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Lumpy Trade and Large Devaluations*

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ABSTRACT

We document that trade flows, at the micro-economic level, are lumpy an infrequent; inventory-management problems faced by importers are more severe than those faced by firms that purchase material inputs domestically; and that a non-trivial component of international trade costs is independent of a shipment's size. We show that a parsimoniously parameterized $(S, s)-$ type economy successfully accounts for these features of the data. We then show that the model predicts that, in response to a large increase in the relative price of imported goods, import values and the number of distinct imported varieties drops immediately, and as result, short-run import elasticities are substantially larger than long-run elasticities. The model also predicts that importers find optimal to reduce markups in response to the increase in the wholesale price of imports and thus partly rationalizes the slow increase in tradeable goods' prices following large devaluations. Our study of 6 current account reversals following large devaluation episodes in the last decade provide strong support for the model's predictions.

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1. Introduction

How does a country's current account respond to a devaluation? A large earlier literature[1] motivated by the deterioration of the British and US current accounts following the 1967 and 1971 devaluations has argued that, because trade elasticities are lower (and in particular less than unity) in the short-run than in the long-run, a devaluation may indeed initially deteriorate a country's current account before improving it, thus exhibiting a J-curve response. The following Wall Street Journal article, quoted by Magee (1973) summarizes this view:

> The worsening U.S. trade deficit in the months after devaluation hasn't really been unexpected. Economists say that only in the long-run are international trading patterns affected by new currency values. "Buying patterns don't change overnight because prices have changed," a U.S. trade expert says.

This view is consistent with the findings of a growing recent literature in international trade, as summarized, for example, by Ruhl (2005) and Yi (2003), that has emphasized that trade elasticties estimated using high-frequency time-series data are centered around 0.5-1.5 and thus much lower than the cross-sectional elasticities in excess of 10 that are necessary to rationalize the large response of trade volumes to trade liberalizations.

The recent sharp current account reversals experienced by Latin American and East Asian economies in the aftermath of large devaluations and real exchange rate depreciations appear thus puzzling in light of the evidence that international quantities respond slowly to international relative price movements. Figure 0 illustrates the experience of Argentina's January 2002 devaluation. Notice that the 3-fold nominal exchange rate devaluation was

[1] See, e.g., Junz and Rhomberg (1973), Magee (1973), Meade (1988).

associated with a 0.45 rise in the (log) relative price of (at-the-dock) imported goods to the producer price index, a 1.4 drop in the dollar value of imports (implying an elasticity of around 3, significantly higher than typical estimates of substitution elasticities based on time-series data), and a negligible change in the value of exports. As a result the current account sharply turned positive, with most of the increase driven by the high sensitivity of imports to the relative price change.

We argue in this paper that two impediments to frictionless international trade can account for this excess sensitivity of trade flows to relative price changes in the aftermath of large devaluations. First, as forcefully documented by Hummels (2001), international trade takes time: lags between orders and deliveries of goods are non-trivial. For instance, shipments from Europe to the US Midwest take 2-3 weeks, those to Middle East as much as 6 weeks. Given demand uncertainty and depreciation of goods, these lags between orders and delivery are non-trivial. Hummels estimates that an additional 30-day lag between orders and delivers acts as a 12%-24% ad-valorem tax on a shipment's value.

Longer distances are not the only factor contributing to the longer delays in transactions associated with trading goods across borders. Man-made bureaucratic barriers are a hinder as well. A recent survey by the World Bank[2] finds that it takes an average of 12 days (OECD) to 37 days (Europe and Central Asia) for importers to assemble together import licences, customs declaration forms, bills of lading, commercial invoices, technical and health certificates, tax certificates and other certificates required to engage in international transactions.

[2] Trading Across Borders. Available at http://www.doingbusiness.org/ExploreTopics/TradingAcrossBorders/

Second, a non-trivial component of the cost of international trade is fixed, that is, independent of a shipment's size. According to this same World Bank report, part of the cost of importing a container into, say, Argentina, includes the cost of documents preparation (750$), customs clearing and technical control (150$), as well as the cost of ports and terminal handling (600$). These costs are arguably independent of a shipment's size and thus provide room for economies of scale in the transportation technology. We document in this paper that these, and other fixed costs of international trade amount to 3%-11% of a shipment's value. Given that most goods transacted across borders are durable, these fixed costs would make it optimal for importers to engage in international transactions infrequently and hold non-zero inventories of imported goods.

We use two independent sources of evidence to document that importers indeed face a non-trivial inventory-management problem. We first document that trade flows, at the micro-economic level, are lumpy and infrequent. Using monthly data on the universe of all US exports for goods in narrowly defined categories (HS-10) against its trading partners, we show that the average "good" is characterized by positive trade flows in only one half of the months during a year, a statistic that overstates the frequency of trade at the good level given that more than one good is typically included in an HS-10 category. Moreover, annual trade is highly concentrated in a few months during the year. The bulk of trade (85%) is accounted for by only 3 months of the year; the top month of the year accounts for 50% of that year's trade on average. Second, using a large panel of Chilean manufacturing plants, we find that importing firms indeed hold roughly double the amount of inventories than firms that only purchase raw materials domestically do.

These two frictions we emphasize imply that, at any point in time, importers hold non-trivial amounts of inventories in order to economize on the fixed costs associated with international trade, as well as in order to insure against unexpected changes in consumer demand. A large, unexpected devaluation, which triggers a change in the relative price of imported goods to the price of domestic firms the importers compete with, will render the importer's original holdings of inventories suboptimally high relative to what they would have chosen given the higher market price of imports. As a result the fraction of firms (the extensive margin) that import will drop immediately following the devaluation, thus exacerbating the effect the relative price change has on a country's import values. Indeed, as the lower-right panel of Figure 0 indicates, the devaluation in Argentina coincides with a 2-fold decrease in the number of varities imported in any given month, from 2000 prior to the crisis, to below 1000 in the aftermath of the devaluation.

Our goal is to quantitatively assess whether the two frictions discussed above, when plausibly parameterized, can indeed account for the sharp current account reversals following the devaluation. We embed these two trade frictions into a model with a continuum of monopolistically competitive importers that are subject to idiosyncratic demand shocks. These frictions lead importers to follow an (S,s) rule in inventory holdings and importing. Thus firms hold substantial inventories of imported goods throughout the year. The idiosyncratic shocks lead to an ergodic distribution of inventory holdings across establishments. We choose the parameters of the model to match the lumpiness of trade observed at the micro-level and the inventory/purchases ratios observed in the Chilean panel of plant-level data. We then study the response of our economy to large devaluations, modeled as changes in the relative price of (at-the-dock) imported to domestic goods. Our main finding is that the model predicts that short-run import demand elasticities are, as a result of fluctuations in the extensive margin of trade (# of imported varieties) 4-times larger than long-run elasticities implied by consumer's Arminton elasticity for imported goods. The model can thus successfuly rationalize the sharp drop in import values following large devaluations.

Moreover, the model also generates import price dynamics that are consistent with the evidence documented by Burstein et al. (2005) for large devaluations that tradable goods prices, at the retail level, respond increase despite the fact that at the-dock prices of imported goods rise almost one-for-one to the nominal exchange rate changes. In particular, importers in our model find it optimal to lower markups charged to consumers following the devaluations by increasing retail prices slowly in response to the change in the wholesale price of imported goods. This imperfect pass-through arises because after the devaluation importers find themselves overstocked with imported goods at the current replacement price. If importers were to fully pass-through the price change, they would hold onto their imports for a long time and substantially increase their inventory carrying costs. Instead, to economize on inventory holding costs, they find optimal to partially increase their price. As inventory holdings are depleted, and firms return to the import market, more firms increase their prices and pass-through rises with time.

This paper brings together three distinct lines of research. First, a number of authors have studied non-convexities of inventory adjustment over the business cycle in partial (Caplin 1985, Caballero and Engel 1991) and general equilibrium environments (Fisher and Hornstein 2000, Khan and Thomas 2007). Unlike these papers which focus on relatively small shocks our emphasis is on large aggregate shocks. Second, our focus on emerging markets business cycles is similar to Neumeyer and Perri (2005) and Aguiar and Gopinath (2007). However, unlike these GE studies, we develop a partial equilibrium model and study only import dynamics in the aftermath of large devaluations. Third, a number of recent papers study changes in the extensive margin around trade liberalizations (Ruhl (2005)) and over the business cycle (Alessandria and Choi (2007) and Ghironi and Melitz (2005)). Unlike these papers, which focus on sunk costs of participating in international trade, we emphasize the storability of internationally-traded goods and the economies of scale associated with international trade. Finally, the literature measuring trade costs, summarized by Anderson and Van Wincoop (), finds large costs of international trade with tariff equivalents of nearly 140 (check) percent. We extend the range of costs considered to include the fixed costs of importing the lags between orders and delivery in international trade.

2. Data

This section uses microdata to document several important and related facts of importing behavior: (i) the lumpiness of trade shipments, (ii) the fixed costs of trading, and (iii) the relationship between inventories (both final goods and materials) and import content. We focus on data for developing countries in documenting these facts, and address each fact in sequence.

A. Lumpiness of International Transactions

We document the lumpiness of international transactions using monthly data from January, 1990 to April, 2005 on U.S. exports to six importing countries that have experienced large devaluations during this period: Argentina (2002), Brazil (1999), Korea (1997), Mexico (1994), Russia (1998), and Thailand (1997). The data is comprehensive of U.S. goods exports over the period and is highly disaggregate (over 10,000 commodities at 10-digit Harmonized System codes) and includes monthly totals of exported quantity, value, and number of individual transactions by destination country and exiting district. We define a good to be a distinct HS code commodity exiting a particular district, and look at the lumpiness of monthly trade flows of these goods to each country.

Table 1 presents presents lumpiness statistics for the (trade-weighted) median good of each of the six countries.[3] Ideally, we would like to capture the extent of lumpiness in the purchases of a single importer. However, as the first row shows, the median good is transacted multiple times in months when it is traded. This is particularly true for Mexico where the median good is traded 32.7 times a month.[4] We view this data as likely aggregating the shipments of multiple importers, and so understating the lumpiness of any individual importer's purchases. The lumpiness of a single importer's purchases is most closely approximated by Argentina (2.3 transactions per month) and Russia (2.7).

The first evidence of lumpiness is that goods are traded infrequently over the course of a year. The second row shows, for each country, the fraction of months that the median good in the sample is exported. This fraction ranges from 0.11 (Thailand) to 0.69 (Mexico), but may overstate lumpiness since some goods move in and out of the sample. The second row gives the fraction of months the median good is exported in years when it is exported to the country at least once. With the exception of Mexico, whose median good is traded quite frequently (0.91 fraction of months) the other countries import their median good roughly half the months (0.43-0.70).

[3]Trade weighted means have comparable lumpiness measures, but the mean number of transactions per month greatly exceed the median.

[4]Mexico is also unique in the data in that much of trade is carried out via ground transportation rather than by sea or air.

Mere frequency of trade also understates the degree of lumpiness, however, because most of the value of trade is concentrated in still fewer months. One way of summarizing this concentration is by using the Herfindahl-Hirschman (HH) index. The HH index is defined as follows:

$$HH = \sum_{i=1}^{12} s_i^2$$

where s_i is the share of annual trade accounted for by month i. The index ranges 1/12 (equal trade in each month) to one (all trade concentrated in a single month). If annual trade were distributed equally across n months in a year, then the HH would equal $1/n$. The HH indexes for all countries but Mexico range 0.26 to 0.45. If all trade were equally distributed across months, these number would translate into roughly 2 to 4 shipments per year.

Finally, the last three rows another measure of concentration, the fraction of annual trade accounted for by the months with the highest trade in a given year for the median good. The numbers show that the top month accounts for a sizable fraction (ranging from 0.36-0.53, excluding Mexixo), while the top 3 months account for the vast majority of trade (0.70-0.85), and the top five months account for nearly all of annual trade (0.86-0.95).

This high level of concentration does not appear to be driven by seasonalities. This is shown in Table 2. The top half of the table reproduces the HH index and fraction of trade numbers from Table 1, where the fractions are the fraction of trade in a given year. The numbers in the bottom half reproduce the analogous numbers for the fraction of trade in a given month (e.g., December) across years in the data. For these numbers, trade is normalized by annual trade to prevent concentrations from developing by secular changes in trade[5]. The numbers show that (except for Mexico), there is even more concentration within a given month, but across years. The numbers are not strictly comparable, however, since the bottom row shows that are fewer years when a good is imported, than months in a year. Nevertheless, the HH numbers greatly exceed 1/total number of years traded, so there is still a great deal of concentration. Hence, lumpiness does not appear to be a result of seasonalities in which goods are traded only in certain months every year, but consistently each year.

