so we do not have to take a stand on the variance of the shocks.[18] Given that we also target the extensive margin elasticity this essentially involves try to fit the model to 4 aggregate series.

Given the pre-set parameters, we calibrate the remaining parameters to match the

[18] We prefer this approach since clearly the shocks in the periods that we have concentrated on are quite different from entire time series.

target statistics in the steady state as shown in Table 4.

Table 4: Parameters

A. Predetermined

β	σ	η	γ
0.99	2	1.5	1.3

B. Calibrated parameters

Parameters	Target
$\theta = 3$	markup =12%
$\overline{B}$	debt/imports=10
f_0	exporter ratio N=25%
f_1	exit rate of exporter $1 - n_1 = 1.5\%$
$v_0 = v_1$	avg. export elasticity: $\varepsilon_x = \frac{1}{16}\sum_{k=1}^{16} \varepsilon_{x,t_0+k}$
α	Ratio of ppi to cpi real exchange rate: $\frac{1}{16}\sum_{k=1}^{16} \Delta rerppi_{t_0+k}/\Delta rercpi_{t_0+k}$
ω	labor for exports $\frac{Nl_1}{Nl_1+l_0} = 15\%$
λ	total labor normalization

In particular, for the average debt level in the steady state, we can set it so that $\overline{B}/M = b$ (debt equal to b times quarterly imports). With imports of 15 percent of GDP this is equivalent to 37.5 percent of GDP.

To explore the importance of getting export dynamics right on aggregate outcomes we also consider a model with a static export decision . In this model, which we call no sunk, $f_1 = f_0$ and entry is immediate. We choose the size of fixed costs so 25 percent of producers export. Because the entry and continuation costs are the same this implies there is substantial churning in export status as only 25 percent of exporters continue each period and that 25 percent of non-exporters start exporting each period. The distribution of fixed costs is set to generate the same average elasticity of exports to the real exchange rate given the shocks we have backed out of the sunk cost model.

G. Disciplining the export elasticity

As we discussed the dynamics of the export elasticity are primarily determined by three parameters, (α, γ, θ). It is straightforward to derive the relationship between these parameters and the elasticity of exports to the real exchange rate from the pricing and external demand equations taking movements in the wages and productivity as given. To begin with, the change in exports per firm depends on the change in exporters and the relative prices

$$\begin{aligned} \Delta EX &= \frac{\gamma - \theta}{\theta - 1}\Delta N - \gamma \Delta P_x \\ \Delta P_x &= \Delta w - \Delta z + \left(\frac{1}{\alpha} - 1\right)\Delta EX \end{aligned}$$

where the change in the export price just depends on the change in marginal cost, which depends in part on the change in exports because of the curvature in production. Substituting out the change in exports yields a formula for the change in the producer's price

$$\Delta P_x = \frac{\Delta w - \Delta z + \left(\frac{1}{\alpha} - 1\right)\frac{\gamma - \theta}{\theta - 1}\Delta N}{1 + \left(\frac{1}{\alpha} - 1\right)\gamma} \approx \frac{\Delta rer + \left(\frac{1}{\alpha} - 1\right)\frac{\gamma - \theta}{\theta - 1}\Delta N}{1 + \left(\frac{1}{\alpha} - 1\right)\gamma}$$

Note changes in relative wages are quite large compared to productivity and closely related to movements in the rer so that $\Delta w - \Delta z \approx \Delta rer$. Obviously the first term just tells us that price of exports will move proportionally to the rer in the short-run ($\Delta N = 0$) where the amount of the movement is increasing in α and decreasing in γ. This is intuitive since a higher α means less curvature in production while a higher γ means a bigger export response. This effect gets unwound a bit as more producers enter and they take market share from the original exporters. Using this approximation and then solving for aggregate nominal exports yields the export elasticity.

$$\frac{\Delta EXR}{\Delta rer} = \left[\frac{\gamma - 1}{\theta - 1} + \frac{(\gamma - 1)\left(\frac{1}{\alpha} - 1\right)\frac{\gamma - \theta}{\theta - 1}}{1 + \left(\frac{1}{\alpha} - 1\right)\gamma}\right]\frac{\Delta N}{\Delta rer} - \frac{\gamma - 1}{1 + \left(\frac{1}{\alpha} - 1\right)\gamma}$$

The final term determines the short-run elasticity. It is decreasing in γ and increasing in α. Over time the elasticity rises as the extensive margin grows gradually, which shows up as the first term increases.

When $\alpha = 1$ these terms reduce to

$$\begin{aligned} \Delta P_x &= \frac{\Delta rer + \left(\frac{1}{\alpha} - 1\right)\frac{\gamma-\theta}{\theta-1}\Delta N}{1 + \left(\frac{1}{\alpha} - 1\right)\gamma} \approx \Delta rer \\ \frac{\Delta EXR}{\Delta rer} &= \frac{\gamma - 1}{\theta - 1}\frac{\Delta N}{\Delta rer} - (\gamma - 1) \end{aligned}$$

which tells us that γ pins down the short-run elasticity while θ and the $\frac{\Delta N}{\Delta rer}$ determines the long-run elasticity. Now recall that we can choose the distribution of entry/continuation costs to get $\frac{\Delta N}{\Delta rer}$ which then means that given a $\gamma > 1$ we can find always find a θ to generate an aggregate response like the data. Given that the short-run response γ is close to 1.15 while in the long-run $\frac{\Delta EXR}{\Delta rer}$ =0.6 while $\frac{\Delta N}{\Delta rer} \approx 1.5$ we can solve for the elasticity as

$$\theta = 1 + \frac{(\gamma - 1)\frac{\Delta N}{\Delta rer}}{\frac{\Delta EXR}{\Delta rer} - (\gamma - 1)} = 1 + \frac{0.15 * 1.5}{0.45} \approx 1.5,$$

:thus the model requires domestic varieties to be very poor substitutes and hence exported varieties must be poor substitutes to get the long-run elasticity given the changes in the extensive margin. When $\alpha < 1$ the model has some more flexibility to match the short- and long-run export elasticity.

4. Results

We summarize the properties of our model in Figure 7 and 8. The data on trade flows is based on bilateral flows with the US so that we can more precisely control for changes in external demand unrelated to movements in relative prices. Figure 7 plots the properties of our model, the data, and a model with no dynamic export decision (identified as no sunk cost) for a set of shocks that closely match the dynamics of output,[19] interest rates, and the real exchange rate in our benchmark model. The top three panels plot our target series. Overall, the fit of the benchmark model is quite good. The largest gap between the model and the data is in the real exchange rate over the first 5 quarters. In the data the real exchange rate overshoots its longer run level by about 10 percentage points while the sunk cost model generates only a modest overshooting. The fourth panel depicts the elasticity of the extensive

[19] We remove a log-linear trend from real output.

margin. We have chosen this to match the average extensive margin elasticity from the data.

The top panel of Figure 8 depicts the productivity, interest rate, and discount factor shocks required for the model to fit output, interest rates, and the real exchange rate. Along with a rise in interest rates, these episodes require a steady increase in productivity and patience of about 10 percentage points over the first six quarters and then very gradually mean revert from then on. The increase in productivity may be surprising given the decline in output and the well-known decline in measured labor productivity around devaluations (see Meza and Quintin, 2007, and Kehoe and Ruhl, 2008). However, in our model, measured labor productivity does not correspond to the shock we put through the model since the resources that are being used to build up the stock of exporters do not increase current output. Measured labor productivity (Y/L) increases substantially less on impact and is on average only 20 percent of the shock over the first year. Over time labor productivity rises slowly but remains far below the TFP shock even four years on. The large gap between TFP and labor productivity arises because substantial resources are directed towards the intangible investment involved in preparing products for the export market. The mismeasurement of labor productivity owing to the resources devoted to building export capacity is potentially as important as other channels which we have abstracted from such as variable capital utilization (Meza & Quintin), costly sector labor reallocation (Kehoe & Ruhl) or mismeasured input prices (Sandleris and Wright, 2010, and Gopinath and Neiman, 2011). The discount factor increases so that the consumers discount the future less.This shock is often interpreted as shocks to the financial sector (Eggertson and Woodford, 2003). While the interest rate shock returns close to normal by the end of our window, the productivity and discount factor shocks remain far from their initial levels 11 quarters on. This is necessary to generate the medium-term increase in output and exports along with the persistent depreciation of the real exchange rate.

Returning to the properties of the model, the fifth panel depicts the export elasticity, measured as the ratio of the change in exports to the change in the real exchange rate. Over the window we focus on, the average response in the model is quite close to the data (0.35 vs 0.37). Because of the dynamics of the extensive margin the model generates some, but not all, of the gradual expansion of the export elasticity. In the model the export elasticity rises from 13 percent to 48 percent, while in the data the increase is from about 10 percent to 60 percent.

The final panel depicts a measure of the movements in net exports relative to the real exchange rate that controls for changes in expenditure growth across countries. Specifically, we measure

$$\varepsilon_t^{nx} = \frac{\Delta \ln \left(EXR_t / M_t \right) - \Delta \left(D_t^* / D_t \right)}{\Delta rer_t},$$

where D^* is a measure of final expenditures in the ROW and D_t is expenditures at home.[20] Removing the difference in expenditure growth across countries allows us to concentrate on how relative prices induce substitution between domestic and foreign goods. In the data, net exports also expand gradually relative to the real exchange rate with our net export elasticity rising from about 50 percent to 150 percent over 12 quarters. The model with the dynamic export decision can capture some, but not all, of this sluggishness. In a standard one good SOE model the elasticity of net exports is by definition infinite.

