Export Dynamics in Large Devaluations[1]

Preliminary

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Abstract

This paper studies 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, interest rates, 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 and sharper contractions in output.

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1. Introduction

It is well-known that following an exchange rate depreciation 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. It is also sometimes suggested that the weak export response arise because devaluations occur in periods of financial distress that make financing export expansion difficult. This gradual export expansion is thought to affect the dynamics of net exports and potentially output (Baldwin and Krugman, 89, Roberts & Tybout, 97). Here, we reconsider empirically and theoretically the source of sluggish export growth. 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 associated with these devaluation episodes.

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 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

[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 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.

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. [Lastly, we examine the dynamics of export prices using the U.S. data and find that export prices tend to fall substantially less than the real exchange rate.

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 interest rates 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 cost 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. It also implies that exports are a return on the foregone resources to build up the stock of exporters.

[3] By the Melitz model, we mean the familiar version in which there are not plant dynamics and the costs of starting to export are the same as the costs of staying in the export market.

[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.

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 generate economic periods associated with devaluations and 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, falling observed productivity, and less impatience. 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 to devote substantial resources to invest in export capacity rather than produce goods for the export market. This intangible investment in export capacity tends to reduce a country's physical output initially and its ability to run a trade surplus and therefore 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, hump shaped 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 (07) 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, when we constrain ourselves to just considering productivity shocks, we find a relatively small impact of the sunk costs. 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 () and Engel and Wang () 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) 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.

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

In this section we document 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. We emphasize four salient features of the data. First, the elasticity of exports to the real exchange rate,[5] 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 weak export response is a weak response 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

[5] 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.

Table 1: List of 11 countries and crisis dates

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

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.

Figure 1 shows the evolution of average exchange rates, interest rates and exports in a 40 quarter window around the large devaluations in these 11 emerging market economies. All data has been deseasonalized. Exchange rates and exports are relative to their levels on the eve of devaluation. The large devaluations are characterized by big real exchange rate depreciations, measured using the producer prices relative to the US producer prices. Moreover, these countries also experienced a spike in interest rates, measured as a JP Morgan EMBI spread. On average the real exchange rate increase by about 40 log points initially and the interest rate spread rises about 1800 basis points. These increases exhibit some mean reversion but are at high levels 8 quarters after the devaluation. In contrast, the response of exports, measured in dollars, was muted. For more than four quarters, exports barely changed from their pre-crisis level and only increased gradually, when real exchange rates were actually

beginning to appreciate again. These export and relative price dynamics suggest there is a relatively low elasticity of exports initially and that this export elasticity increases with time.

The large spike in international borrowing costs suggest that the increase in the interest rate is one possible explanation for the slow growth explanation. 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.[6] 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 2a and 2b show the average interest rate, exports, real exchange rate, and the export elasticity to the real exchange rate in the two groups. Figure 2a present export growth and real exchange depreciation relative to the level of these variables in the crisis date. The implied trade elasticity is defined as the ratio of export growth to the real exchange rate depreciation. In Figure 2b, we detrend the export and real exchange rate using the H-P filter and compute the trade elasticity using the detrended variables. 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 more persistent. However, the export growth for the high interest rate countries is lower through the 24 quarters after the devaluations. The average difference between the export growth rate is more than 10%. The export elasticity to the real exchange rate is substantially below the level for the low interest rate countries. Even after we take out the trend in the export, the export elasticity is lower for the high interest rate countries and high 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.

[6] 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).

B. Micro-evidence on Export Dynamics

In this section we 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 the 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 three 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 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. Lastly, we examine the dynamics of export prices using the U.S. data and find that export prices tend to fall substantially less than the real exchange rate.

Quantities of Exports 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.[7]

We begin by constructing a trade-weighted measure of each country's market share.

[7] 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.

That is, we define country i's share of US imports as

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

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

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

Note, 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 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.[8] Thus we define the extensive margin, $\#_t$,

$$\#_{it} = \sum_{p} \sum_{j} I\left(m_{pijt} > 0\right).$$

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

$$s_{it}^{\#} = \frac{\#_{it}}{\sum\limits_{i,exChina} \#_{it}}$$

Next, since we are looking at the how a country's share of US imports changes, we construct a measure of the real exchange rate purged of changes in the bilateral real exchange rate with the US. Figures 3A and 3B summarize the average dynamics of each of these

[8] We examine a more precise measure of extensive marging using the custom data for Argentina, Colombia, Mexico, and Uruguay in the subsequent subsection.

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.[9] Figure 3A shows how our share measures vary over time. Figure 3B shows our measures vary when we remove a log-linear trend.

The first panel in each figure shows the dynamics of a trade weighted real exchange rate for each country. Real exchange rates are measured using producer prices and consumer prices. Producer price based real exchange rate fluctuations are slightly smaller than consumption based real exchange rates. 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 volume 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 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.[10]

[9] 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.

[10] 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-

The trade elasticities are also bigger for the low interest rate countries than for the high interest rate countries.

Our analysis 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. To adjust for this possibility, we now examine how important are the extensive margins for driving export growth. Following Eaton et al (2007), we disaggregate the intensive margin from the exporters' margins of entry and exit as follows:

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

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.

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devaluation trend.

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

One might still suspect that our measure of the extensive margin understates that importance of the extensive margin since product-level data may hide changes in the number of firms or producers exporting. 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 develop a small open economy model with endogenous entry and exit from exporting to study exports and exporter participation over the business cycle. We assume a unit mass of imperfectly substitutable goods are produced in the small open economy. These goods differ in the costs they require to be shipped overseas so that only a subset of products are exported. The economy faces shocks to the interest rate, R^w, productivity, z, and discount factor, β. The productivity and interest rate shocks are standard while the discount factor shocks are commonly employed in a broad range of DSGE studies (). These shocks lead to endogenous fluctuations in the output and the real exchange rate.[11] Intermediates good producers are subject to the same aggregate productivity shock z and idiosyncratic shocks to the cost of exporting.

All intermediate goods are available for domestic consumption. When consumed domestically, these domestic intermediate goods are modelled as homogeneous.[12] Some intermediates are exported each period by incurring a fixed cost. When sold abroad these intermediate goods are viewed as being differentiated.

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

[12] Because all domestic intermediate goods are available and face the same aggregate productivity, it is without loss of generality to assume that domestic intermediate goods are homogeneous.

The mass of exported products is endogenous and denoted by N. We assume that there is also a one period lag in changing export status. Therefore the measure of exporters which export in the current period is pre-determined. The export cost 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 $F_1(\kappa)$. 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, exporting is an activity that requires an investment.

Given these costs, it is well known that there will be a threshold for non-exporters to start to export κ_0 and a threshold for exporters to continue exporting, $\kappa_{1t,}$. These thresholds will then determine the fraction of non-exporters who start exporting $n_0 = F_0(\kappa_0)$ and the fraction of exporters who continue exporting, $n_1 = F_1(\kappa_1)$. Given these decisions the law of motion for the stock of exporters is

$$(1) \quad N' = n_1 N + (1 - N) n_0,$$

where the total number of new entrants is $(1 - N) n_0$ and the total number of continuing exporters is $n_1 N$.

Production of each variety at home requires labor and is subject to constant returns to scale, so $y_0 = z l_0$. We assume exported intermediates are produced with diminishing returns, $y_1 = (z l_1)^{\alpha}$.

Consumers consume a composite non-traded good made by combining domestic goods and foreign goods imported from abroad. Imports, M are exchanged using the revenue from exporting and the net financing from international borrowing and lending. The borrowing and lending is via one-period discount bonds, as in standard small open economy RBC models. The asset position is denoted by B. The bonds are assumed to be 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.[13]

[13] Any other way of making the economy stationary is fine too. See Smith-Grohe and Uribe () for alternative

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

$$\begin{aligned} V(B,\beta,S) &= \max u(C,L) + \beta EV(B',\beta,S) \\ PC + B - \frac{B'}{1+R} &= wl + \Pi \end{aligned}$$

The first order conditions are:

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

B. Final good market

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

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

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 final good and allocations are:

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

methods to close the small open economy models.