Table 3 shows that lumpiness is also not driven by one particular type of good, but is pervasive across different types of goods. The table presents lumpiness statistics by end use categories (for Argentina). There is some variation, with food being the most lumpy ($HH = 0.53$) and automobiles and automotive parts being the least lumpy ($HH = 0.35$), but even these numbers are similar to the overall number ($HH = 0.42$). The fraction of trade accounted for by the top one, three, and five months are also similar across end use categories.

In summary, annual trade of disaggregated goods is heavily concentrated in very few months. This lumpiness or concentration is pervasive across different types of import goods, and does not appear to be driven by seasonalities. Finally, this evidence of aggregated trade flows likely understates the lumpiness of transactions to individual importers, since the

[5]Shares for month i in year j are defined as follows:

$$\begin{aligned} \tilde{v}_{i,j} &= value_{i,j} / \left(\sum_{i=1}^{12} value_{i,j} \right) \\ \tilde{s}_{i,j} &= \tilde{v}_{i,j} / \left(\sum_{j=1990}^{2004} \tilde{v}_{i,j} \right) \end{aligned}$$

and the Herfindahl-Hirschman index is computed:

$$\widetilde{HH}_i = \sum_{j=1990}^{2004} \tilde{s}_{i,j}^2$$

monthly data contains multiple transactions, that likely reflect multiple purchasers.

One potential reason for this lumpiness is the presence of fixed shipping costs in international trade. We turn now to this evidence.

B. Fixed Costs of International Transactions

A related salient characteristic of international trade are the sizable fixed costs of trade, both in terms of time costs and monetary costs. Data on these costs are available from the World Bank's Doing Business database (World Bank, 2007)[6]. These costs are comprehensive of all costs accrued between the contractual agreement and the delivery of goods, excluding international shipping costs, tariffs, and inland transportation costs.[7] They include document preparation, customs clearing/technical control, and port/terminal handling faced by both the exporting and importing country.[8]

Table 4 summarizes the costs faced for different countries. The first column shows that time costs are considerable. Importing time costs range from 11 (Korea) to 33 (Russia) days, but roughly three weeks is the norm in the other countries.[9] These costs exclude inland transportation on both sides (typically 2 days in the U.S. and 2 days in the destination country), and shipping costs are on the order of a couple of weeks for boats, which is the most common shipping form in the U.S. export data for all but Mexico. Thus, a typical

[6] See Djankov et. al. (2006) for a description of the survey methodology underlying this data.

[7] The costs are based on a standardized container of cargo of non-hazardous, non-military textiles, apparel, or cofee/tea/spice between capital cities. We exclude inland transportation costs on both sides, since these costs may not be specific to international trade.

[8] Common import documents include bills of lading, commercial invoices, cargo manifests, customs cargo release forms, customs import declaration forms, packing lists, shipment arrival notices, and quality/health inspection certificates. U.S. export documents consist of a bill of lading, certificate of origin, commercial invoice, customs export declaration form, packing list, and pre-shipment inspection clean report of findings.

[9] Exporting time costs from the U.S. are roughly a week, but we exclude these since we assume that this is concurrent with the import time costs in the destination country.

shipment takes one to two months from the time of order to receipt of goods.

The second and third columns show the importing and exporting costs respectively. These costs are in U.S. dollars for 2006, and we view most costs as predominantly fixed costs. Importing costs are roughly \$500 for Mexico and Korea, \$1000 for Brazil, Russia, and Thailand, and \$1500, while U.S. export costs are an additional \$625.[10] The median shipments in 2004 from the U.S. export data are in the range of \$10,900 (Mexico) to \$21,000 (Russia), while average shipments are much larger, ranging between \$37,500 (Mexico) to \$89,000 (Korea). Based on these data, importing and exporting costs as a fraction of median shipments range from 0.07 to 0.17, and 0.01 to 0.06 as a fraction of mean shipments.

These costs omit international shipping costs which are also non-neglible. U.S. import data (the counterpart of the export data) contain freight charges for similar sized shipments. These data indicate that freight costs between the U.S. and these countries range from \$500 (South Korea) to \$1000 (Argentina and Brazil), with Mexico being the one exception (\$100) because of the prevalence of trucking. Freight costs contain a substantial fixed cost component, driven in part by containerized shipping technology which greatly increases the per unit costs of shipping less than a full container.

C. Evidence from Chilean plant-level data

Our evidence on lumpy trade suggests establishment face inventory management considerations when purchasing goods internationally. However, this is only indirect evidence. For more direct evidence on the relation between inventory and importing, we use plant-level data on inventories and the source of production inputs. For this we turn to a panel of

[10]Russian import costs omit port/terminal handling charges.

Chilean manufacturing plants. The data covers 7 years (1990 to 1996) and includes 7,234 unique plants and 34,990 observations. This panel has been studied extensively elsewhere (see Roberts and Tybout 1996). The plant-level data is well suited for our purposes as Chile is at a comparable level of economic development to the countries that experienced devaluations and thus Chilean plants are more likely to be similar to plants in these countries.

For each plant j, we have data on beginning and end of year inventories broken down by materials $\left(I^m_{jt+1}, I^m_{jt}\right)$ and goods in process (I^f_{jt+1}, I^f_{jt}) as well as annual material purchases, M_{jt}, sales, Y_{jt} and materials imports, M^{im}_{jt}. We define inventories as the average of beginning and end of period inventories, or $\overline{I}^f_{jt} = (I^f_{jt+1} + I^f_{jt})/2$ and $\overline{I}^m_{jt} = (I^m_{jt+1} + I^m_{jt})$. We measure the import content as the share of materials imported or $s^{im}_{jt} = M^{im}_{jt}/M_{jt}$. To measure each plant's inventory turnover we divide each type of inventory holding by its annual use. For materials, we define the inventory holdings relative to annual purchases $i^m_{jt} = (\overline{I}^m_{jt}/M_t)$ while for finished goods inventories we divide these by annual sales $i^f_{jt} = (\overline{I}^f_{jt}/Y_t)$. Our measure of finished inventories reflects the materials content of final goods. The total investment in inventories is denoted by $i_{jt} = i^m_{jt} + i^f_{jt}$.

Table 5 reports some summary statistics from this panel of manufacturing plants for the whole period for our three different measures of inventory holdings.[11] We report both unweighted averages and averages weighted by annual sales. For the sake of brevity we discuss only the unweighted averages reported in the top panel. On average, the typical manufacturing plant holds approximately 28.5 percent of its annual purchases in inventories. Among non-importers, the typical plant holds 26.2 percent of its annual purchases in inventories while

[11] Over the sample, about 24 percent of our plants imported in a particular year. Over time the share of importers in the sample increases by approximately ten percent.

the typical importer holds 35.6 percent and imports account for 34.5 percent of the value of annual materials inputs. When we split inventory holdings into materials and finished goods, we see that importers hold more at both stages of production.

From table 5 we see clearly that importers hold more inventories than non-importers. However, we would like to know to what extent importers hold more inventories of their imported goods. To get at this we need to control for the fact that importers don't import all inputs. From the following linear regression of inventory holdings on import content,

$$i_{jt} = c + \alpha * s_{jt}^{im} + e_{jt}$$

we find a strong positive relation between import content and inventory holdings. In a range of specifications reported in Table 6, moving from complete domestic sourcing to complete international sourcing is predicted to be associated with between an 85 to 170 percent increase in inventory holdings. Based on the simple unweighted linear regression, in the Chilean data an establishment that sources completely domestically will hold 25 percent of its annual needs in inventories while a complete international sourcer will hold 46 percent. Converting these to monthly numbers, we can infer that firms tend to have 3 months of domestic inputs on hand and 6 months of imported goods on hand. If we just focus on materials, the data says 2.4 months of domestic inputs and 4.2 months of imported inputs.

Labor share

We next compute measures of the labor share in production among the Chilean plants.

We measure labor share as

$$\alpha = \frac{w_t * l_t}{w_t * l_t + M_t},$$

where $w_t l_t$ measures salary payments to white and blue collar workers in the current period and M_t measures current materials purchases. The top panel of Table 7 reports the sample averages for importers, non-importers and all firms. We measure these averages as straight averages and weighted by each plants sales. In total, on an unweighted basis the labor share is approximately 25 percent, while when we weight by sales we find a substantially lower share of 14.5 percent. Notice however that importers, in Panel B of Table 7 that a weighted regression of labor share on importent content predicts that labor share is higher, the larger a firm's import content. A firm that imports all of its raw materials thus has a labor share of about 26 percent.

3. Model

Here we consider the partial equilibrium problem of a monopolistically competitive importer that faces fixed costs of importing a storable foreign good, uncertain demand, and a one-period lag between the ordering and delivery of goods. We start by characterizing the importer's optimal decision rules in an environment in which the only source of uncertainty are demand shocks for its product. We then assume a continuum of importers that are otherwise identical except for the different histories of preference shocks they face and aggregate their decision rules in order to characterize the ergodic distribution of importer-level inventory holdings. We finally characterize the transition dynamics in response to an unticipated change in the relative price of imported to domestically produced goods. We consider both permanent and temporary changes in this relative price.

Formally, we consider a small-open economy inhabited by a large number of identical, infinitely-lived importers, indexed by j. In each period t, the importer experiences one of infinitely many events, η_t. Let $\eta^t = (\eta_0, ..., \eta_t)$ denote the history of events up to period t.

Let $p_j(\eta^t)$ denote the price charged by importer j in state η^t and $\nu_j(\eta^t)$ denote the importer-specific demand disturbance. $\nu_j(\eta^t)$ is assumed *iid* across firms and time. We assume a static, constant-elasticity of substitution demand specification for the importer's product[12]:

$$y_j(\eta^t) = \nu_j(\eta^t) p_j(\eta^t)^{-\theta}$$

Let $\omega_j = \omega$ be the wholesale per-unit cost of imported goods, assumed constant across all importers. We will interpret changes in ω as changes in the relative price of (at-the-dock) imported goods to that of domestic goods. In addition, we assume that the importer faces an additional, fixed cost of importing f, every period in which it imports. Given that the imported good is storable, the firm will find it optimal to import infrequently and carry non-zero holdings of inventories from one period to another. Let $s_j(\eta^t)$ be the stock of inventory the importer starts with at the beginning of the period at history η^t. Given this stock of inventory, the firm has two options: pay the fixed cost f and import $i_j(\eta^t) > 0$ new units

[12]In the background we have in mind a consumer that has preferences over Foreign and Home goods: $c = \left(h^{\frac{\theta-1}{\theta}} + \gamma \int_0^1 \nu_j^{\frac{1}{\theta}} m_i^{\frac{\theta-1}{\theta}} di \right)^{\frac{\theta}{\theta-1}}$ where m_i is consumption of imported good j, h is consumption of the domestic good and γ, the weight on imported goods is assume to be close to 0. Normalizing the price of home goods to 1 would yield the demand functions in text.

of inventory; or save the fixed cost and not import, i.e., set $i_j(\eta^t) = 0$. Implicit in this formulation is the assumption that inventory investment is irreversible, i.e., re-exports of previously imported goods, $i_j(\eta^t) < 0$ are ruled out.

We also assume a one-period lag between orders of imports and delivery. That is, sales of the importer at $\eta^t, q_j(\eta^t)$ are constrained to not exceed the firm's beginning-of-period stock of inventory:

$$q_j(\eta^t) = \min[\nu_j(\eta^t) p_j(\eta^t)^{-\theta}, s_j(\eta^t)]$$

The amount $i_j(\eta^t)$ the importer orders today can be only used for sales next period. In particular, the law of motion for the importer's beginning of the period inventories is:

$$s_j(\eta^{t+1}) = (1-\delta)\left[s_j(\eta^t) - q_j(\eta^t) + i_j(\eta^t)\right]$$

where δ is the depreciation rate. We assume that inventory in transit $i_j(\eta^t)$, depreciates at the same rate as inventory in the importer's wharehouse, $s_j(\eta^t) - q_j(\eta^t)$. Figure 1 summarizes the timing assumptions in the model.

The firm's problem can be concisely summarized by the following system of two functional Bellman equations. Let $V^a(s,\nu)$ denote the firm's value of adjusting its stock of inventory and $V^n(s,\nu)$ denote the value of inaction, as a function of its beginning-of-period stock of inventory and its demand shock. Let $V(s,\nu) = \max[V^a(s,\nu), V^n(s,\nu)]$ denote the firm's value. Then the firm's problem is:

$$
\begin{aligned}
(1) \qquad V^a(s,\nu) &= \max_{p,i>0} q(p,s)p - \omega i - f + \beta EV(s',\nu') \\
V^n(s,\nu) &= \max_{p} q(p,s)p + \beta EV(s',\nu')
\end{aligned}
$$

where

$$q(p,s) = \min(\nu p^{-\theta}, s)$$

and

$$s' = (1-\delta)\left[s - q(p,s) + i\right] \text{ if adjust}$$

$$s' = (1-\delta)\left[s - q(p,s)\right] \text{ if don't adjust}$$

The expectations on the right-hand sides of the Bellman equations are taken with respect to the distribution of demand shocks ν. We assume $\log(\nu) \sim N(0,\sigma^2)$.