To evaluate the role of sluggish export dynamics on the aggregate economy we next consider the aggregate response to the same shocks when there sluggishness by turning to the model with no sunk cost. To undertake this analysis, we set the dispersion in the fixed export costs in this no sunk model to generate the same average export elasticity as in our benchmark model. Because there is no sunk cost and entry is within the same period, there is a sharp increase in exporters in the first period and the average response is a bit smaller. The exporter, export, and net export elasticity increase on impact and have no additional dynamics. Compared to the sunk cost model, exports expand more initially and less later on while net exports expand less initially and more in the long-run. Because the sunk cost model comes closer to matching export and net export dynamics it is clear that it must do a significantly better at explaining the dynamics of imports. As a result of these different export dynamics, output falls much less initially and does not rebound in the long run. Output falls less on impact in the no sunk cost model because it is easier to expand exporting. Indeed in the sunk cost model substantial resources are used up to generate the subsequent expansion

[20]In the data we proxy D with a measure of industrial production.

of exports. In the long-run, output is substantially higher in the sunk cost model since trade is higher and fewer resources are necessary to sustain exports (i.e. keep existing exporters exporting). The real exchange rate depreciates by slightly more than in our benchmark model.

To provide a better sense of how the sluggish export dynamics affects the aggregates we plot impulse response to each of the shocks in the sunk and no-sunk cost models in figure 9. The columns presents the response to productivity, interest rate and discount factor shocks respectively. In short, we find that sluggish exports are quite important with interest rate shocks and much less so for productivity and discount factor shocks. In response to a persistent positive productivity shocks, the sunk cost model generates a smaller initial increase in output and a larger increase after three quarters. The real exchange rate depreciates slightly less initially and slightly more in the long-run in the sunk cost model. These differences are fairly minor and reminiscent of the findings in Alessandria and Choi (2007) that aggregate fluctuations from productivity shocks are largely unaffected by the presence of sunk costs. Net export dynamics are a bit different as the net export response is considerably stronger with no sunk cost as the barriers to expanding exports are quite different. In response to the interest rate shock, we find very different export and aggregate dynamics across the two models. Recall that with an interest rate shock, the economy would like to save (or repay its debts) and so net exports will increase. The source of this increase is quite different across the models. With the sunk cost, the number of exporters actually falls while with the no cost model exporters jump into the market and so exports expands substantially more. The different exporter response across the models arise because the high interest rates make it costly to invest in becoming an exporter. The different export dynamics ultimately lead to a stronger contractionary effect of interest rates with the sunk cost model and a larger depreciation. It is useful to note that interest rate shocks are quite contractionary in this framework as a 1 percentage point increase in the interest rate drops output almost 2 to 2.5 percentage points. In response to shocks to the discount factor shock so that agents become more patient we see that the country would like to shift consumption to the future and thus net exports increase. Output falls as the country cuts back on consumption and the real exchange rate depreciates. Exports and exporters expand more in the long-run with the sunk costs as exporters value future profits by more while output and real exchange rate movements are quite simlar with and without sluggish exports.

The impulse responses show that the effect of interest rates matter quite a bit for export dynamics. To explore this in greater detail we consider we feed the high and low interest paths from the data through our model. Figure 10 plots the interest rate, real exchange rate, export elastictiy and extensive margin elasticity paths for these two alternative models. We see that the higher interest rate path implies a larger real exchange rate depreciation but a lower export and extensive margin elasticity. Quantitatively, in the long-run we find that the export elasticity is about 80 percent as large for the high interest rate economy. If we focus on the growth in the extensive margin, (ie. removing the intensive margin effect which is the same) we see that exports growth about 1/3 more in the low interest rate economy. Thus, the model is clearly capable of delivering some of the observed differences in the export response across our different country groupings.

5. Sensitivity

Here we examine the sensitivity of our findings to our parameter choices and modelling assumptions. First, we explore the relationship between relative prices, the elasticity of substitution, and the Armington elasticity. Next, we consider the implications of alternative, less structural sources of export sluggishness. We find that making external demand sluggish does not approximate our benchmark model very well while making entry costs quite elastic provides a closer approximation. Finally, we explore the effect on aggregates of some alternate ways of making net exports more sluggish. In general we find making the elasticity of net exports more sluggish tends to generate slightly larger drops in output than in our benchmark parameterization..

A key focus of our paper has been on the connection between relative price fluctuations, exports, and aggregate fluctuations. In the model relative price movements are primarily determined by the Armington elasticity and the elasticity of substitution. Figure 11 shows how our choice of the Armington elasticity (γ) and elasticity of substitution (θ) affects the response to our three shocks. We first consider the effect of the elasticity of substitution by boosting it from $\theta = 3$ to $\theta = 35$. This corresponds to lowering the markup from 50 percent to about 3 percent. For the most part this has a very small impact on the dynamics of the economy. In the second case, we increase the Armington elasticity from $\gamma = 1.3$ to $\gamma = 25$, thus making imports and exports quite substitutable. This brings the model closer to the typical one good model explored by Mendoza (1991), Aguiar and Gopinath (2007,) and others. Because goods are quite substitutable relative prices fluctuate little and net exports respond more so that the net export elasticity will be counterfactually high. Specifically, in response to the productivity shock, output and net exports increase by more. In response to an interest rate shock we see that output now goes up whereas previously it fell. The gap is quite substantial as a 100 basis point increase in the interest rate in the high Armington elasticity case increases output by 0.25 percent while it reduces output by close to 3 percent. There are similar differences in the output response to an increase in patience. The contractionary effect of interest rate and discount factor shocks when goods are imperfect substitutes is related to the depreciations induced by the desire to run trade surpluses. The reduction in the price of domestic goods increase the cost of consumption (which is a combination of domestic and imported goods) relative to the return to labor reducing the incentive to consume and work.

We next consider two alternative, more ad-hoc sources of export sluggishness in the model without the sunk cost structure. First, we allow foreign demand to be sluggish by introduce habit. Specifically, we assume individual demand is scaled by a factor of $e^{\xi_x \Delta x}$ where Δx is the log change in real aggregate exports. With $\xi_x < 0$ to increase aggregate exports initially requires a larger drop in the export price. Second, we allow the cost of entering the export market to increase sharply with the change in entry or $f_t = fe^{\xi_N \Delta N}$ where ΔN is the log change in the number of exporters. We calibrate these models to match the average export elasticity, using the dispersion in export costs, as well as come close to the dynamics of the export elasticity in the sunk cost model, using the ξ_x or ξ_N, for the same shocks we used before. Figure 12 plots the usual figures. Making exports sluggish through the demand channel has a small impact on the dynamics of entry while making costs elastic has a very strong impact on entry and ultimately export dynamics. Export habit tends to lower output initially but increase it more in the long-run compared to the plain-vanilla no sunk cost model as exports are lower initially and stronger later on. There remain sizeable differences in output between our benchmark model and the export habit model. The model with elastic export costs generates fluctuations quite similar to the sunk cost model. Exports respond a little more initially and a little less in the long-run while output falls by less initially and rebounds by less. There are two main drawbacks to this approach. First, since export remain a static decision, interest rates will have no effect on the export elasticity. Second, to generate these export dynamics requires costs to be quite sensitive to changes in the number of exporters. The elasticity of export costs is about 77 percent. While we don't have any estimates of the dynamics of export costs, this seems enormous.

We next consider how sluggish net exports affects output and real exchange rates. Specifically, we consider three ways of getting more sluggish net exports. First, we introduce habit for imports in the consumption aggregator

$$\begin{aligned} G\left(M, M_{-1}, D\right) &= \left(D^{\frac{\gamma-1}{\gamma}} + \omega\left(M, M_{-1}\right)^{\frac{1}{\gamma}} M^{\frac{\gamma-1}{\gamma}}\right)^{\frac{\gamma}{\gamma-1}}, \\ \omega\left(M, M_{-1}\right) &= e^{\varepsilon_m \Delta M}. \end{aligned}$$

Our measure of habit allows the weight on imports, $\omega\left(M, M_{-1}\right)$, to depend on the change in imports.[21] Second we introduce habit for consumption in the utility function

$$u\left(C, L\right) = \frac{\left(C - h_c C_{-1} - \lambda L^{\eta}\right)^{1-\sigma}}{1-\sigma}.$$

Both forms of habit are assumed external and will respectively make imports and consumption sluggish. Note that import habit will affect the elasticity of net exports to the real exchange rate while consumption habit will only affect the sluggishness of net exports through its effect on consumption and the real exchange rate. Since we are only interested in the qualitative impact of sluggishness of net exports, we set $\varepsilon_M = 0.15$ for the habit on imports case and $h_C = 0.1$ for the habit on consumption case. Our third approach is to reduce the producer level expansion of exports by lowering θ from 3 to 2.5. This raises markups from 50 percent to 66 percent. This increases the value of being an exporter and makes entry stronger in the medium run. The fixed cost in the model is changed to ensure that 25 percent of producer export but the dispersion in export costs is the same as our benchmark model. Figure 13

[21] A convenient feature of this way of modelling habit is that it does not change our measure of prices.

depicts these three variations of our model. With habit on imports slowing down the shift away from imports we find that production falls by more initially, the real exchange rate by less, and the elasticity of net exports grows more gradually. With consumption habit, output dynamics and real exchange rate dynamics are a bit more muted while the net export elasticity is essentially unchanged. Increasing the markup, makes the export elasticity expand more and leads to more gradual net export dynamics.

6. Conclusions

We have studied the consequence of the observed sluggish export dynamics in emerging market devaluations in a general equilibrium variant of the well-known model of exporter dynamics of Dixit (1989) and Das, Roberts, and Tybout (2007). Five main results stand out from our analysis of these aggregate fluctuations. First, the sluggishness of exports leads to deeper contractions and stronger recoveries of output as substantial resources are shifted from production to the intangible investment of foreign market access. Second, sluggish exports appear to generate about half of the sluggishness in net exports and thus influences the dynamics of debt. Introducing additional net export sluggishness from habit for imports generates larger drops in output as there is less substitution towards domestic non-tradable production initially. Third, the resources devoted to the intangible investment in accessing foreign markets leads observed labor productivity to substantially lag actual productivity initially. This gap is closed with time as investments in export capacity taper and producers shift resources towards producing goods. These productivity effects do not arise when export sluggishness is based on sluggish foreign preferences as in a model with habit. Fourth, we find that in calibrations that lead to real exchange rate movements like those in the data that interest rates are strongly countercyclical. The contractionary impact of interest rates is in contrast to most work in the literature that abstracts from relative prices and arises primarily because we explicitly allow for foreign and domestic goods to be imperfect substitutes. This reduces the incentive to substitute domestic goods for foreign goods leading to a drop in output from a rise in interest rates. This effect is even stronger in when exporting is a dynamic decision since high interest rates discouage exporters from building export capacity. Finally, as we have alluded to, the source of sluggishness in exports and net exports does matter.

