NBER WORKING PAPER SERIES

INVENTORIES, LUMPY TRADE, AND LARGE DEVALUATIONS

George Alessandria
Joseph Kaboski
Virgiliu Midrigan

Working Paper 13790
http://www.nber.org/papers/w13790

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
February 2008

The views expressed here are those of the authors and do not necessarily reflect the views of the Federal Reserve Bank of Philadelphia, the Federal Reserve System or the National Bureau of Economic Research. We thank Don Davis, Timothy Kehoe, and Sylvain Leduc for helpful comments. We thank seminar participants at Cowles Foundation, Penn State, Wisconsin, Central European University, the Federal Reserve Banks of Chicago, Minneapolis, New York and Philadelphia; and the 2007 ASSA and SED Meetings.

Inventories, Lumpy Trade, and Large Devaluations
George Alessandria, Joseph Kaboski, and Virgiliu Midrigan
NBER Working Paper No. 13790
February 2008
JEL No. E31,F12

ABSTRACT

Fixed transaction costs and delivery lags are important costs of international trade. These costs lead firms to import infrequently and hold substantially larger inventories of imported goods than domestic goods. Using multiple sources of data, we document these facts. We then show that a parsimoniously parameterized model economy with importers facing an (S, s)-type inventory management problem successfully accounts for these features of the data. Moreover, the model can account for import and import price dynamics in the aftermath of large devaluations. In particular, desired inventory adjustment in response to a sudden, large increase in the relative price of imported goods creates a short-term trade implosion, an immediate, temporary drop in the value and number of distinct varieties imported, as well as a slow increase in the retail price of imported goods. Our study of 6 current account reversals following large devaluation episodes in the last decade provide strong support for the model's predictions.

George Alessandria
Research Department
Federal Reserve Bank of Philadelphia
Ten Independence
Philadelphia, PA 19106
George.Alessandria@phil.frb.org

Virgiliu Midrigan
Department of Economics
New York University
19 W. 4th St.
New York, NY, 10012
virgiliu.midrigan@nyu.edu

Joseph Kaboski
The Ohio State University
410 Arps Hall
1945 North High Street
Columbus, OH 43210
kaboski.1@osu.edu

1. Introduction

The costs of international trade are large, especially in developing countries.[1] Given its simplicity, iceberg depreciation has been the usual approach to modelling these costs, but understanding trade flows requires a deeper understanding of the nature of frictions involved in international trade. The particular microstructure of trade frictions has implications for whether and which trade costs are policy-mutable, how trade patterns and trade costs change over time, and what the gains to trade are (e.g., Ruhl, 2005, Chaney, 2007, Alessandria and Choi, 2007b). This paper documents two important frictions faced by firms participating in international trade; models their effect on inventory management; and quantitatively evaluates the role they play in accounting for the behavior of prices and trade flows in episodes of large current account reversals.

The two micro-frictions we highlight are time lags between the order and delivery of goods and fixed costs of transacting. These frictions manifest themselves as trade costs not only directly (the time cost/depreciation of lags and the cost of transacting), but also indirectly since they lead firms facing uncertain demand to carry larger, costlier inventories.

There is substantial direct evidence of non-trivial time lags between the order and delivery of goods in international trade, as documented forcefully by Hummels (2001). For instance, delivery times from Europe to the US Midwest are 2-3 weeks, those to the Middle East as much as 6 weeks. Given demand uncertainty and depreciation of goods, these lags are non-trivial. Hummels estimates that an additional 30-day lag between orders and delivery acts as a 12 to 24 percent 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 slow the flow of goods across borders. 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 import licences, customs declaration forms, bills of lading, commercial invoices, technical and health certificates, tax certificates and other

[1] Anderson and van Wincoop (2002) provide an excellent review of the evidence.

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

certificates required to engage in international transactions.[3]

Many bureaucratic procedures are transaction costs that are independent of a shipment's size, and indeed the fixed component of the overall cost of international transactions is also non-trivial. According to the World Bank report mentioned above, 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). We document in this paper that these, and other fixed costs of international trade, amount to 3 to 11 percent of a shipment's value. Given that most goods transacted across borders are storable, these fixed costs make it optimal for importers to engage in international transactions infrequently and hold substantial inventories of imported goods.

Indeed, we provide direct evidence that participants in international trade face more severe inventory management problems. First, using a large panel of Chilean manufacturing plants, we find that importing firms have inventory ratios that are roughly twice those of firms that only purchase raw materials domestically. Second, we show that inventory behavior is different for imported and domestic materials even within the same firm. Using detailed data on the purchasing history of a US steel manufacturer from Hall and Rust (2000, 2002, 2003), we document that the typical international order tends to be about 50 percent larger and half as frequent as the typical domestic order.

We finally document that trade flows, at the micro-economic level, are lumpy and infrequent. This is again evidence of the frictions and inventory problems we highlight. Using monthly data on the universe of all US exports for goods in narrowly defined categories (10-digit Harmonized System code) 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

[3] In related work, delivery lags and the demand for timeliness have been shown to have important implications for gravity equation trade flows (Djankov et al., 2007), location/sourcing decisions (Evans and Harrigan, 2005) and provide a structural interpretation of distributed lags in import demand equations (Kollintzas and Husted, 1984). Delivery lags have also been studied in business cycle models by Backus, Kehoe and Kydland (1994) and Mazzenga and Ravn (2004).

HS-10 category. Moreover, annual trade is highly concentrated in a few months. The bulk of trade (85 percent) is accounted for by only three months of the year; the top month of the year accounts for 50 percent of that year's trade on average. The infrequency, randomness, and high concentration of these trade flows in a few months of the year reflect the importance of fixed transaction costs, uncertainty, and inventory concerns in international trade.

A natural question is whether micro-level lumpiness and micro-trade frictions are quantitatively important for aggregate behavior, and the answer is yes. These frictions and the inventories they lead to have important impacts on short-run responses of trade flows and pricing to economic shocks.[4] We focus on large, unanticipated terms of trade shocks associated with the large devaluations experienced in recent years by developing economies. These are large, easily identifiable shocks that are economically important and exhibit a number of common trade-related patterns. Thus, they are ideal candidates for studying the role of the frictions we emphasize.

Figure 1 summarizes three salient features of these devaluation episodes that we address. First, as documented by Burstein, Eichenbaum and Rebelo (2005), following the currency depreciation there is a gradual and smaller increase in the price of imported goods at the retail level, despite the larger and more immediate increase in the at-the-dock (wholesale) price of imported goods, as measured by the import price index. Second, imports collapse while exports rise only gradually with the decline in imports quite large relative to the change in relative prices, particularly in the short run.[5] Third, the number of goods imported (the extensive margin, here measured by distinct HS-10 codes from the US) contracts and recovers only gradually. These features of devaluations are inconsistent with models with iceberg trade costs, as the change in trade is governed solely by the change in relative prices: relatively small short-run price responses should result in relatively small trade responses.

[4] The role of non-convexities of inventory adjustment over the business cycle has been studied in partial (Caplin 1985, Caballero and Engel 1991) and general equilibrium environments (Fisher and Hornstein 2000, Khan and Thomas 2007a). Unlike these papers, which focus on relatively small shocks in a closed economy, our emphasis is on large aggregate shocks in an open economy.

[5] In these developing countries the relatively large, short-run trade response is the opposite of the small, short-run J-curve type trade response (Magee 1973) observed in more industrialized countries.

We argue in this paper that these three features of emerging market devaluations are an outcome of the inventory-management problem faced by firms participating in international transactions, a problem that becomes even more severe during times of large, unanticipated shocks. To this end, we formulate and calibrate an industry model of importers that face lags between orders and delivery, uncertain demand, fixed costs of importing, and irreversibility. We show that the parsimoniously parameterized model economy can well account for the range of micro-economic facts we document. We then show that the model predicts that in response to an unanticipated devaluation, associated with an increase in the wholesale price of imports, i) importers reduce retail markups, thereby incompletely passing through the wholesale price increase to consumers, ii) imports collapse and they do so in large part because of a iii) large drop in extensive margin: the number of varieties imported.

In the model, the quantitatively important aspect of a devaluation is the large increase in the relative (wholesale) price of imported to domestically produced goods.[6] Given the higher post-devaluation market price of imports, the importer's original holdings of inventories are higher than optimally desired. As a result, the fraction of importers (the extensive margin) drops immediately following the devaluation. The fall in the extensive margin, as well as smaller desired inventories from those who do import (the intensive margin), compounds the effect of the relative price change on a country's import values, causing a short-lived trade implosion.

The response of prices in the model is also novel. The inventory frictions we emphasize make it optimal for the firm's retail price to decrease with its current inventory holdings. Higher inventories reduce the shadow valuation of an additional unit of inventories because they 1) lower the probability of a stockout, 2) postpone the payment of the fixed cost, and 3) increase the likelihood that the current inventory stock will be carried over into the next period, thereby increasing the inventory carrying costs. As a result, the higher than optimally desired inventory holdings immediately after the devaluation make it optimal for importers to keep prices low until they gradually work off their relatively high level of inventories and return to the import market.

[6] Changes in interest rates and consumption have a smaller, secondary role.

Inventory adjustment frictions break the tight link between the replacement cost (wholesale price), which increases immediately upon impact, and the shadow value of the goods in inventory which increases only gradually.

Our model thus suggests that the sharp drop in import values and the extensive margin of trade that characterize the recent devaluation episodes is invariably linked to the failure of retail prices to respond to the large increase in the (at-the-dock) wholesale price of imports documented by Burstein, Eichenbaum and Rebelo (2005). The trade frictions we emphasize thus provide a new channel for the observed slow adjustment of retail prices to changes in international relative prices, a pervasive empirical regularity in the literature.[7] In contrast to explanations that emphasize price adjustment frictions (which break the link between desired and actual markups), or local costs[8] (which argue that an important component of the marginal cost of selling a good to the consumer is unaffected by the terms-of-trade shock), we emphasize quantity adjustment frictions that break the link between a good's replacement cost and its marginal valuation.[9] We view our mechanism as complementary to these alternative ones.

This paper is related to two other lines of research. First, a number of papers attribute an important role to fixed costs in accounting for the pattern of trade. This literature largely focuses on the large, fixed costs that firms incur in starting or continuing to export (see, for example Baldwin, 1988, Roberts and Tybout, 1997, Melitz, 2003, and Das, Roberts and Tybout, 2007).[10] These fixed costs are important in explaining export participation by plants as well as the dynamics of trade over the business cycle (Ghironi and Melitz, 2006, and Alessandria and Choi, 2007a) or following trade reforms (Ruhl, 2005). In an influential paper, Baldwin and Krugman (1989) show that fixed costs are central to explaining the gradual current account reversal following the large depreciation of the dollar in the mid-1980s. A key finding in this

[7] Goldberg and Knetter (1997) provide a thorough summary of exchange rate pass-through.

[8] See for instance Corsetti and Dedola (2003) and Campa and Goldberg, 2006.

[9] In related work, Goldberg and Hellerstein (2007) use a structural model of the retail and wholesale beer industry to decompose incomplete exchange rate pass-through into non-traded costs, price adjustment frictions and markup adjustments. Our mechanism for markup adjustment, which is complementary to theirs, has potential implications for such micro-level studies of pass-through in that we stress an intimate link between import quantities/shipments and prices at the micro-level.

[10] Eaton and Kortum (2005) also study the extensive margin of trade but in a framework without fixed costs.

literature is that, with costs of exporting, in the short run, trade responds less to shocks than in the long run. The type of trade costs we study, fixed ordering costs and delivery lags, combined with the storability of goods, leads to the opposite result: short run trade responses are much larger than long run responses. Second, our focus on business cycles in emerging markets is similar to Neumeyer and Perri (2005) and Aguiar and Gopinath (2007). However, unlike these studies, which abstract from relative price movements, we focus on trade and relative price dynamics in the aftermath of large devaluations.

2. Data

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

A. Direct Evidence on Frictions

An important characteristic of international trade is 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)[11]. 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.[12] They include document preparation, customs clearing/technical control, and port/terminal handling faced by both the exporting and importing country.[13]

Table 1 summarizes the costs faced for different countries. The first column shows that time

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

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

[13] 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.