A. Optimal policy rules

We next characterize the optimal decision rules for the firm's problem[13]. In particular, we are interested in characterizing $p^a(s,\nu), p^n(s,\nu)$, the prices the firm charges conditional on adjusting or not its inventory holdings, $i(s,\nu)$, the firm's purchases of inventory conditional on importing, as well as $\phi(s,\nu)$, the firm's binary adjustment decision.

[13]We solve this problem numerically, using spline polynomial approximations to approximate the 2 value functions, and Gaussian quadrature to compute the integrals on the right-hand-side of the Bellman equations. Details are available from the authors upon request.

Figure 2 depicts the firm's values of adjusting and not adjusting its inventory in the s (beginning-of-period stock of inventories) space. The second argument of these functions is held constant at its steady-state level.

Note that both values are concave in the importer's level of inventory. In this model an increase in s raises the firm's value for 3 reasons: it reduces the probability of a stockout, i.e., the probability that the firm will have insufficient inventories to meet all demand; it reduces the probability that the firm will have to pay the fixed importing cost next period, as well as directly, by raising the value of the firm's assets. Whenever the firm has little inventories, the likelihood of a stockout is high, and, conditional on inaction, the probability of adjustment next period is high as well, hence the firm's value rises faster with s than when the firm has higher levels of inventories. Notice also in this region that the firm that does not adjust values an additional unit of inventory more than the firm that does adjust. Given our assumed lag between orders and deliveries, the choice of not adjusting today implies that the firm will have to sell out of its current (low) stock of inventory not only today, but also next period, thus making each additional unit of inventory today more valuable.

The intersection of these two functions define the firm's inaction region. Whenever its stock of inventory is too low, the firm orders a new batch of inventories and pays the fixed cost f. Similarly, whenever the firm has a sufficiently high stock of inventories it prefers to postpone ordering, thus saving the fixed cost.

We next turn to the optimal price functions, illustrated in Figure III. Clearly, whether the firm orders or not new inventories affects its next period's beginning of period's inventories and thus its marginal valuation of an additional unit of inventory, reflected in the firm's price. Consider first the $p^a(s, \nu)$ schedule, the firm's price, conditional on ordering new inventories.

Again, we supress the ν argument in this figure and set the level of demand to its steady-state mean. Notice that $p^a(s)$ initially decreases with s, then flattens out, and then decreases again when s is sufficiently high. The first portion of this schedule is one where s is sufficiently low for the firm to not be able to meet demand if it charges the price that would be optimal in the absence of the constraint that firm's sales must not exceed its inventory. The importer thus charges a price that ensures that it sells all of its currently available inventory. The firm's price in this region is implicitly defined by:

$$vp^{-\theta} = s$$

Consider next the second, flat region. If the firm does not stock out and adjusts its inventory, its price next period is independent of current inventories for most of the region of the parameter space. This is the region in which $s > vp^{-\theta}$, and thus, as long as the irreversibility constraint $i > 0$ is not binding, the firm's problem is, by inspection of the Bellman equation, independent of s. Intuitively, two firms that today only differ in their current holdings of inventories will choose, conditional on adjustment, to start with the same level of beginning-of-period inventories next period. This is the case as long as reaching this optimal level of inventories does not entail shipping some of the goods back which is an option we rule out. Thus, the firm's next period's beginning-of-period inventories, and thus its shadow valuation of current-period inventories, $\beta E \frac{\partial V(s', \nu')}{\partial s}$ which determines the firm's price, is independent of s.

Finally, when s is sufficiently high, the firm has too much inventory relative to what it would find optimal given the size of its fixed costs and the rate at which the goods depreciate,

δ. In the absence of the irreversibility constraint the firm would like to ship some of its inventory back. Given that we rule this option out, the firm lowers its price to avoid having the good depreciate.

We next turn to the firm's price function conditional on adjusting its stock of inventories, $p^n(s, \nu)$. As Figure 3 illustrates, this price is decreasing in the firm's level of inventories for the entire region of the parameter space, and converges to $p^a(s, \nu)$ whenever s is sufficiently high. Firms that don't adjust value an additional unit of inventory because it lowers the probability of a stockout, as well as the expected fixed cost they have to pay in future periods. The higher the firm's stock of inventory, the lower the probabilities of these two events are, and thus the lower is a non-adjusting firm's shadow value of its inventory, and thus the firm's price.

Figure 4 illustrates the firm's optimal imports $i(s)$ conditional on importing, i.e., the solution to the maximization problem in (1). All firms that have small current levels of inventory choose to import the same amount as all these firms stock out and have the same, zero, level of end-of-period inventories. Further increases in s lead firms to reduce their import purchases one-for-one, as the desired level of next period's value of inventories is the same. For sufficiently high inventory levels the irreversibility constraint is binding and firms choose not to import at all, even conditional on having paid the fixed cost.

4. Model Parametrization

We choose parameters in our model in order to match the salient features of the frequency and lumpiness of trade, as well as the information on inventories from the Chilean plant-level data. We interpret the length of the period as one month, consistent with the evidence that lags between orders and delivery in international trade are 1-2 months. We set the discount factor β to $0.94^{\frac{1}{12}}$ to correspond to a 6% annual real interest rate.

To set the depreciation rate δ, we draw on a large literature that documents inventory carrying costs for the US. Annual inventory carrying costs range from 25% to 55% of a firm's inventories, which imply monthly carrying costs ranging from 2.1 to 4.5 percent.[14]. We thus choose $\delta = 0.025$, in the mid-range of these estimates.

The elasticity of demand for a firm's products, θ, is set equal to 1.5, a typical choice used in the international business cycle literature, that, in turn, reflects the low elasticities of substitution estimated using time-series data. Given that in our model the substitution elasticity is tightly linked to the size of markups (300%) firms charge, we perform robustness checks on this choice of elasticity below.

Two other parameters, f, the size of the fixed cost, and σ^2, the volatility of demand shocks are jointly chosen in order for the model to accord with two features of the micro-data. The first target used to choose these two parameters is the lumpiness of trade flows we have documented in the micro-data. Recall that the mean Herfindahl-Hirschman concentration ratios are equal to 0.42 in Argentina and 0.45 in Russia, the two countries in our sample with the least number of individual transactions per HS-10 digit product category and for which lumpiness at this level of disaggregation most closely corresponds to lumpiness at the firm level. We thus ask our model to match a concentration ratio of 0.44. Our estimates of equation XXX suggest that the annual inventory-to-purchases ratio of a firm that imports all of its raw materials is 36%. This is the second target that we ask our model to accord with. Given that our model abstracts from finished-good inventories, we include both materials and finished-

[14]See, e.g., Richardson (1995).

goods inventories in our definition of inventories in the data. Given the fixed costs of importing and no other frictions or differences in depreciation rates, importers are presumably indifferent between holding the imported intermediate goods as material inventories or finished-good inventories.

In addition to the two parameters above, we report several additional, *"over-identifying"*, statistics from the data. Hummels (2001) provides the following calculation that may be useful in order to assess our choice of parameter values. Using data on air and vessel shipping times, freight rate differentials on air versus vessel transportation modes, as well as the importer's choice of a particular transportation mode, he finds that a 30-day lag between order and delivery is valued by US importers at 12% to 24% of the shipment's value. In our model the 1-period lag is costly for two reasons. First, a proportion δ of the shipment is assumed to depreciate in transit. More importantly, importers that face more uncertain demand will find it optimal to have higher holdings of inventory in order to ensure they have sufficient to meet demand in states of the world when the level of demand is high. Thus, a measure of the firm's losses incurred because of the 1-period lag between orders and delivery may provide useful information about the demand uncertainty an importer faces. We compute the firm's losses by solving the problem of a firm that is subject to fixed costs of importing but no lags in shipping. In particular, the problem of a firm in an environment with no time-to-ship is characterized by

$$\begin{aligned}\hat{V}^a(s,\nu) &= \max_{p,i>0} q(p,s)p - \omega i - f + \beta E\hat{V}(s',\nu') \\ \hat{V}^n(s,\nu) &= \max_{p} q(p,s)p + \beta E\hat{V}(s',\nu')\end{aligned}$$

where, unlike in the previous problem, the firm is assumed able to sell out of its current-period imports:

$$q(p,s) = \min(\nu p^{-\theta}, s+i)$$

We compute the difference between the two firm's values, conditional on adjustment, relative to the present value of an importer's imports in our original setup, $\frac{\hat{V}^a - V^a}{\sum_{t=0}^{\infty} \omega i_t}$ for a firm that enters the period with no inventories.

Another piece of evidence we use to gauge the robustness of our calibration is direct measures of fixed costs. Recall that, depending on whether we use medians or means to compute average shipments, these range from 3% to 11% in the data. Finally, we also report the fraction of months an importers pays the fixed costs and imports, as well as the fraction of one year's trade accounted for by the top, top 3 and top 5 months.

Table 8 reports the moments we ask the model to match, as well as the additional moments, in the model and in the data. Table 9 reports the choice of parameter values that we use. Notice, in Table 9, that we require very volatile demand shocks with a standard deviation $\sigma = 1.1$ in order for importers to be willing to hold the high inventory values we observe in the Chilean data given the frequency with which they import. Moreover, the fixed cost, expressed relative to the average value of a shipment, conditional on the firm importing, is 4.9%. Turning to Table 8, notice that our parsimonious model is capable of reproducing not only the annual import concentration ratios in the US export data and the Chilean inventory/purchases ratios, but also the additional, over-identifying, moments we have not used for calibration. In particular, the top month of the year accounts for 48% of the year's value of trade in the model (53% in the data). The fixed cost per shipment is 4.9% and thus in the neighborhood of the fixed costs we have directly measured in the data. Moreover, the Hummels (2001) thought experiment suggests that the volatility of demand shocks is not excessively large in our model. Imports under our calibration are willing to pay 11% of their average shipment value in order to avoid a 1-period delay, a number that is at the lower bound of similar measures reported by Hummels (12%-24%).

5. Results

Before we describe the numerical experiments we perform on our model, we briefly characterize several salient features of the data following large devaluations. We focus on 6 large devaluations: Argentina (January 2002), Brazil (January 1999), Korea (October 1997), Mexico (December 1994), Russia (August 1998), and Thailand (July 1997).

A. Salient features of large devaluations

Figures 5-10 plot the exchange rate, the relative price of imports to the domestic Producer Price Index, as well as real import values[15] relative to each country's industrial production for one and a half years before and after the respective currency crisis[16]. As documented by Burstein et. al. (2005) each nominal exchange rate devaluation is associated with a rapid and almost one-for-one increase in the country's local currency import price index, but slow rise in domestic prices. As a result, large devaluations are associated with large and prolonged increases in the relative price of imports to local currency producer prices. Moreover, each of

[15]In these graphs we filter out high-frequency fluctuations in import values by plotting the trend of each series constructed using a Hodrick-Prescott (1996) filter with a low smoothing parameter $\lambda = 0.5$.

[16]Given lack of data for Russia, we use the dollar exchange rate instead of the import price index, and industrial employment, as opposed to industrial production.

the countries in our sample experiences a large drop in imports relative to domestic industrial production that reverts only gradually.

We next ask, what accounts for these large drop in import values? In particular, we want to decompose the decline in trade following a crisis into two components: one associated with a decline in the number of goods imported, and one with a decline in the value of shipments for those goods that are traded. Figures 11-16 perform this decomposition using information on each country's imports from US available at the HS-10 disaggregation level. Notice in these figures the same pattern of trade we have documented earlier: imports from US in all countries drops suddenly around the devaluations and almost entirely recovers one to two years after the crisis. Moreover, as the central panel of these figures indicates, the fraction of HS-10 categories imported drops as a result of the crisis as well. The largest drops in the (weighted by total import values over time) fraction of exported goods have been experienced in Argentina (35% to 20%) and Russia (37% to 13%), the two countries in our sample that trade least with US and for which a given product category most closely corresponds to a single good. An average of a 10% drop in the fraction of imported goods is evident in these figures for all other countries in our sample as well. The only exception is Mexico, which, given that as many as 32 transactions are recorded for a particular HS-10 product category in a given period, is least indicative of variation in the number of varieties imported in any given period.

To decompose fluctuations in import values due to the extensive (imports per product category) and intensive (fraction of products imported), notice that, by definition, the total value of trade in a given period, x_t, is the product of two terms: the fraction (weighted by total imports in our sample) of goods that are traded in a particular period, w_t, as well as the mean import value of a particular imported good, $\frac{x_t}{w_t}$. The right panel of Figures 11-16 plot the (log of) each of these three series. For Argentina and Russia the drop in the fraction of imported goods accounts for 33% and 42% of the drop in trade values in month with lowest trade following the crisis. Once again, the importance of the extensive margin is lower for all other countries.