Our findings about the dynamics of trade around devaluations is useful to the recent debate about monetary policy in the Euro area. Much discussion of the recent Euro crisis has centered around the loss of monetary policy independence by stagnating economies on the periphery with some arguing that the inability of periphery countries to devalue has contributed to their stagnation. The common view is that a devaluation would boost GDP by leading to substantial expenditure switching at home and abroad. Here we find that the physical barriers to trade mitigate some of the stimulatory effects of devaluations initially while boosting growth in the long-run.

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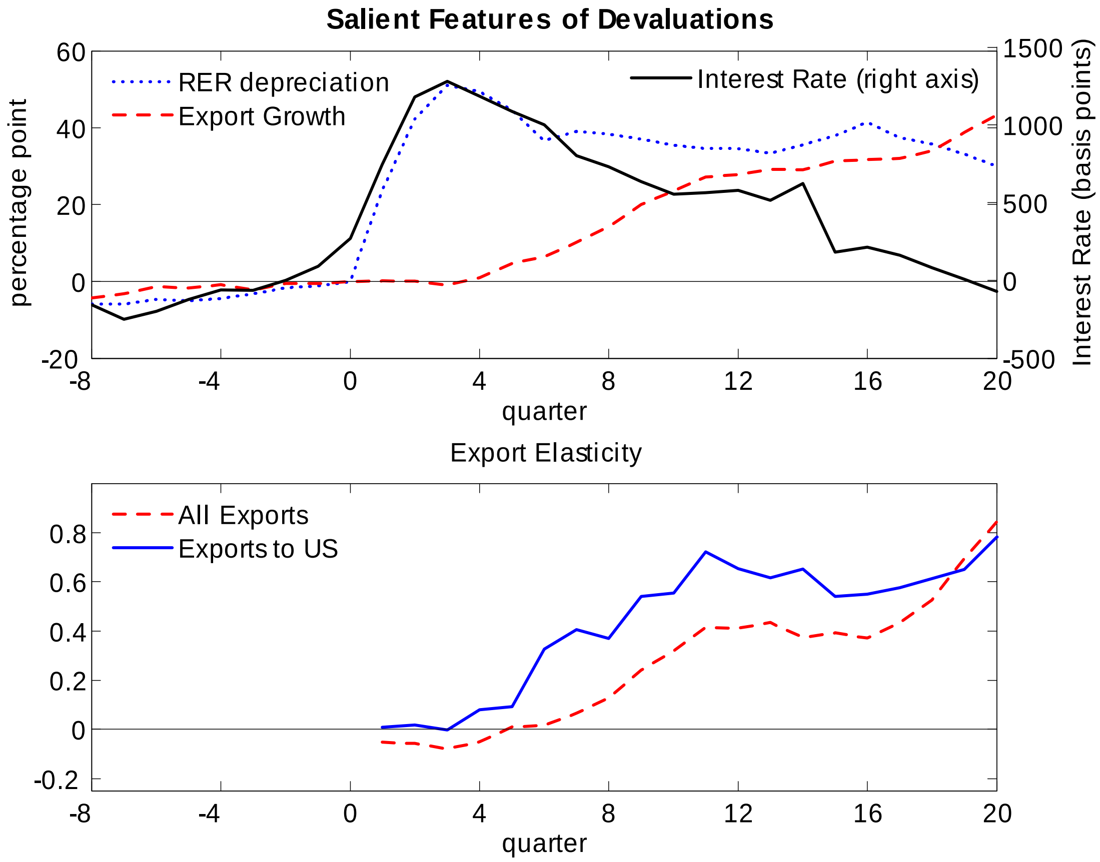