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.[14] These costs exclude inland transportation on both sides (typically two days in the US and two days in the destination country), and shipping times are on the order of a couple of weeks for boats, which is the most common shipping form in the US export data for all but Mexico. Thus, a typical 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 US dollars for 2006, and we view most costs as predominantly fixed costs per transaction. Importing costs are roughly $500 for Mexico and Korea, $1,000 for Brazil, Russia, and Thailand, and $1,500 for Argentina, while US export costs are an additional $625.[15] The median shipments in 2004 from the US 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. US import data (the counterpart of the export data) contain freight charges for similar sized shipments. These data indicate that freight costs between the US and these countries range from $500 (South Korea) to $1000 (Argentina and Brazil), with Mexico being the one exception ($100) presumably because of the prevalence of trucking and its proximity to the US. Freight costs contain a substantial fixed cost component, driven in part by containerized shipping technology that greatly increases the per unit costs of shipping less than a full container.

B. Importer Inventory Management

We argue that the fixed costs and time lags documented above lead to larger inventory ratios and lumpier adjustment of imported goods relative to domestic goods. We document this using two micro data sets: one multi-plant data set from a developing country (Chile) that allows

[14] 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.

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

us to see how inventory behavior varies with the importance of imported goods, and a more detailed data set from a single firm (a US steel importer) that shows that inventory behavior for imports and domestic purchases differs even within the same firm.

Chilean plant-level evidence

The data set covers 7 years (1990 to 1996) and includes 7,234 unique manufacturing plants and 34,990 observations. The data is from the Chilean industrial survey conducted by the Chilean National Statistics Institute and have been used elsewhere (see Hsieh and Parker, 2008). The plant-level data are well suited for our purposes, since Chile is at a comparable level of economic development to the countries that experienced devaluations, and so are likely to be similar to data from 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 $\overline{I}^m_{jt} = (I^m_{jt+1} + I^m_{jt})/2$. 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 ratios, 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 2 reports some summary statistics from this panel of manufacturing plants for the whole period for our three different measures of inventory holdings.[16] We report both simple and annual sales-weighted averages. For the sake of brevity, we discuss only the sales-weighted averages. On average, the typical manufacturing plant holds approximately 21.7 percent of its annual purchases in inventories. Among non-importers, the typical plant holds 17.8 percent of

[16] 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.

its annual purchases in inventories, while the typical importer holds 24.3 percent and imports account for 29.9 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 2 it is clear 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,

$$(1) \quad i_{jt} = c + \alpha * s_{jt}^{im} + e_{jt}$$

we find a strong positive relation between import content and inventory holdings. In a range of specifications reported in Table 3, moving from complete domestic sourcing to complete international sourcing is associated with an increase in inventory holdings of between 85 to 170 percent. Based on the sales-weighted linear regression, in the Chilean data an establishment that sources completely domestically will hold 18.7 percent of its annual needs in inventories while a complete international sourcer will hold 35.5 percent. Converting these to monthly numbers, we can infer that plants tend to have 2.2 months of domestic inputs on hand and 4.3 months of imported goods on hand.

Import Transactions at a US Steel Wholesaler

We now focus on a single wholesaler that purchases both domestically and internationally. The data are from a US steel wholesaler from 1997 to 2006 and are unique in that they are transaction-level data.[17] We confirm that shipments are larger and less frequent for international purchases than domestic purchases. Over this period, this firm purchased 3,573 different types of goods divided between 12,472 domestic purchases and 5,632 international purchases.[18] We

[17] For a summary of the data see Hall and Rust (2000). We thank George Hall and John Rust for providing these data.

[18] We only know whether deliveries are domestic or foreign and have no additional information on the geographic origin.

find that for the typical product, international orders tend to be about 50 percent larger and occur nearly half as frequently as domestic orders.

For each good j delivered on date t either from the US or overseas, $k \in \{D, F\}$, we have data on the value, v_{jt}^k, quantity, q_{jt}^k, (either units or weight) and price, p_{jt}^k, of the transaction. Panel B of Table 4 presents the results of separate regressions of quantity, price, and amount on good and year fixed effects and a dummy for the foreign order

$$\ln x_{jt}^k = c_t + c_j + c_k.$$

Clearly, imported orders are larger in value and quantity and are cheaper. In Panel C we report the results of a regression of the amount imported on

$$\ln q_{jt}^k = c_t + c_j + c_k + \alpha \ln p_{jt}^k$$

We find an elasticity of demand of $\hat{\alpha} = -2.1$ and an order size premium of 48 percent (in logs).

Panel D reports the mean and median interval between orders of each good. To compute these intervals, let D_j^k denote the number of days between the date of the first and last order of good j and let N_j^k denote the number of transactions in this interval.[19] Let $d_j^k = D_j^k / \left(N_j^k - 1\right)$ denote the mean duration between orders of good j from source country k. From panel D, we see that domestic goods are purchased every 100 days, while the foreign goods are purchased every 204.5 days.

C. Lumpiness of International Transactions

To what extent do the lumpy international transactions of a particular US steel importer reflect importing behavior generally?

We document findings of lumpy transactions for a broad range of disaggregate imported goods (over 10,000 goods defined by their 10-digit Harmonized System codes and exiting district)

[19] This measure understates the typical interval since goods with long durations will be censored.

using monthly data on US exports. The data are comprehensive of US merchandise exports from January 1990 to April 2005, and include monthly totals of exported quantity, value, and number of individual transactions by destination country and exiting customs district. We focus on exports to six importing countries: Argentina (2002), Brazil (1999), South Korea (1997), Mexico (1994), Russia (1998), and Thailand (1997). Each of these six countries experienced a large devaluation and so is of particular interest to our quantitative exercise.

Table 5 presents lumpiness statistics for the (trade-weighted) median good of each of the six countries.[20] Ideally, we would like to capture the extent of lumpiness in the purchases of a single importer and a single product. 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.[21] We view these data as likely aggregating the shipments of multiple importers or multiple products, and so they understate the lumpiness of any individual importer's purchases of a single product. 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 (Russia) to 0.69 (Mexico) but may overstate lumpiness, since some goods move in and out of the sample. The third 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).

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 concen-

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

[21] Mexico is also unique in that much of trade is transported by ground rather than by sea or air.

tration 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 from 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 from 0.26 to 0.45. If all trade were equally distributed across months, these numbers would translate into roughly two to four shipments per year.

Finally, the last three rows constitute 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 Mexico), while the top three 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, as Table 6 shows. The top half of the table reproduces the HH index and fraction of trade numbers from Table 5, 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.[22] 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 there 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.

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

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

and the Herfindahl-Hirschman index is computed: $\widetilde{HH}_i = \sum_{j=1990}^{2004} \tilde{s}_{i,j}^2$

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 7 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 is 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 monthly data contain multiple transactions that likely reflect multiple purchasers. Thus, the frictions documented earlier seem to manifest themselves in lumpy international transactions and larger inventory holdings.

3. Model

Here we consider the partial equilibrium[23] problem of a monopolistically competitive importer that faces fixed costs of importing a storable foreign good, a one-period lag between the ordering and delivery of goods, and uncertain demand. We start by characterizing the importer's optimal decision rules in an environment in which the only source of uncertainty is demand shocks for its product.[24] We then assume a continuum of importers that are otherwise identical except for their different histories of preference shocks, and we aggregate their decision rules in order

[23]Understanding the source of the large devaluation and terms of trade movement is beyond the scope of this paper. Our focus is solely on the propogation of this relative price change. General equilibrium models that attribute these relative price movements to productivity, demand or interest rate shocks have proven to be unsuccessful at generating large real exchange rate movements and hence we remain silent about the source of the shock. Similar to Mendoza (1995), we treat the terms of trade as exogenous.

[24]There are many ways to put heterogeneity into the model that will help to capture the large and infrequent orders we observe in the data. Our approach is to have idiosyncratic demand shocks. An alternative approach would be to have idiosyncratric shocks to the cost of ordering (as in Khan and Thomas, 2007a) or idiosyncratic shocks to productivity (as in Alessandria and Choi, 2007a) or uncertainty in the delivery process.

to characterize the ergodic distribution of importer-level inventory holdings. Finally, we characterize the transition dynamics in response to an unanticipated change in the relative price of imported to domestically produced goods, considering both permanent and temporary changes.

Formally, we consider a small open economy inhabited by a large number of identical, infinitely lived importers, indexed by j. In each period t, each 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 let $\nu_j(\eta^t)$ 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:[25]

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

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 (i.e., independent of the quantity imported) cost of importing every period in which it imports. Consistent with the absence of any scale effects in inventory holdings among Chilean plants, we follow Cooper and Haltiwanger (2006) and assume that this adjustment cost is an "opportunity cost," that is, proportional to the firm's revenue. The firm that imports loses a fraction, $(1 - \lambda)$, of its revenue, $p_j(\eta^t) q_j(\eta^t)$, where q is quantity sold by the firm.[26],[27]

Given that the imported good is storable, the firm will find it optimal to import infrequently

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

[26] Assuming a fixed cost that is independent of how much the firm sells would increase the relative importance of adjustment costs the firm faces after an increase in the relative price of imports, ω, (and thus a decline in revenues), and amplify the effect of the shock (by lowering trade volumes, the fraction of importing firms, and raising prices importers charge), without affecting results qualitatively. These alternative results are available from the authors upon request.

[27] The assumption that fixed costs are proportional to measures of firm activity has often been used in earlier work, especially in environments in which shocks have permanent effects, since it is needed to ensure stationarity of decision rules. See, e.g., Danziger (1999) and Gertler and Leahy (2007).

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 adjustment cost $(1-\lambda)p_j(\eta^t)q_j(\eta^t)$ and import $i_j(\eta^t) > 0$ new units 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.[28]

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

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

The amount the importer orders today, $i_j(\eta^t)$, cannot be used for sales until 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 warehouse, $s_j(\eta^t) - q_j(\eta^t)$. Figure 2 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

[28] A justification for this assumption is that one-time re-exports may be prohibitively expensive. In addition to any fixed transaction costs, firms are likely to face large costs involved with exporting as emphasized by Roberts and Tybout (1997). Introducing a fixed cost of returning the good along with a iceberg shipping costs would lead to an upper threshold substantially above the typical ordering point.

firm's problem is:

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

where

$$
\begin{aligned}
q(p,s,v) &= \min(e^v p^{-\theta}, s) \\
s' &= \begin{cases} (1-\delta)\left[s - q(p,s,v) + i\right] & \text{if adjust} \\ (1-\delta)\left[s - q(p,s,v)\right] & \text{if don't adjust} \end{cases}
\end{aligned}
$$

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

A. Optimal Policy Rules

We next characterize the optimal decision rules for the firm's problem.[29] In particular, we characterize $\{p^a(s,\nu), p^n(s,\nu)\}$ 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.

Figure 3 depicts the inaction and adjustment regions in the (s,v) space, together with the optimal level of inventory holdings, s', conditional on firm adjusting. Inventory numbers are normalized relative to mean sales in this economy. The figure shows that all firms that decide to import will start next period with inventories that are roughly 7 periods worth of average sales, regardless of their current state. Notice that the optimal import level satisfies $\omega = \beta(1-\delta)EV_s(s',v')$, and, given the iid nature of demand shocks, s' is independent of the current state of the firm. The figure also shows that the cutoff inventory level that makes a firm indifferent between importing and not decreases in the firm's demand level, v. Firms with high

[29] We solve this problem numerically, using spline polynomial approximations to approximate the two 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.

v face large adjustment costs as their revenue is higher: they therefore adjust only when current inventories hit a sufficiently low level.