These results, although plagued by the measurement issues introduced by our inability to observe firm-level decision rules, provide a lower bound on the importance of the extensive margin of trade in accounting for the sharp current account reversals following a crisis. We next ask whether our calibrated model can account for these features of the data.

B. Model experiments

As Figures 5-10 illustrate, the countries in our sample experience an average increase in the relative price of imported goods of about 0.4 that only gradually reverts over time. We thus start by model a devaluation as a permanent rise in ω by this amount. Moreover, devaluations are also associated with large increases in the interest rates these economies face which affect the opportunity cost of funds tied in the importers' inventories. The EMBI+ spread that captures the average spread of sovereign external debt securities rose by as much as to 7000 basis points in Argentina, 2400 basis points in Brazil, 1600 basis points in Mexico, 1400 basis points in Russia, and 950 points in Thailand. We thus also associate a crisis with a permanent drop in the discount factor to $\beta = .7^{\frac{1}{12}}$, which corresponds to a 24% rise in annual real interest rates.

Figure 17 illustrates the ergodic distribution of firm inventory holdings, as well as their inaction regions, in the pre- and post-crisis steady states. Inventory holdings in both cases are normalized by mean sales of the importer in the pre-crisis steady state. Consider first the upper panel which illustrates the pre-crisis steady-state. Firms that have paid the fixed cost in the previous period have the same level of inventories, roughly 6 periods of mean sales. They account for roughly 21% of all firms in the distribution. The rest of the firms are those that have adjusted in previous periods and are approximately uniformly distributed over their inventory holdings: the further in the past they have adjusted and the larger the demand realizations since they have last adjusted, the larger their inventory holdings are. As a firm's inventory holdings decrease, the larger is the probability that the firm will experience a demand disturbances sufficiently large that it will find it optimal to adjust. The adjustment hazard is thus increasing for firms with lower levels of inventories. As a firm's inventory values reach close to 1.5 periods worth of mean sales, the firm finds it optimal to pay the fixed cost and import with probability one in order to insure against the possibility of a large demand shock next period that will force it to stock out.

The ergodic density and adjustment hazards are qualitatively similar in the post-crisis steady state, as illustrated in the lower panel of the Figure. Now however the higher relative wholesale price of imports makes it optimal for importers to increase the price they charge for their goods and sell less. They now find it optimal to import only 40% of the import values of the pre-crisis steady state. Moreover, the adjustment hazard shifts to the left. As a result firms with inventory holdings that would render adjustment optimal in the pre-crisis steady state are now less likely to pay the fixed costs and import.

We are interested in characterizing the transition to the new post-crisis steady-state. Given the leftward shift of the hazard in Figure 17, one can expect that as a result of the change in the relative price of imported goods firms that would have otherwise imported will now find it optimal to postpone adjustment. As a result the fraction of goods imported will drop precipituously following the crisis as firms run down their now suboptimally high levels of inventories acquired prior to the crisis. Moreover, Figure 18 plots the optimal price rules in the post-crisis steady-state, relative to the price charged by a pre-crisis importer that has adjusted its inventory and does not stock out. The figure illustrates that importers do not find it optimal to pass-through the entire increase in their wholesale price to consumers. Rather, the irreversibility and depreciation of goods, combined with the lower discount factor, lead firms to lower markups in order to avoid storing and paying depreciation costs of the higher-than-optimal stock of inventories. For example, firms that have imported the period prior to the crisis find it optimal to raise prices by only 25% and only pass-through half of the wholesale price increases to the consumer. Thus our model can partly account for the failure of retail imported goods' prices to respond to the increase in the at-the-dock imported goods' prices after a large devaluation that BER (2005) document.

Figure 19 illustrates the response of import values, as well as the fraction of goods that are imported in the months preceeding and following the crisis. Both the value of imports, as well as the fraction of varieties imported drop sharply following the crisis as firms find themselves with suboptimally high inventories. As the inventory holdings run down, more and more firms find it optimal to pay the fixed costs and the fraction of importers gradually recovers to converge to its new steady-state 10 months after the crisis. Notice that following the devaluation increases the long-run fraction of imported varities. Given the higher discount rate, firms find it optimal to pay the fixed costs of importing more frequently in order to save on the depreciation costs. The value of imports gradually recovers as well and converges to a lower level following the crisis.

The right panel of Figure 19 performs our ealier decomposition of the drop in import values into an intensive and extensive margin. As the figure indicates, roughly 1/3 of the initial decline in imports is accounted for by a decrease in the mean value of imports of a firm that adjusts: the rest of the drop is driven by a drop in the fraction of importing firms. In fact, given that the increase in the relative price of imports is permanent in this exercise, firms that do import immediately after the crisis import the same levels as once the economy converges to its steady-state. Thus, the drop in the extensive margin of trade is permanent, and the initial overshooting and then reversion of the total value of trade is entirely due to fluctuations in the fraction of importers. As a result, the short-run elasticity of imports in this model is roughly -6.75, almost 4 times larger than the long-run elasticity of -1.8, which itself is larger than the consumer's demand elasticity (-1.5) because of the fact that the increase in the relative price of imports as well as rise in discount rate amplify the frictions importers are subject to.

Figure 20 illustrates the mean price importers charge as the economy converges to its steady state. As we have anticipated earlier, the surprise increase in the firm's inventory levels relative to expected sales forces firms to respond less than one-for-one to the increase in their wholesale price. The initial increase in the mean prices charged by firms is only 63% of its new-long run value. As firms's inventory holdings decrease, the average price in the economy converges to its new steady state. Notice also that the model predicts a long-run overshooting of prices. The higher wholesale price of imports squeezes the firm's profits and thus decreases the losses to a firm from a stockout. Firms are thus more willing to let their inventories decrease to values close to zero, stock-out more often and thus charge higher prices.

C. Additional experiments

Transitory relative price changes

We next study the response of the economy to a transitory increase in the wholesale price of imported goods. In most countries in our sample the relative price of imports to the domestic producer prices index has halved one year after the crisis. We thus model a devaluation as a 50% increase in ω that geometrically decays to its original level. In particular, we assume

$$\log(\omega_t/\omega_0) = \rho \log(\omega_{t-1}/\omega_0)$$

where $\omega_1/\omega_0 = 1.5$ is the increase in the wholesale price of imports immediately after the crisis. We choose ρ to ensure a half-life of 12 months. In addition, we again assume a permanent change in β to $0.7^{\frac{1}{12}}$.

As Figures 21 and 22 indicate, the economy with a transitory but persistent increase in the relative price of imports responds to the devaluation similarly to our original economy. Imports drop somewhat more as importers prefer to wait for the lower ω in future periods and postpone adjustment. As a result the short-run elasticity of substitution is somewhat higher: -7.5. Prices also evolve in a similar manner: firms are initially reluctant to raise prices one-for-one with the shock, and then overshoot the increase in ω because of the decrease in the discount factor.

Local factor content

We next consider an economy in which importers produce final output using labor l and imported materials m according to

$$y = l^a m^{1-\alpha}$$

In the Chilean data the share on labor is 25%; we thus set α equal to 0.25. The experiment we consider is again a one-time, permanent rise in ω and decrease in β of the same magnitudes as those in our benchmark experiment. Consistent with the evidence, we assume that local wages do not respond to the devaluation. Figures 23-24 illustrate the economy's transition to the new steady state. Our results are qualitatively similar. Prices no longer overshoot as the importer's marginal cost of producing the good rises less than ω. Similarly, the drop in trade volumes is smaller.

Higher elasticity experiment

Recall that typicall estimates of the Armington elasticity of substitution we have used above, $\theta = 1.5$, imply counterfactually high markups. We next perform a robustness experiment to check whether our results are robust to our choice of this substitution elasticity. In particular, we now assume that consumers have preferences

$$c = \left(h^{\frac{\theta-1}{\theta}} + \gamma m^{\frac{\theta-1}{\theta}}\right)^{\frac{\theta}{\theta-1}}$$

where m is a composite good made up of a continuum of varities of imports:

$$m = \left(\int_0^1 m_i^{\frac{\gamma-1}{\gamma}} di \right)^{\frac{\gamma}{\gamma-1}}$$

This choice of preferences allow us to maintain the empirically justified low Armington elasticity, by setting $\theta = 1.5$, but allows us to vary the markup importers charge. In particular, we choose $\gamma = 4,$ a number in the range of those estimated by Hummels (2001), Gallaway (2003), and Broda and Weinstein (2006), which corresponds to a frictionless markup of 33%. Given these preferences, consumers' demand for an importer's product is

$$m_i = \left(\frac{p_i}{P_m} \right)^{-\gamma} P_m^{-\theta}$$

When solving for the transition path to the new steady-state, we require consistency of firm decision rules with the path for P_m use to derive these decision rules. This economy features strategic complementarities in firm decision rules: the lower are the prices charged by a firm's competitors, the lower a firm's sales, and thus the larger the inventory-holding costs: thus firms find it optimal to lower their prices. It turns out that these complementarities are weak in the model as the firm's problem is dynamic and current P_m have less effect on the firm's decision rules than in a static economy. As a results, as Figure 25 illustrates, the response of this economy to a permanent rise in ω and drop in β is similar to that of our benchmark setup. Table 9 shows that the major difference between the economies with high and low markups is in the parameter values necessary to match the lumpiness of trade and inventory-to-purchase ratios in the data. The high elasticity economy requires more volatile demand shocks and lower fixed costs relative to the value of shipments as the economy with higher markups is one in which fixed costs per profits are smaller and firms are more willing to pay these fixed costs and import more frequently.

No change in discount factor

How important is our assumption that a devaluation is, in addition to a change in the relative price of imported goods, associated with the rise in the discount rate? We next consider the transition of our benchmark economy to a increase in ω only, by keeping the discount factor to its pre-crisis level. Notice in Figure 26 that this change has only a minor impact on the economy's transition to the new steady-state, suggesting that the relative price change is the more potent force in our benchmark model. The economy with higher discount factor converges to a steady-state with somewhat higher trade values and a smaller fraction of varieties imported in a given period, as firms are willing to hold larger inventories, import less frequently and charge somewhat lower prices.

Fixed costs vs. time-to-ship

What is the relative strength of the two frictions to international trade we emphasize in this paper? To understand their separate contributions in generating the large drop in import values after the devaluations, we solve the transition following a permanent rise in ω and drop in the discount factor in which all parameter values are set to their values in the benchmark economy, but in which the pre-crisis steady-state is solved for assuming no fixed costs of importing. Firms nevertheless find themselves holding non-trivial inventory levels in order to ensure against unexpected demand fluctuations. As Figure 27 illustrates, the key friction in our benchmark parametrization is indeed the lag between orders and delivery, rather than the fixed cost of international trade: the economy in which the fixed cost is set to zero exhibits virtually the same path for imports as the benchmark economy and converges to the new steady-state at roughly the same speed. This is not surprising, since firm in our economy would be willing lose 11% of the average shipment value as a result of the time-to-ship and high demand volatility, whereas fixed costs amount to 4.9% of a shipment's value[17].

These results do not suggest however that fixed costs of international trade are, on their own, in the absence of lags between ordering and delivery, incapable of generating large fluctuations in import values. To see this, we next perform an experiment in which we assume away lags between orders and delivery. In this experiment we keep the demand volatility of the benchmark calibration, but choose the size of the fixed costs in order to match the HH concentration ration in the data. As Table 8 indicates, this parametrization implies that firms hold smaller inventory/purchases ratios: 0.14 relative to 0.35 in the benchmark model. Moreover, as Table 9 shows, the fixed cost, relative to shipment values, is larger in this experiment. Ability to respond to large demand disturbances as these are realized makes the benefit of importing larger and subsequently fixed costs must be larger in order to prevent firms from ordering too frequently. Fig 28 shows that this economy indeed exhibits a smaller drop in real trade values following the devaluation. The drop in the initial period implies an elasticity of only -2.8 (relative to -6.7 in the Benchmark setup). The drop in the fraction of imported varieties is smaller, and accounts for only 40% of the drop in imports (relative to

[17]One might argue that setting $f = 0$ and leaving the other parameter values unchanged is not the relevant comparison as the new economy must be recalibrated to accord with the moments used in the original parametrization. Notice however that without fixed costs of international trade firms order each period and one can't match the lumpiness statistics in the data. Moreover, the average annual inventory/purchases ratio is now 0.30 (compared to the 0.35 in the benchmark economy), suggesting that the two economies do not differ much along this second dimension and that the main inventory-holding motive for firms in our benchmark economy is indeed insurance against unexpected demand disturbances.

2/3 in the Benchmark model)[18].

