The Great Trade Collapse of 2008-09: An Inventory Adjustment?*

George Alessandria   **Joseph P. Kaboski**   **Virgiliu Midrigan**

Federal Reserve Bank   Notre Dame   New York University

of Philadelphia   and NBER   and NBER

First Draft: October 2009

Revision: May 2010

Abstract

This paper examines the role of inventories in the decline of production, trade, and expenditures in the US in the economic crisis of late 2008 and 2009. Empirically, we show that international trade declined more drastically than trade-weighted production or absorption and there was a sizeable inventory adjustment. This is most clearly evident for autos, the industry with the largest drop in trade. However, relative to the magnitude of the US downturn, these movements in trade are quite typical. We develop a two-country general equilibrium model with endogenous inventory holdings in response to frictions in domestic and foreign transactions costs. With more severe frictions on international transactions, in a downturn, the calibrated model shows a larger decline in output and an even larger decline in international trade, relative to a more standard model without inventories. The magnitudes of production, trade, and inventory responses are quantitatively similar to those observed in the current and previous US recessions.

JEL classifications: E31, F12.

Keywords: Trade collapse, fixed costs, lags, inventory.

1. Introduction

From August 2008 through April 2009, the US experienced a nearly 27 percent fall of (non-petroleum real) imports and exports.[1] This collapse in trade was massive, substantially larger than the 15 percent drop in industrial production in manufacturing, as well as widespread, occurring on a global level. The cause and nature of the drop in trade have become a key question for international economists.

The answer to this question has important implications for the length of recovery, optimal policy response, as well as for whether similar drops in trade should be expected in future recessions or are unique to the particular nature of this crisis. If the drop in trade is primarily a result of trade financing drying up, a widespread hypothesis (ICC, 2008, Economist, 2009a, Dorsey, 2009, Dougherty, 2009, Auboin, 2009, Amiti and Weinstein, 2009, Chor and Manova, 2009), then it follows that the recovery would be as persistent as the underlying shock, and so tightly linked to the financial recovery and the return of trade credit. Looking forward, collapses in trade should be unique to downturns stemming from the financial system. Moreover, the disproportionate drop in trade would stem from an increase in the relative cost/price of imported goods.

This paper explores the role of inventory adjustment in response to an economic downturn, an explanation with strikingly different implications. The mechanism is simple and well-known in the closed-economy literature (see Ramey and West, 1999). Since production is equal to sales plus inventory investment, production is more volatile than sales whenever inventory investment is procyclical. In an open economy, if inventories are particularly important for goods traded internationally, imports and exports can be even more volatile than both sales and production. The inventory explanation would lead to a drop in trade that is steep but shorter-lived relative to underlying shocks. That is, if inventories play an important role in the downturn, once the inventory adjustment is over, trade should recover quite rapidly. The drop in inventories should not be particular to a financial crisis but would be robust to more general shocks causing economic downturns. Finally, the economic costs of

---

[1]Including petroleum-based goods, which experienced very large terms of trade movements along with a substantial shock to US oil production from Hurricane Ike, over this period, exports fell 27.5 percent and imports fell 22 percent.

the volatility in trade would be less than those implied in a model without inventories to smooth final output.

In the paper, we evaluate the inventory channel in the drop in US trade, both empirically and quantitatively, through the lens of an open economy model. We make three points.

First, in documenting features of trade and inventory dynamics, we show that the responsiveness of trade in the recent recession has not been unusual when compared to other recessions. Thus, *prima facie,* it appears to be the *size* rather than the *nature* of the shock that explains the large drop in trade. Second, both aggregate and disaggregate data show a strong role for inventories that are quantitatively important, though again these movements appear to be consistent with earlier episodes. Third, the cyclical features of trade are well-accounted for in a model with inventories when trade frictions are relatively more severe than domestic frictions.

We establish the first point, that the trade decline is not unusual, by comparing the aggregate dynamics of trade in the current recession with those of the six most recent (i.e., post-1970) past recessions. The observed decline in trade in the recent recession is not only large when compared to economic activity but also when compared to the drop in either the production or consumption of tradables. Specifically, the drop in trade is roughly four times the drop in output, and 50 percent more than the drop in industrial production or trade-weighted expenditures (i.e., real sales) of tradable goods.[2] Most important, the recent recession does not appear to be unusual. During the median recession, both exports and imports are about 50 percent more volatile than industrial production or expenditures on tradables.

We use multiple sources of data to establish our second point: the important role for inventories in past recessions. The aggregate data alone indicate an important role for inventories in the most recent recession that started in the fourth quarter of 2007 and deepened substantially in September 2008. Focusing on just the period beginning in September 2008,

---

[2]Real sales are a proxy for expenditures for US production, and so without inventory adjustment or a change in the relative price of foreign to domestic goods, a pure demand shock for US goods should move one-for-one with exports. Similarly, a simple shock to demand for US consumers should move imports one-for-one with real sales.

when the collapse in trade accelerated, we find that in the 12 months ending in August 2009, total real imports declined by \$238 billion compared to the annualized level in the 3 months ending in August 2008, and exports fell \$202 billion. At the same time, the stock of US business inventories fell approximately \$102 billion from the end of August 2008 to the end of August 2009. Thus, there is a substantial adjustment of inventories that coincided with the collapse in trade. From the end of August 2008 through end of April 2009, the inventory-to-sales ratios rose 5 percent overall, 6 percent in (non-auto) consumer goods and 19 percent in capital goods. Again, however, the current recession does not appear unusual; the elasticity of the inventory-sales ratio is quite close to the median over the past seven recessions. Finally, the quick and stark recovery in trade since the trough in 2009Q2 is consistent with a role for inventories, given the short-run nature of inventory dynamics that we noted above. Following the massive collapse in trade and reduction in inventory, the recovery has been strong; by 2009Q4, trade has recovered to levels consistent with the levels of production, expenditure, and inventories.

Aggregate inventory numbers by themselves cannot establish a direct link between inventory dynamics and international trade. To do this, we focus on the auto industry, which is ideal for two reasons. One, it was the industry that showed the largest drop in trade, and so it is a quantitatively important industry that played a leading role in the collapse. Second, for the auto industry we have data on foreign and domestic sales, orders, and inventories, which enable a direct connection.

In these data, both imports and sales of foreign automobiles began dropping in mid-2008, and the inventory-to-sales ratios rose roughly 45 percent over six months. Over the first three months of 2009, sales began to recover somewhat, but imports continued to fall precipitously, while the inventory-to-sales ratios adjusted downward by 40 percent. The fall in auto imports began to level off only in the 2nd quarter of 2009, after this adjustment. Again, these dynamics do not appear to be peculiar to the recent recession. We show similar dynamics in the US auto market in the 1970s and in Japan in its last four recessions.

Our third contribution is a model-based quantitative analysis of the mechanism we propose: an economic shock, which raises inventory-to-sales ratios above desired levels, causing a more precipitous drop in economic activity, especially international trade. We embed

the partial equilibrium model of trade and inventory adjustment in Alessandria, Kaboski, and Midrigan (forthcoming) (AKM, hereafter), into a two-country general equilibrium model of international business cycles. Inventory holdings here are microfounded in that distributors face fixed transaction costs of ordering, shipping lags, and overall demand uncertainty.

We discipline the model using both aggregate and microdata on trade and inventories. The model accounts for the relatively larger drop in imports than production because the frictions are particularly large for importers, leading them to hold a larger stock of inventories (relative to sales), consistent with the data.[3] We calibrate the frictions to match the aggregate inventory-to-sales ratios, as well as the evidence on the lumpiness of transactions and the relative importance of inventories for importers vs. non-importers.

We then perform several experiments to quantify the model's predictions for trade, inventory, and sales dynamics. First, we consider the dynamic response of real variables in a global recession that arises from a simultaneous increase in the cost of financing labor expenditures in both countries. Our model with inventories shows a substantially deeper (37 percent larger) drop in trade relative to the drop in production. Inventory-to-sales ratios increase substantially but then decline (and actually overshoot) before stabilizing. Moreover, the magnitudes of responses are comparable to those observed in the recent recession. Our results are robust to introducing alternative disturbances that change the intertemporal cost of borrowing, as well as to other reasonable perturbations of the model.

Our findings are related to several papers examining the trade collapse and crisis of 2008-09. Levchenko et al. (2009) analyze the cyclical properties of US trade and conclude that the decline in trade was indeed unusually large in absolute terms. We agree that the decline in trade was large but emphasize that relative to the large decline in production, the decline in trade was not unusual. Indeed, as Imbs (2009) points out, what is unusual is that the recession was both large and synchronized across countries. Levchenko et al. (2009) also examine trade dynamics at the sectoral level and find no relation between inventory holdings of manufactures and the decline in trade, however. We caution against concluding

---

[3] AKM document the severity of these frictions and their relative importance for importers. Their partial equilibrium model performs relatively well in explaining the quantitatively large and short-lived drops in imports experienced in developing countries (e.g., Argentina, Brazil, Korea, Mexico, Thailand, and Russia) during recent financial crises characterized by large devaluations.

that inventories played a limited role, since imported inventories can be held at many stages of production (e.g., manufacturers, wholesalers, or retailers), as other authors have noted (e.g., Ramey and West, 1999). Our study of motor vehicles is a prime example, where US retailers and wholesalers hold nearly four times the inventory of manufacturers. Empirical work that controls for these downstream inventories would be useful to evaluate this channel. In our previous work, AKM, we found that following a large devaluation in emerging markets, goods with high inventory experienced greater drops in trade in the subsequent year.

Recent work also examines explanations that are different, though perhaps complementary to the inventory mechanism. One potential explanation is that the demand for tradables is more volatile than GDP simply because its composition differs. That is, perhaps the high volatility reflects the composition of tradables in general, regardless of whether they are domestic- or foreign-sourced. Our paper shows that composition is indeed an important part of the story but is nonetheless an incomplete explanation. Trade-weighted expenditure, our proxy for demand, is substantially more volatile than GDP, but still 50 percent less volatile than trade itself. Our findings, which focus on the past seven recessions in the US, are consistent with those of Eaton et al. (2009), who perform a detailed analysis of data across countries using a multi-sector, multi-country model for the most recent recession. They attribute the relatively large drop in trade to a second potential explanation: trade costs increased. This is the natural alternative in the static model of Eaton et al., which lacks a dynamic inventory mechanism, and indeed they impute how large the increase in trade costs would need to be to explain the data.

Others have argued for particular channels that increased trade costs. As discussed above, several authors have posited that trade costs have increased because of the importance of finance and trade credit in international trade. In this vein, Chor and Manova (2009) study the decline in US imports at the sector and country level; their regressions relate the fall in trade to credit market indicators in the source country. Related, Amiti and Weinstein (2009) use regression analyses on earlier data from the Japanese bank failures in the 1990s to show that when banks become troubled, the exports of firms that borrow fall disproportionately. In addition to higher financing costs, protectionist policies have also been mentioned as a potential source of higher trade costs (Baldwin and Evenett, 2009, Economist 2009b). We

note that all of the trade cost explanations differ from our inventory mechanism in one key way: the decline in real trade involves a substitution story that requires an increase in the relative price of imported goods.