We next turn to the optimal pricing of the firm.[30] Notice that when current inventory holdings do not constrain current sales, the optimal price the firm charges is generally proportional to the firm's marginal valuation of an additional unit of inventories (which will, in this economy with inventory frictions, differ from the replacement cost ω). If the firm adjusts its inventory holding it charges

$$p = \frac{\theta}{\theta - 1}\frac{1}{\lambda}\beta(1-\delta)EV_s(s', v'),$$

and if it does not, it charges

$$p = \frac{\theta}{\theta - 1}\beta(1-\delta)EV_s(s', v').$$

In turn, the marginal value of inventories, V_s, decreases with the current stock of inventories. Ultimately, the value of the marginal unit of inventory is realized when the firm next adjusts inventory. At that time, it is either valued at ω, since it reduces needed inventory purchases, or it is sold in a stock-out situation, in which case it has a higher valuation. High inventory levels lower the probability that the marginal unit will be needed in a stock-out situation, and, in expectation, it shifts the next adjustment date into the future. Higher expected discounting and depreciation costs lower its expected value. Hence, both the marginal valuation and the price are falling in the stock of inventories.

Figure 4 illustrates the firm's price functions, in the s space. Clearly, the decision of whether to order new inventories affects next period's beginning of period inventories and thus the marginal valuation of an additional unit of inventory. This marginal valuation is reflected in the firm's price. Consider first the $p^a(s, \nu)$ schedule, the firm's price, conditional on importing.

[30] Aguirregabiria (1999) and Hall and Rust (2000) also study the optimal markup decisions in economies with inventory adjustment frictions but without lags.

Again, we suppress 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, because two firms that adjust today start with the same level of inventories next period, they will also charge identical prices. Thus, the firm's beginning-of-period inventories next period, and thus its shadow valuation of current-period inventories, $\beta(1-\delta)EV_s(s',\nu')$, and its price are all independent of s.

Finally, when s is sufficiently high (such that next period's inventories are above the return point in Figure 3), the firm has more inventory than it would find optimal to hold given the size of its fixed costs and the rate at which the goods depreciate, δ. In this region, every additional unit of inventories increases the likelihood that this inventory will not be exhausted for one additional period, and therefore increases the carrying cost of inventories. The firm therefore lowers its price to increase its sales and lowers this inventory carrying cost.

We next turn to the firm's pricing function conditional on adjusting its stock of inventories, $p^n(s,\nu)$. As Figure 4 illustrates, this price is decreasing in the firm's level of inventories for the entire region of the parameter space and converges to $\lambda p^a(s,\nu)$ whenever s is sufficiently high and $EV_s(s',v')$ is equal for firms that adjust and those that do not. Firms that do not adjust value an additional unit of inventory because it lowers the probability of a stockout, as well as the expected time until the next adjustment, which lowers the adjustment costs. 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.

To conclude, our economy is characterized by the familiar (S,s) adjustment rules for inventories whereas firms import every time their inventory stock drops beyond a threshold that depends on current demand conditions. Moreover, firm prices in general decrease in the firm's current stock of inventories.

4. Model Parameterization

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 percent 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 non-interest inventory carrying costs range[31] from 19 to 43 percent of a firm's inventories, which imply monthly carrying costs ranging from 1.5 to 3.5 percent.[32]. We thus choose $\delta = 0.025$, in the mid-range of these estimates. Given that Gausch and Kogan (2001) find that inventory costs in developing countries are about three times higher than in the US, we also consider an alternate, high depreciation rate parameterization.

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, which, in turn, reflects the low elasticities of substitution between imported and domestic goods estimated using time-series data. Given that in our model the substitution elasticity is also tightly linked to the firms' markups, we break this link between the Armington elasticity for imports and firm markups in a robustness check below.

[31] These include taxes, warehousing, physical handling, obsolescence, pilfering, insurance, and clerical controls.
[32] See, e.g., Richardson (1995).

Two other parameters, λ, the adjustment cost, and σ^2, the volatility of demand shocks are jointly chosen in order for the model to accord with two features of the microdata. The first target is the lumpiness of trade flows documented in the microdata. Recall that the trade-weighted median HH indexes 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. Second, consistent with the Chilean data, we target an annual inventory-to-purchases ratio of 36 percent.[33]

In addition to the two parameters above, we compare several additional "over-identifying" moments in the model and the data. Hummels (2001) provides the following calculation that may be useful in assessing our choice of demand volatility. 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 percent of the shipment's value. In our model, the one-period lag is costly for two reasons. First, a proportion δ of the shipment is assumed to depreciate in transit. More important, importers that face more uncertain demand will find it optimal to have higher holdings of inventory in order to ensure they have sufficient inventory 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 one-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.

[33] Our model abstracts from finished-good inventories so we include both materials and finished-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 particular, the problem of a firm in an environment with no time-to-ship is characterized by

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

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 firms' values, conditional on adjustment, relative to the expected present value of an importer's imports in our original setup, $\frac{\hat{V}^a - V^a}{E\sum_{t=0}^{\infty}\beta^t \omega i_t}$ 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 percent in the data. Finally, we also report the fraction of months an importer pays the fixed costs and imports, as well as the fraction of one year's trade accounted for by the top month and the top three months.

The upper panel of Table 8 reports the moments we ask the model to match, as well as the additional moments, in the model and in the data. The lower panel of Table 8 reports the choice of parameter values that we use. Notice, in the lower panel, that we require demand shocks with a standard deviation of $\sigma = 1.1$ 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. This number should not be interpreted literally, since given our calibration strategy and parsimonious setup, it reflects additional sources of uncertainty (productivity shocks, as well as shocks to the cost or lags in delivering goods) that lead importers to hold the high levels of inventory observed in the data. For example, Burstein and Hellwig (2007) find that a standard deviation of demand shocks equal to 0.21-0.30 is necessary to account for the joint comovement of prices and quantities in grocery stores, a number much smaller than our estimate of demand volatility. This suggests that other sources of uncertainty are necessary in order to account for the large inventory holdings observed in the Chilean data and is consistent with the findings of Khan and Thomas (2007b) that stockout-avoidance motives for inventory holdings are difficult to reconcile with the large inventory holdings observed in the data.

The fixed cost of importing amounts to $1 - \lambda = 0.14$ in our calibration: the firm loses 14 percent of its current revenues every time it adjusts. Turning to the upper panel of 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 50 percent of the year's value of trade in the model (53 percent in the data). The average cost of importing, expressed relative to the value of the average shipment, is 4.4 percent and thus is in the range of the fixed costs we have directly measured in the data. Moreover, the thought experiment in Hummels (2001) suggests that the volatility of demand shocks is not excessively large in our model. Importers under our calibration are willing to pay 4.3 percent of their average shipment value in order to avoid a one-period delay, a number that is much lower than similar measures reported by Hummels (12 to 24 percent).[34]

5. Results

Before we describe the numerical experiments we perform on our model, we briefly show that the salient features of the terms of trade and trade flows observed in Argentina's devaluation are also present in the devaluations in Brazil (January 1999), Korea (October 1997), Mexico (December 1994), Russia (August 1998), and Thailand (July 1997).

[34] This low number in part reflects the fact that an additional cost of demand uncertainty (uncertainty in the size of the adjustment cost the firm faces that leads firms to hold higher inventories) is not eliminated here when we eliminate the lag in shipment. In the earlier version of this paper with a fixed cost independent of importer revenue, the corresponding Hummels statistics was 11 percent.

A. Salient Features of Large Devaluations

The first column of Figure 5 plots the change in the terms of trade, measured as the ratio of the import price to the domestic PPI. In logs, the peak change ranges from about 31 percent in Korea to nearly 100 percent in Russia, with the peak generally within the first few months of the initial devaluation. In all countries, the terms of trade remains elevated after 15 months.

The second column of charts plots the change in the real value of imports from the US and in total. All countries experience a large and fairly rapid decline in both import measures immediately following the devaluation.[35] While US trade flows are generally more volatile than total imports, US trade tracks total imports quite well. Focusing on imports from the US provides two distinct advantages. First, it allows us to study high-frequency changes in trade flows at a very disaggregate level. Hence we can measure both the extensive and intensive margins of trade. Second, because trade is measured at the US dock, we can measure the immediate response of trade shipments rather than deliveries, which are more subject to delivery lags.[36]

The third column of charts plots two measures of the dynamics of the extensive margin. The first measure is the number of distinct HS-10 varieties imported from the US The second, more disaggregate, measure is a count of the number of transactions. In all countries, both measures of the extensive margin follow a pattern similar to real imports, with the peak decline ranging from 50 to 100 percent of the overall decline in trade volume.

Table 9 shows that alternate measures of changes in the extensive margin that weight goods by their importance in trade are consistent with the simple counts reported in Figure 5. For each country and each measure, we report the share of the drop in the US import volume accounted for by the change in the extensive margin.[37] The top panel reports the role of the

[35] Thailand's trade and price dynamics are a bit more gradual. This is in part due to the two major devaluation episodes in a six-month period.

[36] In the 6 years around the large devaluations, changes in US exports to a destination are positively correlated with changes in imports in that country for all but Thailand. For Argentina, Russia, and Thailand, US exports tend to slightly lead changes in total imports.

[37] To remove the changes in imports from NAFTA from the Mexican data, we weight Mexican goods by their pre-NAFTA (pre 1994) trade flows in all experiments. As evident from comparing methods 2 and 3, weighting either based on trade in the pre-devaluation period or the whole sample has a very minor impact on our measures

extensive margin in the month in which imports bottom out, while the bottom panel reports the average role of the extensive margin in a 3-month window around this month. For each weighting/filtering method, we report a measure of changes in the number of transactions and the number of goods imported. In all cases, the transaction-based measures attribute a more important role to the extensive margin. On average, focusing on the bottom panel, the data shows that the extensive margin accounts for about two-thirds of the decline in peak trade flows.

In addition to the salient features documented in Figure 5 and Table 9, Burstein et al. (2005) persuasively show that each nominal exchange rate devaluation in these countries is also associated with a rapid and almost one-for-one increase in the country's local currency import price index, but a slower rise in the domestic price of importables.

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 Figure 5 illustrated, the countries in our sample experience an average increase in the relative price of imported goods of about 50 percent that only gradually reverts over time. We thus start by modeling a devaluation as an unanticipated,[38] permanent increase in ω by this amount.[39]

Figure 6 illustrates the ergodic distribution of firm inventory holdings, as well as the adjustment hazards, in the pre- and post-devaluation 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

of the extensive margin for the other 5 countries.

[38] While interest rates tend to rise prior to crises, the increases tend to be small relative to the subsequent depreciation, suggesting from uncovered interest parity that a large part of the devaluation is unanticipated.

[39] Our approach follows the tradition in the small open-economy literature of taking changes in relative prices and later interest rates as exogenous. We then work out the implications of these changes in relative prices holding all else equal.

the previous period have the same level of inventories, roughly 6.5 periods of mean sales. They account for roughly 22 percent of all firms in the distribution. The rest of the firms are those that have adjusted in previous periods: the further in the past they have adjusted and the larger the demand realizations, the smaller their inventory holdings are. As a firm's inventory holdings decrease, there is an increased probability that the firm will experience a demand disturbance 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 one period's worth of mean sales, the firm finds it optimal to pay the fixed cost and import with probability one.

The qualitative shapes of the ergodic density and adjustment hazards are virtually identical. 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 lower imports by $-\theta\Delta\omega$ (in logs) relative to the pre-crisis steady state. Prices and quantities change proportionally given that the fixed cost is proportional to revenues. 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 6, 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 precipitously following the crisis as firms run down their now higher-than-desired levels of inventories acquired prior to the crisis. This drop in the extensive margin of trade will last until firms exhaust their higher-than-desired levels of inventories and the economy converges from the pre- to the post-devaluation steady state.

The optimal price functions that were illustrated in Figure 4 also shift to the left by a factor of $1.5^{-\theta}$ and up by 1.5 as a result of the change in the relative price of imports. As a result, given the downward sloping price-inventory schedule in this economy and the high initial inventory holdings during the transition, firms will not pass-through the increase in the wholesale price of imports fully to consumers, thus lowering their markups.

The left panel of Figure 7 illustrates the response of prices in our model economy (the response in the benchmark economy discussed above is illustrated using a solid line). Notice that on impact the retail price of imports (the consumption-weighted average price of imported goods) rises slower than the wholesale price of imports: the pass-through immediately after the change in relative prices is only 75 percent. As firms exhaust their inventory holdings, they find it optimal to raise prices and the economy converges to the new steady state. The central insight here is that even without price adjustment costs, sources of strategic complementarities or local factor content, firms will choose to pass-through changes in international relative prices less than one-for-one to consumers, since their optimal prices are proportional to their marginal valuation of inventories, which, in times of crisis, may differ substantially from the replacement cost of inventories.