D. Evidence from devaluations

We have shown above that trade frictions of the type observed in the data, and in particular fixed costs of importing and lags in trade imply that the very short-run elasticity of a country's demand for imports is larger than the response in the longer run. We ask whether the data indeed support this prediction of the model. In other words we ask: is the drop in the volumes of imports following the devaluations larger than what can be accounted for by static substitution by consumers away from the more expensive foreign imports? Notice in Figures 5-10 that the relative price of imported goods to the producer price index increased by roughly 0.3 to 0.5 in all the countries in our sample, except for Russia, where the relative price change was around 1. In contrast, as Figures 11-16 indicated, the drop in imports from US was, at its peak, as large as -1.4 in Argentina, -0.8 in Brazil, -1.1 in Korea, -0.4 in Mexico, -.9 in Thailand, and -2.5 in Russia. Thus, with the exception of Mexico, the elasticity of these country's imports to the relative price changes was in the neighborhood of 2-3. This response is larger than that predicted by standard time-series estimates of elasticities of substitution for imports, that typically range from 0.5 to 1.5. These low substitution are not a characteristic of developed economies, for which these import demand equations are typically estimated. For a example, a regression of changes in relative price on changes in relative imports for countries in our sample prior to the crisis yields coefficients that are in all cases less than 1.5 in absolute value[19], and are, for several countries, very close to 0 or

[18] SHOULD WE PUT UP PICTURES FOR AIR VS. VESSEL IN THE DATA TO SHOW THAT FOR BOTH THERE IS LARGE DROP IN EXTENSIVE MARGIN?

[19] Levels regressions yield somewhat higher coefficients, but the two series do not appear to be cointegrated in ADF-type unit-root tests of the residuals in these regressions.

even positive. Thus, the drop in import values in these countries following the devaluation is larger than that predicted by substitution effects from relative price movements predicted by frictionless theory.

6. Conclusions

We have documented that trade flows, at the micro-economic level, are lumpy an infrequent; inventory-management problems faced by importers are more severe than those faced by firms that purchase material inputs domestically; and that a non-trivial component of international trade costs is independent of a shipment's size. We show that a parsimoniously parameterized $(S, s)-$ type economy successfully accounts for these features of the data. We then show that the model predicts that, in response to a large increase in the relative price of imported goods, an event that typically accompanies large devaluations, that import values and the number of distinct imported varieties drops sharply immediately following the shock, and as result, short-run import elasticities are substantially larger than long-run elasticities. The model also predicts that importers find optimal to reduce markups in response to the increase in the wholesale price of imports and thus partly rationalizes the slow increase in tradeable goods' prices following large devaluations. Our study of 6 current account reversals following large devaluation episodes in the last decade provide strong support for the model's predictions.

Table 1: Lumpiness Statistics of Disaggregate U.S. Exports to Different Destination Countries

	Argentina	Brazil	Korea	Mexico	Russia	Thailand
# of transactions (in months with trade)	2.3	3.6	4.8	32.7	2.7	3.2
fraction of months good exported	0.23	0.18	0.34	0.69	0.11	0.23
fraction of months in year good exported	0.45	0.58	0.70	0.91	0.43	0.55
Hirschman-Herfindahl index	0.42	0.37	0.26	0.16	0.45	0.37
fract. of ann. trade in top mo.	0.52	0.46	0.36	0.24	0.53	0.46
fract. of ann. trade in top 3 mos.	0.84	0.76	0.70	0.53	0.85	0.78
fract. of ann. trade in top 5 mos.	0.95	0.90	0.86	0.74	0.95	0.91

Table 2: Concentrations Across Months (Within Years) vs. Across Years (Within Months)

	Argentina	Brazil	Korea	Mexico	Russia	Thailand
Within Year, Across Month						
Hirschman-Herfindahl index	0.42	0.37	0.26	0.16	0.45	0.37
fract. of ann. trade in top mo.	0.52	0.46	0.36	0.24	0.53	0.46
fract. of ann. trade in top 3 mos.	0.84	0.76	0.70	0.53	0.85	0.78
fract. of ann. trade in top 5 mos.	0.95	0.90	0.86	0.74	0.95	0.91
Across Year, Within Month						
Hirschman-Herfindahl index	0.50	0.60	0.33	0.15	0.75	0.45
fract. of trade in top mo.	0.60	0.69	0.45	0.25	0.80	0.55
fract. of trade in top 3 mos.	0.96	0.99	0.87	0.54	1.00	0.95
fract. of trade in top 5 mos.	1.00	1.00	0.99	0.75	1.00	1.00
median years traded	8	5	9	14	4	7

Table 3: Lumpiness by End Use (Argentina)

Lumpiness Statistic	Overall	Food	Intermed. Goods	Capital Goods	Autos & Parts	Consumer Goods
fract. of mos. exported	0.23	0.12	0.28	0.20	0.36	0.27
fract. of mos. in year exported	0.45	0.33	0.45	0.36	0.68	0.45
Hirschman-Herfindahl index	0.42	0.53	0.40	0.52	0.35	0.41
fract. of ann. trade in top mo.	0.52	0.59	0.49	0.61	0.42	0.51
fract. of ann. trade in top 3 mos.	0.84	0.89	0.83	0.90	0.74	0.84
fract. of ann. trade in top 5 mos.	0.95	0.97	0.94	0.97	0.88	0.94
Fraction of Imports from U.S.	1.0	0.02	0.42	0.13	0.06	0.07

Notes: Lumpiness statistics reflect the country-specific, trade-weighted median good. Fractions of imports sum to only 0.70 across end uses shown. The remaining goods end uses were military (0.19), unclassified (0.10), and re-exports.

Table 4: Time and Monetary Costs of Importing

Country	Number of Days	Import Cost*	U.S. Export Cost	Median Shipment Value from the U.S.	Total Costs as a Fraction Median Shipment	Median Shipment Value from the U.S.	Total Costs as a Fraction of Mean Shipment
Argentina	19	$1,500	$625	$12,400	0.17	$37,500	0.06
Brazil	23	$945	$625	$13,900	0.11	$63,000	0.02
Korea	11	$440	$625	$14,700	0.07	$89,300	0.01
Mexico	23	$595	$625	$10,900	0.11	$39,700	0.03
Russia	33	$937	$625	$21,000	0.07	$85,510	0.02
Thailand	20	$903	$625	$12,000	0.13	$46,147	0.03
Mean					0.11		0.03

Notes: Import and Export Costs are U.S. dollar costs for 2006. Average shipment values are for 2004. Costs include all costs accrued between the contractual agreement and the delivery of goods, excluding international shipping costs, tariffs, and inland transportation costs. Russian import costs exclude port/terminal handling fees.
Source: World Bank (2007), http://www.doingbusiness.org/ExploreTopics/TradingAcrossBorders/

Table 5: Imports and Inventories of Chilean Manufacturers (1990 to 1996)

		Obs.	Importers
Total		34967	0.239

		Import content		Inventory			Materials Inventory			Finished Inventory		
		Importers	Total	Non	Importers	Total	Non	Importers	Total	Non	Importers	Total
Unweighted	mean	0.345	0.082	0.249	0.335	0.269	0.197	0.253	0.210	0.052	0.087	0.060
	std dev	0.286	0.203	0.823	0.368	0.741	0.788	0.324	0.706	0.162	0.438	0.257
Weighted	mean	0.299	0.178	0.178	0.243	0.217	0.129	0.174	0.156	0.049	0.069	0.061
	std dev	0.281	0.262	0.510	0.227	0.370	0.483	0.177	0.337	0.112	0.096	0.103

Table 6: Regression Results of Inventory Holdings on import content (t-stats below)

	Unweighted		Weighted		Robust		Fixed	
	s_{im}	c	s_{im}	c	s_{im}	c	s_{im}	c
Inventory	0.213	0.252	0.168	0.187	0.253	0.147	0.109	0.260
	10.9	59.0	22.5	78.7	59.4	157.5	5.2	61.6
Materials inventory	0.155	0.198	0.130	0.133	0.184	0.101	0.073	0.204
	8.3	48.6	19.1	61.3	59.5	149.3	3.6	50.3
Finished inventory	0.058	0.054	0.038	0.054	0.044	0.011	0.037	0.056
	14.5	61.7	18.2	81.3	67.2	79.6	8.9	66.7
Finished inventory controlling for ln employment	0.186	0.179	0.172	0.229	0.204	0.037	0.108	0.258
	9.2	11.8	22.8	23.3	48.4	11.7	5.0	15.9

Weighted results are by total sales; Robust uses Robust Regression algorithm to control for outliers, Fixed includes industry fixed effects

Table 9: Model Parameters

	Benchmark	High elasticity
Calibrated		
fixed costs, relative to mean shipment, f	0.049	0.025
std. dev. of demand, σ	1.21	1.70
Assigned		
Period length	1 month	1 month
Elasticity of demand for imports, θ	1.5	1.5
Elasticity of subs. across imported goods	-	4
Discount factor, β	$0.94^{1/12}$	$0.94^{1/12}$
Depreciation rate, δ	0.025	0.025

Table 8: Moments in model and data

	Data	Benchmark	High elasticity	No lag
Used for calibration				
Herfindhal-Hirschmann ratio	0.44	0.45	0.45	0.44
Inventory to annual purchases ratio	0.36	0.35	0.35	0.24*
Other moments				
Fraction of months good is imported	0.44	0.21	0.22	0.14
Fraction of annual trade accounted by top month	0.53	0.48	0.48	0.49
Fraction of annual trade accounted by top 3 months	0.85	0.98	0.96	0.97
Fraction of annual trade accounted by top 5 months	0.95	1.00	1.00	1.00
Value of avoiding 30-day lag (per shipment)	12%-24%	11%	13%	N/A
Fixed cost per shipment, %	3%-11%	4.90%	2.53%	7.96%

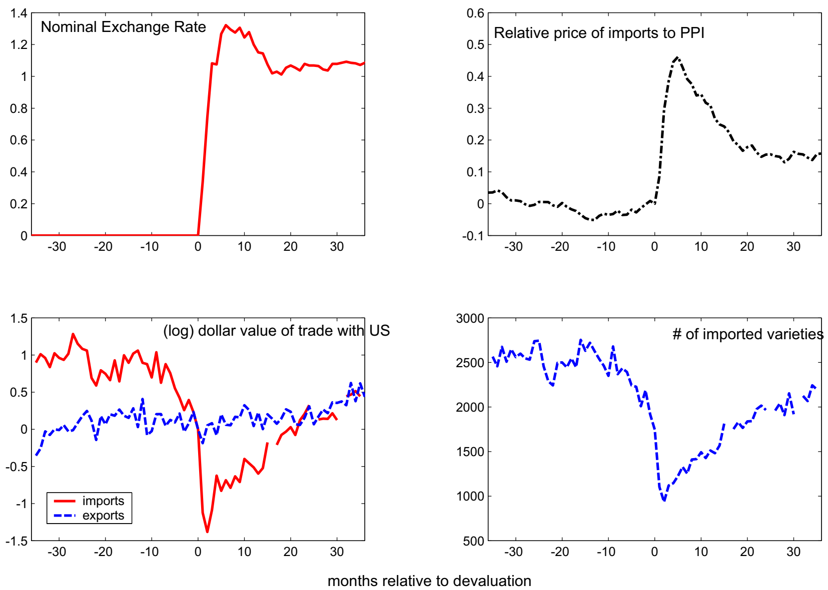
* Indicates that this moment was not used for calibration

Table 9: Model Parameters

	Benchmark	High elasticity	No lag
Calibrated			
fixed costs, relative to mean shipment, f	0.049	0.025	0.079
std. dev. of demand, σ	1.1	1.70	1.1*
Assigned			
Period length	1 month	1 month	1 month
Elasticity of demand for imports, θ	1.5	1.5	1.5
Elasticity of subs. across imported goods	-	4	-
Discount factor, β	$0.94^{1/12}$	$0.94^{1/12}$	$0.94^{1/12}$
Depreciation rate, δ	0.025	0.025	0.025