Several other studies examine the propagation of the crisis across countries. Using an international input-output structure, Bems, Johnson and Yi (2009) examine the idea in Yi (2009) that international trade in intermediate inputs contributed to the global propagation of the crisis, also finding that the decline in trade was relatively large compared to the decline in final absorption or production of traded goods. However, they also find that very little of the US downturn was propagated through trade to the rest of the world. Finally, at a more macroeconomic level, Lane and Milesi-Ferretti (2009) and Rose and Spiegel (2009) examine the link between the severity of the crisis across countries and pre-crisis fundamentals.

The rest of the paper is organized as follows. The next section documents the cyclical properties of trade and inventories in the US with an emphasis on the most recent crisis. Section 3 develops the model, while Section 4 presents the calibration. In Section 5, we report the quantitative results and Section 6 concludes.

2. Empirics

This section documents two key features of trade flows. First, in downturns trade tends to fall much more than measures of income, production, or expenditure. That is, there is a relatively high income elasticity. The relatively high volatility of trade is well-known (see Backus, Kehoe and Kydland, 1992, for instance) and often attributed to the traded basket being comprised primarily of durables (see Boileau, 1999, or Engel and Wang, 2007). While this is clearly part of the story, even when using final expenditures on traded goods rather than income, we still find a relatively high elasticity of trade. By these measures, we find that the reduction in trade in the current recession is not unusual. Indeed, what is unusual is the magnitude of the US recession. Second, we provide evidence that there is an important role for inventory holdings in downturns, particularly for trade dynamics. We show that aggregate inventory dynamics in the current recession are also not unusual. We focus further on autos because trade in autos fell the most in the current recession, and, for autos, we can separately measure domestic sales of imported autos and imports of autos. These data

6

show substantial differences between domestic sales of imported autos and auto imports that must be filled by inventory holdings. The auto data suggest that the high elasticity of trade may not reflect substantial variation in final purchase of imports, but rather a substantial inventory adjustment. Finally, we discuss some evidence that inventory holdings of goods sold overseas may exceed those of goods sold at home.

A. Trade Dynamics

We now describe the cyclical properties of trade (exports and imports) in the US. A key feature of trade flows is that they are more volatile than production or absorption of traded goods.

Table 1 presents key summary moments for US business cycles for the years 1967Q1-2009Q4, where the data have been HP filtered with a smoothing parameter of 1600.[4] We focus on this recent period, since the inventory series is first available in 1967. In any case, trade is most relevant for this recent period.[5]

Trade is about 1.5 times more volatile than manufacturing industrial production (measured by the ratio of standard deviations). Because income (measured by GDP) is less volatile than industrial production, trade is even more volatile relative to income, with roughly a relative volatility of 3.5 (1.49/0.43=3.47 for imports and 1.64/0.43=3.81 for exports).

Given our emphasis on inventories, an equally relevant question is whether trade is more volatile than expenditures on traded goods. In constructing a measure of final expen-

---

[4]Our results are robust to a variety of detrending methods and controlling for the different composition of production and expenditure from trade (see Appendix). Given the enormous increase in trade relative to production, we believe it is necessary to detrend the data. An additional reason to detrend is that we can then more easily compare trade dynamics in mild and major recessions.

To more concretely understand the necessity of detrending, suppose that trade growth can be decomposed into a part due to the trend and a cyclical part, which is always g_y times the cyclical part of income. For simplicity assume that income has no trend, so that changes in income, Δy, are purely cyclical. Thus, if income grows 1 percent, trade will grow g_y percent + trend. Clearly, the elasticity of trade with respect to income is $(g_y * \Delta y + trend)/\Delta y = g_y + trend/\Delta y$. For a decline, the trend term will counteract the cyclical term, but this term is less important for larger declines. Thus, the elasticity on data that isn't detrended will appear larger, the larger the drop in income.

[5]The ratio of exports plus imports to GDP fluctuated between 4 and 6 percent from 1947 to 1967, but rose from 6 to over 20 percent between 1967 and 2009. Also changes in inventory management have occurred recently, including movement to just-in-time management principles. The increase in international trade has likely led to the increased importance of inventories, while these practices may have reduced their quantitative importance. In aggregate, the inventory/sales ratios have been relatively stable, rising from about 1.4 in the late 1960s to above 1.5 in the 1980s before falling to 1.3 in the 2000s.

ditures on traded goods, it is important to realize that the durable/nondurable composition of trade itself differs starkly from overall output and also from typically tradable goods (i.e., equipment, consumer durables, and consumer nondurables). When constructing our measure of the expenditures on traded goods, Y_t^T, we therefore weight expenditures on durables (investment in equipment, $I_{EQ,t}$, and consumer durables, $C_{D,t}$) plus expenditures on consumer non-durables, $C_{ND,t}$ appropriately:

$$Y_t^T = \alpha \left(\frac{I_{EQ,t} + C_{D,t}}{I_{EQ,0} + C_{D,0}} \right) + (1 - \alpha) \frac{C_{ND,t}}{C_{ND,0}},$$

Here the weight α is equal to the share of equipment and durables in trade flows (approximately 0.70; see the Appendix for calculation details) and everything is measured relative to a base year. Notice that while Y_t^T is a measure of the absorption of traded goods, it does not distinguish between domestic and foreign traded goods. Because this measure of final expenditures for traded goods is slightly less volatile than industrial production, trade is roughly 1.75 times (1.49/0.88=1.69 for imports and 1.64/0.88=1.86 for exports) as volatile as corresponding final expenditures.

Using the HP-filtered data, Figure 1 shows the drop in trade and our measures of economic activity relative to trend for the most recent recession. (The analogs to Figure 1 in the previous six recessions are available in the Appendix.) The dashed vertical line indicates the beginning of the recession according to NBER dating, and we normalize all series using the quarter prior to the recession. From the fourth quarter of 2007 through the second quarter of 2009, output had fallen almost 5 percent relative to trend, while industrial production and traded goods expenditures had fallen by about 13 percent. Still, the response in trade is substantially larger, with exports and imports falling nearly 19 and 22 percent, respectively, relative to trend. The magnitude of these declines in trade are thus in line with the cyclical movements from Table 1.

Still, across recessions, the timing of imports and exports does not always line up with output or expenditures (see the Appendix). To make the declines in trade flows comparable across the diverse recessions, Table 2 reports the elasticity of trade relative to each measure of absorption in the quarter of the peak drop in trade (so that the peak drop in imports

8

and exports may be in different quarters). The top two panels report the import and export elasticity. To take into account the fact that exports tend to rise after the start of a recession, the bottom panel reports the peak to trough drop in exports. Clearly, trade falls more than our measures of income, production, or absorption across recessions.

In terms of the elasticity of the import response, the recent recession does not appear to be atypical. While there is variation across recessions, the most recent recession actually yields an import elasticity of 1.70, below the median import demand elasticity of 2.38. With regard to exports, the decline in exports relative to industrial production of 1.41 in the most recent recession is also the median relative decline. The peak to trough drop in exports relative to industrial production of 1.75 is only slightly larger than the median drop of 1.53. Thus, in many respects the decline in trade does not appear to be too unusual.

While our focus is on the downturn, the cyclical properties in Table 1 suggest robust recoveries in trade as well. To date, the current recovery in trade seems consistent with this behavior. In the last two quarters of 2009, imports and exports rose almost 12 percentage points, while industrial production and expenditures on traded goods rose less than 5 percent. Thus, the sudden, relatively large drop in trade does not appear to be very persistent. Moreover, the recovery in trade has occurred even though economic activity itself has not yet fully recovered. Production, sales, inventory, and trade are all about 8 to 10 percent below their levels (relative to trend) at the start of the recession.

B. Inventory Response

We now return to the previous figures and tables to consider the comovement of inventory holdings and trade flows. As is well known, the inventory-to-sales ratio is strongly countercyclical (the correlation with industrial production is -0.67 in Table 1). The bottom panel of Table 2 shows that the response of the inventory-to-sales ratio is not atypical in this recession. Across the seven most recent recessions, the median log change in the inventory-to-sales ratio relative to industrial production is -0.56, while that in the most recent recession is a slightly lower -0.49. With only seven recessions, it is difficult to discern a change in the cyclical properties of inventories over the cycle.

The peak in the inventory-to-sales ratio tends to precede the peak decline in imports or

exports, however. In Figure 1, we see that the inventory-to-sales ratio rises at the aggregate level and peaks in the first quarter of 2009, prior to the peak decline in imports or exports. This pattern occurs in all the recessions we consider, except for the 1990 recession when the peak increase in inventory and declines in trade occurred in the same quarter.

One might be concerned that the nearly 6 percent increase in the inventory-to-sales ratio from Figure 1 is too small relative to the declines in trade to account for much of the relatively large fall in trade. This is not the case, since business inventories, a stock, are approximately equal to 10 months of imports, a flow, at the August 2008 rate of imports.[6] Indeed, using monthly data, we find that the stock of business inventory in the US fell approximately $100 billion from the end of August 2008 to the end of August 2009 while the cumulative drop in imports of goods over this period, relative to the average rate from June to August 2008, was $238 billion and for exports the drop was $202 billion.[7] Thus, potentially the inventory adjustment may account for nearly 40 percent of the decline in imports. Of course, inventory of both domestic and foreign inputs fell over this period suggesting perhaps a smaller role for inventories. However, without data that separate inventory holdings of imported goods from domestic goods as well as sales of domestic and imported goods, it is challenging to evaluate the inventory mechanism fully. Our subsequent empirical analysis of autos and our model-based quantitative analysis overcome this challenge.

C. Disaggregated Inventory Dynamics

Although we see large increases in inventories that appear to lead the drop in trade and suggest that part of the drop in trade reflects an inventory adjustment, we cannot say precisely whether the drop in trade reflects a drop in final sales of imported goods or an adjustment in the inventory of imported goods, since most industries do not report sales and inventory data separately for domestic and foreign goods. To understand the connection between inventory holdings and international trade, we focus on the auto industry. A key

---

[6]This is equivalent to saying that investment is not important for the business cycle because the capital stock does not change much in the short-run. One must be careful in comparing the change in stocks (inventories) against the change in a flow (trade).

[7]Comparing the twelve months ending in August, in 2008/9, exports fell about $146 billion and imports fell $278 billion. Constructing a measure of the drop in inventory holdings in the rest of the world is challenging, but there is clear evidence of inventory disinvestment in other countries in this period as well.

advantage of the auto industry is that there are direct measures of domestic sales of imported autos and imports of autos. There are also some measures of foreign and domestic inventory held by retailers from Ward's Automotive. Moreover, autos are an important traded good (accounting for 10.8 percent and 17.8 percent of US non-petroleum exports and imports, respectively, from 1999 to 2008).