The middle panel of Figure 7 illustrates the response of import volumes. The higher relative price of imports leads initially to a trade implosion: a drop in import values that is 4 times larger than the change in the relative price, much larger than the $\theta = 1.5$ drop that a frictionless economy would generate. As the right panel of Figure 7 shows, this large initial drop in imports is to a large extent accounted for by a sharp drop in the extensive margin of trade: the fraction of importing firms drops to 40 percent of its steady state value (close to -1 in logs). Thus the extensive margin accounts for roughly 2/3 (-1/-1.6) of the drop in imports in the model economy immediately after the devaluation. As firms run down their higher-than-desired inventories, import volumes converge to the new steady state level of $1.5^{-\theta}$ and the fraction of importing firms returns to 22 percent. This transition lasts for about 10 months.

C. Sensitivity

Devaluations are also associated with sharp increases in interest rates and consumption declines in the affected economies. In the next set of experiments we show that adding these forces as exogenous shocks in our model economy lowers the initial pass-through of prices and amplifies the trade implosion during the transition. In addition, we illustrate the role of local factor content, size of markups, persistence of the relative price shocks as well as decompose the role of lags in shipment and fixed costs of importing in accounting for our results.

Interest Rate Increase

We first focus on the increase in interest rates. The EMBI+ spread that captures the average spread of sovereign external debt securities rose by as much as 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 percent rise in annual real interest rates, in addition to the 1.5-fold increase in ω. As the left panel of Figure 8 (dotted line) shows, this additional shock makes firms even more reluctant to raise prices in response to the increase in the wholesale price of imports. The drop in β increases the carrying cost of inventories and makes firms even more willing to exhaust current inventory holdings by keeping retail prices low. The initial increase in retail prices is only 0.23 and only 50 percent of its long-run level. Notice also that retail prices overshoot the wholesale price in the new steady state given the permanently higher inventory carrying cost associated with the interest-rate increase. Firms hold smaller inventory levels now and import more frequently and are thus more likely to stockout and charge higher prices.

Additional Consumption Drop

The next experiment, also illustrated in Figure 8 using dash-dot lines, associates the devaluation with an additional 15 percent exogenous drop in demand for imports to capture the aggregate consumption drops in episodes of devaluation. The forces discussed above are even stronger with this experiment since the incentive to shed higher-than-desired inventories is stronger, and, indeed, changes in consumption are merely a transformation of changes in ω. As a result, the initial drop in trade is even more severe and the pass-through of retail prices smaller than in the benchmark economy.

Local Factor Content

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

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

Consistent with the Chilean data, we set the share of labor, α, to 25 percent. The experiment we consider is again a one-time, permanent rise in ω of the same magnitude as that in our benchmark experiment. Consistent with the evidence, we assume that local wages do not respond to the devaluation.[40] Figure 8 (the line marked with circles) illustrates the economy's transition to the new steady state. Our results are qualitatively similar. Prices at the retail level respond less than one-for-one even in the long run since the importer's marginal cost of producing the good rises less than ω. Similarly, the drop in trade volumes is smaller.

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 imports after the devaluations, we solve the transition following a permanent rise in ω in economies identical to our benchmark economy except for assuming 1) no lags between orders and delivery, and 2) no fixed costs of importing. These economies are not re-calibrated; rather, all parameter values (except for the fixed cost in the no cost economy) are set to their values in the benchmark economy. Table 8 shows that the degree of lumpiness in the 'no lag' economy is the same as in the benchmark setup; the difference is that firms now hold 75 percent of the level of inventories in the economy with lags since now the stockout-avoidance motive for holding inventories is reduced. In contrast, the absence of fixed costs reduces the degree of lumpiness and lowers inventories even more, to 60 percent of their value in the benchmark economy. Thus it appears that fixed costs of importing are a stronger motive for holding inventories than the lags in

[40] More precisely, prices are relative to the domestic good, so we are assuming that wages move one-for-one with domestic prices.

shipment. Figure 8 confirms this insight. The figure shows that the pass-through of prices is lower in the economy without lags in which the fixed costs are the only motive for holding inventories than in the economy with no fixed costs and firms hold inventories to insure against demand variation. Roughly two-thirds of the incomplete pass-through in the model is thus due to fixed costs, whereas the rest is due to lags in shipping. Finally, notice that although the initial reduction in trade flows is sharper in the economy with no fixed costs, the transition is much shorter so that the over shooting in trade is larger in the 'no lags' economy.[41]

Low Markups

Recall that typical 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

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

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

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

This choice of preferences allows 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, McDaniel and Rivera (2003), and Broda and Weinstein (2006), which corresponds to a frictionless markup of

[41] These results are, however, sensitive to our assumption that fixed costs are proportional to revenue. The reasons fixed costs are the main source of inventory holdings is that they are very volatile and firms insure against the possibility of several high demand periods in which importing is prohibitively expensive. In an earlier version of this paper, with fixed costs independent of revenue, shipping lags were the stronger friction.

33 percent. 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 to derive these decision rules.[42] Figure 8 (line marked with circles) illustrates that the response of this economy to a permanent rise in ω is similar to that of our benchmark setup, as long as this economy is recalibrated to match the inventory holdings and lumpiness in the data. Table 8 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 that a large share of revenues is lost when importing.

High Depreciation of Goods

The benchmark calibration assumed that non-interest inventory holding costs are similar to U.S. levels. However, Gausch and Kogan (2001) present evidence that logistic costs are substantially higher in developing countries; therefore, we consider an alternate parametrization with $\delta = 0.04$, which is at the upper end of the range of U.S. inventory depreciation rates.[43] From the last column in Table 8, to match the lumpiness of trade and inventory levels requires that fixed costs represent about 25 percent of a month's sales revenue and demand volatility of $\sigma = 1.3$. Compared to the benchmark, with a higher rate of inventory depreciation the fixed costs and demand uncertainty must be larger to get firms to hold the same level of inventories.

From Figure 9, with a higher depreciation rate, represented by the line with circles, we see that the price response is much more gradual while the extensive margin response is only slightly weaker than in our benchmark calibration. Similar to the high interest rate example,

[42] This economy features strategic complementarities in firms' decision rules: the lower 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. These complementarities turn out to be weak in the model, since the firm's problem is dynamic and current P_m have a smaller effect on the firm's decision rules than in a static economy.

[43] They also present evidence that inventory levels are higher in developing country, which we interpret as evidence that trade costs we emphasize are higher for developing countries.

the higher depreciation rate raises the cost of holding inventories. Following the shock to import prices, firms now face larger inventory holding costs. To economize on these future inventory costs, firms sell more today by raising prices by less than in the benchmark case. With smaller price increases, firms work through their excess inventories faster and thus the extensive margin declines by less.

Transitory Relative Price Changes

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 percent 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. As Figure 9 indicates, 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. Moreover, the initial pass-through is reduced as the shadow value of inventories rises less when firms expect the wholesale price of imports to mean-revert. As inventory holdings are depleted, the retail price of imports overshoots the wholesale price as fewer firms import and firms hold smaller inventories on average in expectation of a lower future replacement cost of inventories.

6. Conclusions

We have documented that importers face delivery lags and fixed transacting costs. These frictions lead to inventory-management problems that are more severe for importers and international transactions are lumpy at the micro level. We show that a parsimoniously parameterized $(S, s)-$ type economy successfully accounts for these features of the data. We then show that the model incorporating the observed micro frictions predicts that in response to a large increase in the relative price of imported goods, as is typical in large devaluations, import values and the number of distinct imported varieties drops sharply immediately following the shock. The model also predicts that importers find it 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. These predictions of the model are quite different than what one would get using standard forms of trade costs, namely iceberg costs or fixed costs of exporting. Our model's predictions are supported by the events in 6 current account reversals following large devaluation episodes in the last decade.

The trade costs we study are particularly large for developing countries as are inventories. An avenue for further research would be to examine whether these frictions play a role in explaining differences in business cycles and net export dynamics between developed economies and emerging markets. Also, the mechanism may play a role in explaining the relatively low levels of inflation experienced after devaluations in prices of non-traded goods as well.

References

Aguiar, Mark and Gita Gopinath, 2007. "Emerging Market Business Cycles: The Cycle Is the Trend," *Journal of Political Economy*, 115(1), 69-102.

Aguirregabiria, Victor, 1999. "The Dynamics of Markups and Inventories in Retailing Firms," *The Review of Economic Studies*, 66(2), 275-308.

Alessandria, George and Horag Choi, 2007a. "Do Sunk Costs of Exporting Matter for Net Export Dynamics?" *The Quarterly Journal of Economics*, 122(1), 289-336.

Alessandria, George and Horag Choi, 2007b. "Establishment Heterogeneity, Exporter Dynamics, and the Effects of Trade Liberalization," Federal Reserve Bank of Philadelphia Working Paper 07-17.

Anderson, James E. and Eric van Wincoop, 2004. "Trade Costs," *Journal of Economic Literature*, 42(3), 691-751.

Backus, David, Patrick Kehoe and Finn Kydland, 1994. "Dynamics of the Trade Balance and the Terms of Trade: The J Curve?" *American Economic Review*, 84(1), 84-103.

Baldwin, Richard, 1988. "Hysteresis in Import Prices: The Beachhead Effect," *The American Economic Review*, 78(4), 773-785.

Baldwin, Richard and Paul Krugman, 1989. "Persistent Trade Effects of Large Exchange Rate Shocks," *Quarterly Journal of Economics*, 104(4), 821-854.

Burstein, Ariel, Martin Eichenbaum and Sergio Rebelo, 2005. "Large Devaluations and the Real Exchange Rate," *Journal of Political Economy*, 113(4), 742-784.

Burstein, Ariel and Christian Hellwig, 2007. "Prices and Market Shares in a Menu Cost Model," mimeo.

Broda, Christian and David Weinstein, 2006. "Globalization and the Gains from Variety," *The Quarterly Journal of Economics*, 121(2), 541-585.

Caballero, Ricardo and Eduardo Engel, 1991. "Dynamic (S,s) economies," *Econometrica*, 59(6), 1659-1686.

Campa, Jose and Linda Goldberg, 2006. "Distribution Margins, Imported Inputs, and the Sensitivity of the CPI to Exchange Rates," NBER Working Paper 12121.

Caplin, Andrew, 1985. "The Variability of Aggregate Demand with (S,s) Inventory Policies," *Econometrica*, 53(6), 1395-1409.

Chaney, Thomas, 2007. "Distorted Gravity: The Intensive and Extensive Margins of International Trade," mimeo.

Cooper, Russell and John Haltiwanger, 2006. "On the Nature of Capital Adjustment Costs," *The Review of Economic Studies* 73(3), 611–633.

Corsetti, Giancarlo and Luca Dedola, 2005. "A Macroeconomic Model of International Price Discrimination," *Journal of International Economics*, 67(1), 129-155.

Danziger, Leif. 1999. "A Dynamic Economy with Costly Price Adjustments," *The American Economic Review,* 89(4), 878-901.

Das, Sanghamitra, Mark Roberts and James Tybout, 2007. "Market Entry Costs, Producer Heterogeneity, and Export Dynamics," *Econometrica*, 75(3), 837-873.

Djankov, Simeon, Caroline Freund and Cong S. Pham, 2006. "Trading on Time," World Bank Policy Research Working Paper 3909.

Eaton, Jonathan and Samuel Kortum, 2002. "Technology, Geography, and Trade," *Econometrica,* 70(5), 1741-1779.

Evans, Carolyn and James Harrigan, 2005. "Distance, Time, and Specialization: Lean Retailing in General Equilibrium," *The American Economic Review*, 95(1), 292-313.

Fisher, Jonas and Andreas Hornstein, 2000. "(S, s) Inventory Policies in General Equilibrium," *The Review of Economic Studies*, 67(1), 117-145.

Gallaway, Michael, Christine McDaniel and Sandra Rivera, 2003. "Short-run and Long-Run Industry-Level Estimates of US Armington Elasticicities," *The North-American Journal of Economics and Finance*, 14, 49-68.