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 fixed cost shocks depends on current export status. Shocks to 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: $EX(p) = EX_t p^{-\theta}$, where EX_t is a demand shifter that depends on the state of the economy. We assume that the production for home and abroad is segmented with production for export subject to diminishing returns $EX(p) = (zl_x)^{\alpha}$. We first consider the export decision taking the intratemporal pricing decision as given and then study the pricing decision

Export decision

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

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

where $\pi(S)$ denotes the profits from exporting and the cost of exporting depends on the cost draw κ and the price of exporting. (The idea here is that you have to hire κ workers and that productivity shocks equally affect the efficiency of producing goods and exporting services). The stochastic discount factor is $q(S')$. 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

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

Because entry shocks are iid, the gain in export value is independent of the current export status and therefore the threshold for starting and continuing 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

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

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 future profits, export costs, and the future gain from exporting,

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

Focusing on the steady state 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.

Pricing decision

Now consider the determination of inputs. The firm faces a downward sloping demand curve $\overline{EX}_t p_x^{-\theta}$ and cost of labor of w. The term $\overline{EX}_t$ is a time varying demand shifter that depends on the number of exporters from the same country active in the market. The final producer solves the following problem:

$$\begin{aligned} \pi &= \max p_x EX(p_x) - wl_x \\ EX(p_x) &= (zl_x)^\alpha = \overline{EX}_t p_x^{-\theta} \end{aligned}$$

The optimal price is a markup over marginal cost

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

Combining these we get the pricing rule in the model of

$$p_x = \left[\frac{\alpha (\theta - 1)}{\theta} \overline{EX}_t^{1 - \frac{1}{\alpha}} / \frac{w}{z} \right]^{\frac{1}{-\frac{\theta}{\alpha} - 1 + \theta}}$$

D. Export Supply Function

We assume that given the a price of exports p_x and N exporters that aggregate export revenue equals[14]

$$(2) \quad EXR = N^{\frac{\gamma - 1}{\theta - 1}} p_x^{1 - \gamma} Y_t,$$

where θ denotes the elasticity of substitution between varieties and γ the elasticity of substitution between exports and domestic goods in the ROW. This equation can be derived from the optimization problem of a representative agent in the ROW. 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 the export supply function. For example, if $\gamma = 1.25$ and $\theta = 2.5$ then doubling the number of exporters increase export revenues by 25 percent holding the price of inputs constant. If $\gamma = \theta$ then doubling exporters doubles exports. This export supply function is derived from the consumer maximization problem that the rest of the world solves, where the demand for exports from the SOE is the export supply function in our model. This formula is derived in the appendix.

E. Equilibrium

We first describe the steady state equilibrium. We will calibrate and solve the model dynamics numerically in the subsequent subsection. To simplify the calculation, we as-

[14] The appendix presents the details of the problem that the rest of the world solves, where the demand for exports from the SOE is the export supply function in our model.

sume the following functional forms for the preference and technology. We assume that $G(D,M) = \left[D^{\frac{\gamma-1}{\gamma}} + \omega^{\frac{1}{\gamma}} M^{\frac{\gamma-1}{\gamma}}\right]^{\frac{\gamma}{\gamma-1}}$, where ω is the Armington weight on the imported goods, and γ is the elasticity of substitution between home and foreign goods.[15] Next, 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

[15] We assume that the economy and ROW have the same preference and thus the same elasticity of substitution parameter.

are $\{l_x, l, \kappa^*\}$. Collecting the equations we have

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

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

$$Y = \overline{p_d}D+\overline{p_x}EX$$

where bars denotes steady state prices. Finally, we measure net exports scaled by gross trade

flows

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

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.

We assume the distribution of entry and continuation costs have an exponential structure

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

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 (2001), 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 $\theta = 3$ to achieve a markup of 50 percent on exports. This markup may appear high but because of the entry decision in steady state export profits as a share of export revenue are only about 10 percent. We set $\gamma = 1.25$ to come close to the average export elasticity following these devaluations. This is well within the range of typical values used in quantitative studies.

In terms of the shocks in the model, we assume the shocks 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. Given we also target the extensive margin elasticity this essentially involves try to fit the model to 4 aggregate series.

Table 4: Pre-determined parameters

β	σ	η	γ	α	$v_1 = v_0$	θ
0.99	2	1.5	1.25	2/3	4.5	2.5

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

target statistics in the steady state as shown in Table 5.

Table 5: Calibrated parameters

Parameters	Target
$\overline{B}$	debt/imports=10
f_0	exporter ratio N=25%
f_1	exit rate of exporter $1 - n_1 = 1.5\%$
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 no sunk costs. In this model $f_1 = f_0$. 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 much too much churning in export status that only 25 percent of exporters continue and that 25 percent of non-exporters start exporting each period. We choose the distribution of fixed costs 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. We

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 equation and export supply 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 on the change in exports. 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.

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 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 $\frac{\Delta EXR}{\Delta rer}$ =0.8 while $\frac{\Delta N}{\Delta rer} \approx 1.5$ we can solve for the elasticity as

$$\theta = 1 + \frac{(\gamma - 1)\frac{\Delta N}{\Delta rer}}{\frac{\Delta EXR}{\Delta rer} - (\gamma - 1)} = 1 + \frac{0.15 * 1.5}{0.65} \approx 1.35,$$

thus the model requires domestic varieties to be very poor substitutes and hence quite a large markup on exports to get the long-run elasticity given the changes in the extensive margin.

When $\alpha < 1$ the relationship is a little different

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

and the model provides a bit more flexibility to match the short-run and long-run trade elasticity.

4. Results

Figure 9 plots the properties of our model, the data, and the model with no sunk cost for a set of shocks that closely match the dynamics of output, interest rates, and the real exchange rate in our benchmark sunk cost model. The first three panels plot our target series. Overall, the fit of the sunk cost model is quite good. The largest gap between the model and the data is in the real exchange rate over the first 6 quarters. In the data the real exchange rate overshoots its longer run level by about 10 percentage points while the sunk cost model generates a fairly smooth transition to the long run level. The fourth panel depicts the elasticity of the extensive margin. We have chosen this to match the average extensive margin elasticity from the data.

Figure 10 depicts the productivity, interest rate, and discount factor shocks we infer from the model. Perhaps surprisingly these episodes are characterized by increases in productivity. Note that this measure of productivity does not correspond to the measure from the national accounts since it does not account for the resources that are being used to build up the stock of exporters. Measuring labor productivity, which includes the labor used in export costs, we actually find that productivity falls. The discount factor increases initially making agents more patient so that the consumers discount the future less. In DSGE papers this are often interpreted as shocks to the financial sector. While the interest rate shock appears to

be stationary we find that the productivity and discount factor shocks remain far from their initial levels 11 quarters on. This is necessary to generate the 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 slightly larger than in the data (0.36 vs 0.33). 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 25 percent to 50 percent, while in the data the increase is from about 5 percent to 50 percent. The final panel depicts net exports (scaled by gross trade flows). Here we see that the model generates slightly stronger movement than in the data. Specifically the data show a sizeable increase in net exports of about 25 percent of gross trade flows while the model generates a stronger increase of almost 35 percent. As in the data, in the model it takes about a year to get the maximum response of net exports. The larger long-run response primarily reflects the larger export elasticity from our experiment.