Figure 1: RER, Interest Rates, and Exports for 11 Countries

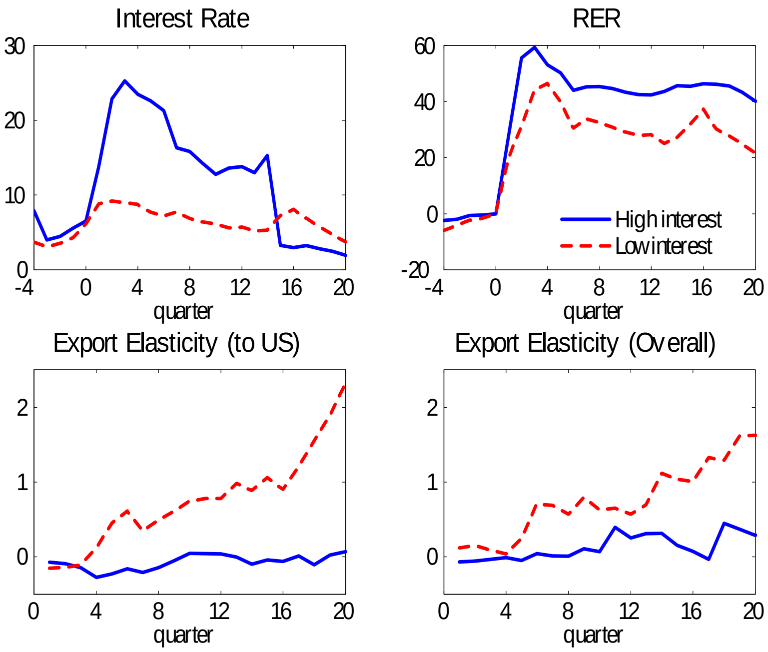


Figure 2: High Interest Rate Countries v.s. Low Interest Rate Countries

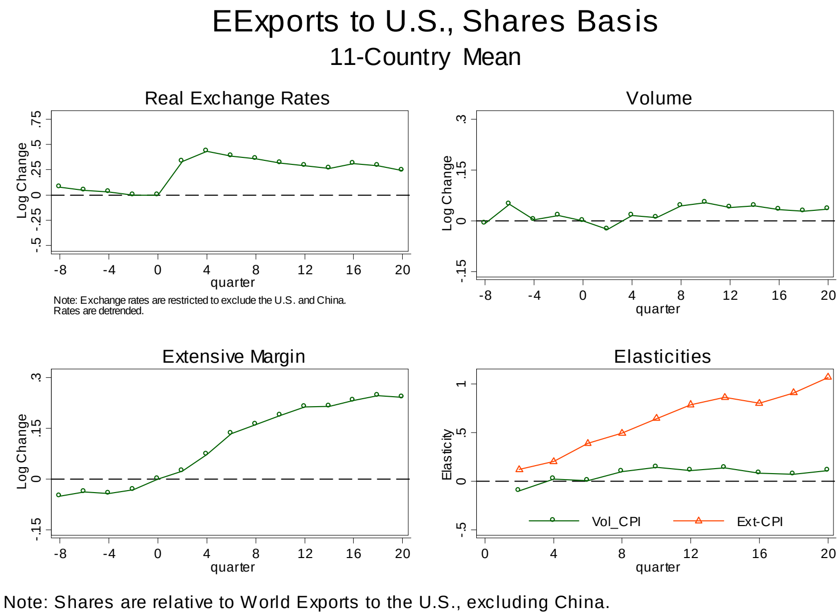


Figure 3A: Dynamics of Exports to US - Share basis

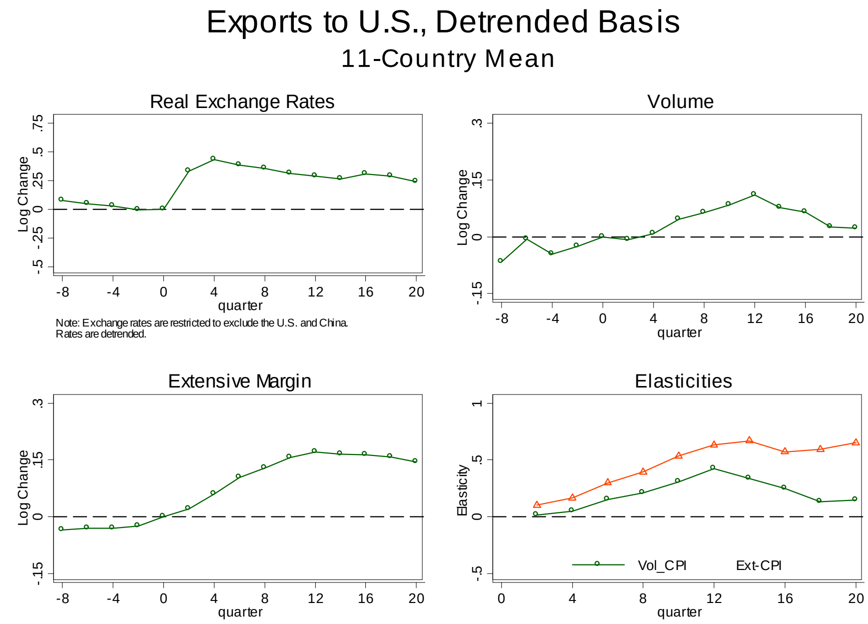


Figure 3B: Dynamics of Exports to US - Detrended

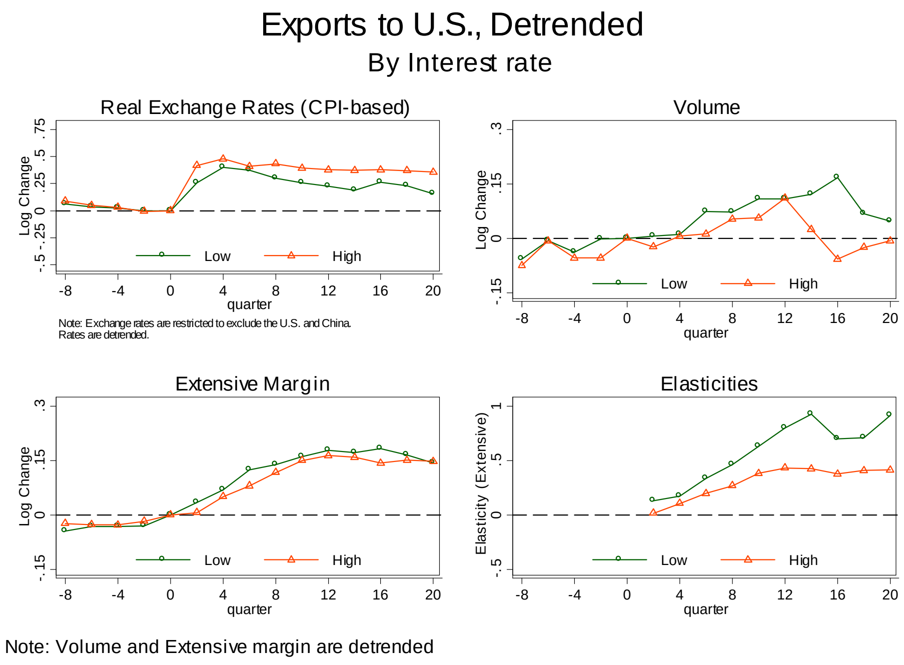


Figure 4: Exports to U.S. by Interest Rate

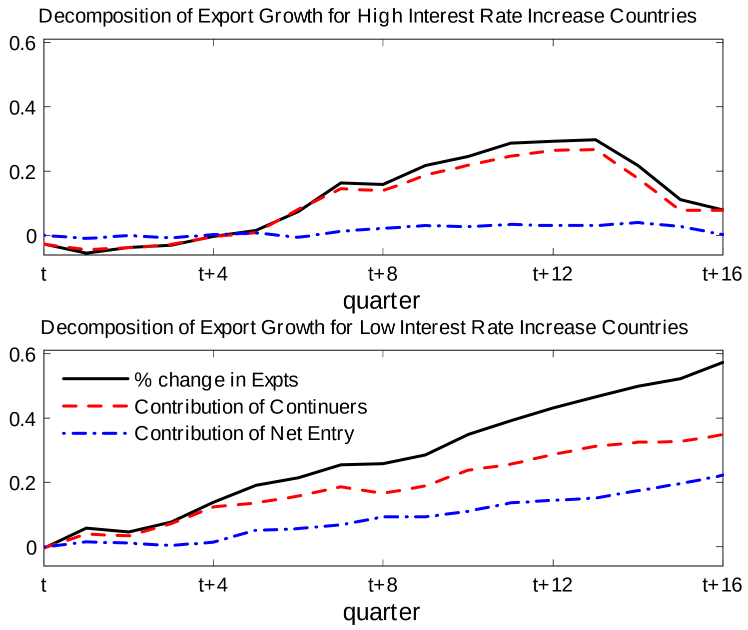


Figure 5: Decomposition of Export Growth for High and Low Interest Rate Increase Countries