Guasch, J. Luis and Joseph Kogan, 2001. "Inventories in Developing Countries: Levels and Determinants, a Red Flag on Competitiveness and Growth," In Policy Research Working Paper 2552. The World Bank.

Gertler, Mark and Leahy, John, 2006. "A Phillips Curve with an Ss Foundation," NBER Working Paper 11971.

Ghironi, Fabio and Marc Melitz, 2005. "International Trade and Macroeconomic Dynamics with Heterogenous Firms," *The Quarterly Journal of Economics*, 120(3), 865-915.

Goldberg, Pinelopi and Michael Knetter, 1997. "Goods Prices and Exchange Rates: What Have We Learned?" *Journal of Economic Literature*, 35(3), 1243-1272.

Goldberg, Pinelopi and Rebecca Hellerstein, 2007. "A Framework for Identifying the Sources of Local-Currency Price Stability with an Empirical Application," Federal Reserve Bank of New York Staff Report 287.

Hall, George and John Rust, 2000. "An Empirical Model of Inventory Investment by Durable Commodity Intermediaries," *Carnegie-Rochester Conference Series on Public Policy*, 52, 171-214.

Hall, George and John Rust, 2002. "Econometric Methods for Endogenously Sampled Time Series: The Case of Commodity Price Speculation in the Steel Market," mimeo.

Hall, George and John Rust, 2003. "Simulated Minimum Distance Estimation of a Model of Optimal Commodity Price Speculation with Endogenously Sampled Prices," mimeo.

Hummels, David, 2001. "Time as a Trade Barrier." mimeo.

Hsieh, Chang-Tai and Jonathan Parker, 2008. "Taxes and Growth in a Financially Underdeveloped Economy: Evidence from the Chilean Investment Boom," *Economia*, forthcoming

Junz, Helen and Rudolf Rhomberg, 1973. "Price Competitiveness in Export Trade Among Industrial Countries." *The American Economic Review*, 63(2), 412-418.

Khan, Aubhik and Julia Thomas, 2007a. "Inventories and the business cycle: An equilibrium analysis of (S,s) policies." *American Economic Review*, 97(4), 1165-88.

Khan, Aubhik and Julia Thomas, 2007b. "Explaining Inventories: A Business Cycle Assessment of the Stockout Avoidance and (S,s) Motives," *Macroeconomic Dynamics,* 11(5), 638-64.

Kollintzas, Tryphon and Steven Husted, 1984 "Distributed Lags and Intermediate Good Imports," *Journal of Economic Dynamics and Control*, 8(3), 303-27.

Magee, Steven, 1973. "Currency Contracts, Pass-through and Devaluations," *Brookings Papers on Economic Activity*. 1973(1), 303-325.

Mazzenga, Elisabetta and Morten Ravn, 2004. "International Business Cycles: The Quantitative Role of Transportation Costs," *Journal of International Money and Finance*, 23(4), 645-71.

Meade, Ellen, 1988. "Exchange Rates, Adjustment, and the J-Curve."Federal Reserve Bulletin, 74(10): 633-644.

Melitz, Marc, 2003. "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity," *Econometrica*, 71(6), 1695-1725.

Mendoza, Enrique. 1995. "The Terms of Trade, the Real Exchange Rate, and Economic Fluctuations," *International Economic Review*, 36(1), 101-137.

Neumeyer, Pablo and Fabrizio Perri, 2005. "Business Cycles in Emerging Economies: the Role of Interest Rates." *Journal of Monetary Economics*, 52(2), 345-380.

Richardson, Helen, 1995. "Control Your Costs Then Cut Them," *Transportation and Distribution*, 94-96

Roberts, Marks and James Tybout, 1997. "The Decision to Export in Colombia: An Empirical Model of Entry with Sunk Costs," *The American Economic Review*, 87(4), 545-564.

Ruhl, Kim, 2005. "The Elasticity Puzzle in International Economics," mimeo.

Data Section

- The US steel wholesaler data is from Hall and Rust (2000). The data contains information on deliveries by date, good, value, quantity, and source (domestic or foreign).
- US trade data used to measure characteristics of trade flows is from the Census US Exports of Merchandise History DVD.
- Labor share at Chilean plants: for plant j let $\alpha_{jt} = \frac{w_{jt} * l_{jt}}{w_{jt} * l_{jt} + M_{jt}}$, where $w_{jt} l_{jt}$ measures salary payments to white and blue collar workers in the current period and M_{jt} measures current materials purchases. The top panel of the following table reports the sample averages for importers, non-importers and all plants. We measure both simple averages and sales-weighted averages. In total, using simple averages, the labor share is approximately 25 percent, while when we weight by sales we find a substantially lower share of 14.5 percent. However, the weighted regression of labor share on import content predicts that labor share is higher, the larger a plant's import content. A plant that imports all of its raw materials thus has a labor share of about 26 percent.

Labor share in Chilean Plants

A. Mean Labor share		
	Unweighted	Weighted
Importers	0.230	0.153
Total	0.251	0.164
B. Controlling for import content and log employment		
Constant	-0.039*	0.082*
Import content	0.25*	0.186*

* Significant at 99 percent

Notes on Figures and Tables

1. Table 1: Importing costs: World Bank Doing Business Survey. Mean and Median shipments: Census US Exports of Merchandise - History DVD.
2. Tables 2 and 3: Plant level data from the Chilean census (Hsieh and Parker, 2008). Materials inventory measures the ratio of the average stock of material inventory to material purchases, $i^m_{jt} = \frac{I^m_{jt+1}+I^m_{jt}}{2M_t}$. Finished inventory measures the ratio of the average stock of material in process or finished to the annual sales, $i^f_{jt} = \frac{I^m_{jt+1}+I^m_{jt}}{2M_{jt}}$. Inventory denotes the sum of materials inventory and finished inventory, $i_{jt} = i^m_{jt} + i^f_{jt}$. Import content measures the ratio of imported materials to total materials, $s^{im}_{jt} = M^{im}_{jt}/M_{jt}$.
3. Table 4: Steel data from Hall and Rust (2000)
4. Tables 5 to 7 and 9: Constructed using Census US Exports of Merchandise – History DVD.
5. Figures 1 and 5:

- Panel 1 of Figure 1: All data from BER (2005). Available at http://www.econ.ucla.edu/arielb/AdditionalMaterialLargeDevJPE.html in pricedataJPE.xls. CPI imports constructed using microdata in BER (2005) on CPI for disaggregated product categories and origin classification. NER denotes monthly average Argentine Peso/$ exchange rate.
- Panel 2 of Figure 1 and Column 1 of Figure 5: The relative price of imports is the ratio of the Import price deflators and Manufacturing Producer Price Indices (PPI). For import price indices we use
  1. Argentina: WPI Imports from MECON, PPI from IFS (21363...ZF...)
  2. Brazil: Índice de preco das importacoes from FUNCEX (http://www.funcex.com.br/basesbd/). This index is denominated in US dollars. We convert it into local currency using nominal exchange rate data from IFS (223..AE.ZF...). PPI from IFS (22363...ZF...)
  3. Korea: Import price index from IFS (54276.X.ZF...), PPI from IFS (54263...ZF...)
  4. Mexico: Índice de precios de las importaciones from Bank of Mexico. Convert into local currency using exchange rate data from IFS (273..AE.ZF...). PPI from IFS (27363...ZF...)
  5. Thailand: Import price index from IFS (57875...ZF...), PPI from IFS (57863...ZF...)
  6. Russia: given lack of data, we use nominal exchange rate from IFS (922..AE.ZF...) instead of Import price index, PPI from IFS (92263.XXZF...).
- Panels 3 and 4 of Figure 1, Columns 2-3 of Figure 5: US Nominal Exports, transactions and HS 10 varieties by destination are from the Census' US Exports of Merchandise History DVD. Total imports are from the IFS nominal dollar value and are C.I.F. Total imports and US exports are deflated by the BLS's U.S. Export Price Index.
- All variables are normalized to zero in the period prior to the exchange rate devaluation.