To evaluate the role of sluggish export dynamics on the aggregate economy we consider the aggregate response to the same shocks in the no sunk cost model. The dispersion in the fixed export costs in this no sunk model has been calibrated to generate the same average export elasticity as in the data. Because there is no sunk cost the only gradualness in export growth comes from the one period lag delaying entry. Indeed, when we consider the elasticity of the extensive margin, we see that there is a sharp increase in exporters in the first period and that the average response is a bit smaller. There is some sluggishness in the exporter elasticity because the shocks lead to a series of surprises over the first four quarters. Because of these dynamics of the extensive margin, the export elasticity grows very little after the first period and is decreasing after four quarters. Compared to the sunk cost model, exports expand more initially and less later on. As a result of these different export dynamics, output falls much less initially and much more in the long run. The weaker initial drop in output in the no sunk cost model arises because fewer resources are used up to generate the initial increase in exports than in the sunk cost model. In the long-run, output is substantially lower as more resources are used to sustain exports (i.e. cover the fixed costs of exporting). The

real exchange rate depreciates by slightly more than in our benchmark model and there is slightly larger net exports reversal of close to 40 percent compared to 35 percent in the sunk cost model. Because the sunk cost model comes closer to matching export and net export dynamics it is clear that it must do a significantly better job of explaining the dynamics of imports.

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 11. The columns presents the response to productivity, interest rate and discount factor shocks respectively. 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 while the net export response is considerably stronger with no sunk cost as the barriers to repaying are quite different[16]. In response to the interest rate shock, we find very different export dynamics across the two models. With the sunk cost, exports actually fall while with the no cost model exports expand. In terms of net exports, there is a stronger response in the no sunk cost model. The different export dynamics ultimately lead to a slightly stronger contractionary effect of interest rates with the sunk cost model. 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 5 percentage points. The differing export response arise because the high interest rates make it costly to invest in becoming an exporter. 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. The .

Finally, we next explore the effect of interest rates on exports and the economy. Specifically, we consider a high and low interest rate calibration. Figure 12 plots the interest rate, real exchange rate, export elastictiy and extensive margin elasticity paths for these two alter-

[16] These differenes are much larger if one normalizes net exports by steady state trade since trade is much higher in the no sunk cost model.

native 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, depending on the horizon we consider the export elasticity is between 80 to 100 percent as large for the high interest rate economy. The similarity arises because the intensive margin response (or short-run response) is essentially identical across the models. If we focus on the difference between the export response at longer horizons and the short run horizon (i.e. on impact), then we see that the high interest rate economy generates between 0 and 30 percent of the growth in the export elasticity of 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

To be completed (sensitivity to θ, γ, α,exporter persistence, Indebtedness)

6. Conclusions

We study empirically and theoretically export dynamics following a devaluation in a number of emerging markets. We document two key features of exports. First, exports grow gradually with the elasticity rising from 0 to nearly 50 percent over 3 years. This export growth reflects a gradual expansion in the extensive margin of trade with the elasticity of product-destinations growing by about twice that of export volume. Second, we find evidence that high interest rates tend to depress exports. These export dynamics are a challenge for standard trade models.

We embed a dynamic model of exporting subject to sunk costs into an otherwise standard SOE model. As is well known, with these sunk costs, the stock of exporters is a state variable of the economy and expanding this stock requires an intangible investment. In response to shocks similar to those experienced by devaluing countries, exports and exporters grow gradually. We find the model can capture the very low initial response of exports and exporters following the devaluation as well as the average response over the first six years following the devaluation. We also find that the model can generate an important role for interest rates in depressing exports. Similar to the data, we find that a smaller elasticity of exports to the real exchange rate when interest rate increases are larger.

By contrasting our model with one in which there is no sluggish export response we find a potentially important macroeconomic role for this sluggishness. The sluggishness in the export response also implies emerging market recessions are deeper while depreciations are actually milder. Without the gradual export expansion, the trade balance reversal would be larger initially so that international indebtedness would rise by less.

Our findings about the dynamics of trade around devaluations is useful to the recent debate about monetary policy in the Euro. 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.

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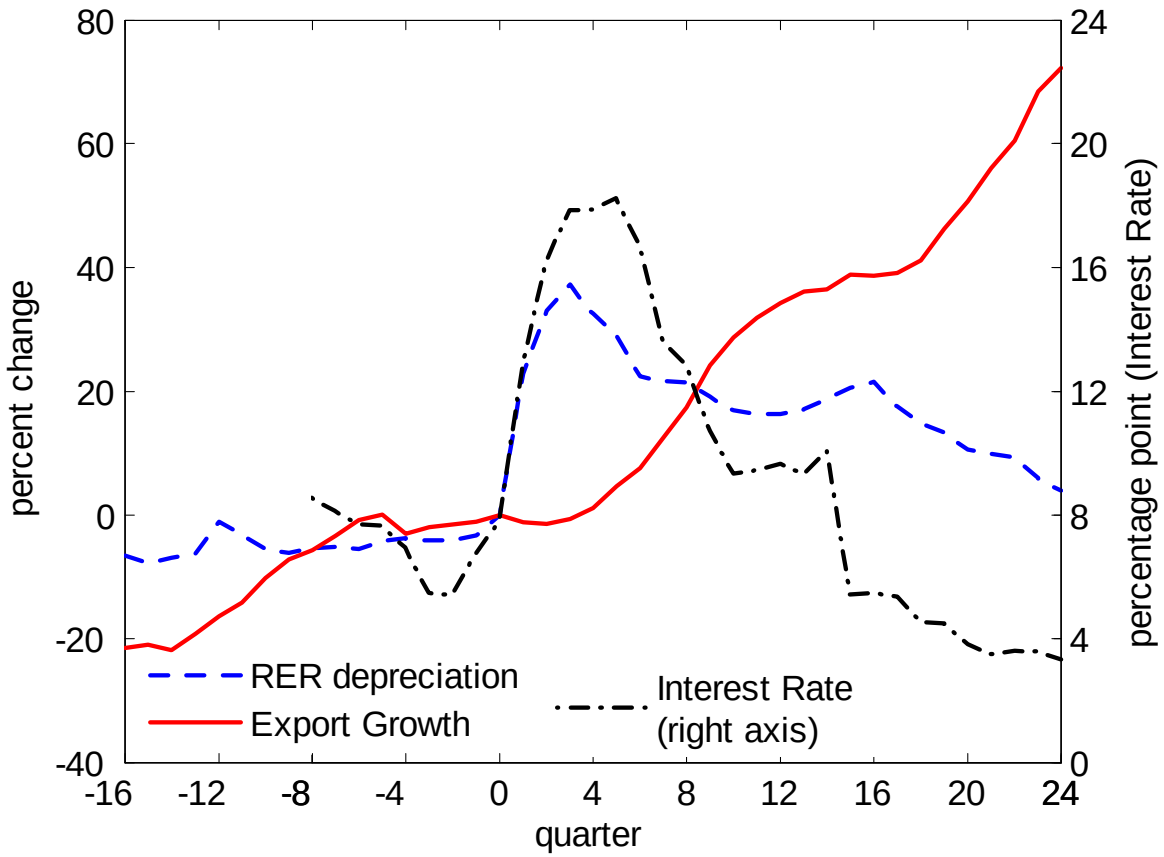