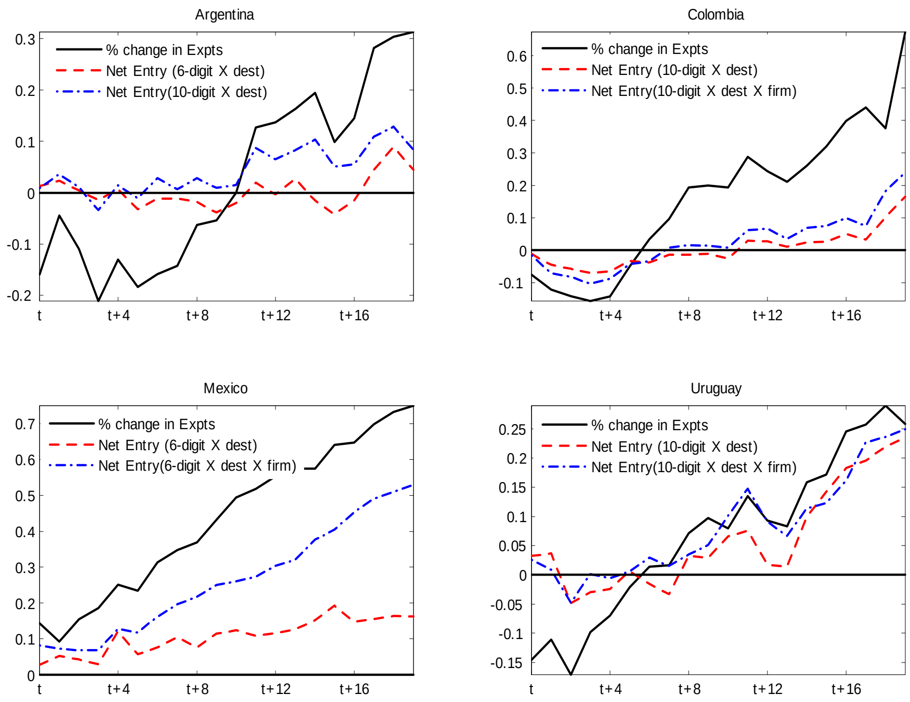


Figure 6: Decomposition of Export Growth by Extensive Margin Measures

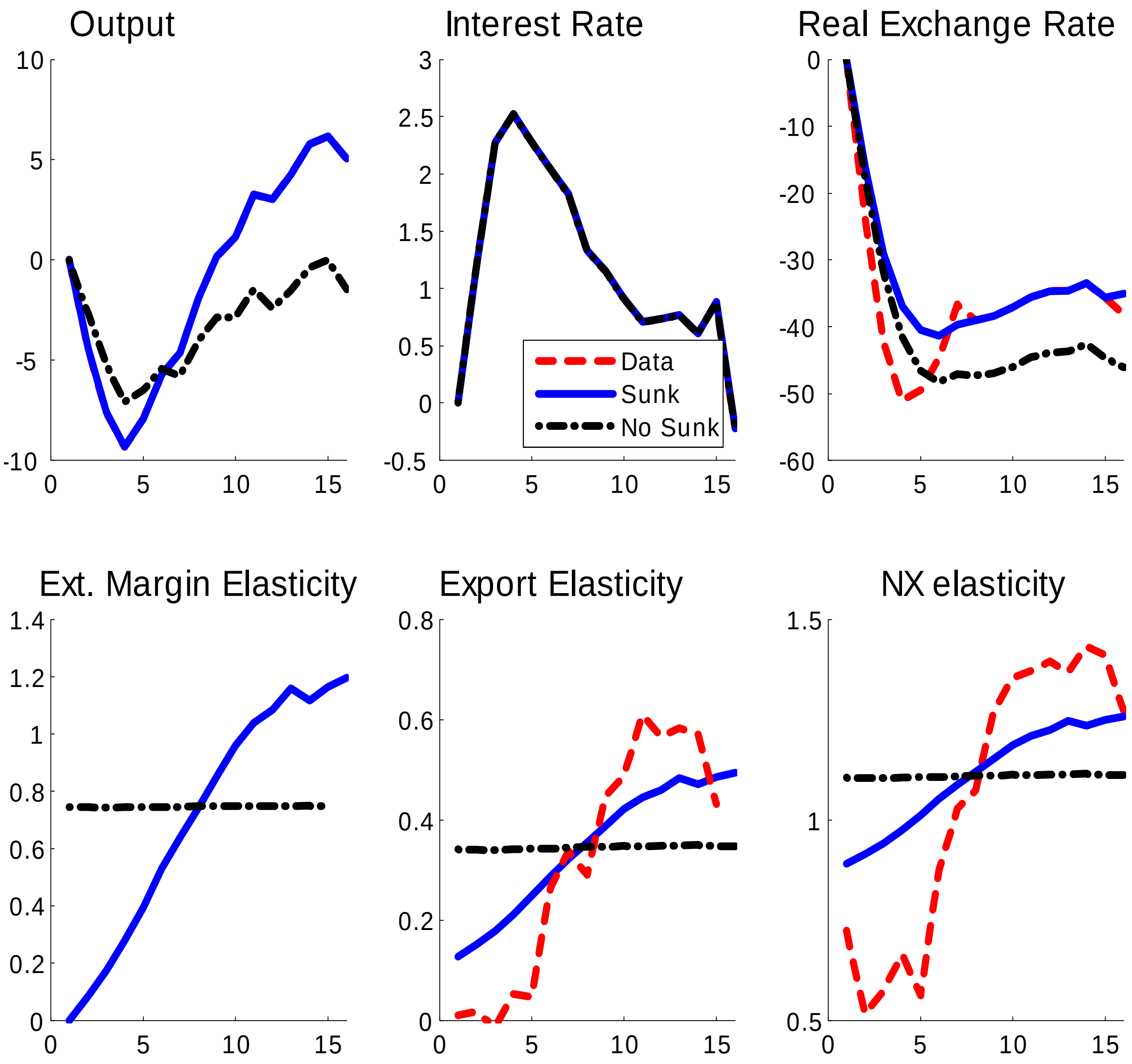


Figure 7: Aggregates in Data and Models

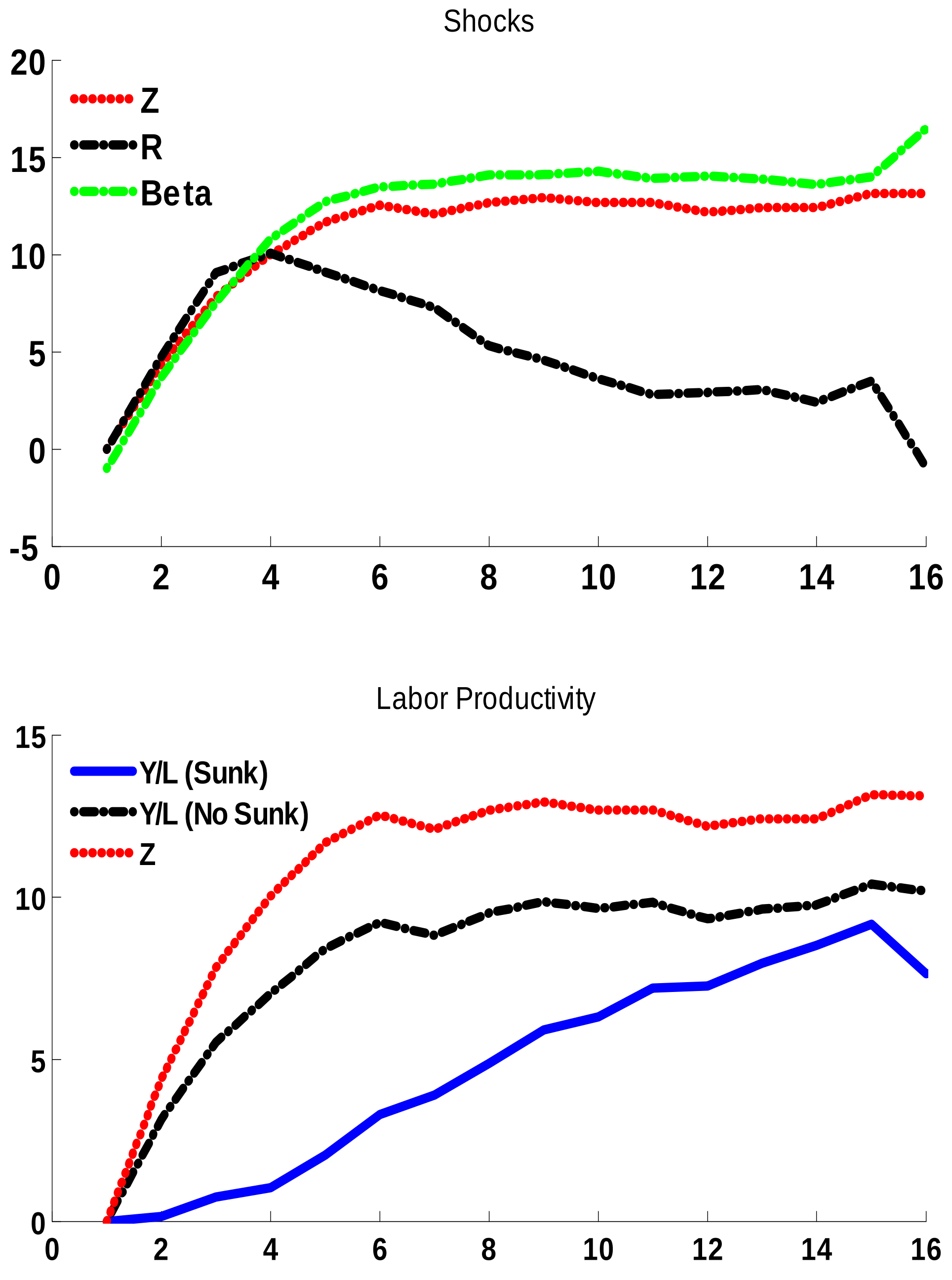


Figure 8: Productivity, Interest Rates, Discount factor, Labor Productivity

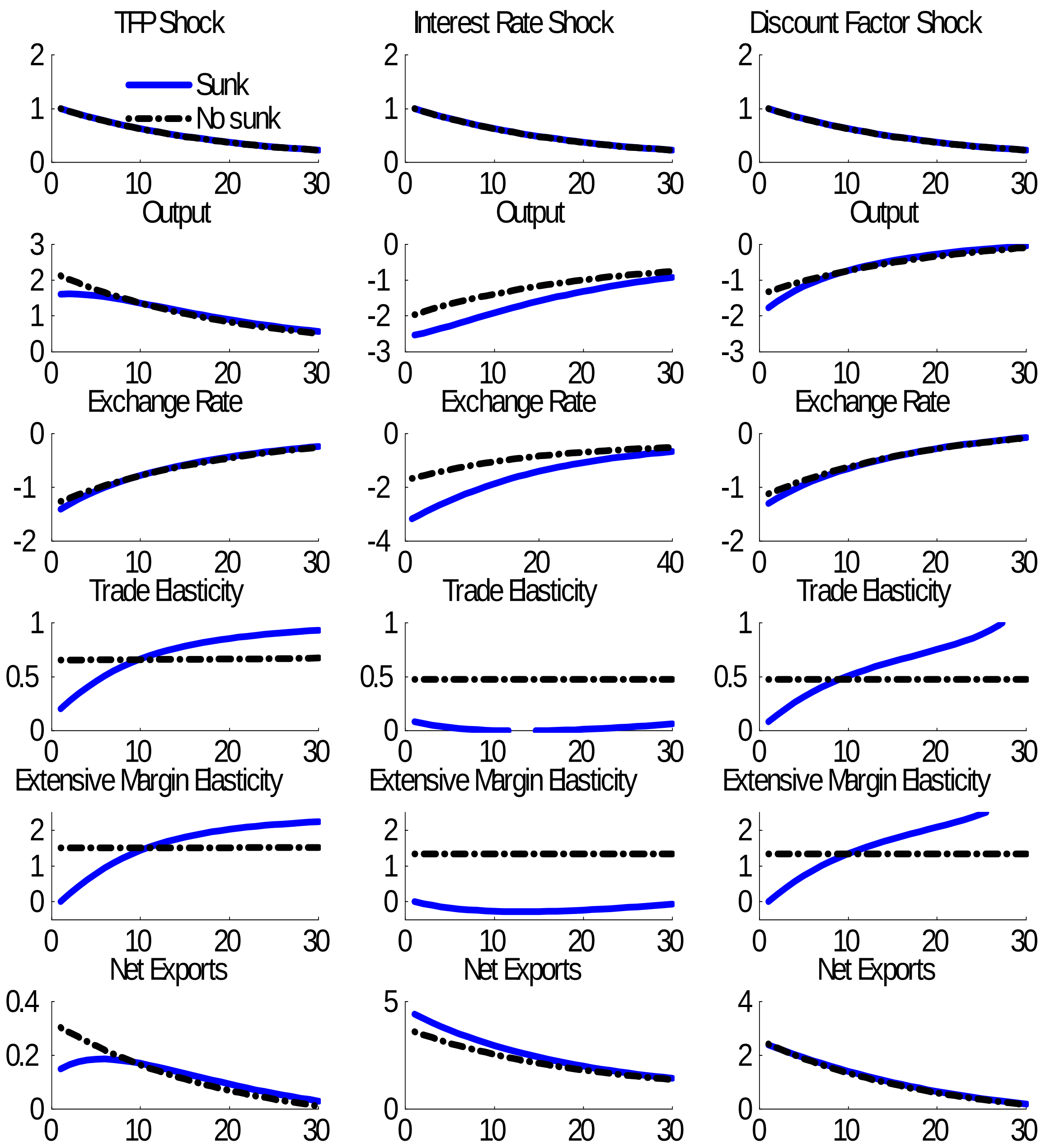


Figure 9: Impulse Response

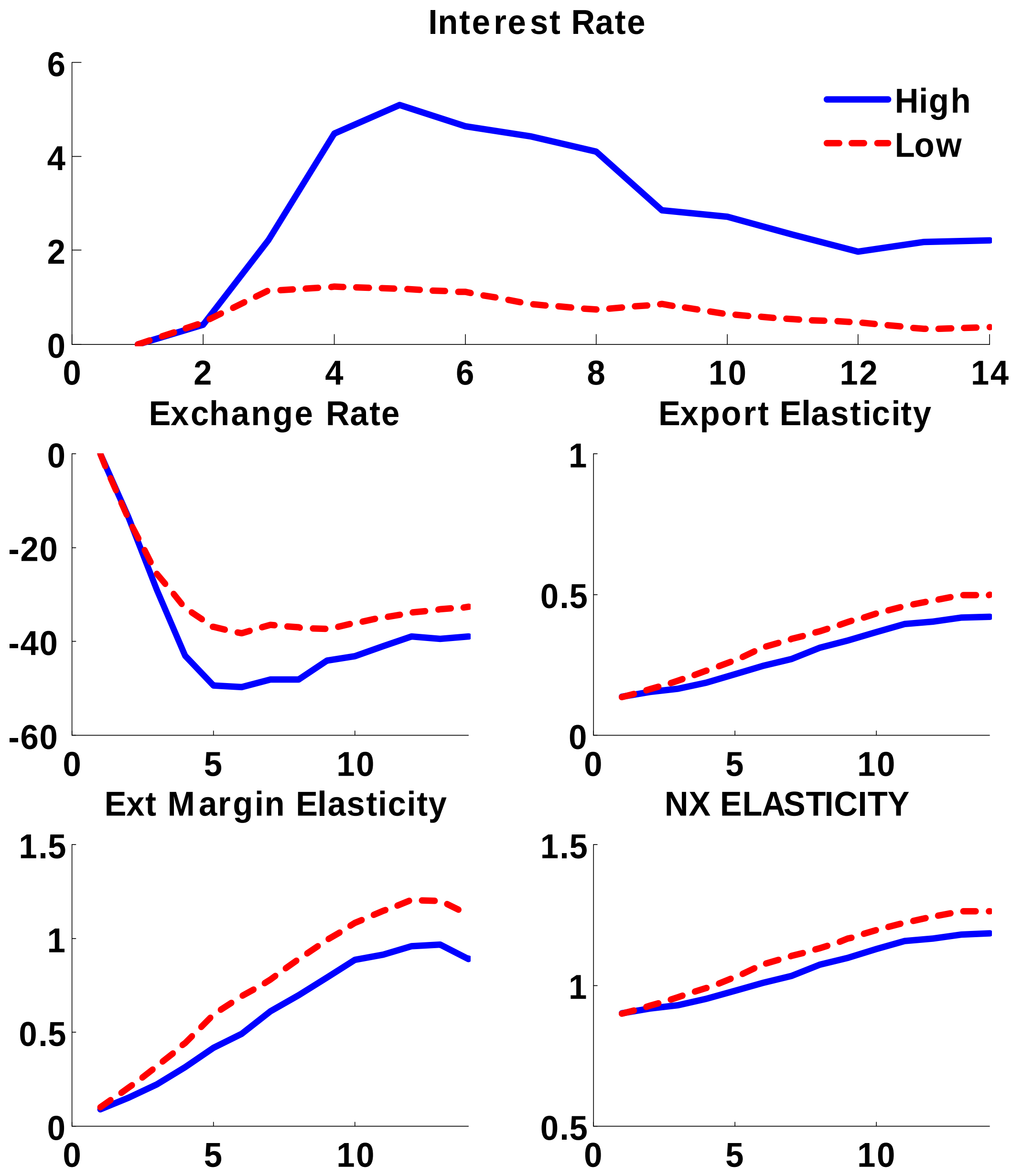


Figure 10: Response to different interest rates shocks

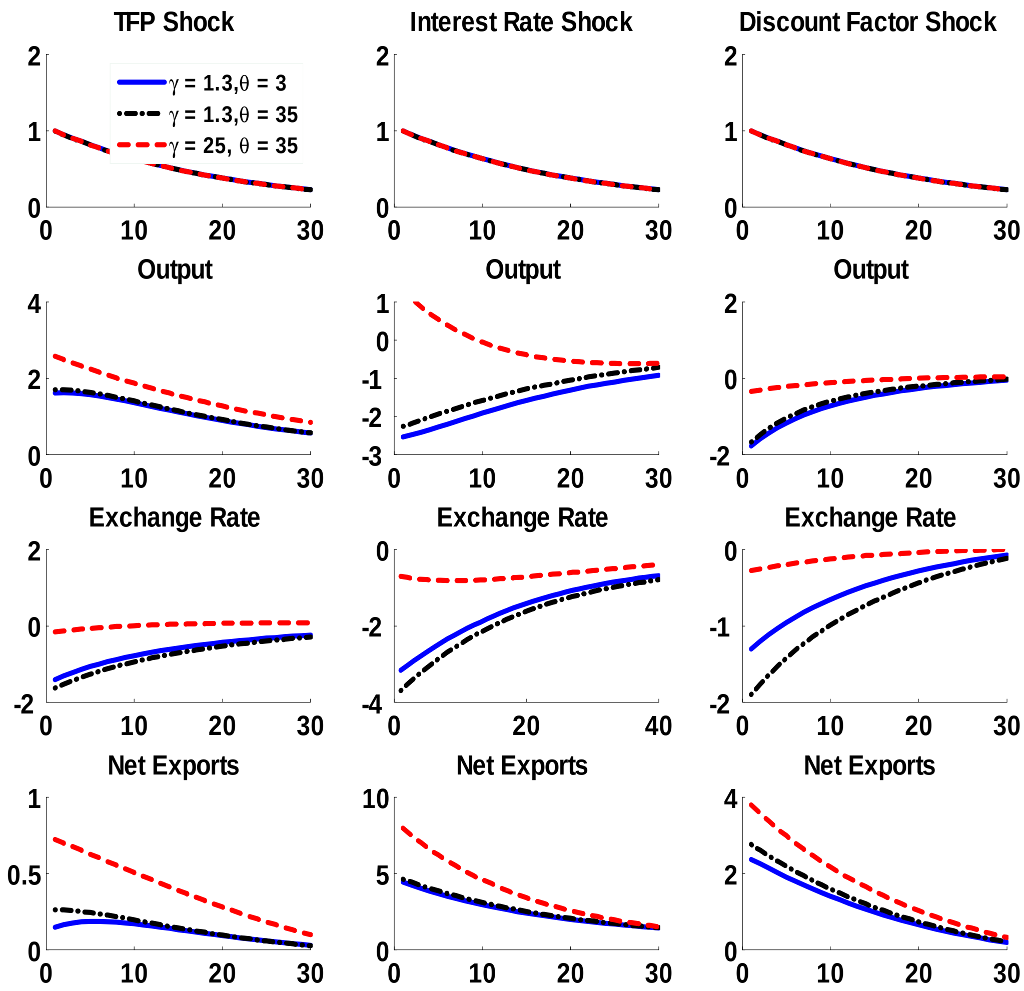


Figure 11: Sensitivity to Armington elasticity and elasticity of substitution

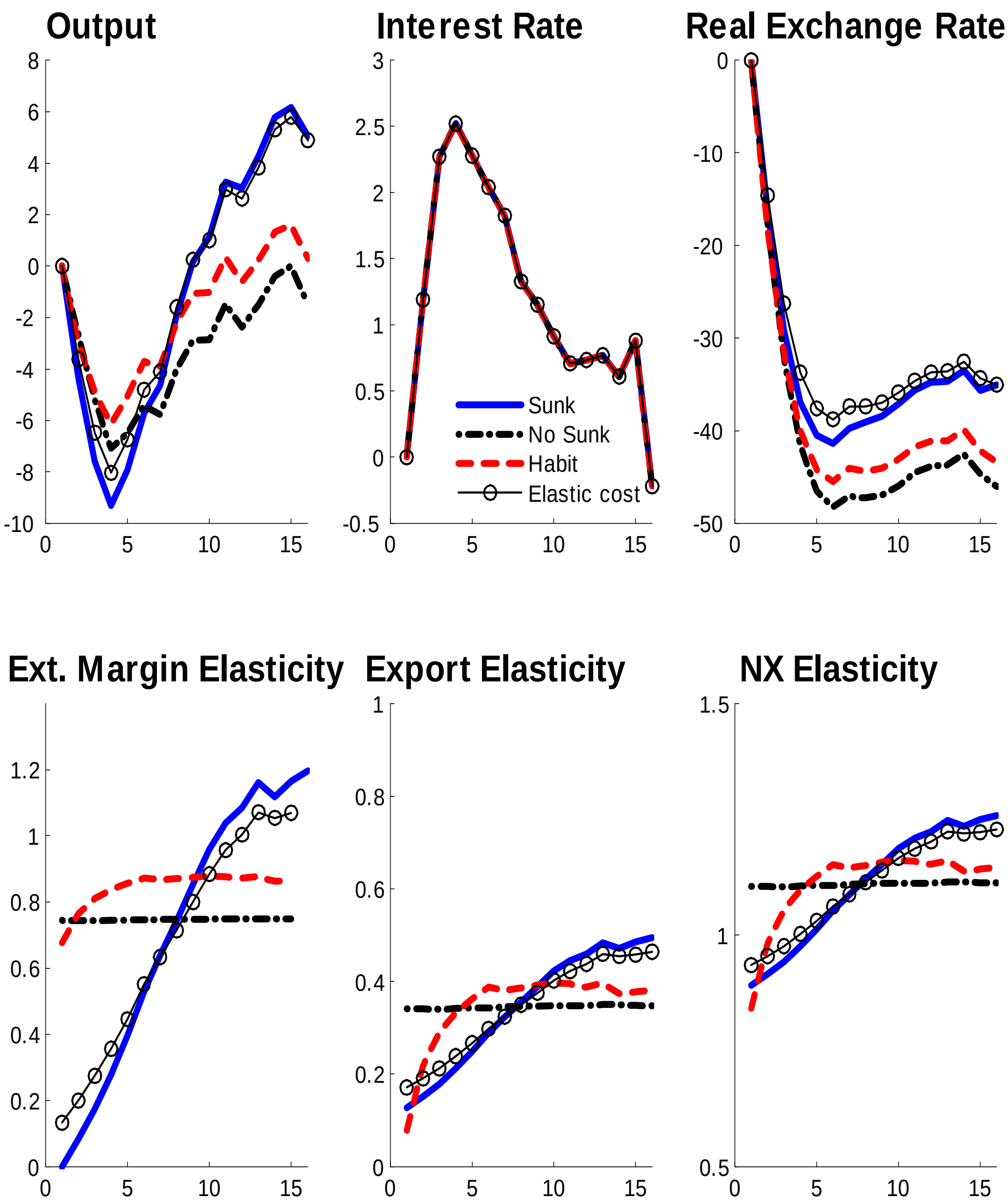


Figure 12: Making exports sluggish in no sunk cost model

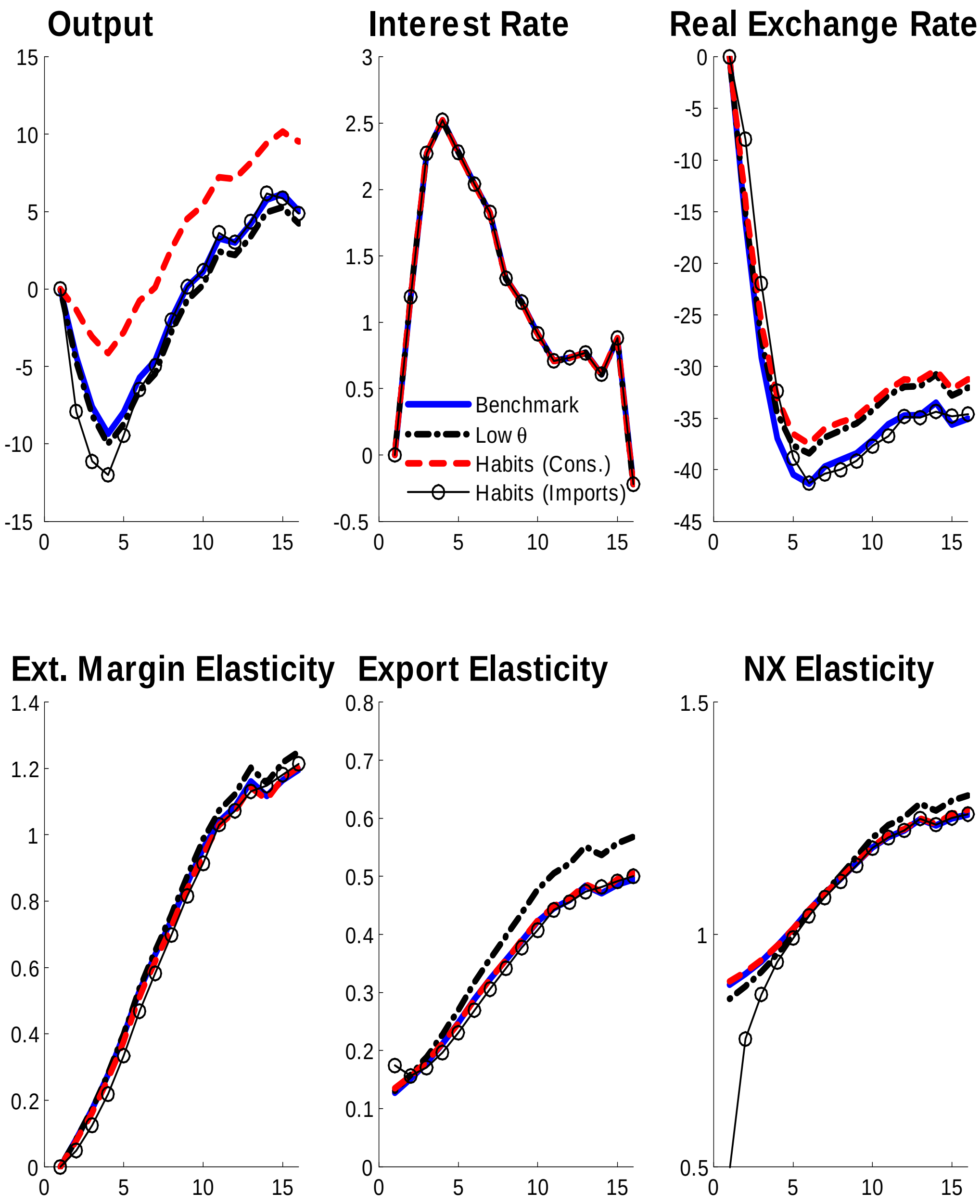


Figure 13: Sluggish Net Exports

7. Appendix 1: The Export Supply Function

This appendix describes the derivation of export demand from the ROW. In the ROW final goods are produced using only home and foreign intermediate goods (these are Argentinian goods). A final good producer can purchase from any of the home intermediate good producers but can purchase only from those foreign intermediate good producers that are actively selling in the home market. In each period there are $N(s^t)$ identical foreign intermediate producers selling in the home country

The production technology of the firm is given by a constant elasticity of substitution (henceforth CES) function

$$(4) \quad D(s^t) = \left\{ a_1 \left[\int_0^1 y_h^d(i, s^t)^{\frac{\theta-1}{\theta}} di \right]^{\frac{\theta}{\theta-1}\frac{\gamma}{\gamma-1}} + (1-a_1) \left[\int_0^{N(s^t)} y_f^d(i, s^t)^{\frac{\theta-1}{\theta}} di \right]^{\frac{\theta}{\theta-1}\frac{\gamma-1}{\gamma}} \right\}^{\frac{\gamma}{\gamma-1}},$$

where $D(s^t)$ is the output of final goods and $y_h^d(i, s^t)$ and $y_f^d(i, s^t)$ are inputs of intermediate goods purchased from home firm i and foreign firm i, respectively. The parameter a_1 determines the weight of home goods in final good consumption. We will assume that a_1 is close to 1. The elasticity of substitution between intermediate goods that are produced in the same country is θ, and the elasticity of substitution between home and foreign aggregate inputs is γ.

The final goods market is competitive. In each period t, given the final good price at home $P(s^t)$, the i_{th} home intermediate good price at home $P_h(i, s^t)$ for $i \in [0, 1]$, and the i_{th} foreign intermediate good price at home $P_f(i, s^t)$ for $i \in [0, N]$, a home final good producer chooses inputs $y_h^d(i, s^t)$ for $i \in [0, 1]$, and $y_f^d(i, s^t)$ for $i \in [0, N]$ to maximize profits,