Figure 1: Devaluation in Argentina 2002

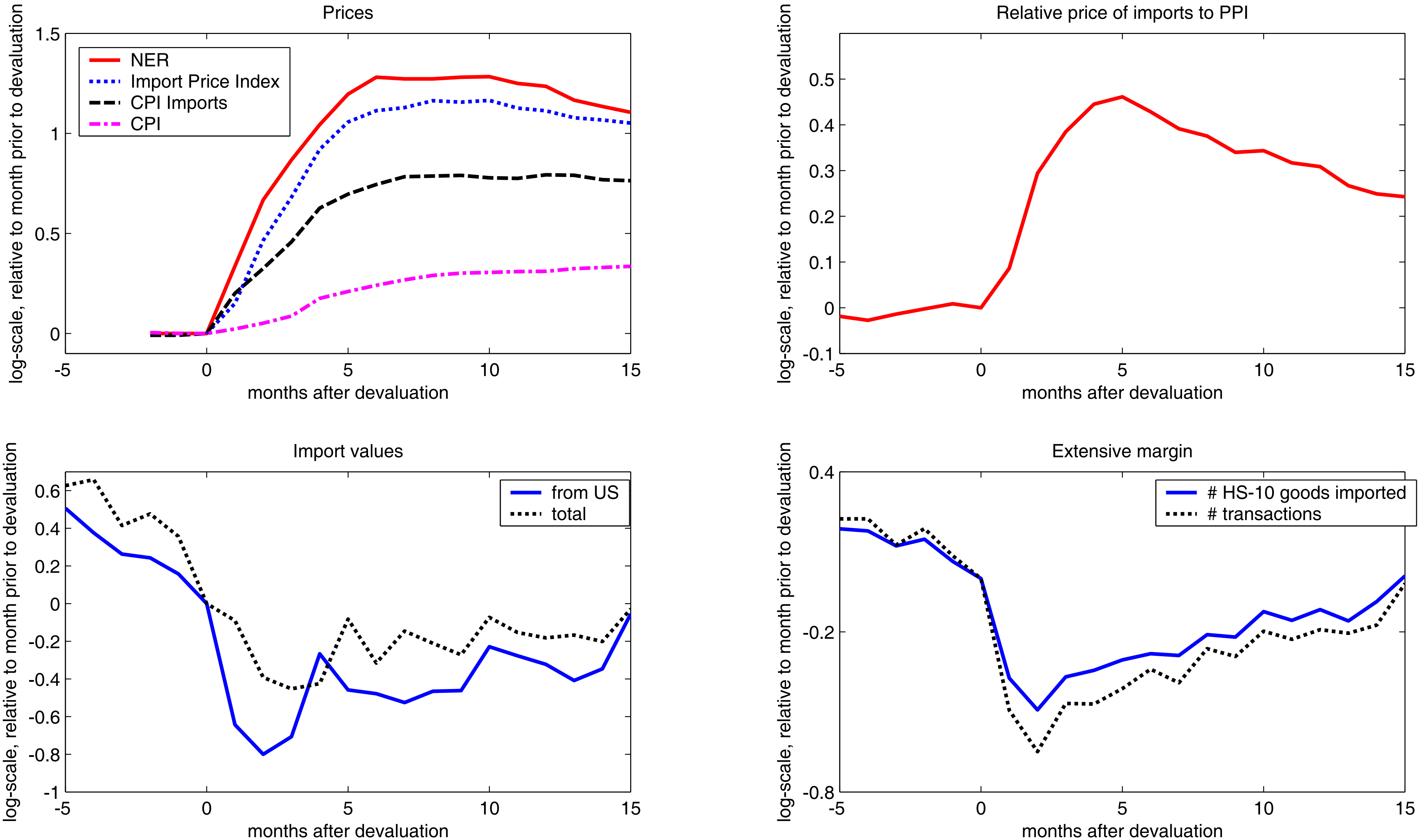

Figure 2: Timing assumptions

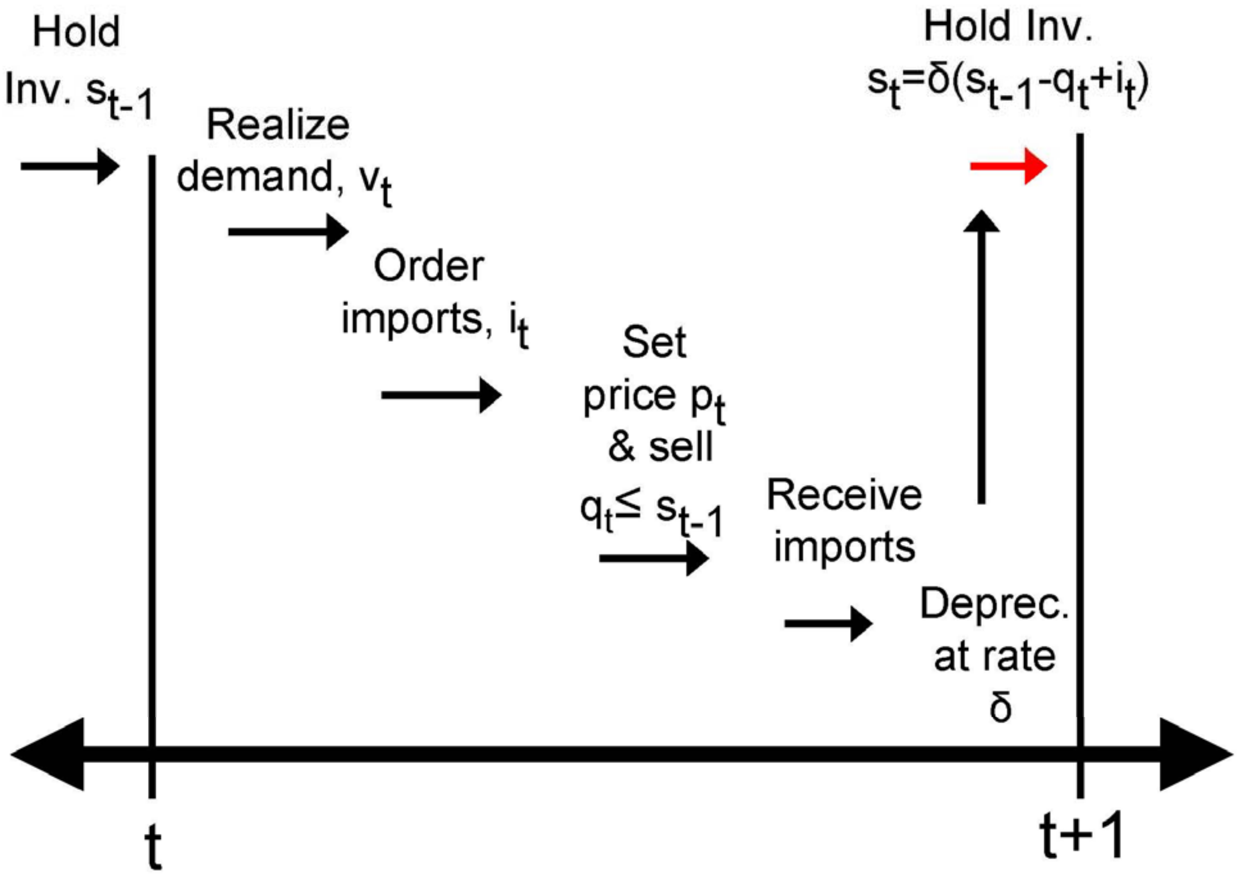

Figure 3: Optimal import rules

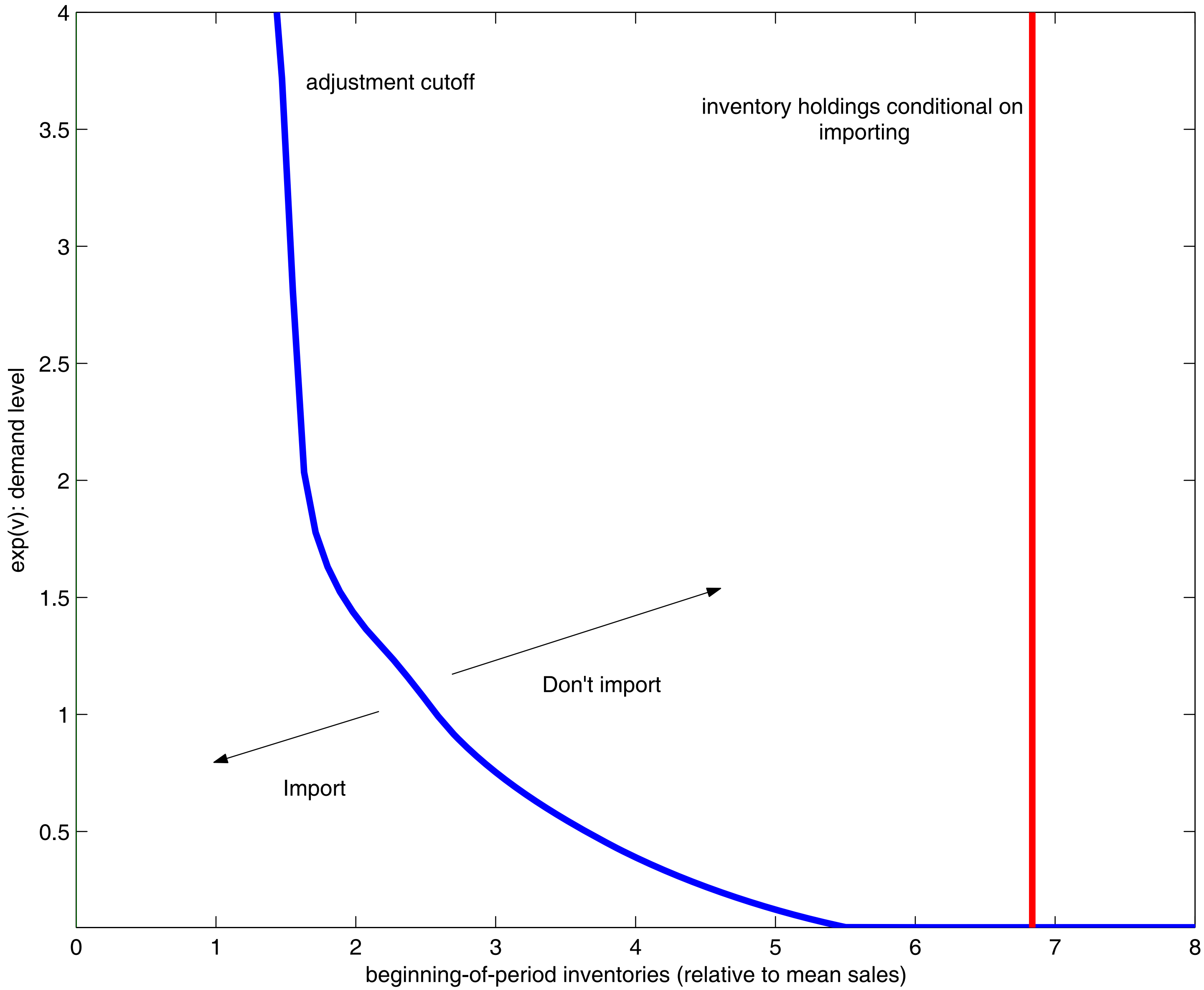

Figure 4: Optimal price functions

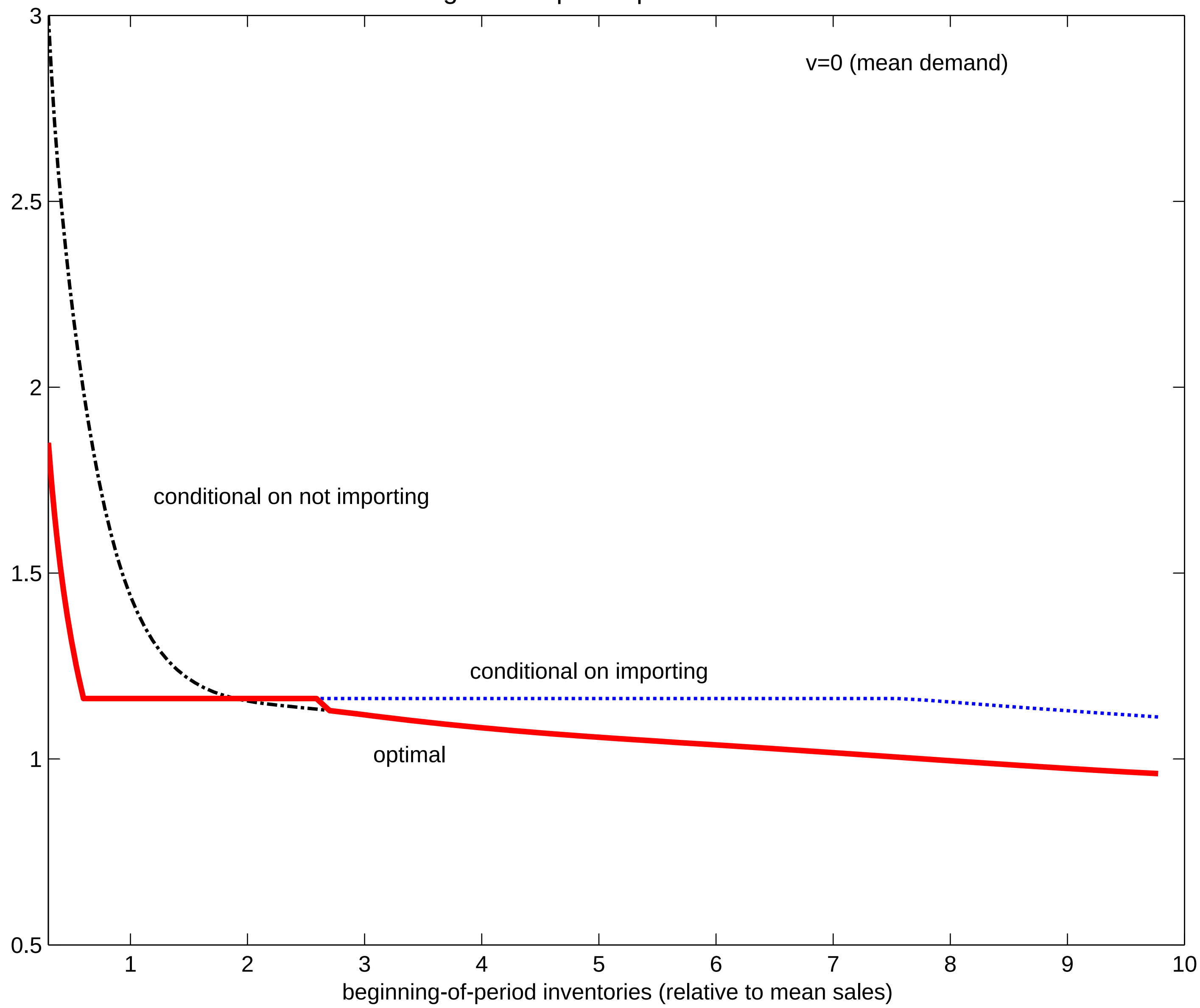

Figure 5: Salient features of large devaluations

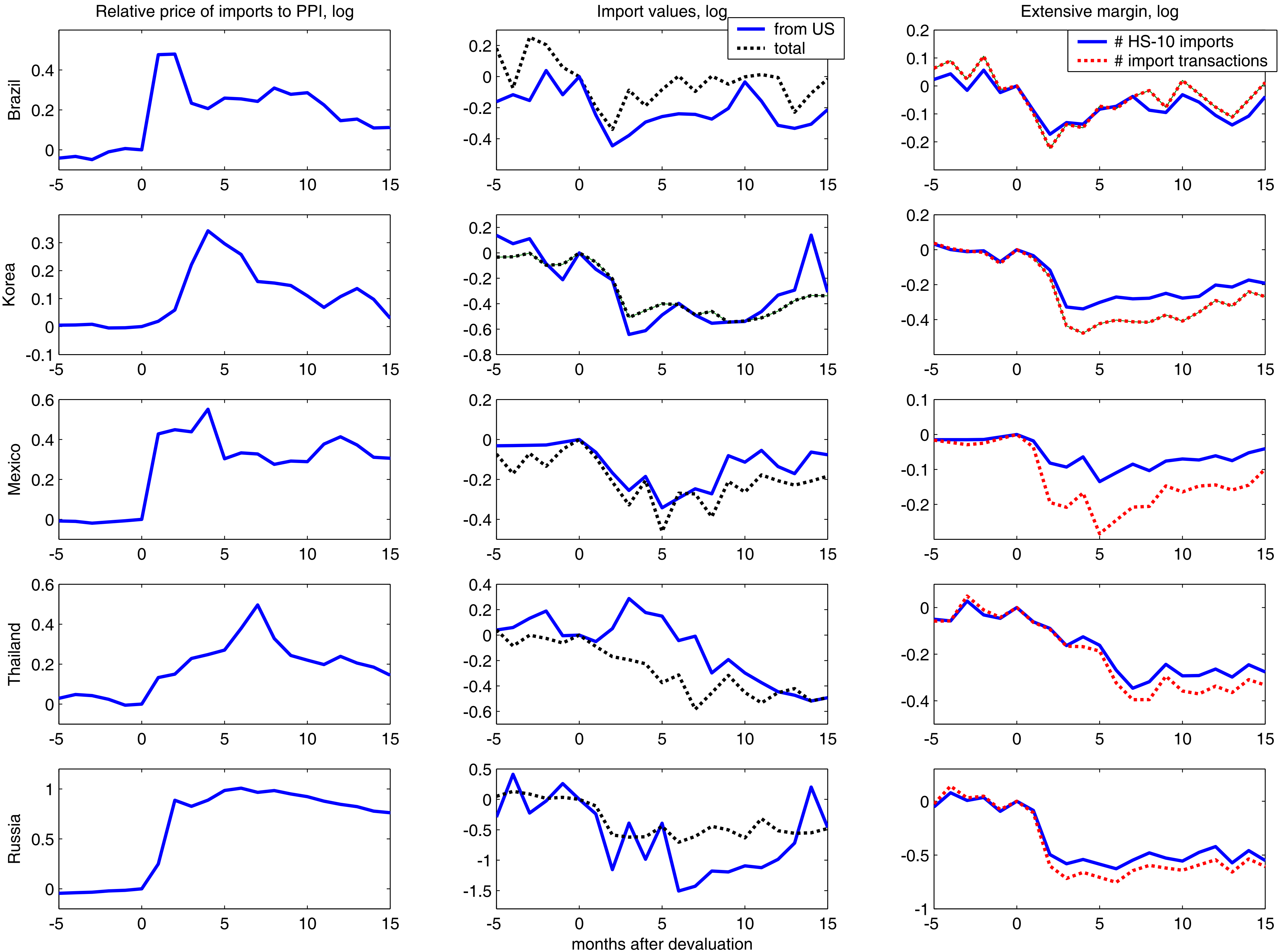

Figure 6: Ergodic distribution of beginning-of-period inventories and adjustment hazard