Another key reason to study the auto industry, beyond the availability of data, is that this industry had the largest and most immediate decline in trade in this recession. From Figure 2, which plots monthly real exports and imports by end-use category relative to their August 08 levels, we see that imports and exports of motor vehicles and parts from December 08 had fallen twice as much as total trade flows and no other end-use category had fallen close to as much. Given the strength and immediacy of the collapse in auto trade, we believe that any explanation of the trade collapse must be able to explain autos to have a chance of explain the aggregates more generally.

Figure 3 plots monthly US sales, imports, inventory (measured in units), and the inventory-to-sales ratio of autos produced outside North America in the current recession through February 2010. Here we plot log changes from the average level in the second quarter of 2008. As with the aggregate trade data, imports fall substantially more than domestic absorption of imported autos and there is a substantial inventory adjustment. At its worst – the drop in trade in the 7 months, February to August 2009 – real imports had dropped 77 log points, while sales had only fallen 30 log points, relative to 2008Q2. Thus, for imported cars, the drop in trade over this 7-month period was over 2.5 times the drop in sales.

This period of low trade was necessary to bring inventory levels more in line with sales. Leading up to the collapse in auto imports, the inventory of foreign autos had risen about 12 percent even as sales had fallen over 33 percent; hence, the inventory-to-sales ratio increased substantially, roughly 45 log points at its peak. The massive collapse in auto imports starting in January 2009 was necessary to bring inventory holdings in line with lower sales levels. The slight rebound in sales of imported autos starting in December 2008, just prior to the collapse in imports, is consistent with the presence of excess inventories: importers reduced inventory by both increasing sales and reducing imports. By September 2009, inventory levels had

fallen more in line with sales, and thus, imports and sales are quite similar from September 2009 to January 2010.

In sum, the automobile data provide very strong evidence for a high elasticity of imports relative to absorption, since these data are unlikely to suffer from a compositional mismatch between our measure of imports and absorption.[8] They also point to an important role for inventory considerations in trade dynamics.

These inventory dynamics in the auto industry are not peculiar to the recent recession but have also occurred in other periods with large trade swings. Figure 4 plots the dynamics of imports, sales, and inventory holdings[9] of foreign autos in the US using quarterly data from 1972 to 1977 and provides clear evidence of a gap between imports and final sales of imported goods that is filled by inventory holdings. In particular, this period was marked by a collapse of imports of nearly 40 log points in two quarters (from third quarter of 1974 to the first quarter of 1975) that followed a substantial inventory accumulation of 35 log points (from the first to the third quarter of 1974). It also was marked by a robust rebound in imports and inventory holdings that preceded a boom in final sales of imported autos.

While autos provide a clean guide to the connection between inventory and trade flows, a similar connection may hold for consumer and capital goods. Figures 5 and 6 plot the dynamics of imports, final expenditures (trade weighted), and inventory levels for consumer and capital goods in the current recession. As we saw with autos, and the aggregates, within these narrow categories imports have fallen more than final expenditures (29 percent vs. 18 percent for capital goods at the trough in April 2009, and 13 vs. 5 percent for consumer goods through April 2009) and have been associated with an increase in inventory-to-sales ratios (peaking up 19 percent for capital goods and up 6 percent for consumer goods).

Finally, inventory and trade dynamics are not particular to the US but are also evident

---

[8]These import and sales dynamics are similar across the three major non-North American source countries of U.S. automobiles, Germany, Japan, and Korea.

[9]We do not have data on inventory holdings of foreign autos in this period, but instead construct them using the law of motion for inventory

$$INV_t^M = INV_{t-1}^M + M_t - S_t^M,$$

where INV_t^M denotes real inventory holdings of imported goods at the end of period t, M_t denotes real imports of motor vehicles in t, and S_t^M denotes real final sales of autos imported from outside North America.

in the aggregate in Japan. Figure 7 plots the manufacturing inventory-to-sales ratio, industrial production, and import and export dynamics in the four downturns in Japan since 1990: the 2007 to 2009 downturn, the 2001 recession, the East Asian Crisis (1997 to 1999), and the 1991 downturn. For each period, we plot time zero as the peak in industrial production. Much as for the US, these four downturns are associated with substantial increases in inventory levels relative to sales and substantial declines in trade flows and production. Unlike in the US, the declines in trade flows tend to be steeper for exports than imports (in 3 of the 4 periods) and exports tend to fall more than production while imports fall less. While not our main focus, these steeper declines in exports may reflect greater downstream inventory of Japanese goods (such as autos destined for the US market) or may reflect a higher weight on durables in exports than imports.

D. Asymmetries in Transaction Costs and Inventory

The auto industry provides clear evidence that inventory considerations contributed to the relatively large decline in imports relative to sales of imported autos. Indeed, from the closed economy literature, it is well known that inventory considerations can generate production that is more volatile than sales (Ramey and West, 1999, and Khan and Thomas 2007a,b). However, for inventories to explain the observed disproportionate fall in imports (relative to domestic production), inventory considerations for foreign goods must not only be present, but they must be stronger than those for domestically sourced goods. Here we discuss some evidence that this is indeed so: the inventories of traded goods exceed those of domestically produced goods destined for domestic sale. The discussion focuses on evidence from three sources: the US auto industry, US industries more generally, and firm-level evidence from our previous work on the topic (AKM 2009)

We first clarify how inventories should be measured in light of the theory we develop below. In our stylized model, only retailers hold inventories, and retailers of imported goods will endogenously have higher inventory-to-sales ratios. Nevertheless, in the data, wholesalers and manufacturers also hold inventories (of intermediate and final goods), and the mechanism we present is indifferent to the stage in the distribution chain at which inventories are held. For our purposes, a good should be included in foreign inventory from the time it is shipped

out of the factory gate[10] to the foreign market.[11] From a measurement standpoint, these inventories could be held by the manufacturer, in which case it would mean that firms that export should hold more inventory, or they could be held by the wholesaler/retailer, in which case it would mean that firms that import should hold more inventory.

To operationalize a comparison of imported and domestically sourced inventories, we start with Ward's data on inventories at the retail level. However, the issues above are particularly relevant for autos, since distribution channels are quite different for foreign and domestic cars. While domestic autos are shipped directly to retailers, imported autos are primarily shipped to wholesalers and then on to retailers.[12] Indeed, there is also evidence that imported inventory at wholesalers reached record highs during the crisis, leading importers to find extra storage space at the docks, on rail cars, and even boats.[13,14] We use BEA data on inventories at the wholesaler and manufacturer level to construct total inventory-to-sales ratios for imported $(\widetilde{IS}_t^M)$ and domestic cars $(\widetilde{IS}_{tt}^D)$ as follow:

$$\widetilde{IS}_t^M = \frac{\text{Wholesale Inventory} + \text{Retail Inventory of Imported Autos}}{\text{Retail Sales of Imported Autos}}$$
$$\widetilde{IS}_t^D = \frac{\text{Manufacturers' Inventory} + \text{Retail Inventory of Domestic Autos}}{\text{Retail Sales of Domestic Autos}}$$

A caveat with the formulas above is that they are based on an implicit assumption that all manufacturers' inventories are for the domestic market and all wholesalers' inventories

---

[10]Indeed, it could actually be sooner than this. For instance, consider a car manufactured in Japan that is produced exclusively and irreversibly for the US market. The inventory of these cars in the factory should also be included in our measures of foreign inventory.

[11]Consider a transaction between a plant in China and a customer in the US that takes 12 weeks from factory door to factory door. If the shipment is purchased at the Chinese factory, it will immediately enter into the US plant's inventory. On the other hand, if the shipment is sold on delivery, then it will remain in the Chinese plant's inventory for the 12-week voyage. Thus, the delays in shipping by themselves could affect the inventory holdings of both an importer and an exporter. Similarly, if the exporter is trying to economize on international transactions costs, it has an incentive to build up a stock of inventory before shipping overseas.

[12]Dunn and Vine (2006) study seperately the inventory levels of dealers of imported and domestic autos. They find that once you control for the different nature of dealer networks and composition of sales that the inventory-sales ratios are about the same domestic and imported autos.

[13]A number of articles point to the problems that importers of cars faced in storing the cars that had been shipped. In one case, Toyota rented a ship in the port of Malmo, Sweden to store 2,500 unsold autos when its logistic center reached its limit of 12,000 autos (Wright, 2009).

[14]More evidence of the importance of wholesale inventories of imported autos is that from the retail inventory data the imputed drop in imported cars at the peak is larger than the actual decline in imports, implying a rise in wholesale inventories consistent with the above behavior.

are imported cars. The relative direction of these biases is unclear. While we cannot definitively quantify the different inventory holdings without more micro data, these imperfect adjustments measures are preferred to the Ward's retail data, which miss out entirely on wholesalers' and manufacturers' inventory.

Figure 8 plots the time series of both the raw Ward's retail data for imports and domestic autos (denoted "Wards"), our adjusted measures (denoted "BEA/Wards"), and a measure for the US auto industry overall (denoted "US Autos (BEA)"). Comparing the adjusted and unadjusted measures clearly shows that a focus on the retail measures (Wards) alone substantially understates the stock of autos overall. The retail and overall measures also tell starkly different stories in terms of relative inventories. The retail data suggest that importers hold less inventory than sellers of domestic autos, and our adjusted series suggest that the inventory of imported cars is about 1.5 months larger than that of domestic cars.

Beyond the auto industry, there is other evidence that inventories are more important for imported and exported goods more generally. The data we use are 3-digit SIC manufacturing level from the period 1989 to 2001. We estimate the relationship between inventory holdings, exports, and imported inputs as

$$IM_{it} = c + \alpha_0 EXS_{it} + \alpha_1 MM_{it} + \varepsilon_{it},$$

where our variables are defined as

$$
\begin{aligned}
IM_{it} &= \text{inventory(eop)}_{it}/\text{material costs}_{it} \\
EXS_{it} &= \text{exports}_{it}/(\text{imports}_{it} + \text{sales}_{it}) \\
MM_{it} &= \text{imports}_{it}/(\text{imports}_{it} + \text{material costs}_{it})
\end{aligned}
$$

Because we lack data on direct exports or imports of inputs, we adjust our measures of the export share and import content to ensure these shares are less than one. To compensate for re-exports in some industries, our proxy of the amount being exported, EXS_{it}, is equal to the amount of goods in industry i available to export in period t. Likewise, since in some industries domestic production is small relative to imports, for our measure of the import content of inputs, MM_{it}, we measure this as share of material costs plus imports. In total,

these adjustments lower the median import and export shares by a few percentage points.