Figure 1: RER, Interest Rates, and Exports for 11 Countries

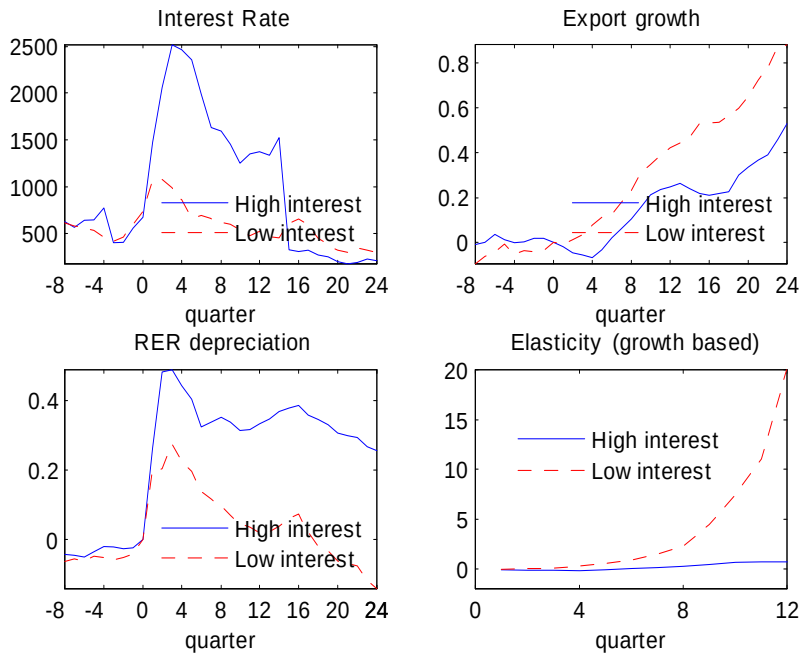


Figure 2a: High Interest Rate Countries v.s. Low Interest Rate Countries

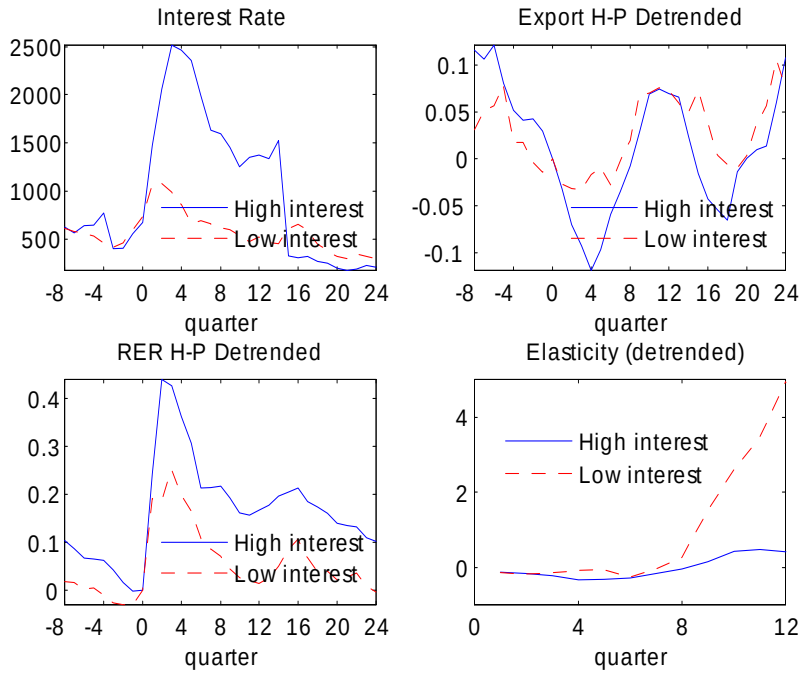


Figure 2b: High Interest Rate Countries v.s. Low Interest Rate Countries

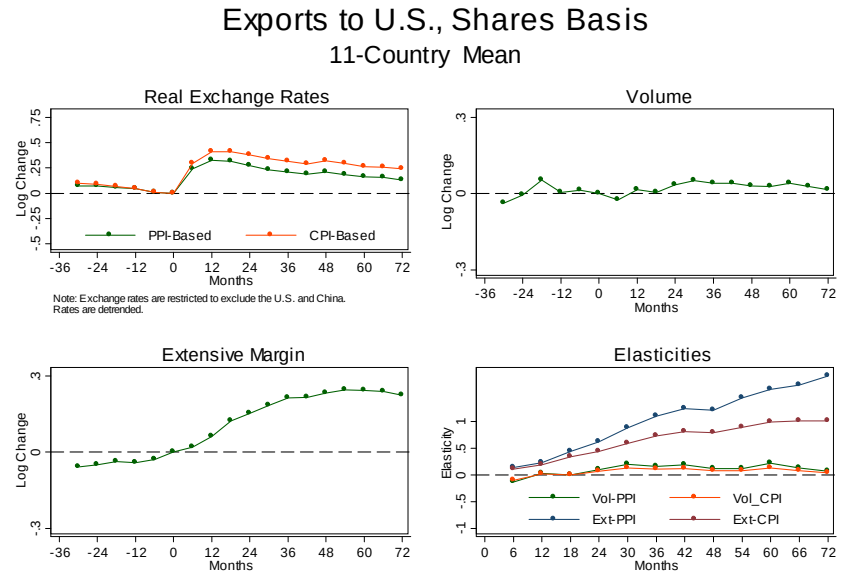


Figure 3A: Dynamics of Exports to US - Share basis

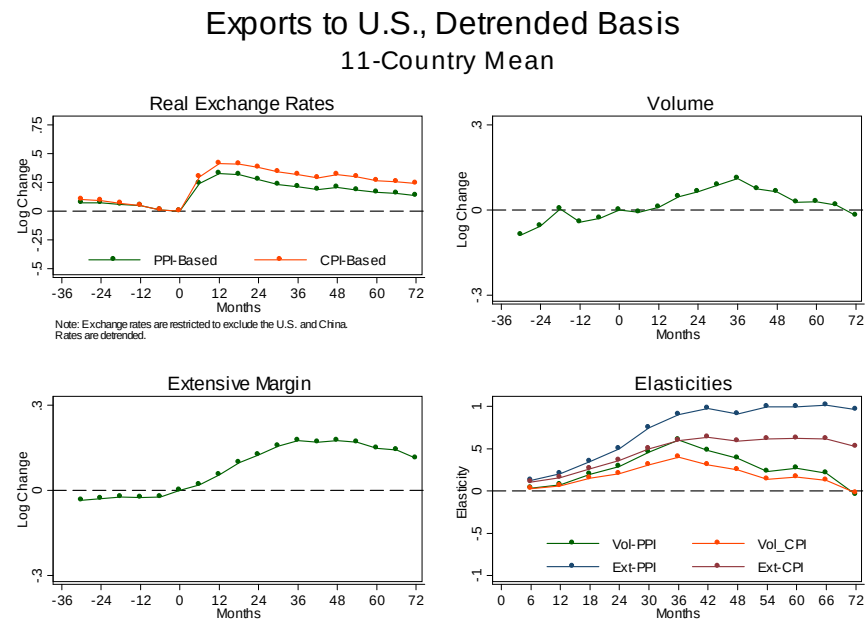


Figure 3B: Dynamics of Exports to US - Detrended

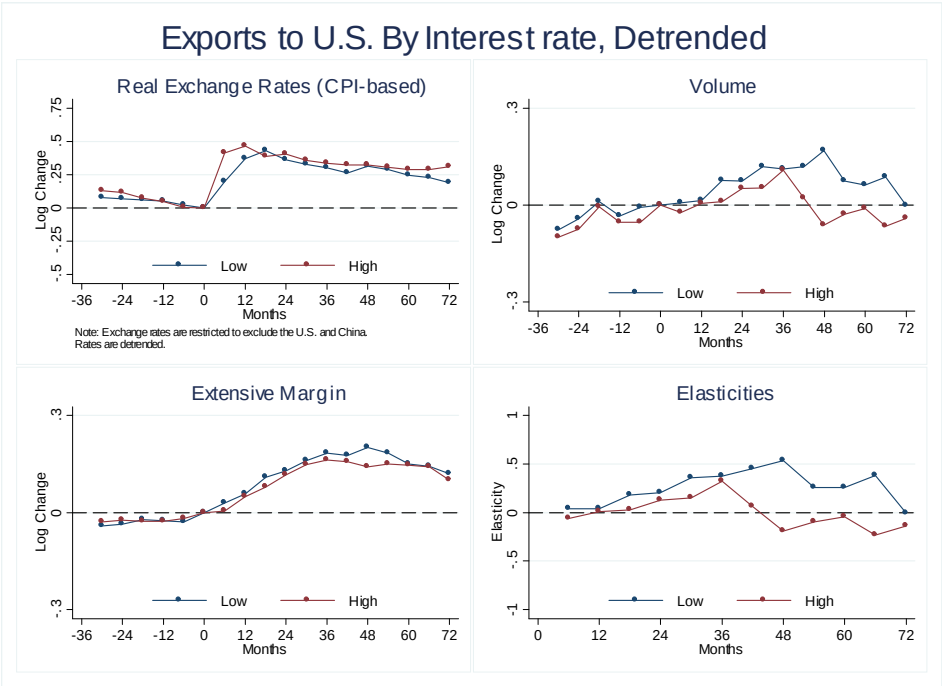


Figure 4: Exports to U.S. by Interest Rate

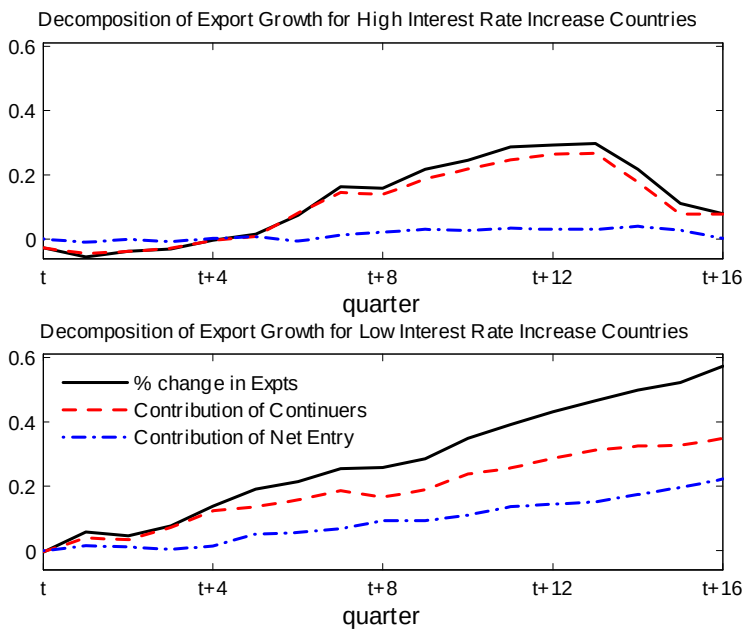


Figure 5: Decomposition of Export Growth for High and Low Interest Rate Increase Countries