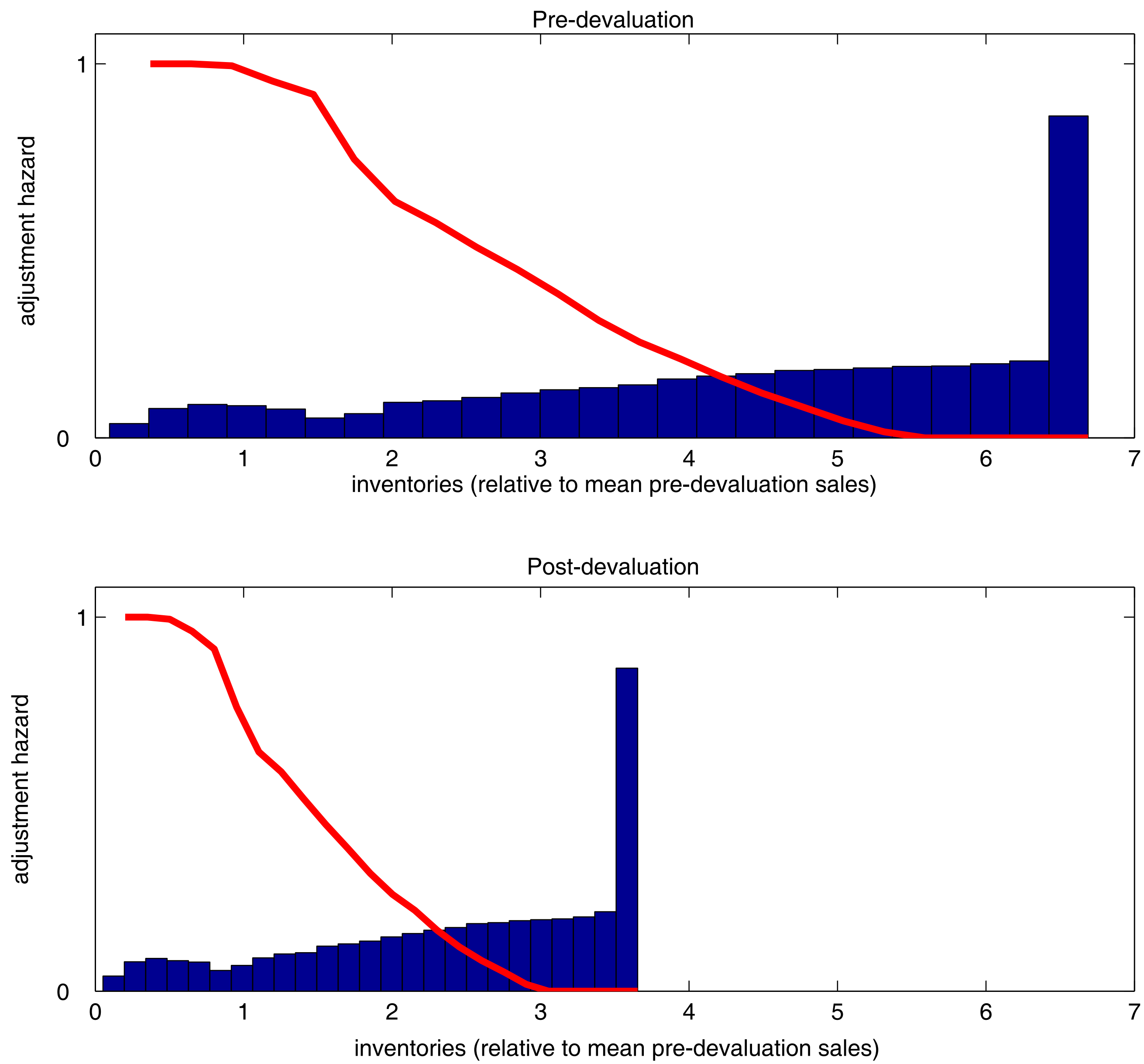

Figure 7: Response of model economy to devaluation

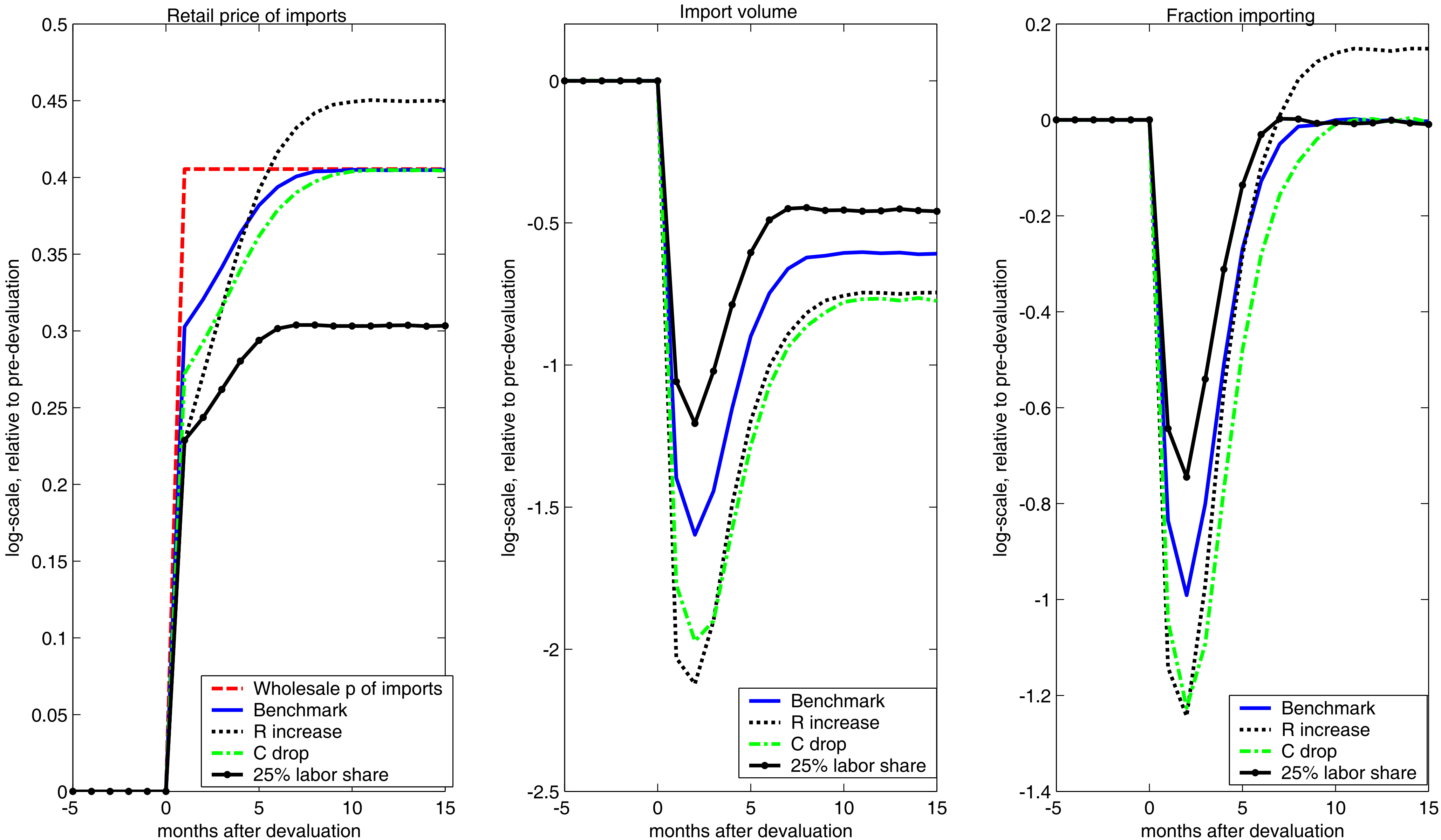

Figure 8: Response of model economy to devaluation, other experiments

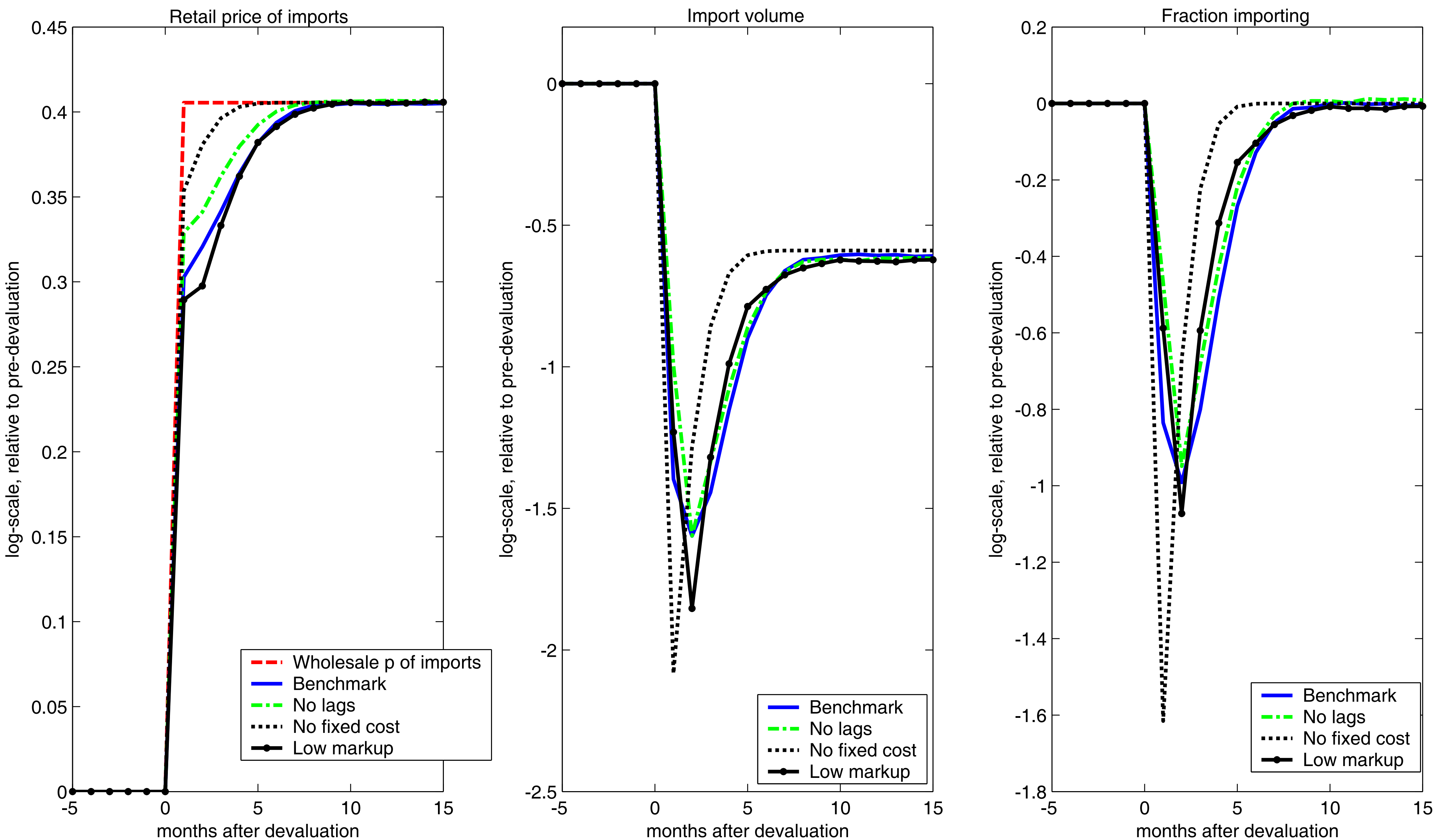

Figure 9: Transitory shock and high elasticity

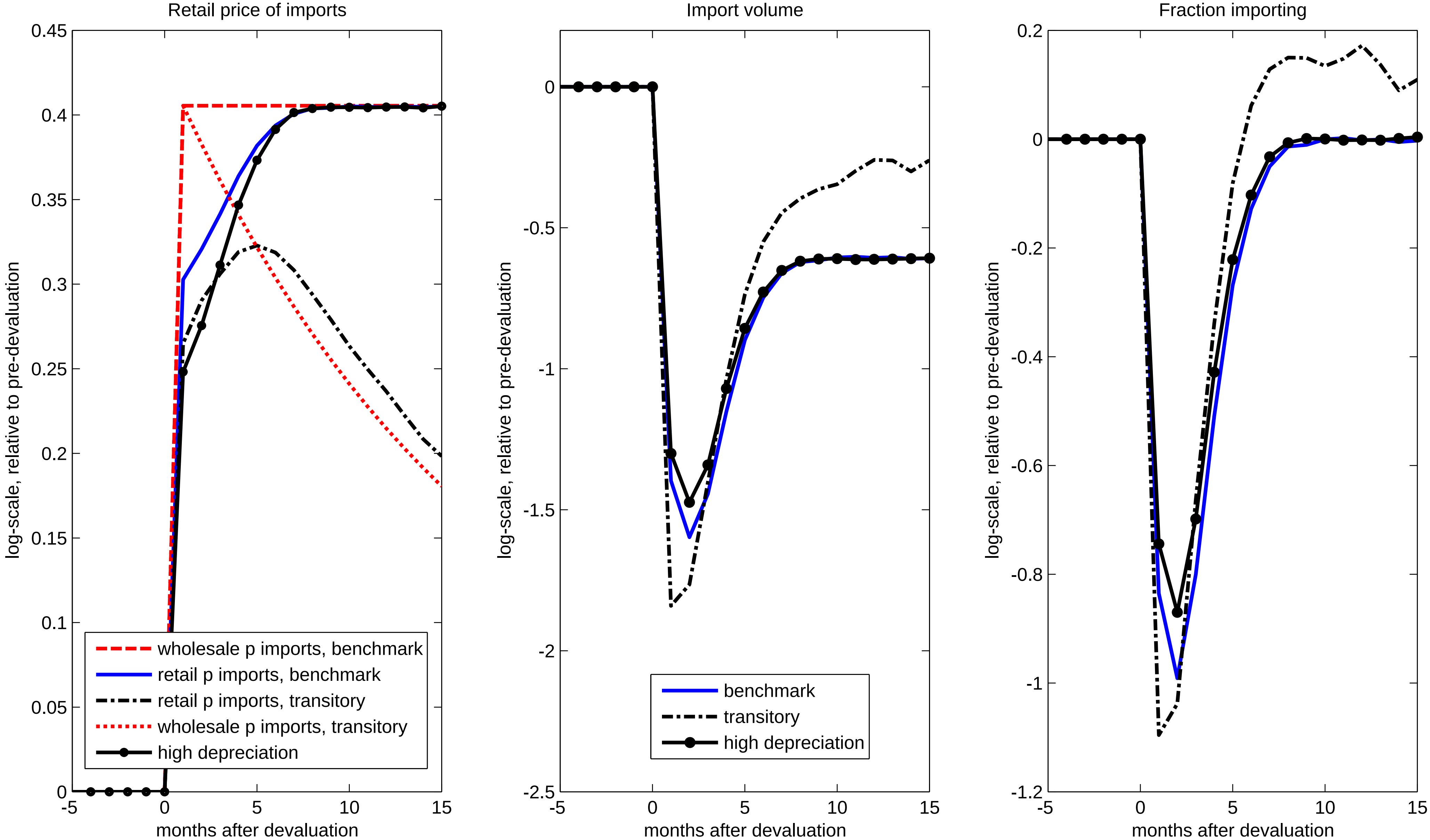

Table 1: Time and Monetary Costs of Importing

Country	Number of Days	Import Cost	U.S. Export Cost	Median Shipment Value from the U.S.	Total Costs as a Fraction Median Shipment	Mean 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 2: 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

Share of annual usage

Table 3: Regression Results of Inventory Holdings on Import Content

	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
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

Notes: tstats in paretheses. "Weighted" results are by total sales. "Robust" uses a robust regression algorithm to control for outliers. "Fixed" includes industry fixed effects.

Table 4: Statistics on Lumpiness at a US Steel Wholesaler

A: Summary Statistics

	Domestic		Foreign	
Goods	Purchases	Value	Purchases	Value
3573	12472	$134 mln	5632	$87.8 mln

B: Premium on Imported Goods (good-yr fixed effects)

Amount	Weight	Price
0.211	0.345	-0.08
(7.0)	(12.8)	(5.6)

C: Import Size Premium Controlling for Price (good-yr fixed effects)

Price	Weight premium
-2.1	0.48
(39.0)	(19.1)

D: Mean and Median Interval (Days)

	Domestic	Foreign
Mean	100	204.5
Median	55.9	140.5

Notes: t stats in parentheses.

Table 5: Lumpiness Statistics of Disaggregate US 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
Herfindahl-Hirschman 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 6: Concentrations Across Months (Within Years) vs. Across Years (Within Months)

	Argentina	Brazil	Korea	Mexico	Russia	Thailand
Within Year, Across Month						
Herfindahl-Hirschman 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						
Herfindahl-Hirschman 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 7: 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
Herfindahl-Hirschman 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 end use of the remaining goods were military (0.19), unclassified (0.10), and re-exports.

Table 8: Moments and Parameters

Moments

Used for calibration	Data	Benchmark	High elasticity	No lag	No fixed cost	High depreciation
Herfindhal-Hirschmann ratio	0.44	0.44	0.42	0.44	0.13	0.44
Inventory to annual purchases ratio	0.36	0.36	0.34	0.27	0.22	0.35

Not used for calibration	Data	Benchmark
Fraction of months good is imported	0.44	0.21
Fraction of annual trade by top month	0.53	0.48
Fraction of annual trade by top 3 months	0.85	0.98
Fraction of annual trade by top 5 months	0.95	1.00
Value of avoiding 30-day lag (per shipment)	12%-24%	4.3%