The first column of Table 3 shows that US industries more involved with trade (both on the export and import side) tend to hold more inventory. Interpreting these results, we note that an industry that imports 100 percent of inputs and exports 100 percent of output would hold almost 3 times the inventory of an industry that used only domestic inputs and sold only domestically.

One might be concerned that our findings for the US industries do not reflect micro level behavior but instead reflect some sort of aggregation bias of heterogeneous producers. Perhaps big plants hold more inventory than small plants and are also more likely to import and export.

Unfortunately, we do not have plant-level data for the US. However, in AKM, we examined plant-level data in Chile and found that plants involved in trade hold more inventory, even after controlling for industry. Here we use these data to examine whether the aggregation bias drives the results in our plant-level data from Chile. In the second column of Table 3, we present the results of a similar industry-level regression using a panel of Chilean plants aggregated to the 3-digit industry level from 1990 to 2001. Here we see a smaller coefficient on imports and a negative coefficient on exports. Finally, in the third column we reproduce our regression results on the individual plant-level data. For Chile, we see that the coefficients at the plant level are substantially larger than at the industry level, suggesting that if the aggregation bias in Chile is similar to the US, then our US industry measures may understate how trade affects inventory holdings.

One might be concerned that our estimates of the inventory premia on trade are larger for US industries than Chilean industries. Obviously without plant-level data it is not possible to fully understand these differences, but one possible explanation is that relative to Chile, the US is a fairly closed economy that is actually quite distant from its trading partners and so international transaction costs are relatively larger for the US than for Chile.

Finally, we make one more note on plant-level evidence within the US. In AKM, we examined data from a single US firm that sources both domestically and internationally. We found that all else equal, international orders are bigger and less frequent than domestic orders.

Our evidence here suggests that firms use higher inventory holdings to economize on international transactions cost. In our quantitative section, we explore the impact of these frictions for the dynamics of trade, production, and sales.

3. Model

Before describing our full model, we consider a simple stylized example that illustrates why goods with high inventory holdings experience relatively larger drops in imports or production in response to a drop in sales.

Suppose that an importer has a desired inventory-to-sales ratio equal to 3. That is, it orders goods so as to ensure that it has three periods worth of sales at the end of each period. Imagine that its sales are equal to 10 units initially, so the firm has 30 units of inventories and imports 10 units. Consider next the effect of a 1-unit drop in this firm's sales. Since the firm desires a stock of 27 (9*3) units now, its imports drop by 4 units, 1 unit due to a drop in sales, and 3 units due to a drop in its stock of inventories. Clearly, the larger the firm's inventory-to-sales ratio, the larger is the decline in orders necessary to restore the desired inventory-to-sales ratio: a firm with an inventory-to-sales ratio equal to 1 would only experience a drop in imports equal to 2 units. The table below summarizes this discussion

t	Sales	Inventories (eop)	Imports	Inventory-to-Sales
1	10	30	10	3
2	9	27	6	3
3	9	27	9	3

We now develop a model of optimal inventory adjustment and international trade to examine the quantitative relevance of inventory decisions for trade dynamics. We extend the partial equilibrium sS model of international trade and inventories in AKM to a two-country general equilibrium environment. The model extends Backus, Kehoe, and Kydland (1994) to include a monopolistic retail sector that holds inventories of both domestic and imported intermediates. Specifically, in each country, a continuum of local retailers buy imported and domestic goods from a competitive intermediate goods sector in each country, and each retailer acts as a monopolist supplier in selling its particular variety of the good to consumers. Consumers purchase these varieties and then use an aggregation technology to

transform home and foreign varieties into final consumption. Retail firms are subject to two frictions that lead them to hold inventories: (i) fixed costs of ordering goods from intermediate producers; and (ii) a lag between orders and deliveries of goods. These frictions are more severe for retailers that sell imported goods, thus leading them to hold higher inventories. We also abstract from capital accumulation (see Alessandria, Kaboski, and Midrigan, 2009).

A. Environment

Formally, consider an economy consisting of two countries, Home and Foreign. In each period of time t, the economy experiences one of finitely many states η_t. Let $\eta^t = (\eta_0, ..., \eta_t)$ be the history of events up to date t, with the initial state η_0 given. Denote the probability of any particular history η^t as $\pi(\eta^t)$.

The commodities in the economy are labor, a continuum of intermediate goods (indexed by $j \in [0, 1]$) produced in Home, and a continuum of intermediate goods produced in Foreign. These intermediate goods are purchased and sold as retail goods to consumers. Finally, consumers combine intermediate goods to form final goods (consumption and capital), which are country-specific because of a bias for domestic intermediates. We denote goods produced in the Home with a subscript H and goods produced in Foreign with a subscript F. (Allocations and prices for the foreign country are denoted with an asterisk.) In addition, there are a full set of Arrow securities.

Consumers

The consumer has standard expected utility preferences over consumption and leisure:

$$(1) \quad \sum_{t=0}^{\infty} \sum_{\eta^t} \beta^t \pi\left(\eta^t\right) U\left[C\left(\eta^t\right), 1 - L\left(\eta^t\right)\right].$$

Using Home consumers as an example, final consumption is produced by aggregating purchases of a continuum of domestic retail goods $c_H(j, \eta^t)$ and a continuum of imported retail goods $c_F(j, \eta^t)$, (where $j \in [0, 1]$ indexes the good in the continuum).

$$(2) \quad C\left(\eta^t\right) = \left[\begin{array}{c} \left(\int_0^1 v_H\left(j, \eta^t\right)^{\frac{1}{\theta}} c_H(j, \eta^t)^{\frac{\theta-1}{\theta}} dj\right)^{\frac{\theta}{\theta-1} \frac{\gamma-1}{\gamma}} \\ +\tau^{\frac{1}{\gamma}} \left(\int_0^1 v_F\left(j, \eta^t\right)^{\frac{1}{\theta}} c_F(j, \eta^t)^{\frac{\theta-1}{\theta}} dj\right)^{\frac{\theta}{\theta-1} \frac{\gamma-1}{\gamma}} \end{array} \right]^{\frac{\gamma}{\gamma-1}}$$

Here the weights $v_H\left(j,\eta^t\right)$ and $v_F\left(j,\eta^t\right)$ are subject to idiosyncratic shocks that are iid across j and t. The parameter $\tau \in [0,1]$ captures the lower weight on Foreign goods (i.e., a Home bias). The Foreign consumer uses an analogous technology except that the lower weight τ multiplies the Home goods. The idiosyncratic shocks to preferences are not necessary but provide a simple way to generate heterogeneity across retailers that help to smooth out the effect of the non-convexities in the retailers' ordering decision. [15]

The household purchases domestic and imported retail goods at prices $p_H\left(j,\eta^t\right)$ and $p_F\left(j,\eta^t\right)$, respectively, supplies labor at a wage $\tilde{W}\left(\eta^t\right)$, and earns profits $\Pi\left(\eta^t\right)$ (from retailers).

In addition, it trades Arrow securities $B\left(\eta^{t+1}\right)$ that are purchased at time t and pay off one unit next period in state η^{t+1}. We denote the price of the security in state η^t at time t as $Q\left(\eta^{t+1}|\eta^t\right)$. The consumer's period t budget constraint is therefore:[16]

$$\int_0^1 p_H\left(j,\eta^t\right)c_H(j,\eta^t)dj + \int_0^1 p_F\left(j,\eta^t\right)c_F(j,\eta^t)dj \ +\sum_{\eta^{t+1}}Q(\eta^{t+1}|\eta^t)B\left(\eta^{t+1}\right) =$$

$$(3) \quad \tilde{W}\left(\eta^t\right)L\left(\eta^t\right) + \Pi\left(\eta^t\right) + B\left(\eta^t\right)$$

The budget constraint for the Foreign consumer is analogous except that prices and profits are those in the Foreign country. The prices of Arrow securities $Q(\eta^{t+1}|\eta^t)$ are the same in both countries, since they can be traded internationally at no cost.

The consumer takes prices and profits as given and maximizes (1) by choosing a series labor supply, retail purchases, investment, and Arrow securities subject to (2) and (3).

The maximization can be solved step-wise, with the consumer choosing an allocation of retail purchases $c_H(j,\eta^t)$ and $c_F(j,\eta^t)$ to minimize the expenditure necessary to deliver $C\left(\eta^t\right)$ units of aggregate consumption. The cost-minimizing first-order conditions define the

---

[15] Alternatively, we could have followed Alessandria and Choi (2007) and modelled firm productivity as being stochastic, or Khan and Thomas (2007a,b) in modelling inventory order costs as being stochastic.

[16] We also need to set a borrowing limit in order to rule out Ponzi schemes, $B(\eta^t) > \underline{B}$, but this borrowing limit can be set arbitrarily large, i.e., $\underline{B} << 0$.

demand for retail varieties:

$$c_H(j, \eta^t) = v_H(j, \eta^t) \left(\frac{p_H(j, \eta^t)}{P_H(\eta^t)}\right)^{-\theta} \left(\frac{P_H(\eta^t)}{P(\eta^t)}\right)^{-\gamma} C(\eta^t)$$

$$(4) \quad c_F(j, \eta^t) = v_F(j, \eta^t) \tau \left(\frac{p_F(j, \eta^t)}{P_F(\eta^t)}\right)^{-\theta} \left(\frac{P_F(\eta^t)}{P(\eta^t)}\right)^{-\gamma} C(\eta^t)$$

where we have defined the following aggregate price indexes for Home-produced output, Foreign-produced output, and output overall:

$$(5) \quad P_H(\eta^t) = \left(\int_0^1 v_H(j, \eta^t) \, p_H(j, \eta^t)^{1-\theta} \, dj\right)^{\frac{1}{1-\theta}}$$

$$(6) \quad P_F(\eta^t) = \left(\int_0^1 v_F(j, \eta^t) \, p_F(j, \eta^t)^{1-\theta} \, dj\right)^{\frac{1}{1-\theta}}$$

$$(7) \quad P(\eta^t) = \left[P_H(\eta^t)^{1-\gamma} + \tau P_F(\eta^t)^{1-\gamma}\right]^{\frac{1}{1-\gamma}}$$

Producers

For each country, we model a single representative producer that supplies to both the Home and Foreign markets. Intermediate goods in the Home country are produced by competitive firms using the following technology:

$$(8) \quad M(\eta^t) = l(\eta^t)$$

where $M(\eta^t)$ is output of intermediates, and $l(\eta^t)$ is labor hired. We assume an analogous production function for Foreign-produced intermediates.