$$(5) \quad \max P\left(s^t\right) D\left(s^t\right) - \int_0^1 P_h\left(i, s^t\right) y_h^d\left(i, s^t\right) di - \int_0^N P_f\left(i, s^t\right) y_f^d\left(i, s^t\right) di,$$

. Solving the problem in (5) gives the input demand functions,

$$(6) \quad y_h^d(i, s^t) = a_1^\gamma \left[\frac{P_h(i, s^t)}{P_h(s^t)} \right]^{-\theta} \left[\frac{P_h(s^t)}{P(s^t)} \right]^{-\gamma} D(s^t),$$

$$(7) \quad y_f^d(i, s^t) = (1-a_1)^\gamma \left[\frac{P_f(i, s^t)}{P_f(s^t)} \right]^{-\theta} \left[\frac{P_f(s^t)}{P(s^t)} \right]^{-\gamma} D(s^t), i \in [0, N]$$

where $P_h(s^t) = \left[\int_0^1 P_h(i, s^t)^{1-\theta} di \right]^{\frac{1}{1-\theta}}$, and $P_f(s^t) = \left[\int_0^N P_f(i, s^t)^{1-\theta} di \right]^{\frac{1}{1-\theta}}$. The zero-profit condition in the perfectly competitive market determines the price level of the final good as

$$(8) \quad P(s^t) = \left[a_1^\gamma P_h(s^t)^{1-\gamma} + (1-a_1)^\gamma P_f(s^t)^{1-\gamma} \right]^{\frac{1}{1-\gamma}}.$$

Now we are assuming that we have N identical exporters each charging $p_f(s^t) = p_f(i, s^t)$ and so $P_f(s^t) = N(s^t)^{\frac{1}{1-\theta}} p_f(s^t)$. Aggregating over the different exporters we get

$$\begin{aligned} EX\left(s^t\right) &= \int_0^{N\left(s^t\right)} y_f^d(i, s^t) = \int_0^{N\left(s^t\right)} (1-a_1)^\gamma \left[\frac{P_f(i, s^t)}{P_f(s^t)}\right]^{-\theta} \left[\frac{P_f(s^t)}{P(s^t)}\right]^{-\gamma} D(s^t) \\ &= N\left(s^t\right)(1-a_1)^\gamma \left[\frac{P_f(i, s^t)}{P_f(s^t)}\right]^{-\theta} \left[\frac{P_f(s^t)}{P(s^t)}\right]^{-\gamma} D(s^t) \\ &= N\left(s^t\right)(1-a_1)^\gamma \left[\frac{1}{N(s^t)^{\frac{1}{1-\theta}}}\right]^{-\theta} \left[\frac{N(s^t)^{\frac{1}{1-\theta}} p_f(s^t)}{P(s^t)}\right]^{-\gamma} D(s^t) \end{aligned}$$

Now lets take log deviations from the

$$\ln EX\left(s^t\right) \propto \ln\left[\frac{(1-a_1)(\theta-1)}{\theta}\right] + \frac{1-\gamma}{1-\theta}\ln N\left(s^t\right) - \gamma \ln\left[\frac{p_f(s^t)}{P(s^t)}\right] + \ln D(s^t)$$

Lets define the terms of trade τ

$$\tau_t = \frac{p_f(s^t)}{P(s^t)}$$

then we can rewrite log deviation of export demand as

$$\widehat{ex}_t = \left(\frac{1-\gamma}{1-\theta}\right)\ln \widehat{N}_t - \gamma \ln \widehat{\tau}_t + \ln \widehat{D}_t$$

In terms of revenue

$$\widehat{exr}_t = \left(\frac{1-\gamma}{1-\theta}\right)\ln \widehat{N}_t + (1-\gamma)\ln \widehat{\tau}_t + \ln \widehat{D}_t$$

Appendix 2: Data sources

To be completed

US Trade data:

All Haver series are seasonally adjusted with the Haver seasonal adjustment function, and all non-Haver series are seasonally adjusted using X-12-ARIMA in EViews.