* Indicates assigned parameter

Figure 0: Argentina January 2002 devaluation



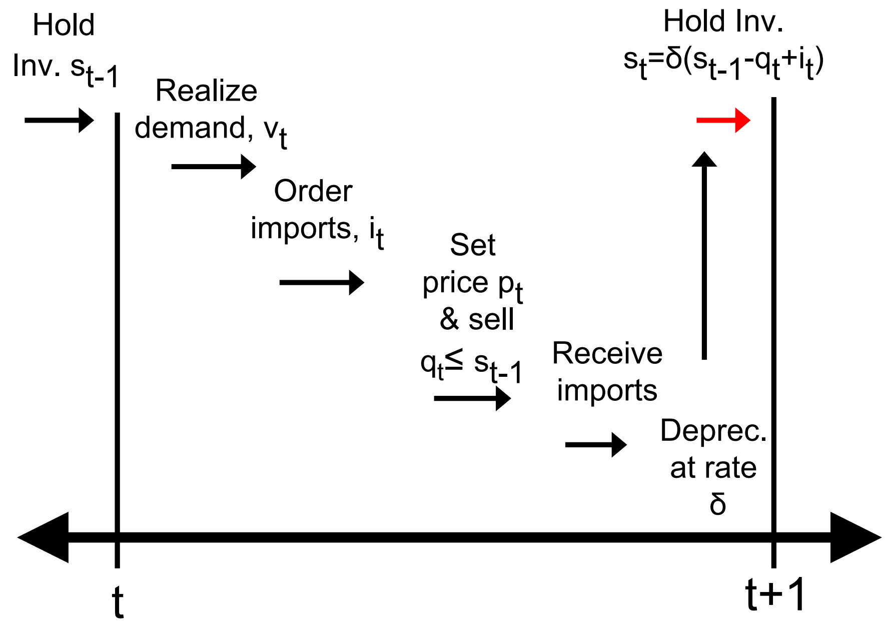


Figure 2: value functions

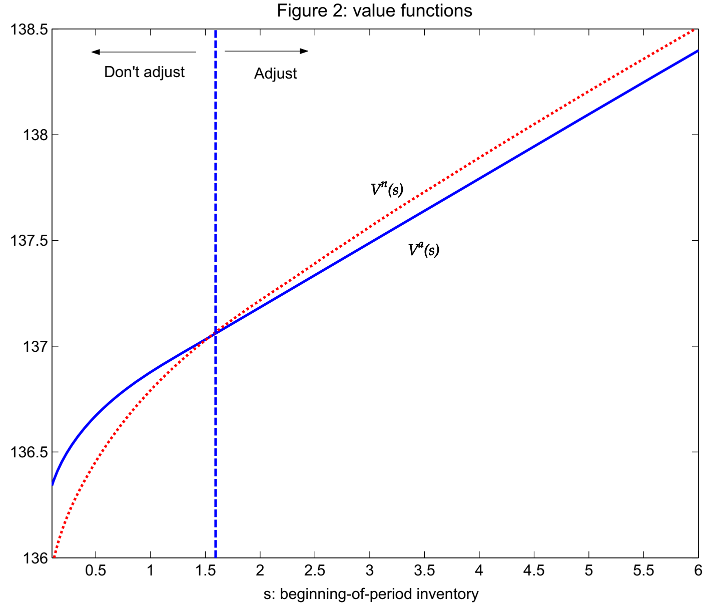


Figure 3: price functions

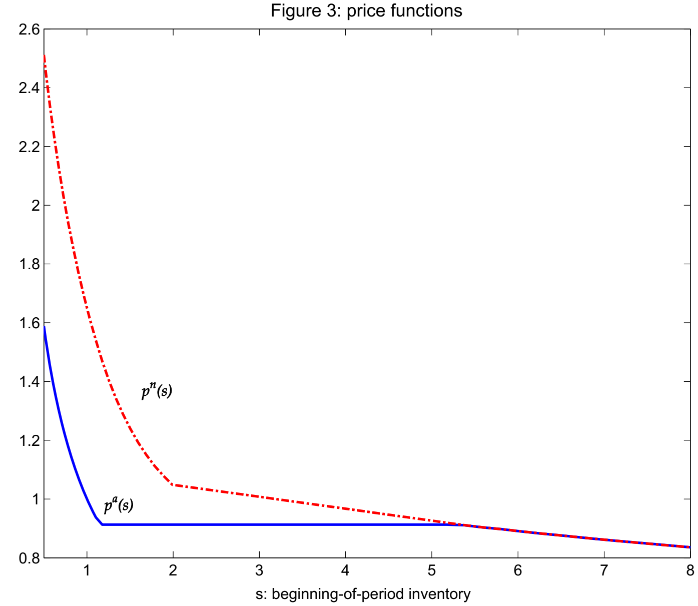


Figure 4: imports conditional on adjustment

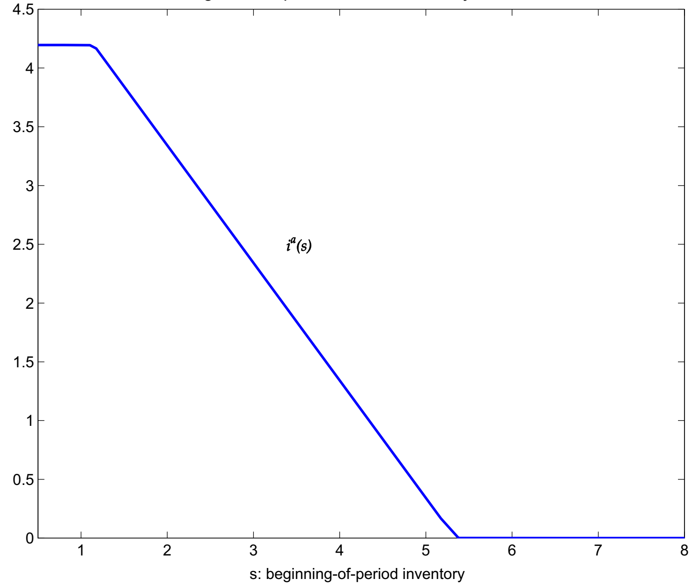


Figure 5: Argentina, January 2002

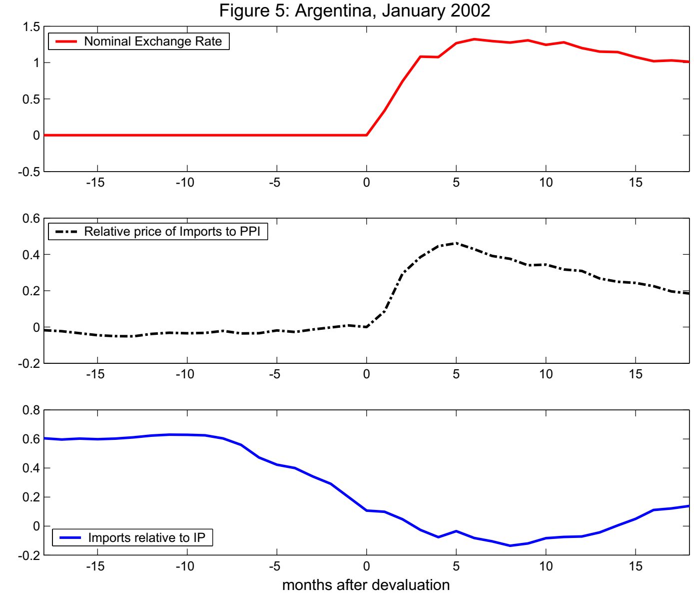


Figure 6: Brazil, January 1999

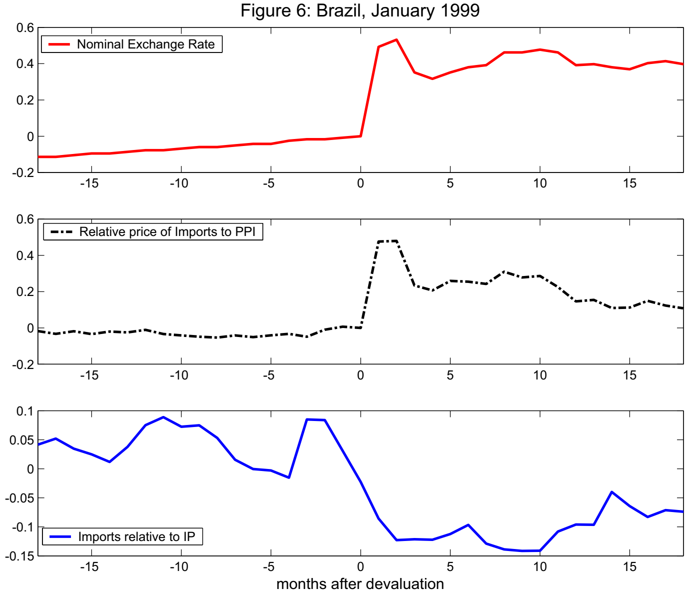


Figure 7: Korea, October 1997

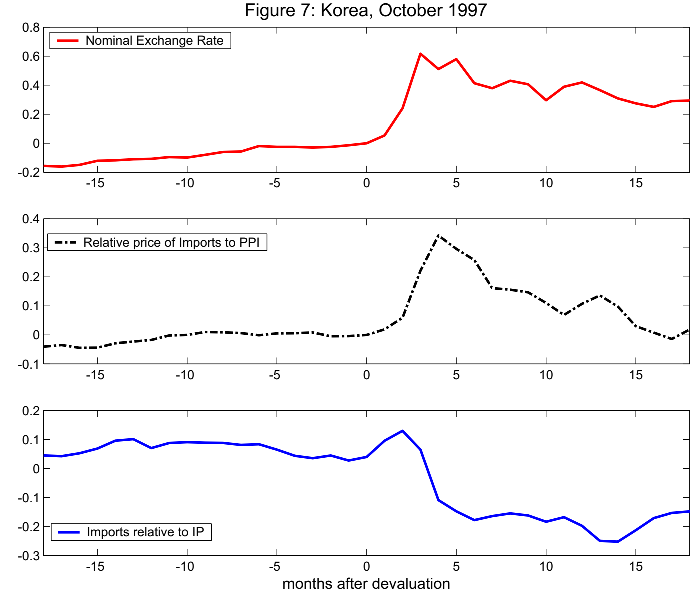


Figure 8: Mexico, December 1994

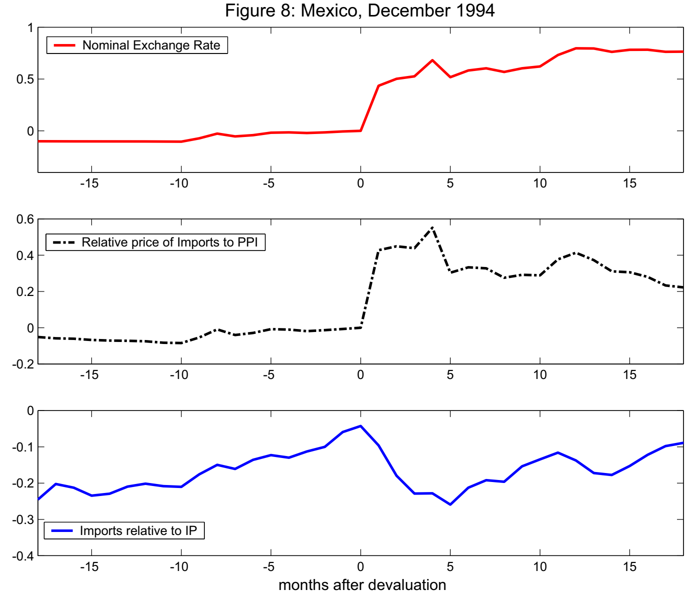


Figure 9: Thailand, July 1997

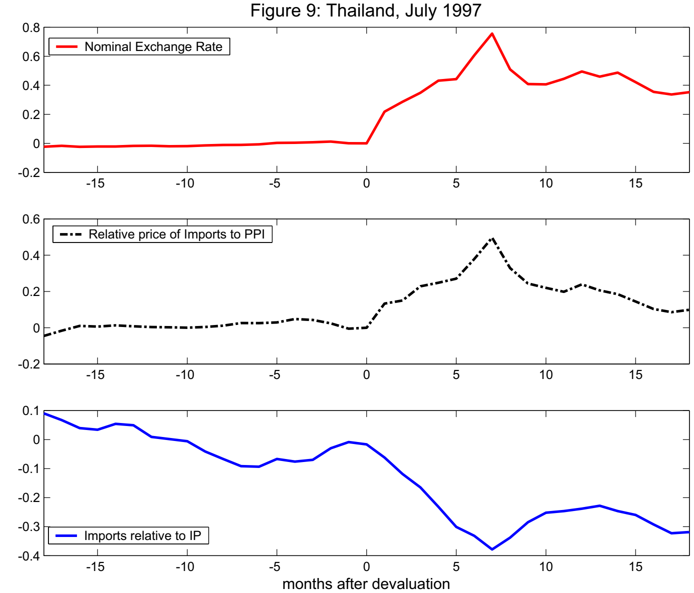


Figure 10: Russia, August 1998

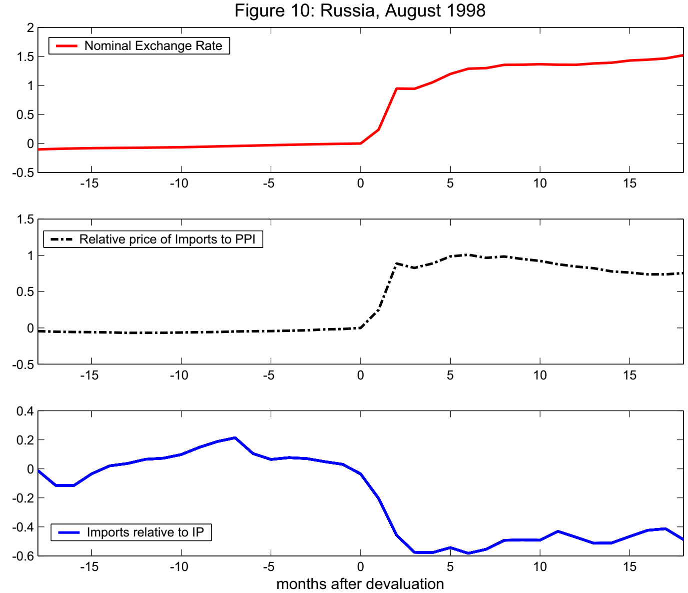


Figure 11: Argentina: imports from US

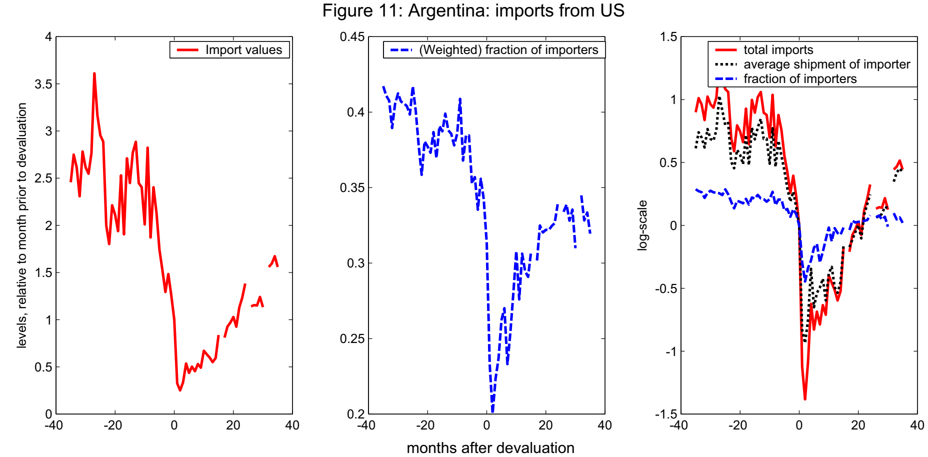