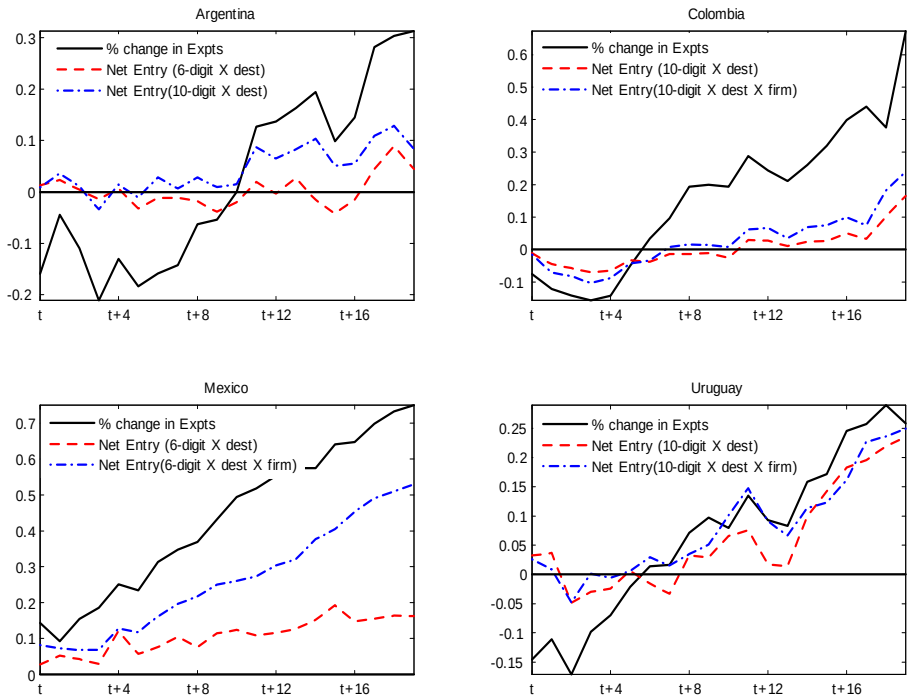


Figure 6: Decomposition of Export Growth by Extensive Margin Measures

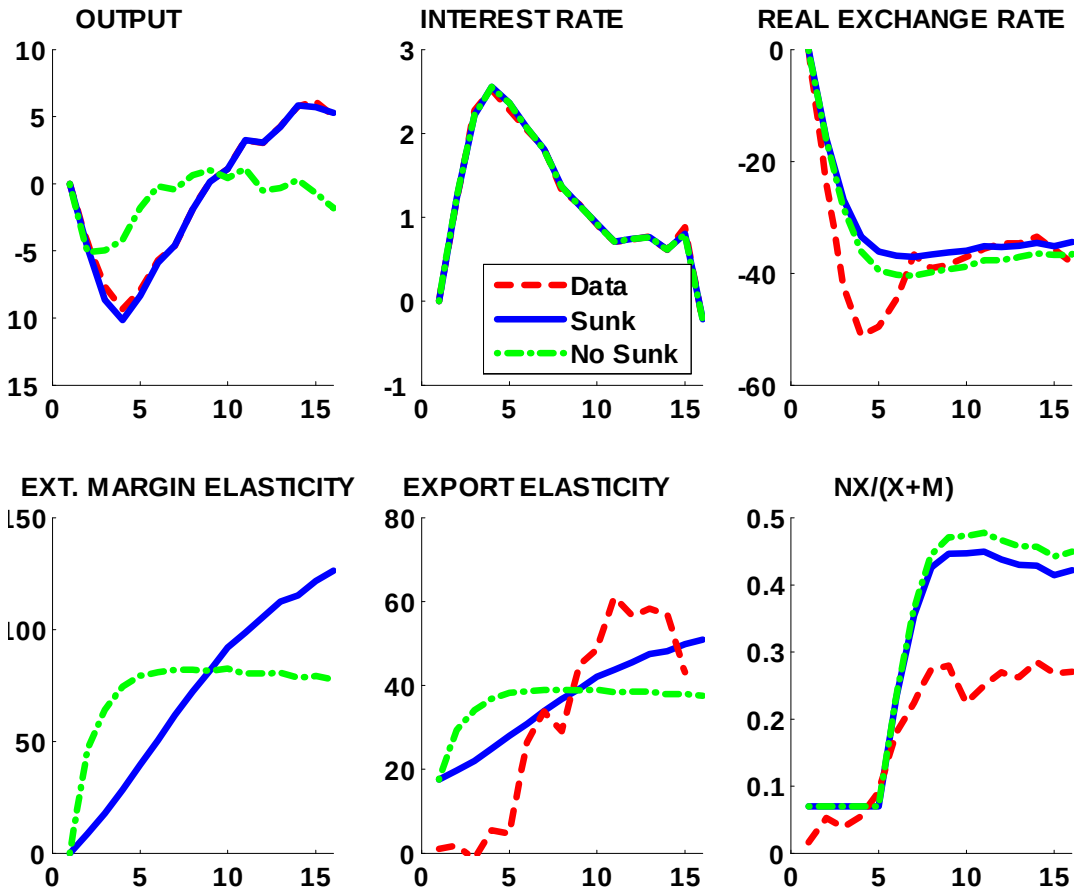


Figure 9: Aggregates in Data and Models

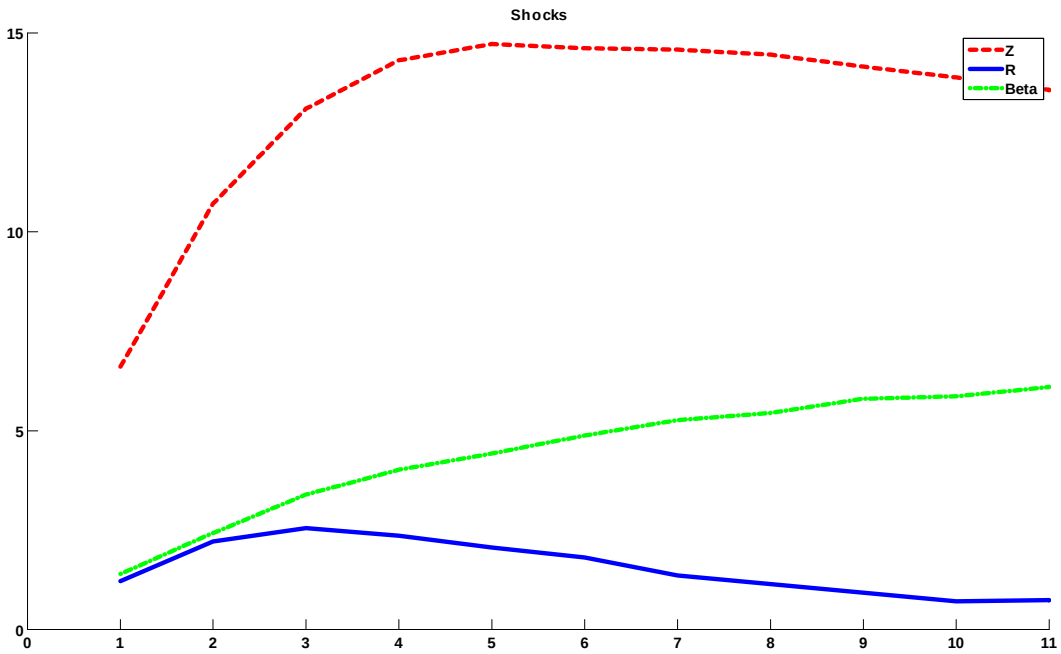


Figure 10: Productivity, Interest Rates, and Discount factor shocks

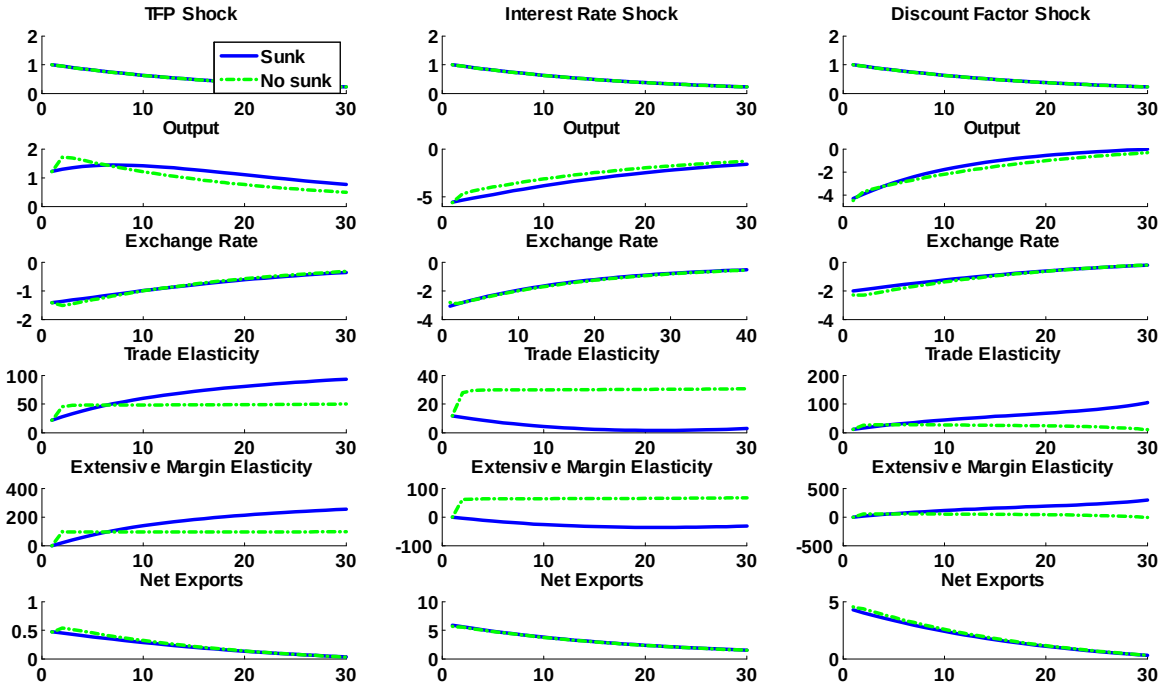


Figure 11: Impulse Response

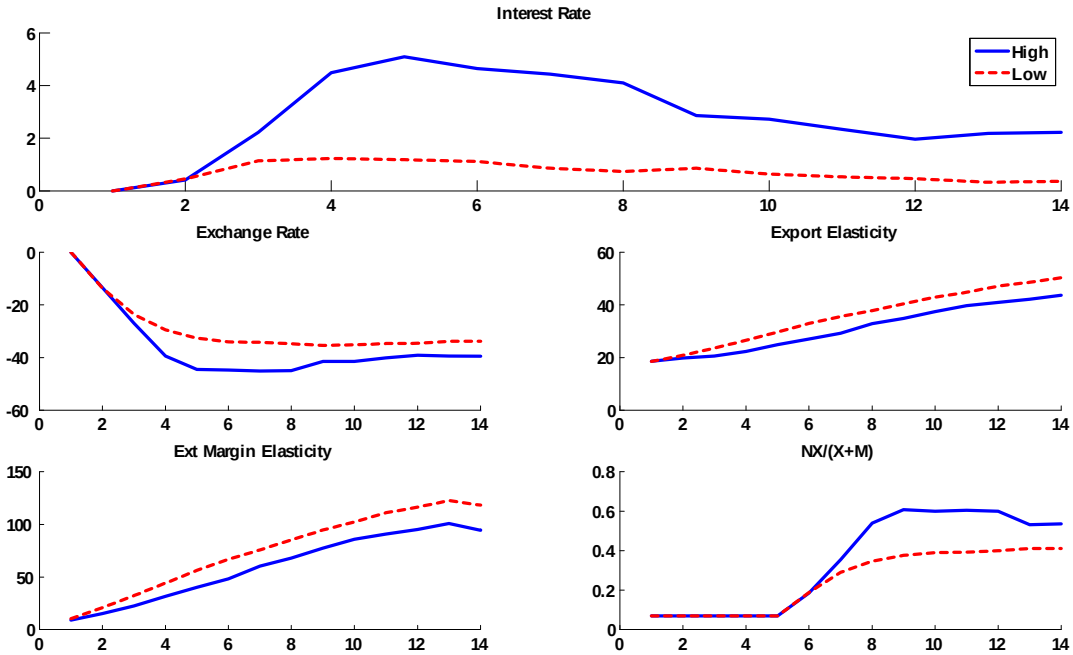


Figure 12: Response to different interest rates shocks

7. Appendix 1: The Export Supply Function

This appendix describes the derivation of the export supply function. 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

$$(3) \quad D(s^t) = \left\{ a_1 \left[\int_0^1 y_h^d(i,s^t)^{\frac{\theta-1}{\theta}} di \right]^{\frac{\theta}{\theta-1}\frac{\gamma}{\gamma-1}} + (1-a_1) \left[\int_0^{N(s^t)} y_f^d(i,s^t)^{\frac{\theta-1}{\theta}} di \right]^{\frac{\theta}{\theta-1}\frac{\gamma-1}{\gamma}} \right\}^{\frac{\gamma}{\gamma-1}},$$