Fixed cost per shipment, %	3%-11%	4.4%

Parameters

Calibrated	Benchmark	High elasticity	No lag	No fixed cost	High depreciation
λ (1-share of revenue lost if import)	0.86	0.55	0.86	1	0.75
std. dev. of demand, σ	1.1	1.80	1.1	1.1	1.3

Assigned	Benchmark	High elasticity	No lag	No fixed cost	High depreciation
Period length	1 month	1 month	1 month	1 month	1 month
Elasticity of demand for imports, θ	1.5	1.5	1.5	1.5	1.5
Elasticity of subs. across imported goods	-	4	-	-	-
Discount factor, β	0.995	0.995	0.995	0.995	0.995
Depreciation rate, δ	0.025	0.025	0.025	0.025	0.04

Additional Experiments

Change in consumption: ΔC=-0.15
Interest rate change: β=0.70 (annually)

Table 9: Change in the Extensive Margin

A: Share of output drop due to drop in extensive margin in month with worst trade drop

	Method 1		Method 2		Method 3		Method 4		Method 5	
	# cards	# goods	# cards	# goods	# cards	# goods	# cards	# goods	# cards	# goods
Argentina	1.12	0.84	1.25	0.60	1.33	0.71	1.12	0.71	1.05	0.73
Brazil	0.78	0.47	1.07	0.30	1.08	0.43	0.81	0.28	0.89	0.45
Korea	0.89	0.67	0.57	0.23	0.74	0.33	0.79	0.25	0.82	0.35
Mexico	1.35	0.54	1.09	0.02	1.31	0.12	0.94	1.34	1.18	0.07
Thailand	0.66	0.58	0.29	0.06	0.53	0.29	0.51	0.28	0.71	0.44
Russia	0.58	0.39	0.95	0.38	1.10	0.57	0.59	0.31	1.10	0.66
Average	0.90	0.58	0.87	0.26	1.02	0.41	0.79	0.53	0.96	0.45

B: Average share of output drop due to drop in extensive margin in 3 month window around worst month

	Method 1		Method 2		Method 3		Method 4		Method 5	
	# cards	# goods	# cards	# goods	# cards	# goods	# cards	# goods	# cards	# goods
Argentina	0.90	0.74	0.97	0.52	1.06	0.62	0.89	0.65	0.88	0.66
Brazil	0.54	0.36	0.49	0.20	0.51	0.30	0.51	0.20	0.91	0.55
Korea	0.95	0.70	0.78	0.21	0.90	0.32	0.85	0.27	0.90	0.31
Mexico	1.55	0.31	1.36	-0.02	1.63	0.09	0.99	1.58	1.33	0.03
Thailand	0.75	0.71	0.27	0.06	0.52	0.34	0.58	0.35	0.75	0.43
Russia	0.63	0.44	1.00	0.45	1.18	0.62	0.63	0.37	1.09	0.69
Average	0.89	0.54	0.81	0.24	0.96	0.38	0.74	0.57	0.98	0.44

Goods denote distinct HS-10 categories and cards represent total number of transactions across all categories.

Method 1: no weighting; Method 2: weight by total value of imports 1990-2004; Method 3: weight by total value of imports 1990-devaluation; Method 4: drop smallest total (1990-2004) value goods that account for lowest 20% import value. No weighting; Method 5: weight by total value of imports per good (when computing # goods) and per transaction (when computing # transactions).

* For Mexico, to remove the effect of NAFTA in methods 2, 4, and 5 we base the weighting/filtering on the pre-NAFTA period. Also, to remove changes in HS-10 codes and transactions from changes in the classification system, we forced the change from December to January each year to equal the average change in the previous three months.