We assume that producers must pay their workers a wage $\tilde{W}(\eta^t)$ at the beginning of period t, while revenues are received at the end of the period. Producers must therefore borrow from financial intermediaries at an interest rate $r(\eta^t)$ in order to finance labor expenditure. Their unit cost of labor is therefore equal to $W(\eta^t) = \tilde{W}(\eta^t)(1 + r(\eta^t))$. Since our focus is on studying the dynamics of inventories, we do not explicitly model the financial sector or the source of a financial crisis. Rather, we assume $r(\eta^t)$ is exogenous and study the response of our economy to an exogenous increase in $r(\eta^t)$. Jermann and Quadrini (2009) explicitly model financial frictions and show how a tightening of borrowing constraints acts, in the

model, equivalent to an increase in the tax on labor paid by consumers.

We assume perfect competition in the market for intermediate goods. Producers choose labor in order to maximize their profits, given the intermediate price $\omega\left(\eta^t\right)$ and wage $W(\eta^t)$. Free entry ensures that the intermediate price equals the minimum unit cost of production (essentially the producer price index):

$$(9) \quad \omega\left(\eta^t\right) = W\left(\eta^t\right)$$

Retailers

In Home there is a unit mass of retailers selling goods that were produced in Home, and another unit mass of retailers selling goods that were produced in Foreign. Retailers purchase intermediates from producers and sell them to consumers. For a Home retailer of good j produced in Home, retail sales are again denoted $c_H\left(j,\eta^t\right)$, while purchases from intermediate goods producers are denoted $z_H\left(j,\eta^t\right)$. We focus on Home retailers operating in Home, retailers operating in Foreign face an identical problem, as do Foreign retailers operating in Home. (The subscript F continues to distinguish goods *produced* in Foreign, while an asterisk continues to denote the corresponding arguments for the *retailers* in the Foreign market.)

Retailers enter the period with a stock of inventories $s_H(j, \eta^t)$. They face the following constraints on their ability to order new goods:

1. Purchases must be non-negative, $z_H\left(j, \eta^t\right) \geq 0$,
2. Any positive purchase $(z_H\left(j, \eta^t\right) \geq 0)$ requires a fixed amount ϕ^d of local labor.
3. With probability μ^d, purchases made at date t arrive in $t+1$ (otherwise they arrive immediately), and
4. Retailers can only sell goods on hand: $c_H\left(j,\eta^t\right) \leqslant s_H(j,\eta^t) + z_H\left(j,\eta^t\right)$ if the order arrives immediately (with probability μ^d), or $c_H\left(j,\eta^t\right) \leqslant s_H(j,\eta^t)$ otherwise.

The assumption of random arrivals is intended to capture some of the uncertainty in the lags between orders and delivery that retailers face, but more important, it allows us to flexibly vary the average length of these lags by changing μ^d. The lag structure is meant

to capture the time between production of goods by producers and arrival of deliveries to retailers. We define ξ_t to be the random variable that takes a value of 1 if orders arrive immediately. We define a partition of the state as $\eta^t = \{\tilde{\eta}^t, \xi^t\}$, since the realization of ξ_t is known before prices are set, but not until after inventories are ordered. Thus, orders $z_H\left(j, \tilde{\eta}^t, \xi^{t-1}\right)$ are independent of the current ξ_t, while the price that retailers charge $p_H\left(j, \eta^t\right)$ can depend on the current ξ_t. Retailers choose these prices given consumer demand in equation (4). They take the intermediate price $\omega\left(\eta^t\right)$ and wage $W\left(\eta^t\right)$ as given. The problem of a Home retailer selling home-produced goods is therefore:

$$
\max_{z_H\left(j, \tilde{\eta}^t, \xi^{t-1}\right), p_H\left(\eta^t\right)} \sum_{t=0}^{\infty} \sum_{\eta^t} Q\left(\eta^t\right) \left[\mu^d p_H\left(j, \eta^t, 0\right) c_H\left(j, \eta^t, 0\right) + \left(1 - \mu^d\right) c_H\left(j, \eta^t, 1\right) y_H\left(j, \eta^t, 1\right)\right.
$$

$$
\left. -\omega\left(\eta^t\right) z_H\left(j, \eta^t\right) - W\left(\eta^t\right) \phi^d \times 1_{z_H\left(j, \tilde{\eta}^t, \xi^{t-1}\right) > 0}\right]
$$

$$
s.t. \quad c_H\left(j, \eta^t\right) = \min \left[\begin{array}{c} v_H\left(j, \eta^t\right) \left(\frac{p_H(j, \eta^t, 1)}{P^H(\eta^t)}\right)^{-\theta} \left(\frac{P^H\left(\eta^t\right)}{P(\eta^t)}\right)^{-\gamma} Y\left(\eta^t\right), \\ s_H\left(j, \eta^t\right) + \xi_t z_H\left(j, \tilde{\eta}^t, \xi^{t-1}\right) \end{array} \right]
$$

$$
s_H\left(j, \eta^{t+1}\right) = \left(1 - \delta_s\right) \left(s_H\left(j, \eta^t\right) - c_H\left(j, \eta^t\right) + z_H\left(j, \tilde{\eta}^t, \xi^{t-1}\right)\right)
$$

$$
z_H\left(j, \eta^t\right) \geq 0
$$

Profits are valued at $Q\left(\eta^t\right)$, the Arrow-Debreu price in period 0 of a security paying one unit in state η^t. Also, note that both beginning-of-period inventories and orders depreciate at a rate δ_s.

Retailers of imported materials (e.g., Home retailers of Foreign-produced goods) face the analogous constraints, except that the fixed cost and probability of receiving orders are specific for importing, ϕ^{imp} and μ^{imp}, respectively. The constraints on Foreign retailers are completely symmetric.

B. Equilibrium

In this economy, an equilibrium is defined as (i) an allocation of aggregate quantities $\{C\left(\eta^t\right), L\left(\eta^t\right), M\left(\eta^t\right), B\left(\eta^t\right), \Pi\left(\eta^t\right)\}_{t=0}^{\infty}$, j-specific factor allocations, $\{l\left(j, \eta^t\right)\}_{t=0}^{\infty}$, and disaggregate goods $\left\{\left\{c_i\left(j, \eta^t\right), s_i\left(j, \eta^t\right), z_i\left(j, \tilde{\eta}^t, \xi^{t-1}\right)\right\}_{i=H,F}\right\}_{t=0}^{\infty}$ for both Home and Foreign,

and (ii) prices of goods $\left\{ \{p_i(\eta^t)\}_{i=H,F}, \omega(\eta^t) \right\}$ and factors in $\left\{ W(\eta^t), \tilde{W}(\eta^t) \right\}_{t=0}^{\infty}$ for both Home and Foreign, and (iii) Arrow security prices $\{Q(\eta^{t+1}|\eta^t)\}_{t=0}^{\infty}$, such that:

- Given prices, the allocations satisfy the consumers' problems, the intermediate producers' problems, and retailers' problems in Home and Foreign; and

- The retail goods, labor, and capital markets clear in each country, and the intermediate goods markets and Arrow security markets clear for the world economy.

We briefly describe the market clearing conditions. First, Arrow securities are in zero net supply, so the bond market clearing condition is $B(\eta^t) + B^*(\eta^t) = 0$. Second, labor demand includes both labor used in the production of intermediates as well as that used by retailers in purchasing, i.e.,

$$\int \left[l(j, \eta^t) + \phi^d \times 1_{z_H(j, \tilde{\eta}^t, \xi^{t-1}) > 0} + \phi^i \times 1_{z_F(j, \tilde{\eta}^t, \xi^{t-1}) > 0} \right] dj = L(\eta^t)$$

Next, the resource constraint for intermediate goods requires that production is equal to orders:

$$
\begin{aligned}
M(\eta^t) &= \int_0^1 z_H(j, \eta^t)\, dj + \int_0^1 z_H^*(j, \eta^t)\, dj \\
M^*(\eta^t) &= \int_0^1 z_F(j, \eta^t)\, dj + \int_0^1 z_F^*(j, \eta^t)\, dj
\end{aligned}
$$

Notice that intermediate goods produced in Home, $M(\eta^t)$, have two uses: they go to domestic retailers of Home goods, $z_H(j)$, and to exporters of Home goods, $z_H^*(j)$. Similarly, intermediate goods produced in Foreign are either sold to domestic retailers of Foreign goods, $z_F^*(j)$ or are imported into Home, $z_F(j)$.

The end-of-period stock of inventories of any retailer j obeys:

$$s_i(j, \eta^t) = (1 - \delta_s)\left(s_i(j, \eta^t) + z_i(j, \eta^t) - c_i(j, \eta^t) \right)$$

The aggregate stock of inventories held in Home is then given by

$$S(\eta^t) = \int_0^1 s_H(j, \eta^t)\, dj + \int_0^1 s_F(j, \eta^t)$$

4. Parameterization

We now describe the functional forms and parameter values considered for our benchmark economy. The parameter values used in the simulation exercises are reported in Table 4. The instantaneous utility function is given as $U(C, 1 - L) = \log(C) + \psi \log(1 - L)$. Our calibration involves several parameters that are relatively standard in the international real business cycle literature, and so we assign typical values. These parameters include the preference parameters $\{\psi, \gamma, \tau, \beta\}$ and technology parameters $\{\delta_s, \alpha\}$. We choose ψ, the relative weight on leisure in the utility function in order to match a labor supply of $1/3$. We assign the elasticity of substitution between domestic and imported goods $\gamma = 1.5$, a standard value.

Our focus in this paper is on production of storable goods, and the dynamics of output, inventories, and sales for this sector. We thus choose parameters so as to match facts about the relative share of imports and the inventory-to-sales ratio for goods, excluding the service sector. Accordingly, we choose the Home bias parameter, τ equal to 0.31 in order to match a share of imports (equivalently exports since the two countries are symmetric) in GDP of 23 percent.[17] This trade share is higher than typical for the entire US, since services are mostly not traded.

In order to facilitate comparison with available data, we model a period to be a quarter. We therefore assign a discount factor of $\beta = 0.99$. We assign the depreciation rate on inventories using various estimates of annual non-interest inventory carrying costs range.[18] These range from 19 to 43 percent of a firm's inventories, which implies quarterly carrying costs ranging from 4.5 to 11 percent.[19] Our assigned value of $\delta_s = 0.075$ is in the mid-range of these estimates.

We have several other parameters, $\{\theta, \sigma_v, \mu^d, \mu^{imp}, \phi^d, \phi^{imp}\}$, that are particular to our inventory/retailing set-up. We start by assigning $\theta = 3$, a typical estimate in industrial organization studies. The standard deviation of demand shocks σ_v is set at 0.8.[20]

---

[17] This parameter must be jointly chosen with the inventory and retailing parameters, since these parameters affect the relative retail costs (and prices) of imported and domestic goods.

[18] These include taxes, warehousing, physical handling, obsolescence, pilfering, insurance, and clerical controls.

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

[20] The shocks generate heterogeneity across firms, which helps to smooth out the aggregate response in a model with non-convexities. With the lag structure, they also generate a precautionary motive for inventories.