Figure 12: Brazil: Imports from US

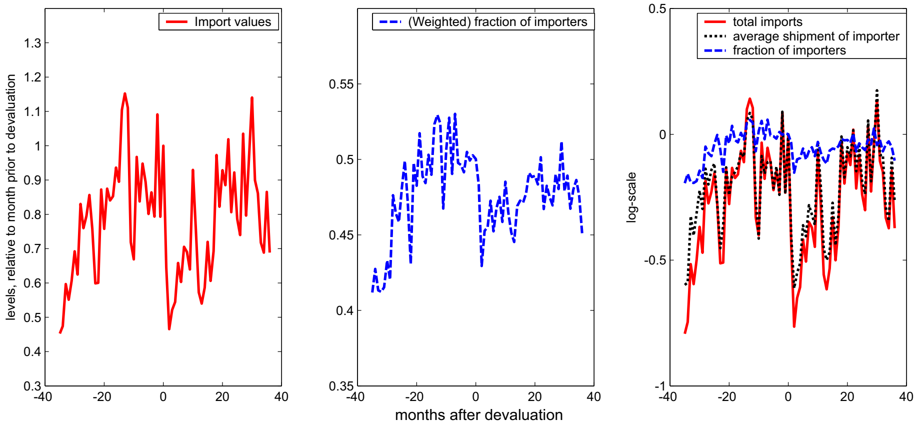


Figure 13: Korea: imports from US

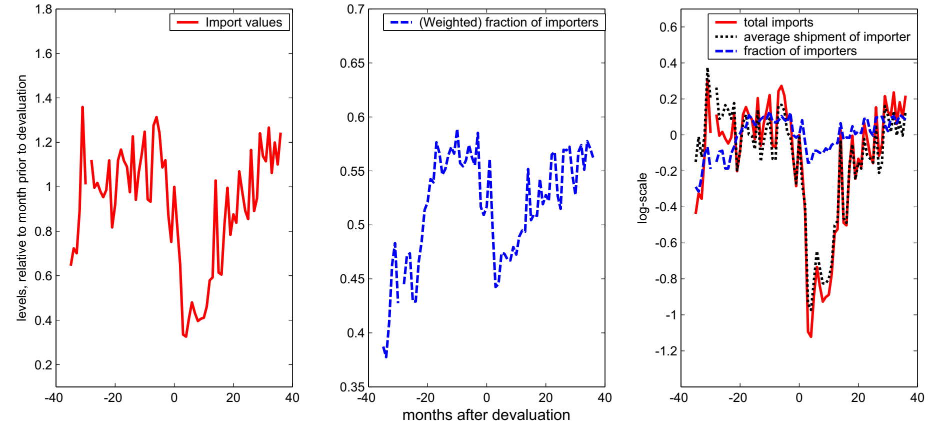


Figure 14: Mexico: imports from US

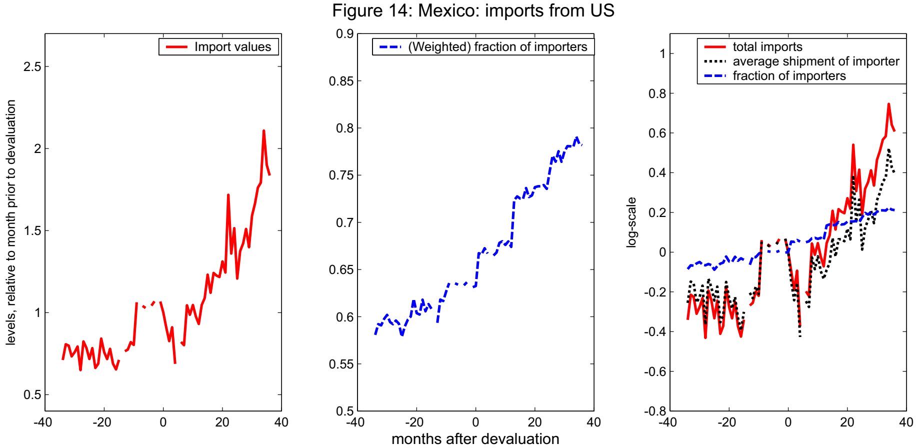


Figure 15: Thailand: imports from US

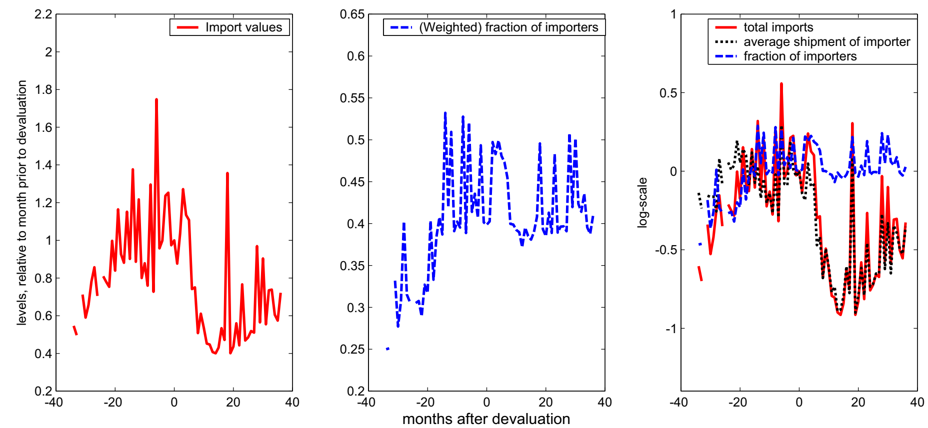


Figure 16: Russia: imports from US

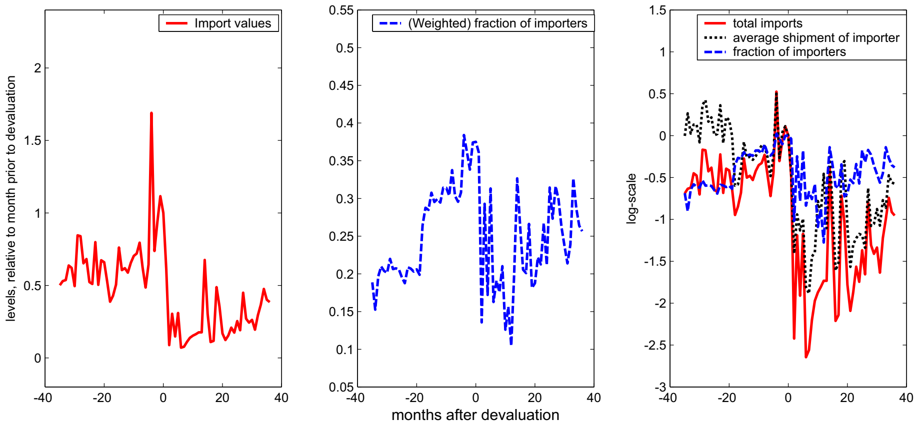


Figure 17: Ergodic density of inventory holdings and adjustment hazard

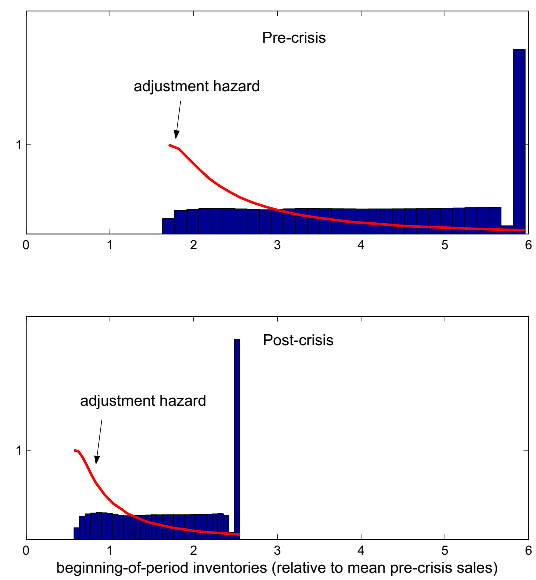


Figure 18: price functions post-crisis

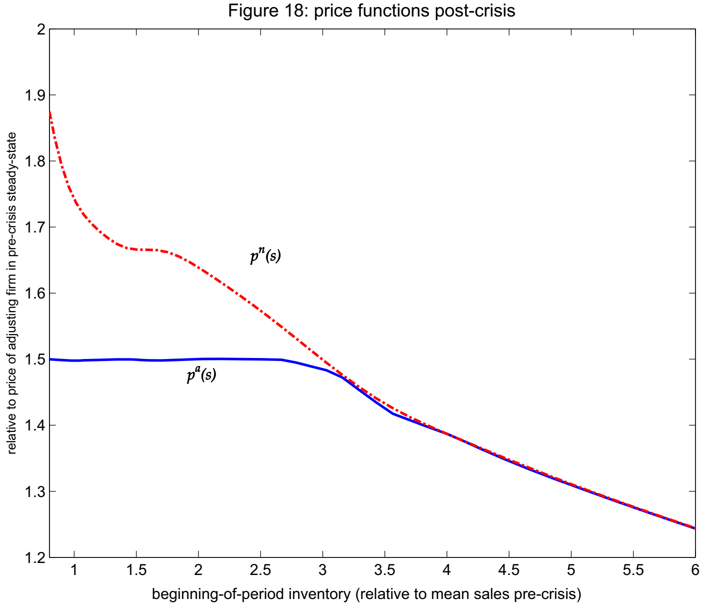


Figure 18: price functions post-crisis

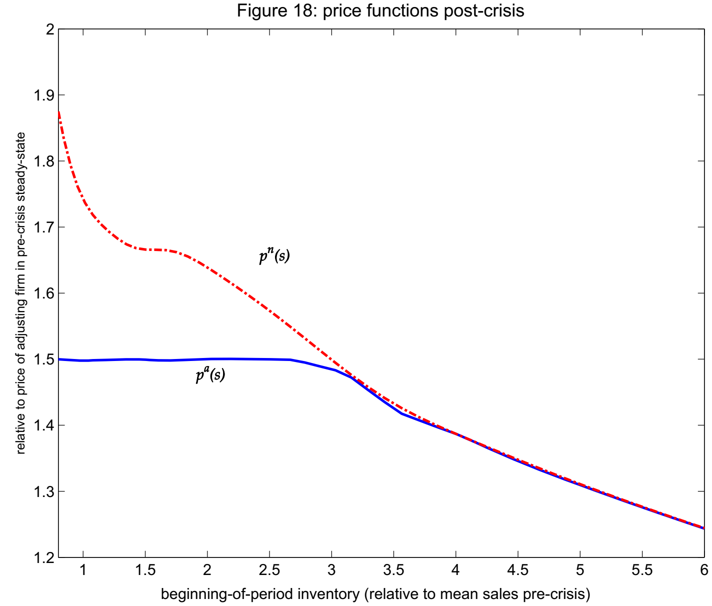


Figure 19: Response of model economy to large devaluation, benchmark experiment

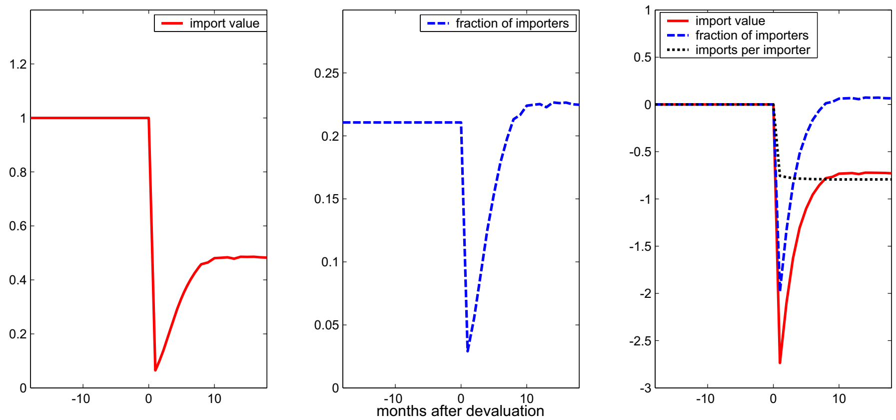


Figure 20: Mean price charged by importers