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,

$$(4) \quad \max P\left(s^t\right) D\left(s^t\right) - \int_0^1 P_h\left(i,s^t\right) y_h^d\left(i,s^t\right) di - \int_0^N P_f\left(i,s^t\right) y_f^d\left(i,s^t\right) di,$$

. Solving the problem in (4) gives the input demand functions,

$$(5) \quad y_h^d(i,s^t) = a_1^\gamma \left[\frac{P_h(i,s^t)}{P_h(s^t)}\right]^{-\theta} \left[\frac{P_h(s^t)}{P(s^t)}\right]^{-\gamma} D(s^t),$$

$$(6) \quad y_f^d(i,s^t) = (1-a_1)^\gamma \left[\frac{P_f(i,s^t)}{P_f(s^t)}\right]^{-\theta} \left[\frac{P_f(s^t)}{P(s^t)}\right]^{-\gamma} D(s^t), i \in [0,N]$$

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

$$(7) \quad P(s^t) = \left[a_1^\gamma P_h(s^t)^{1-\gamma} + (1-a_1)^\gamma P_f(s^t)^{1-\gamma}\right]^{\frac{1}{1-\gamma}}.$$

Now we are assuming that we have N identical exporters each charging $\frac{\theta}{\theta-1}\frac{w_f\left(s^t\right)}{A_f(s^t)}$ and so $P_f(s^t) = N\left(s^t\right)^{\frac{1}{1-\theta}}\frac{\theta}{\theta-1}\frac{w_{f(s^t)}}{A_f(s^t)}$. Aggregating over the different exporters we get

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

Now lets take log deviations from the

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

Lets define the terms of trade τ

$$\tau_t = \frac{w_{f(s^t)}}{A_f\left(s^t\right)}/P(s^t)$$

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

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

The key challenge is then to identify the terms of trade separate from productivity shock or shock to wages..

Appendix 2: Data sources

To be completed

Crisis Dates: We define the end of the pre-crisis period as the month prior to a large devaluation:

- Argentina: December 2001
- Brazil: December 1998
- China: December 1993
- Columbia: June 2002
- India: February 1993
- Indonesia: April 1997
- Korea: October 1997
- Malaysia: July 1997
- Mexico: December 1993
- Russia: July 1998
- Thailand: June 1997
- Turkey: January 2001
- Uruguay: June 2002

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@USECON), Brazil (FXDBRZBC@USECON), China (FXDCHIBC@USECON), Columbia (FXDCOLBC@USECON), India (FXDINDBC@USECON), Indonesia (FXDINBC@USECON), Korea (FXDKORBC@USECON), Malaysia (FXDMALBC@USECO Mexico (FXDMEXBC@USECON), Russia (FXDRUSBC@USECON), Thailand (FXDTHABC@USECO Turkey (FXDTURBC@USECON), and the United States (FXDUSBC@USECON)
- Real Effective Exchange Rate (all fund members, Consumer Price Basis), IMF: Uruguay (C298EIRC@IFS), Uruguay Consumer Prices, IMF (C298PC@IFS), Uruguay Wholesale Prices, IMF (C298PW@IFS)

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@IFS), Columbia (C233EIRC@IFS), Korea (C542EIRC@IFS), Malaysia (C548EIRC@IFS), Mexico (from IMF website directly), Russia (C922EIRC@IFS), United States (C111EIRC@IFS), and Uruguay (C298EIRC@IFS)
- 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. Then we calculated the restricted real exchange rate as:

$q_{x,ROW} = \frac{(1-\alpha_{CHI,US}-\alpha_{US,CHI})q_x+(\alpha_{x,US}+\alpha_{x,CHI}-\alpha_{CHI,US})q_{US}+\left(\alpha_{x,CHI}+\alpha_{x,US}+a_{US,CHI}\right)q_{CHI}}{\left(1-\alpha_{x,US}\right)\left(\alpha_{US,x}+\alpha_{S,CHi}\right)+\alpha_{CHI\_x}-\alpha_{x,CHI}}$/(1-$\alpha_{x,US}$ ($\alpha_{US,x}$ + α_{US}

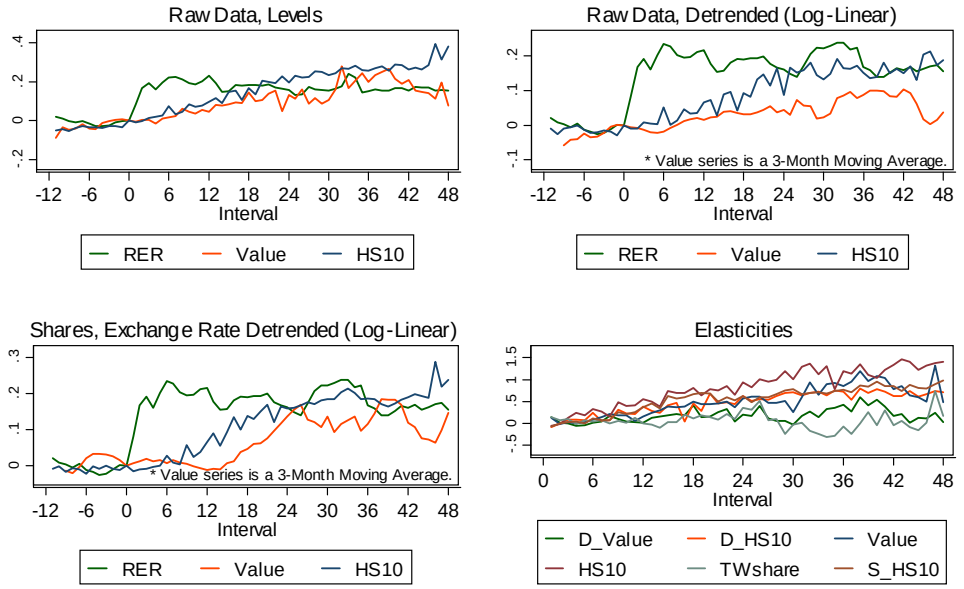
■_(x,CHI) (■_(CHI,x)+ ■_(CHI,US) ■_(US,x)))

Argentina aggregate

- Downloaded from http://www.mecon.gov.ar/peconomica/basehome/infoeco.html
- Production: Índices de Volumen Físico (IVF) en la industria manufacturera [CUADRO 1.15: Encuesta industrial (Total del país, por rama (base 1997=100))]
- Workers: Obreros Ocupados (IOO) en la industria manufacturera [CUADRO 1.15: Encuesta industrial (Total del país, por rama (base 1997=100))]
- Hours: Horas trabajadas (IHT)en la industria manufacturera [CUADRO 1.15: Encuesta industrial (Total del país, por rama (base 1997=100))]
- Spreads: Argentina: Lending Rate: Foreign Currency (% per annum) from the International Monetary Fund minus the 1-Month Nonfinancial Commercial Paper (% per annum) from the Federal Reserve Board
- EMBI -JP Morgain's EMBI dataset
- RERC, RERCUS, RERPUS are downloaded from the [CUADRO 4.14 Tipo de cambio real con EE.UU, Brasil y Europa, y tipo de cambio nominal]
- TOT is measured as the ratio of import prices to producer prices of manufacturers and energy. [CUADRO 4.6 Indice de precios internos al por mayor (IPIM), tasas mensuales y anuales de variación]
- TOT_NIPAY and TOT_NIPAPX use the implicit price deflators from the national accounts: [CUADRO 1.7b Índice de precios implícitos de la Oferta y Demanda Globales por componente, a precios de comprador (1)]
- GDP, C, GFI, EX, M are from [CUADRO 1.2 Oferta y Demanda Globales a valores constantes - Datos desestacionalizados (1)]