What is key for our study of the dynamics of trade is the different characteristics of imported and domestic inputs, particularly the lags and fixed costs. Given our focus on these differences, we let $\mu^{imp} = 1$, so that imported goods arrive with a one-quarter lag. It is common to have a such a lag on inventories in the closed economy inventory literature (see Christiano, 1988). We then calibrate the delay on domestic goods μ^d, the fixed cost of ordering domestic intermediates ϕ^d, and the fixed cost of ordering imports ϕ^{imp} so that the steady state in the model jointly matches three key moments in the data. Table 4 (column labeled "Benchmark) reports the parameter values we use and Table 5 reports the targets used to pin down the value of these parameters.

The first target is the aggregate inventory to (quarterly) sales ratio (for all firms in the US) of 1.3. We choose this to match the average ratio of total business (retail + wholesale + manufacturing) inventory to quarterly final expenditures on goods (measured as equipment investment and consumption expenditure on goods) from 1998 to 2007. Two explanations are in order about this target, particularly the denominator. First, because we only measure final expenditures on goods, our measure exceeds stocks of inventory relative to private GDP by a factor of 2.5. Large sectors such as education, finance, health, and other services constitute a large share of GDP but hold very little inventory. However, given our focus on movements in trade relative to production and sales of traded goods, we abstract from these sectors in our quantitative analysis just as we have in the empirical analysis. Second, business inventory-to-sales ratios are often reported to be roughly 1.3 months rather 1.3 quarters as we have targeted. This commonly cited figure includes all sales, not just final sales, and so it counts the same good multiple times (from parts supplier to manufacturer to wholesaler to retailer). Since in our model we measure the inventory-to-sales ratio using final sales in the denominator:

$$IS\left(\eta^t\right) = \frac{\int_0^1 s_H\left(j,\eta^t\right)dj + \int_0^1 s_F\left(j,\eta^t\right)}{\int_0^1 c_H\left(j,\eta^t\right)dj + \int_0^1 c_F\left(j,\eta^t\right)}$$

as opposed to total sales (to consumers and to retailers):

$$IS_{total}\left(\eta^t\right) = \frac{\int_0^1 s_H\left(j,\eta^t\right)dj + \int_0^1 s_F\left(j,\eta^t\right)}{\int_0^1 \left[z_H\left(j,\eta^t\right) + c_H\left(j,\eta^t\right)\right]dj + \int_0^1 \left[z_F\left(j,\eta^t\right) + c_F\left(j,\eta^t\right)\right]dj}$$

25

we target the ratio of inventories to final rather than total sales. Below we conduct a sensitivity check and show how our results change when we target a smaller inventory-to-sales ratio.

The second target is that importing firms hold twice the inventory (relative to sales) as firms that source domestically. This ratio is consistent with inventory-sales ratios for importers vs. domestic firms that we observe for Chilean plants and for US manufacturing industries. Our third target is the relative frequency of imported orders vs. domestic shipments. Using shipment-level data of a single US steel wholesaler, in AKM we found that this firm places orders for imports half as frequently as domestic orders.

As Table 4 (column labeled "Benchmark") shows, the resulting value of μ^d is equal to 0.5. This implies an average delay of 1.5 months on domestic transactions and an additional 1.5 month delay on imported transactions. The six week additional delay for international trade compares well with the evidence presented on shipping by Hummels (2001) and customs/processing times in Djankov, Evans and Pham (2006). Consequently, the base 1.5 month delay on domestic purchases is somewhat lower than the one quarter delay often assumed in the inventory literature (see Christiano, 1988). The values for ϕ^d and ϕ^{imp} imply that fixed costs account for roughly 3.7 percent and 23.9 percent of mean revenues, respectively (these costs are not incurred each period so their share in total revenue is much smaller). Our calibration targets and additional implications of the model are summarized in Table 5. Notice that domestic firms order with a frequency of 0.6 per quarter, while importers do so with a frequency of 0.3 per quarter.

Tables 4 and 5 contain several additional columns that describe several sensitivity checks we have performed. The column labeled "Low I/S" refers to an experiment in which we target an aggregate inventory-to-sales ratio equal to 0.7, the ratio of the stock of inventories to *total* quarterly sales in the US. This experiment downplays the role of inventories, since in the model we continue to compute the ratio of inventories-to-final sales. To match this lower level of inventories, we set $\mu^{imp} = 0.4$, as well as lower the fixed cost of domestic and foreign purchases, so as to keep the rest of our moments unchanged.

Finally, the column labeled "Low import premium" considers an economy in which importers only hold a 50 percent higher stock of inventories (relative to sales) than domestic

firms. We lower the importer's inventory-to-sales ratio by reducing the fixed cost of ordering to 6.9 percent of period revenues (compared to 23.9 percent earlier). We describe these and several additional experiments below.

A. Policy Rules

We next discuss the optimal policy rules of retailers in the stationary distribution with no aggregate uncertainty.[21] We start by noting that the retailers' problem can be written recursively. We therefore drop the time and state notation from variables and note that in a steady state, the ordering decision is only a function of the current values of inventory s_H and the taste/demand shock ν_H, while the pricing decision is a function of (s_H, ν_H), and the delivery shock, ξ_H.

Figure 9 plots the ordering policy of retailers selling either domestic or foreign goods for a given demand shock. Generally, the more inventory on hand, the smaller the order a retailer places. The presence of a fixed cost creates a region of inaction and an adjustment region that depends on (s, v). An importer only orders when its inventory level is below a threshold. All firms that start with inventories below this threshold order an amount that does not depend on the initial inventory stock because the firm sells all of its current inventory to its customers. Compared to an importer, a retailer selling domestically produced goods has a higher threshold to reorder, but the amount ordered is much smaller. Moreover, because goods may arrive in the current period, the amount ordered now is decreasing in the current inventory level. The relatively large frictions of ordering internationally create a wider band of inaction leading to larger inventory holdings on average and less frequent transactions.

Figure 10 plots the pricing policy as a function of inventory holdings for the same idiosyncratic demand shock. Focusing first on the pricing policy of an importer, there are two regions divided by the order threshold. For inventory holdings below the order threshold, the importer sets the price to absorb its total inventory. Above the order threshold, the firm charges a price equal to a markup of $\frac{\theta}{\theta-1}$ over the marginal value of an additional inventory. Thus in this region the price charged is falling in inventory holdings. The pricing policy of

---

[21] Given that idiosyncratic uncertainty is an order of magnitude greater than aggregate uncertainty, these steady state decision rules approximate well those in the economy with aggregate uncertainty. Of course, our solution method allows for these rules to be state-dependent.

a domestic firm depends on whether or not its ordered inputs have arrived. If the products have not arrived, the rationale for two pricing regions will be similar to that described for the importer. On the other hand, if the products have arrived, then the firm will carry some inventory into the next period and will charge a price equal to a markup over the marginal value of an additional inventory. Its price will be very much like the price of a firm that has substantial inventory and has decided not to order this period.

5. Experiments

In this section, we quantitatively evaluate the role of inventory holdings on aggregate trade dynamics. To isolate the role of inventory holdings we compare the impulse response dynamics for our benchmark inventory economy to an alternative economy without invento- ries. The no inventory economy uses the identical model and parameter values, except that we eliminate the fixed cost and delivery delay frictions. That is, we assign $\phi^d = \phi^i = 0$ and $\mu^d = \mu^i = 0$, so that retailers do not hold inventories in equilibrium. Comparing these models provides an estimate of the role of inventory holdings on trade flows in the crisis.

We consider several experiments designed to give insight into key aspects of the global economic crisis for trade flows. Namely, we consider a shock to the cost of labor through the *intra*temporal interest on labor expenditures, and a shock to the *inter*temporal interest rate. The intratemporal interest rate shock is effectively a labor wedge, raising costs and reducing labor supply/output, while the intertemporal interest rate shock increases inventory carrying costs. Thus, both capture the key elements of the financial crisis. These shocks do a very good job of capturing the dynamics of trade and so we do not consider a separate shock to financing of international trade along the lines of that suggested by Amiti and Weinstein (2009) or Chor and Manova (2009). Such a shock is like a worsening of the terms of trade and would clearly raise the price of imported goods, lower sales, and lower trade. The effects of movements in the terms of trade on trade and prices in the presence of inventories was the main focus of AKM.

A. An Increase in $r(\eta^t)$

Our first experiment considers a persistent increase in the interest rate producers pay to finance spending on labor, $r(\eta^t)$, in both countries, designed to capture the global decline

in economic activity.[22] In particular, we assume that $r = 0$ in the steady state and then consider the effect of an increase in r to $r_1 = \exp(0.075) - 1$, which subsequently mean-reverts:

$$\ln(1 + r_t) = \rho \ln(1 + r_{t-1}) \text{ for } t \geqslant 2$$

with $\rho = 0.75$. Since we calibrate steady-state hours to $\bar{l} = 1/3$, the frictionless economy would respond with a $(1 - \bar{l}) \times 0.075 = 5$ percent drop in consumption, production, imports and all other real variables.

Figure 11 reports the response of these variables in our economy with inventories. The upper-left panel shows that both production and imports decline substantially more than in the frictionless model. Most important, imports decline much more than domestic production. To understand the decline, note that in our model the following identity holds:

$$Y_t = S_t + \Delta I_t$$

where Y_t is production (or imports), S_t is sales, and ΔI_t is inventory investment. A good that is produced is either a) sold to the consumer or b) enters the retailer's stock of inventories. The subsequent two panels (upper-right and lower-left) present the dynamics of sales and inventories in our model. Notice that although inventories initially decline less than sales (since a number of firms have made orders in the period prior to the shock and these arrive with a lag), the decline in inventories exceeds that of sales in subsequent periods. Hence, as in the data, the inventory-to-sales ratio initially increases in response to the shock and then declines. Disinvestment in inventories thus amplifies the effect of the shock, causing a reduction in output much greater than the reduction in sales (lower-right panel).

The stock of inventories declines for two reasons in our model. First, sales drop, thus reducing the returns to holding inventories, that is, the probability that retailers have insufficient inventories to meet demand. A second channel of intertemporal substitution is

---

[22] An earlier draft of this paper assumed the recession is driven by a TFP shock and found very similar results, both quantitatively and qualitatively. Both types of shocks increase the cost of production and thus act in very similar ways.

quantitatively more important, however. Since the recession is associated with an increase in labor costs, retailers sell out of the existing stock and postpone new orders for future periods when the cost of labor is expected to decline. This second channel explains why the inventory-to-sales ratio eventually declines in our model, as it does in the data for imported autos in Figure 3.

Notice finally that the decline in inventories and sales is not too dissimilar for imported and domestic goods. The reason imports decline much more than production is that the stock of inventories (relative to sales) is twice greater for imported goods. Hence a larger decline in inventory investment is necessary to bring the inventory-to-sales ratio to the desired level for imported goods, as in the stylized example we presented earlier.