PPI-Based Real Exchange Rates

- JP Morgan Broad Real Effective Exchange Rate Index (trade-weighted, 2005 = 100, Monthly Averages): Argentina (FXDARGBC), Brazil (FXDBRZBC), China (FXDCHIBC), Columbia (FXDCOLBC), India (FXDINDBC), Indonesia (FXDINBC), Korea (FXDKORBC), Malaysia (FXDMALBC), Mexico (FXDMEXBC), Russia (FXDRUSBC), Thailand (FXDTHABC), Turkey (FXDTURBC), and the United States (FXDUSBC). From @USECON database.

- Real Effective Exchange Rate (all fund members, Consumer Price Basis), IMF: Uruguay (C298EIRC), Uruguay Consumer Prices, IMF (C298PC), Uruguay Wholesale Prices, IMF (C298PW). From @IFS database

CPI-Based Real Exchange Rates

- Real Effective Exchange Rate (trade-weighted, all fund members, Consumer Price Basis, 2005 = 100), IMF: Brazil (from IMF website directly), China (C924EIRC), Columbia (C233EIRC), Korea (C542EIRC), Malaysia (C548EIRC), Mexico (from IMF website directly), Russia (C922EIRC), United States (C111EIRC), and Uruguay (C298EIRC). From @IFS database
- Real Effective Exchange Rate (trade-weighted, CPI-based, broad indices, monthly averages, 2005 = 100), Bank for International Settlements (BIS): Brazil, India, Indonesia, Thailand, and Turkey (All from the BIS website directly)

Trade Weights (Used to restrict trade-weighted real exchange rates to exclude the U.S. and China)

- JP Morgan Broad Index Trade Weights (Based on 2000 trade in manufactured goods) (Available through Haver's website): All countries except Uruguay. Since we do not have trade weights for Uruguay, we did not make the restriction calculation for it

Exports to the U.S. (Volume)

- U.S. Imports of Merchandise, U.S. Census Bureau: All countries (From U.S. Merchandise Trade CDs/DVDs)
- Among other things, this dataset breaks U.S. import values down by HS10 commodity, country of origin, and district of entry.
- U.S. Import Price Index: All Imports (NSA, 2000=100), BLS (PMEA@USECON)
- U.S. Real Manufacturing & Trade Sales: All Industries (SA, Mil.Chn.2005$), BEA (TSTH@USECON)
- Note: We convert the U.S. Imports of Merchandise into real terms using the U.S. Import Price Index and normalize them using the U.S. Real Manufacturing & Trade Sales.

Exports to the U.S. (Extensive Margin)

- U.S. Imports of Merchandise, U.S. Census Bureau: All countries (From U.S. Merchandise Trade CDs/DVDs)
- Among other things, this dataset breaks U.S. import values down by HS10 commodity, country of origin, and district of entry.

- We calculate the extensive margin as the number of distinct HS10 commodity-country-district pairs imported having strictly positive volume.