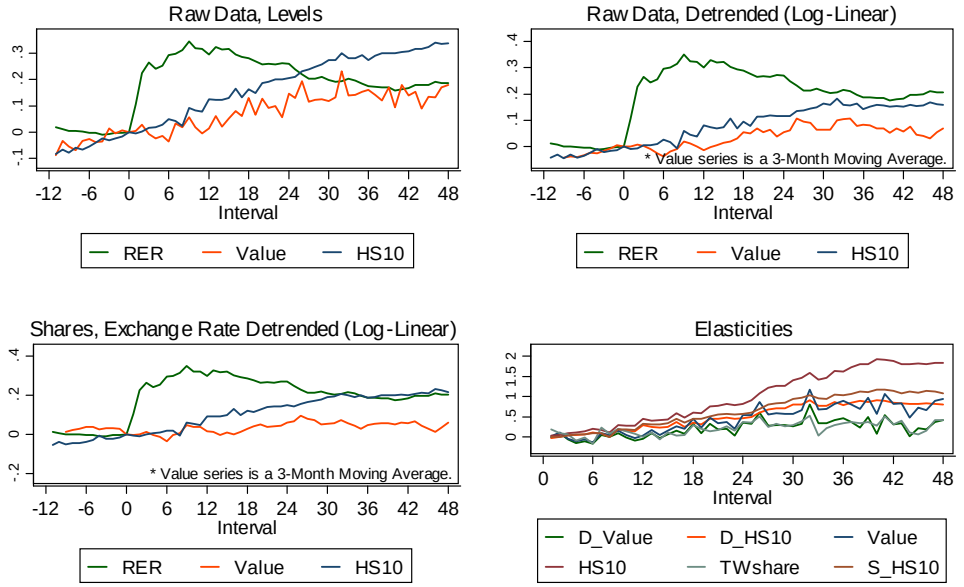
Appendix Figure 1A: Exports to U.S.

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

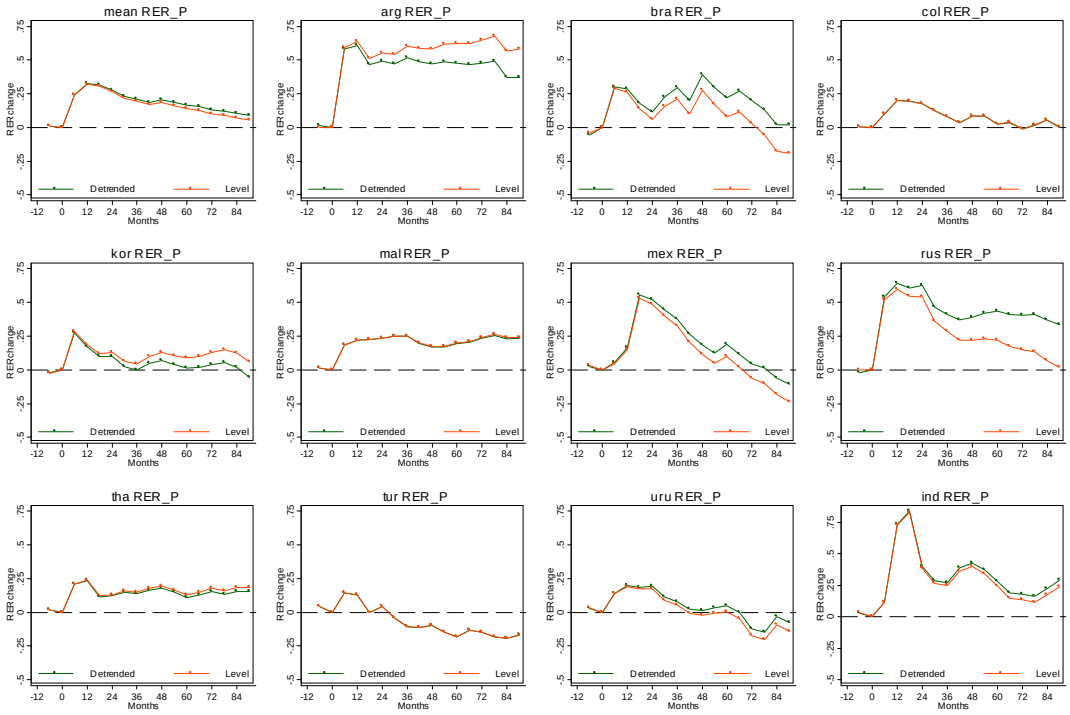


Appendix Figure 1B: Exports to U.S.

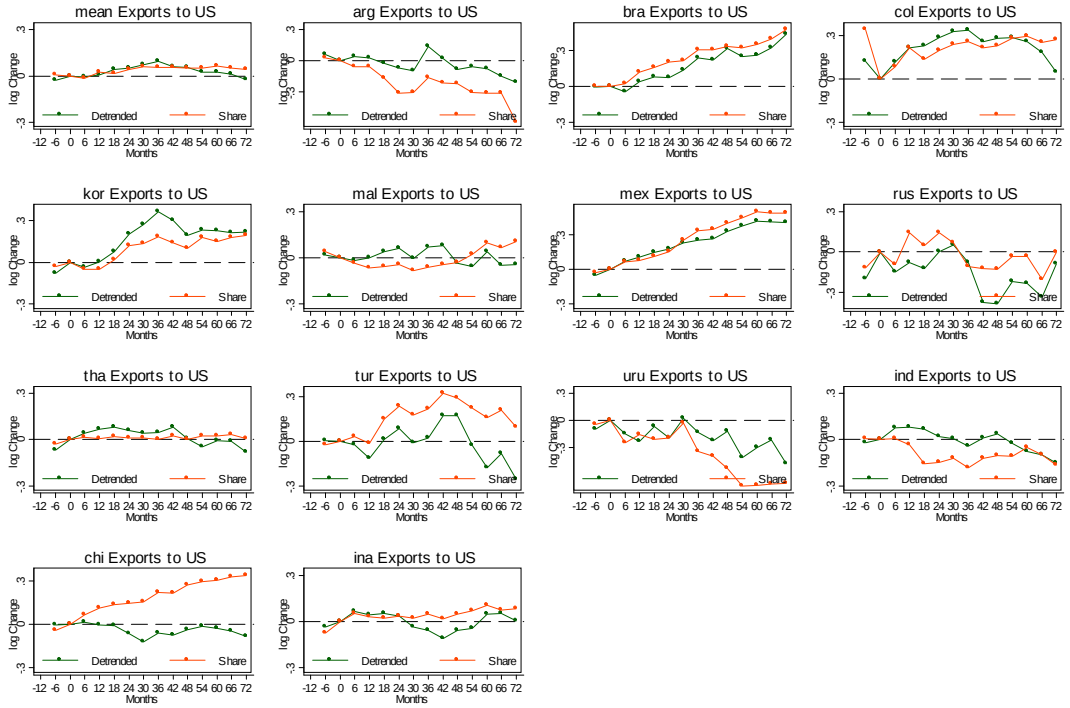
1-Month Intervals: 11-Country Mean (PPI-Based)



Appendix Figure 2A: Real Exchange Rates



Appendix Figure 2B: Exports to U.S.



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