Table 6 summarizes this discussion by reporting the elasticity of imports to production and sales in our model. We compute two measures of these elasticities. The first is the peak-to-trough drop in imports relative to the peak-to-trough drop in sales. Since our model exhibits lots of lumpiness arising from inventory adjustment, we mostly focus on a second measure by computing the ratio of the cumulative drop in imports (the area under the impulse response function) to that of the cumulative drop in production and sales, respectively. Obviously, there is no empirical counterpart to the cumulative drop, but it is nonetheless a useful statistic to compare the properties of different calibrations. Notice that the cumulative drop in imports is 1.37 greater than the cumulative drop in production, and 1.61 greater than the cumulative drop in sales. Similarly, the peak-to-trough drop in imports is 1.31 times greater than the drop in production and 3.5 times greater than the drop in sales. The reason the short-run elasticity with respect to sales is so much larger is that sales decline much more gradually initially in the model, as inventories help smooth consumption in face of the negative shock.

We conclude that our model produces responses that are qualitatively and quantitatively in line with the data. Recall from Table 1 that imports and exports are roughly 50-60 percent more volatile than industrial production, and 70-80 percent more volatile than sales: our model thus predicts that inventories alone account for a sizable proportion of this volatility.

B. A Gradual Shock

In the data, the stock of inventories relative to sales has initially increased in the immediate aftermath of the recession, before declining. (see, for e.g., the evidence in Figure 3 on autos). Our model can rationalize such dynamics for inventories if the shock to the interest rate is gradual, rather than immediate, as in the experiments reported above. To illustrate this point, we next assume a gradual increase in interest rates. Specifically, we assume that

$$r_1 = \exp\left(\frac{0.0725}{2}\right) - 1, r_2 = \exp\left(0.0725\right) - 1$$

$$\ln\left(1 + r_t\right) = \rho \ln\left(1 + r_{t-1}\right) \text{ for } t \geqslant 2$$

We assume that all agents learn this process at date 1 and anticipate the subsequent increase and decline in interest rates. Figure 12 reports the dynamics of our model to these shocks.

Notice that the decline in inventories is much more gradual now than in our previous experiment and that the inventory-to-sales ratio is above its steady-state level several periods after the shock. The reason is that retailers prefer to invest in inventories at date 1, in anticipation of future increases in the cost of production, and this initial investment imparts additional dynamics to our model economy. As in the previous experiment, retailers eventually decrease their stock of inventories, both to respond to the lower sales, as well as for intertemporal substitution reasons. Once again, production declines more than it does in the frictionless environment, and imports decline more than overall production. Table 6 shows that the cumulative drop in trade in this experiment is 1.29 greater than that of production, and 1.6 times greater than that of sales. Similarly, the peak-to-trough drop in imports is 1.48 greater than that of production and 4.1 times greater than the drop in sales. The gradual shock exacerbates the short-run response but dampens the cumulative response.

C. A Shock to Intertemporal Prices

So far we have modelled the financial shock as an increase in the effective cost at which firms are borrowing to finance their labor expenditures within a period, i.e., as a shock to the labor wedge. We next consider the effect of an additional increase in intertemporal price

of current and future consumption, i.e., a shock to the interest rate. We model this shock as an increase in the date - 0 price of goods from $Q(\eta^t)$ to $Q(\eta^t)(1 + \tau^q(\eta^t))$. Notice from the bond Euler equation that

$$\frac{Q(\eta^{t+1})(1 + \tau^q(\eta^{t+1}))}{Q(\eta^t)(1 + \tau^q(\eta^t))} = \beta\pi(\eta^{t+1})\frac{u_c(\eta^{t+1})}{u_c(\eta^t)}$$

so that an increase in $\tau(\eta^t)$ corresponds to an increase in the interest rate at which consumers are effectively borrowing (or, alternatively, in the rate at which firms discount future profits). We choose the initial jump in $\tau(\eta^t)$ to generate a 100-basis-points increase in the interest rate, and assume

$$\log(1 + \tau_t^q) = \rho\log(1 + \tau_{t-1}^q) \text{ for } t \geqslant 2$$

where $\rho = 0.75$.

Figure 13 reports the response of real variables in our model economy to this additional shock, which we assume happens simultaneously as the shock to the intratemporal cost of borrowing. Clearly, the dynamics in this economy are very similar to those in our benchmark experiment, though the declines are greater. The reason output and imports drop more now is an even greater adjustment in the stock of inventories. A greater cost of borrowing leads retailers to postpone orders even further and contributes to the decline in real activity. Notice in Table 6 in the column titled "Financial Shock" that the cumulative decline in imports is even greater than that of production: trade declines 1.6 times more than production and 2.2 times more than sales. These numbers are very similar to those observed in the data.

6. Sensitivity

Here we explore the sensitivity of our model to several variations, including changing the inventory-to-sales ratio in the economy, lowering the importer premium on inventory, increasing the Armington elasticity of substitution, and lowering the magnitude of the shock. Our findings of a relatively high sensitivity of trade relative to production and sales are robust across these different environments. These experiments are reported in Table 7, and recall that Table 4 and Table 5 present the parameter values used and the moments we have

targeted.

A. Smaller Shock

How does the elasticity of trade to production vary with the size of the drop in output? Recall that in the data most recessions, independent of their size, produce similar elasticities of trade to production. We next ask whether our model is indeed consistent with this feature of the data by studying the response to a 3 percent increase in the intratemporal rate at which firms are borrowing to finance their labor expenditures.

Notice in Table 7, in the column labeled "Smaller shock" that the cumulative drop in trade is 1.28 times greater than that of production, and 1.65 times greater than that of sales, thus is not too dissimilar from the response to a much larger shock (recall that these elasticities are equal to 1.37 and 1.61, respectively). The difference in these numbers, we conjecture, has to do with the irreversibility constraint on purchases playing a smaller role with a smaller shock. Interestingly, the short-run decline in trade, as measured by the peak-to-trough elasticity, is greater in the economy with a smaller shock (1.34 and 3.84 for production and sales, respectively).

B. Lower Inventory-to-Sales Ratio

Turning to our low inventory experiment (recall that we calibrated this economy to match a 0.7 inventory-to-sales ratio), we find, not surprisingly, that the effect on the trade elasticity is reduced since inventory adjustment plays a less important role. The cumulative drop in imports in now 28 percent greater than that of production (recall 37 percent in the benchmark economy with a higher inventory-to-sales ratio), and 55 percent greater than that of sales (recall 61 percent in the benchmark economy).

Interestingly, we find that in this economy the short-run drop in imports is greater than earlier. For example, the peak-to-trough drop in imports in 47 percent greater than that of production (31 percent earlier). We conjecture that this happens because now only 40 percent of importers receive their order with a 1-period delay (we choose this lower number so as to generate the lower inventory-to-sales ratio by reducing the precautionary-investment motive), and hence importers can more readily react to a negative shock by decreasing the size of orders in the immediate aftermath of the shock.

C. Lower Import Premium

Recall that we now choose parameters so as to ensure that importers only hold 50 percent more inventories than domestic retailers, in contrast to the 100 percent premium we have assumed earlier. With a lower importer inventory premium, we find that the model once again generates a smaller cumulative drop in trade and inventories (reflecting a slightly lower stock of inventories to begin with) and similar drops in production and sales. Thus, relative to the cumulative drop in production or sales, we get a smaller cumulative drop in trade: 24 percent and 45 percent, respectively).

Once again, these long-run elasticities do not tell the whole story, however. Now, the peak to trough drop is actually larger than in our benchmark economy, with an elasticity of imports to production of 1.71 versus 1.31. This seemingly counterintuitive result arises because in our low importer premium model there are more firms closer to the adjustment margin than in our benchmark economy, since now importers are ordering roughly every other period compared to every third period in our baseline example. Thus, the extensive adjustment accounts for a bigger short-run adjustment since the negative shock leads importers to work through their inventory problems faster by delaying their order.

D. Higher Armington Elasticity

We also consider the impact of the elasticity of substitution on the dynamic properties of the model. There is much debate about this value. The literature that studies long-run trade flows emphasizes a higher number than ours, while the literature on business cycles emphasizes a smaller number. Here we consider a slightly larger elasticity of 2.5 and find quite similar short-run and long-run impacts on trade to those we reported earlier. Relative to production, the peak drop in trade now falls to 1.26 from 1.31, while the cumulative drop rises to 1.42 from 1.37. These small differences reflect the fact that there are no important direct relative price movements, since we have assumed a global shock that affects the Home and Foreign economy alike. All movements in relative prices operate indirectly through the effect that changes in inventory costs have on the different inventory holdings of domestic and foreign goods, but these effects are fairly likely too small to change our results much.

34

7. Conclusion

This paper examines the role of inventory dynamics and international trade empirically and theoretically, especially with regard to the dramatic drop (and strong rebound) in trade of the most recent US recession. Empirically, we show that trade is more volatile than either measures of trade-weighted production or expenditures, and that inventory dynamics play an important role in this volatility. However, we also find that trade dynamics in this current recession are not unusual. As Imbs (2009) points out, what is unusual is the magnitude and synchronization of the downturn.

The role of inventories is most clearly evident for trade in autos, a sector for which we can separately measure retail sales of imported autos and imports. Indeed, we see that imports of autos fell off a cliff in December 2008 even as final sales of autos recovered somewhat. The gap between sales and imports can be explained in part because inventory levels had become quite large relative to the rate of sales. Given that auto trade fell the soonest and the most in this recession, we believe any explanation of the decline in aggregate trade must be able to explain these dynamics.

To study these issues for the aggregate economy, we embed an sS model of inventory adjustment and trade in a two-country general equilibrium model, where inventory holdings differ for domestic and imported products because of larger frictions to international trade. We then use the quantitative theory to show that the relatively high elasticity of trade over the business cycle may arise from inventory considerations.

To account for the current synchronized global decline in trade, our model requires a global negative shock. With such a shock, the model can generate drops in production and international trade and movements in inventory-to-sales ratios that are of comparable magnitude to those in the US economy. We also explore the role of changes in financing costs on trade flows and find that these amplify the drop in trade even further.

In summary, we find that inventory concerns may play an important role in the propagation of shocks across countries. It appears that the role of trade in the most recent recession has not been exceptional. Trade has been particularly important in past recessions. What has been exceptional is the size of the shock itself. We plan, in future research, to consider the role of inventories in the propagation of international business cycles more generally.

References

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

[2] Alessandria, G., Kaboski, J. and Midrigan, V. "Inventories, Lumpy Trade and Large Devaluations." *American Economic Review*, forthcoming.

[3] Alessandria, G., Kaboski, J. and Midrigan, V. "Inventories and the Propagation of International Business Cycles." working paper, 2009

[4] Amiti M., and D. Weinstein, "Exports and Financial Shocks," mimeo, 2009.