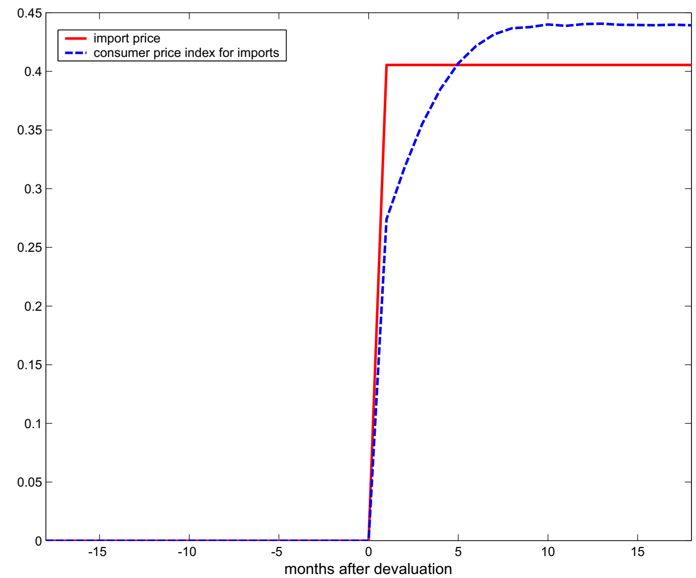


Figure 21: Response of model economy to transitory increase in relative price of imports

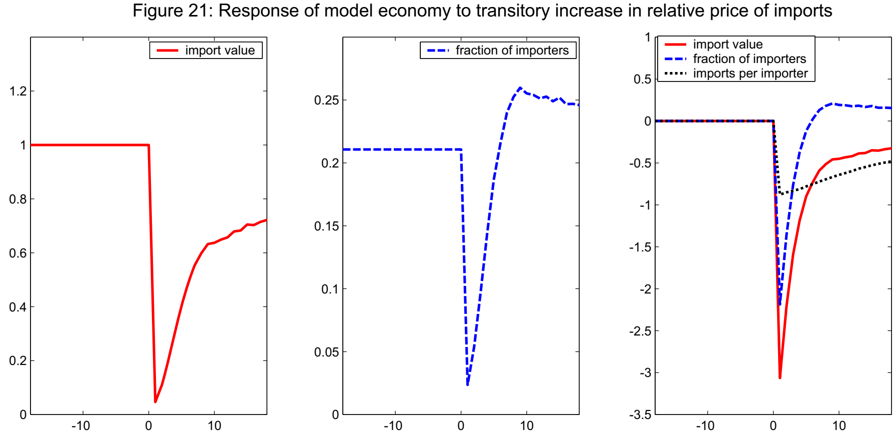


Figure 22: Mean price charged by importers, transitory ω shock

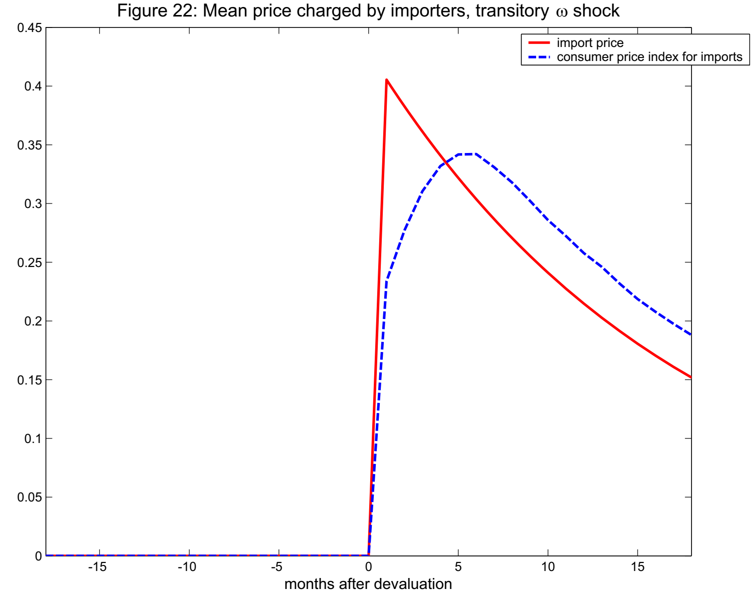


Figure 23: response to large devaluation, local factor content

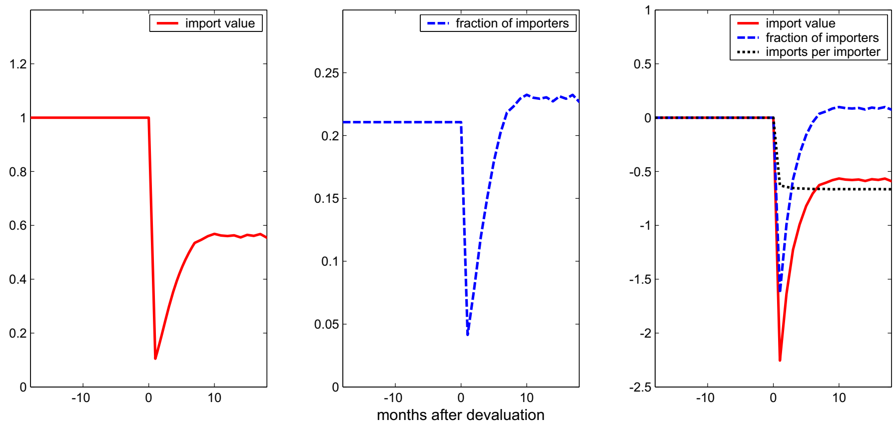


Figure 24: mean price of importers, local wages

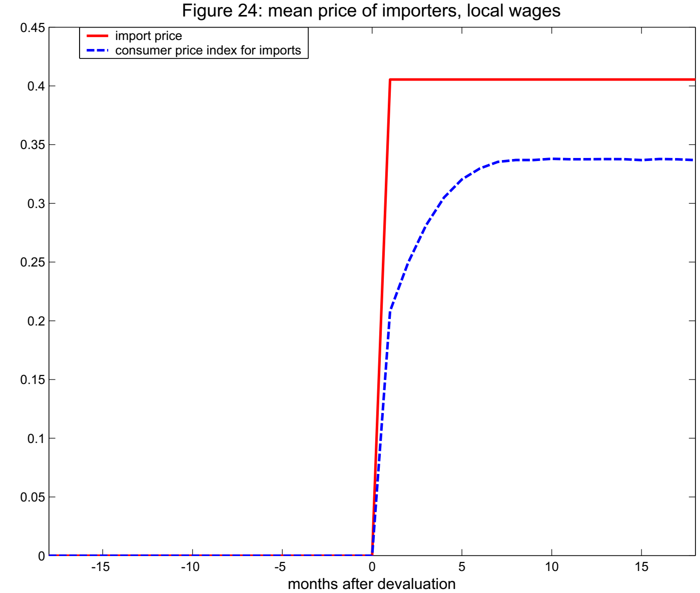


Figure 25: Response of model economy to large devaluation, high elasticity experiment

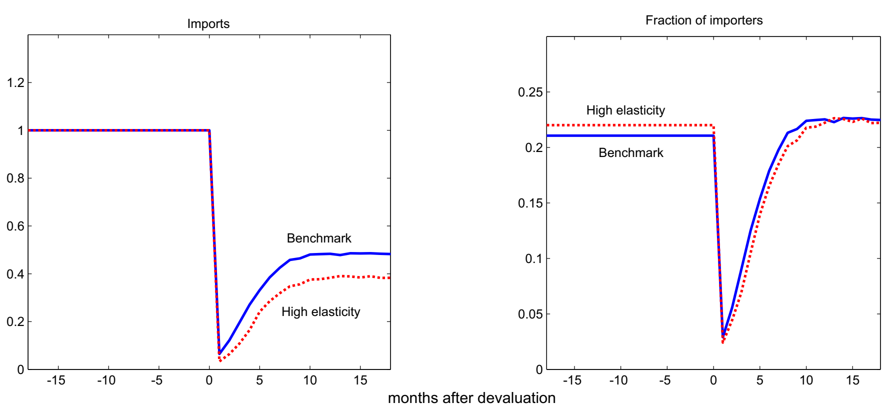


Figure 26: No change in discount factor

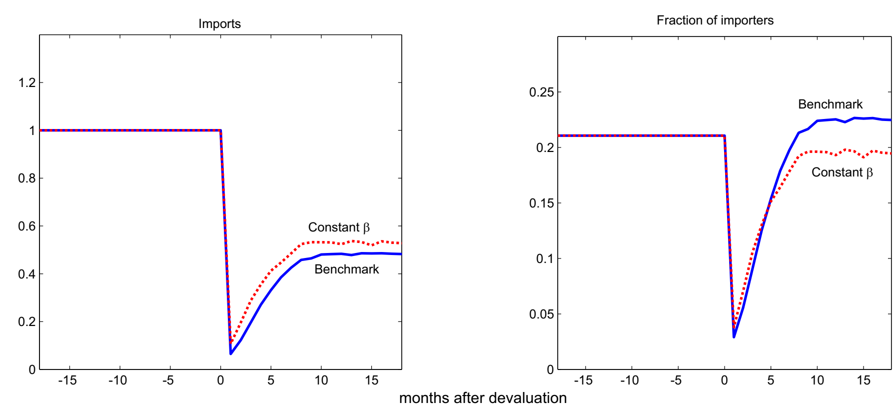


Figure 27: No fixed cost economy

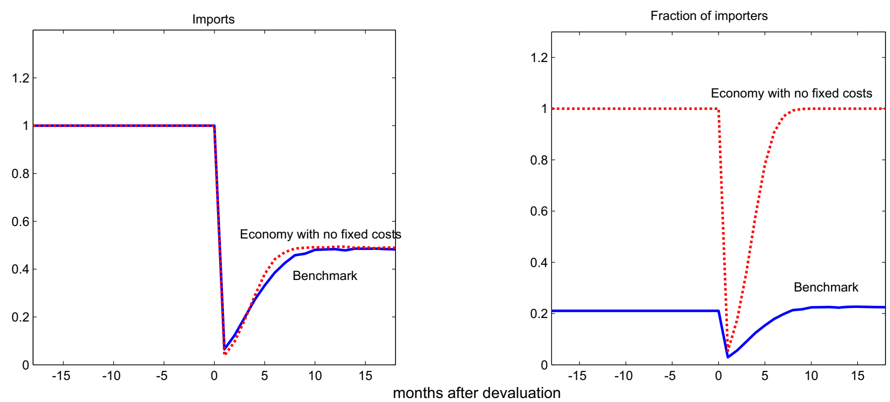


Figure 28: No lag economy

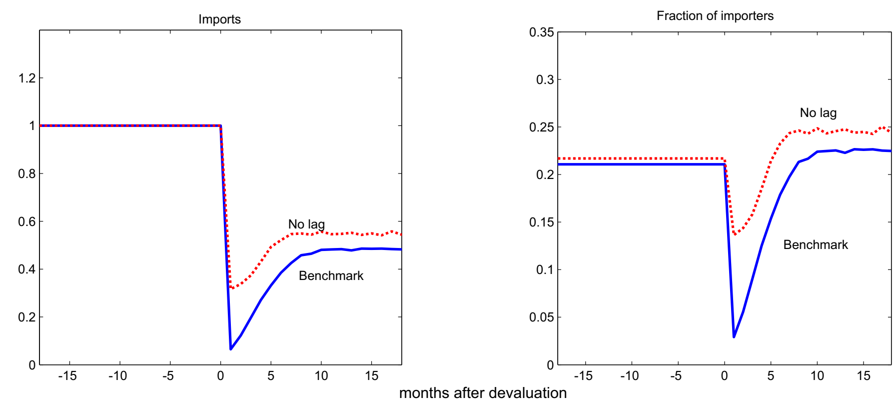


Figure 28: No lag economy