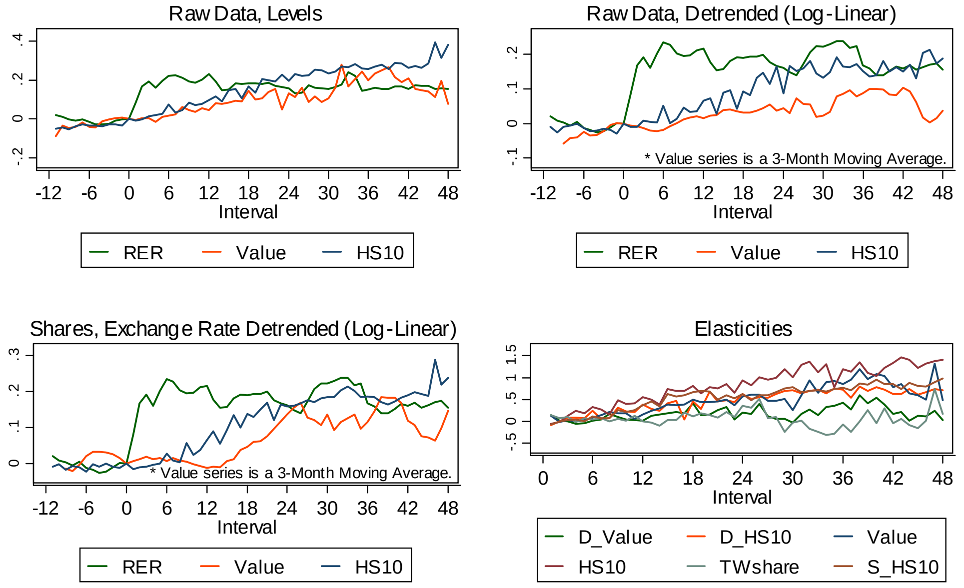
RESTRICTED REAL EXCHANGE RATES CALCULATION

- For any country x, let qx be the trade-weighted real exchange weight of country x, measured in log changes.
- For any countries x and y, let $\alpha_{x,y}$ be the trade weight, measuring the fraction of x's trade that is with y.
- For any countries/parts of the world x and y, let qx,y be the real exchange rate between x and y, measured in log changes.
- Now, let x be the country whose RER we are looking to restrict, and let ROW be the world, excluding x, the U.S., and China (C). Then we calculated the restricted real exchange rate as:

$$q_{x,ROW} = \frac{(1 - \alpha_{C,US} - \alpha_{US,C})q_x + (\alpha_{x,US} + \alpha_{x,C} - \alpha_{C,US})q_{US} + (\alpha_{x,C} + \alpha_{x,US} + a_{US,C})\, q_C}{(1 - \alpha_{x,US})\,(\alpha_{US,x} + \alpha_{S,C}) + \alpha_{C\_x} - \alpha_{x,C}}$$

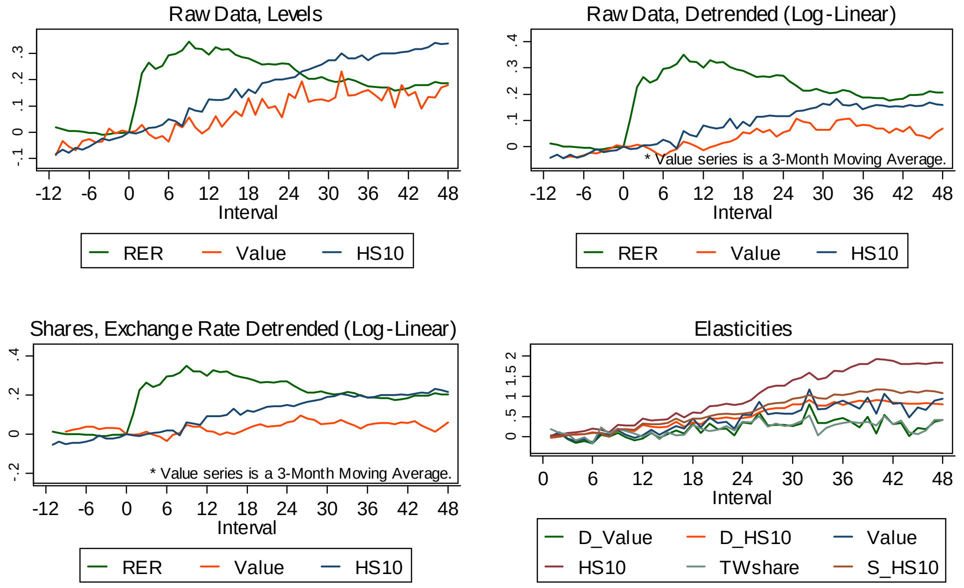
Appendix Figure 1A: Exports to U.S.

1-Month Intervals: 11-Country Median (PPI-Based)

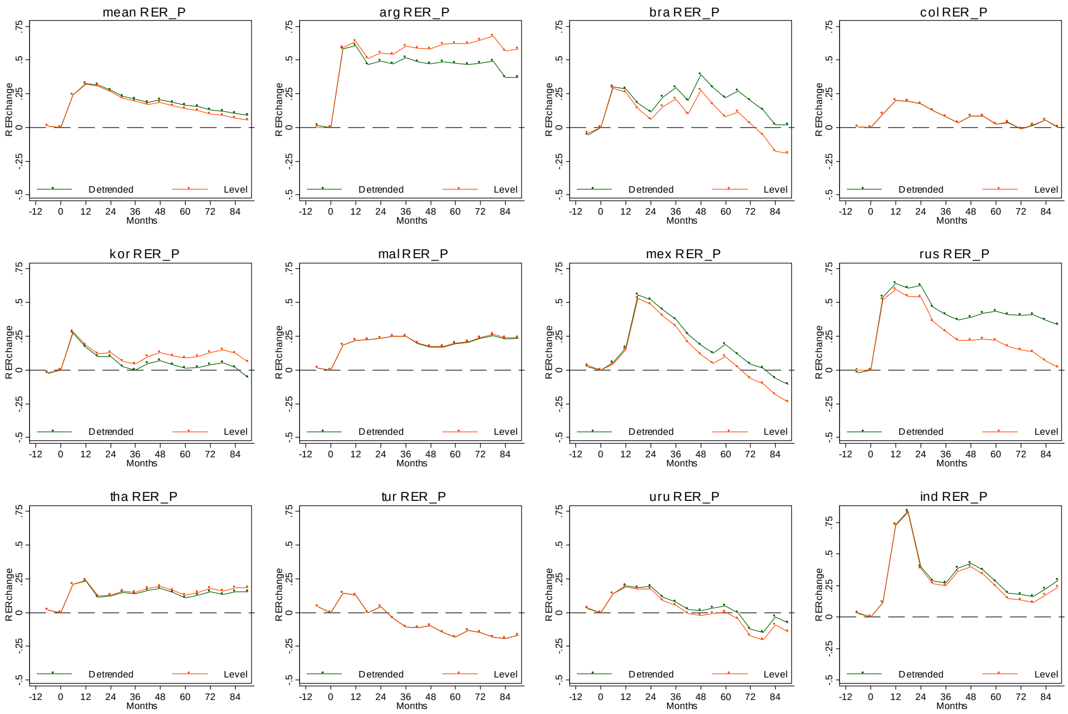


Appendix Figure 1B: Exports to U.S.

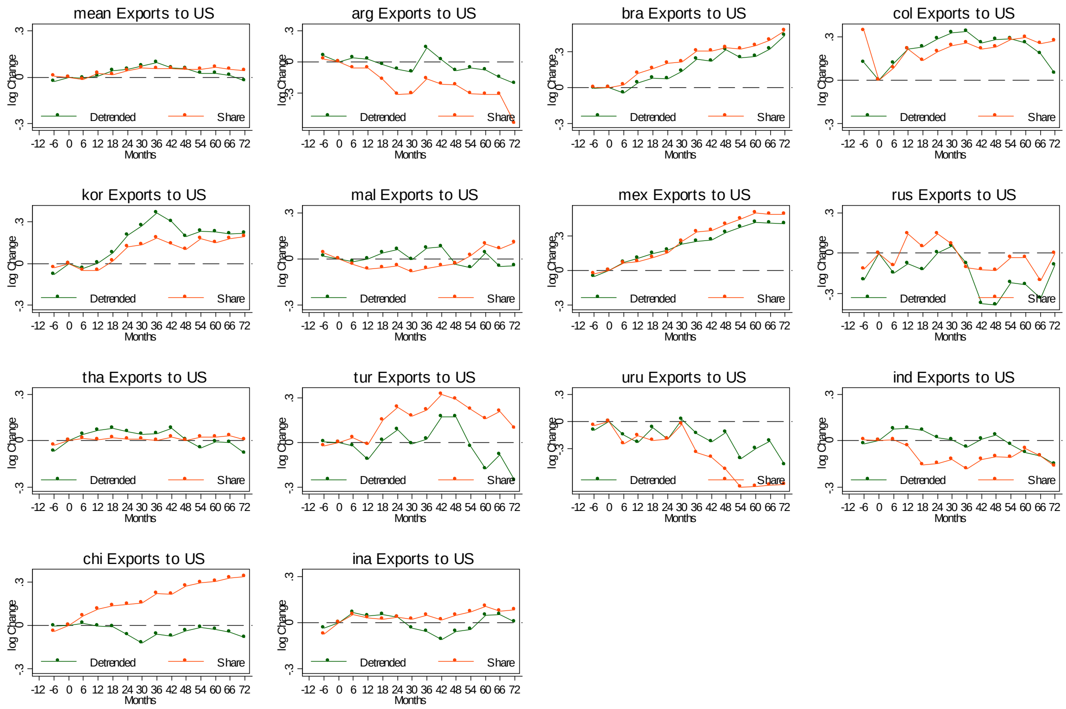
1-Month Intervals: 11-Country Mean (PPI-Based)



Appendix Figure 2A: Real Exchange Rates



Appendix Figure 2B: Exports to U.S.



Appendix Figure 2C: Extensive Margin of Exports to U.S.