[5] Auboin, M. "Restoring trade finance: what the G20 can do," in Baldwin, Richard and Simon Evenett eds. The collapse of global trade, murky protectionism, and the crisis: Recommendations for the G20. London: Center for Economic Policy Research, 2009.

[6] Backus, D., Kehoe, P. and Kydland, F. "International Real Business Cycles." *Journal of Political Economy*, 100 (Aug., 1992): 745-775

[7] Backus, D., Kehoe, P. and Kydland, F. "Dynamics of the Trade Balance and the Terms of Trade: The J-Curve?" *American Economic Review*, 84, (March, 1994): 84-103

[8] Baldwin, Richard and Simon J. Evenett. 2008. "The crisis and protectionism: Steps world leaders should take"

[9] Bems, R., R. Johnson, and K. Yi, 2009. "The Role of Vertical Linkages in the Propagation of the Global Downturn of 2008."

[10] Boileau, M. "Trade in Capital Goods and the Volatility of Net Exports and the Terms of Trade," *Journal of International Economics* 48, 347-36, 1999.

[11] Chor, D. and K. Manova. 2009. "Off the Cliff and Back: Credit Conditions and International Trade during the Global Financial Crisis," mimeo.

[12] Christiano, Lawrence. 1988. "Why Does Inventory Investment Fluctuate so Much?" *Journal of Monetary Economics*.

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

[14] Dorsey, T. "Trade Finance Stumbles." March, 2009 http://www.imf.org.

[15] Dougherty, C. "Trade Finance Shrivels: Pushing Downturn Deeper." *The New York Times,* March 3, 2009

[16] Dunn, W and D. Vine. 2006. "Inventory-Sales Ratios at US Auto Dealerships: Why Does Days' Supply Differ So Much Between Brands?" mimeo.

[17] Eaton, J., Kortum, S., Neiman, B., and Romalis, J. . "Trade, Geography, and the Global Recession" University of Chicago, mimeo, 2009

[18] Engel, C. and Wang, J. "International Trade in Durable Goods: Understanding Volatility, Cyclicality, and Elasticities," mimeo 2007.

[19] Hummels, David. 2001. "Time as a Trade Barrier." Purdue University Global Trade Analysis Project Working Paper 1152.

[20] Imbs, J. (2009). "The First Global Recession in Decades." mimeo.

[21] International Chamber of Commerce "Trade Finance in the Current Financial Crisis: Preliminary Assessment of Key Issues" November, 2008 http://www.iccwbo.org/uploadedFiles/ICC_Report_Trade_Finance_11_Nov_2008.pdf

[22] Jermann, U and V. Quadrini. 2009. "Macroeconomic Effects of Financial Shocks," mimeo.

[23] 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.

[24] 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.

[25] Lane, P. R. and G.M. Milesi-Ferretti. (2009). "The Cross-Country Incidence of the Global Crisis," mimeo.

[26] Levchenko, Andrei A., Logan T. Lewis and Linda L. Tesar. "The Collapse of International Trade During the 2008-2009 Crisis: In Search of the Smoking Gun," mimeo, University of Michigan, 2009.

[27] The Economist "Going Under," March 24, 2009a.

[28] The Economist "The Nuts and Bolts Come Apart," March 26, 2009b.

[29] Ramey V. and K. West. 1999. "Inventories" Handbook of Macroeconomics.

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

[31] Rose, Andrew and Mark Spiegel. 2009. "Cross-Country Causes and Consequences of the 2008 Crisis: International Linkages and American Exposure," NBER Working Paper 15358.

[32] Wright, Robert. 2009. "Out-of-work ships used as storage for unsold cars." *Financial Times*, February 4, 2009.

[33] Yi, K. "The collapse of global trade: the role of vertical specialisation." VOXEU, March 2009, http://voxeu.org/index.php?q=node/3199

Table 1: Summary Statistics on US Business Cycles

	SD (relative to IP)	Corr with IP	Corr with Expenditures	Autocorrelation
Industrial Production (IP)	1.00	1.00	0.90	0.89
Exports	1.49	0.52	0.46	0.74
Imports	1.64	0.81	0.79	0.75
Expenditures (TW)	0.90	0.87	0.92	0.87
GDP	0.43	0.90	1.00	0.87
Inventory	0.52	0.67	0.63	0.91
IS Ratio	0.64	-0.67	-0.65	0.81

Notes: Based on quarterly data from 67:1 to 09:04. Data are HP filtered with a smoothing parameter of 1600.

Table 2: Peak Drop in Trade Relative to Absorption

	Median	1971Q1	1975Q2	1980Q3	1982Q4	1991Q1	2001Q4	2009Q2
IMPORTS								
Y	**4.67**	4.67	4.63	5.21	2.38	2.59	6.00	4.81
IP	**1.64**	1.15	1.64	2.41	1.18	1.54	1.97	1.66
Expenditures	**2.38**	2.43	2.38	2.80	2.36	1.54	5.61	1.70

	Median	1971Q2	1975Q2	1980Q4	1982Q4	1990Q4	2002Q1	2009Q2
EXPORTS								
Y	**2.54**	2.54	1.51	0.22	3.52	1.80	7.04	4.10
IP	**1.41**	0.69	0.54	0.15	1.74	1.53	2.25	1.41
Expenditures	**1.45**	1.54	0.78	0.09	3.48	1.39	3.35	1.45

	Median	1971Q2	1975Q2	1980Q4	1982Q4	1990Q4	2002Q1	2009Q2
EXPORTS (peak to trough)								
Y	**3.33**	3.33	2.43	1.61	3.52	1.80	7.04	5.09
IP	**1.53**	0.90	0.86	1.05	1.74	1.53	2.25	1.75
Expenditures	**1.80**	2.02	1.25	0.64	3.48	1.39	3.35	1.80

	Median	1971Q2	1975Q2	1980Q4	1982Q4	1990Q4	2002Q1	2009Q2
INVENTORY-SALES Ratio								
IP	**-0.56**	-0.40	-0.77	-1.15	-0.56	-0.77	-0.13	-0.49

Notes: Measured from start of recession based on the NBER dates. The third panel measures the difference in exports between the peak and trough, where the peak is either the start of the recession if exports fall immediately. All data are HP filtered with a smoothing parameter or 1600, and so the drop is measured relative to the trend.

Table 3: Inventory and Trade by Industry (US and Chile)

Variable	US Industry	Chile Industry	Plant
Export share (EXS)	0.197	-0.074	0.247
	4.8	-2.3	2.7
Import share (MM)	0.193	0.067	0.145
	11.4	3.1	11.1
Constant	0.222	0.209	0.218
	31.5	23.0	48.8
Observations	1751	325	58546
R2	0.11	0.041	0.002

Notes: US Industry data based on 3 digit SIC (1987) data from 89 to 01. Chile data based on 3 digit ISIC data from 90 to 01. t-statistics are based on White robust standard errors

Table 4: Parameter Values

		Benchmark	Low I/S	Low import premium
Assigned Parameters				
gamma	Armington elasticity of H vs. F	1.5	1.5	1.5
theta	elasticity across varieties in H & F	3	3	3
beta	discount factor	0.99	0.99	0.99
deltas	inventory depreciation	0.075	0.075	0.075
sv	std. dev. taste shocks	0.8	0.8	0.8
muf	probability foreign orders arrive immediately	1	0.4	1
Calibrated Parameters				
tau	Home bias	0.31	0.31	0.31
muh	probability domestic orders arrive immediately	0.475	0.23	0.475
phih	fixed cost domestic orders (fraction mean revenue, %)	3.65	0.68	3.65
phif	fixed cost imports (fraction mean revenue, %)	23.88	9.89	6.86

Table 5: Moments

	Data	Benchmark	Low I/S	Low import premium
		Used for Calibration:		
Aggregate Inventory-to-Sales ratio	1.3	1.3	0.7	1.18
Ratio I/S imports to I/S domestic	2	2	2	1.5
Share imports in GDP	0.23	0.23	0.23	0.23
Ratio of frequency of domestic vs. imported orders	2	2	2	1.2
		Other implications		
I/S domestic retailers		1.06	0.57	1.06
I/S imported retailers		2.12	1.15	1.59
Frequency of orders, domestic		0.60	0.86	0.60
Frequency of orders, imports		0.30	0.43	0.52

Table 6: Model Predictions

	Data	Benchmark	Gradual shock	Financial shock
Peak to Trough				
Δ Imports / Δ Production	1.51	1.31	1.48	1.40
Δ Imports / Δ Sales	1.97	3.54	4.05	5.36
Δ Imports		0.13	0.13	0.18
Δ Sales		0.04	0.03	0.03
Δ Production		0.10	0.09	0.13
Δ Inventories		0.05	0.04	0.07
Cumulative				
Δ Imports / Δ Production		1.37	1.29	1.60
Δ Imports / Δ Sales		1.61	1.60	2.18
Δ Imports		0.34	0.32	0.44
Δ Sales		0.21	0.20	0.20
Δ Production		0.25	0.25	0.27
Δ Inventories		0.37	0.27	0.52

Notes: The data column reports the average of the median elasticities of imports and exports
"Gradual Shock" considers 2 consecutive, anticipated, equally sized increases in the labor wedge
"Financial Shock" adds an additional wedge in the date-0 prices, raising the interest rate by an additional 1%.

Table 7: Sensitivity Analysis

	Benchmark	Low import premium	Lower I/S ratio	High Armington elasticity	Smaller shock
Peak to Trough					
Δ Imports / Δ Production	1.31	1.72	1.47	1.26	1.34
Δ Imports / Δ Sales	3.54	4.82	4.68	3.58	3.84
Δ Imports	0.13	0.17	0.16	0.12	0.05
Δ Sales	0.04	0.04	0.04	0.03	0.01
Δ Production	0.10	0.10	0.11	0.10	0.04
Δ Inventories	0.05	0.05	0.11	0.04	0.02
Cumulative					
Δ Imports / Δ Production	1.37	1.24	1.28	1.42	1.28
Δ Imports / Δ Sales	1.61	1.45	1.55	1.68	1.65
Δ Imports	0.34	0.28	0.29	0.31	0.12
Δ Sales	0.21	0.20	0.19	0.18	0.07
Δ Production	0.25	0.23	0.23	0.22	0.09
Δ Inventories	0.37	0.34	0.62	0.29	0.12

Figure 1: Log Deviations from Trend in the Recent Recession

Inventory/Sales

GDP

Inventories

Demand

IP

Exports

Imports

Log Change from 2007Q3

0.1

0

-0.1

-0.2

-0.3

2007:Q3 2007:Q4 2008:Q1 2008:Q2 2008:Q3 2008:Q4 2009:Q1 2009:Q2 2009:Q3 2009:Q4
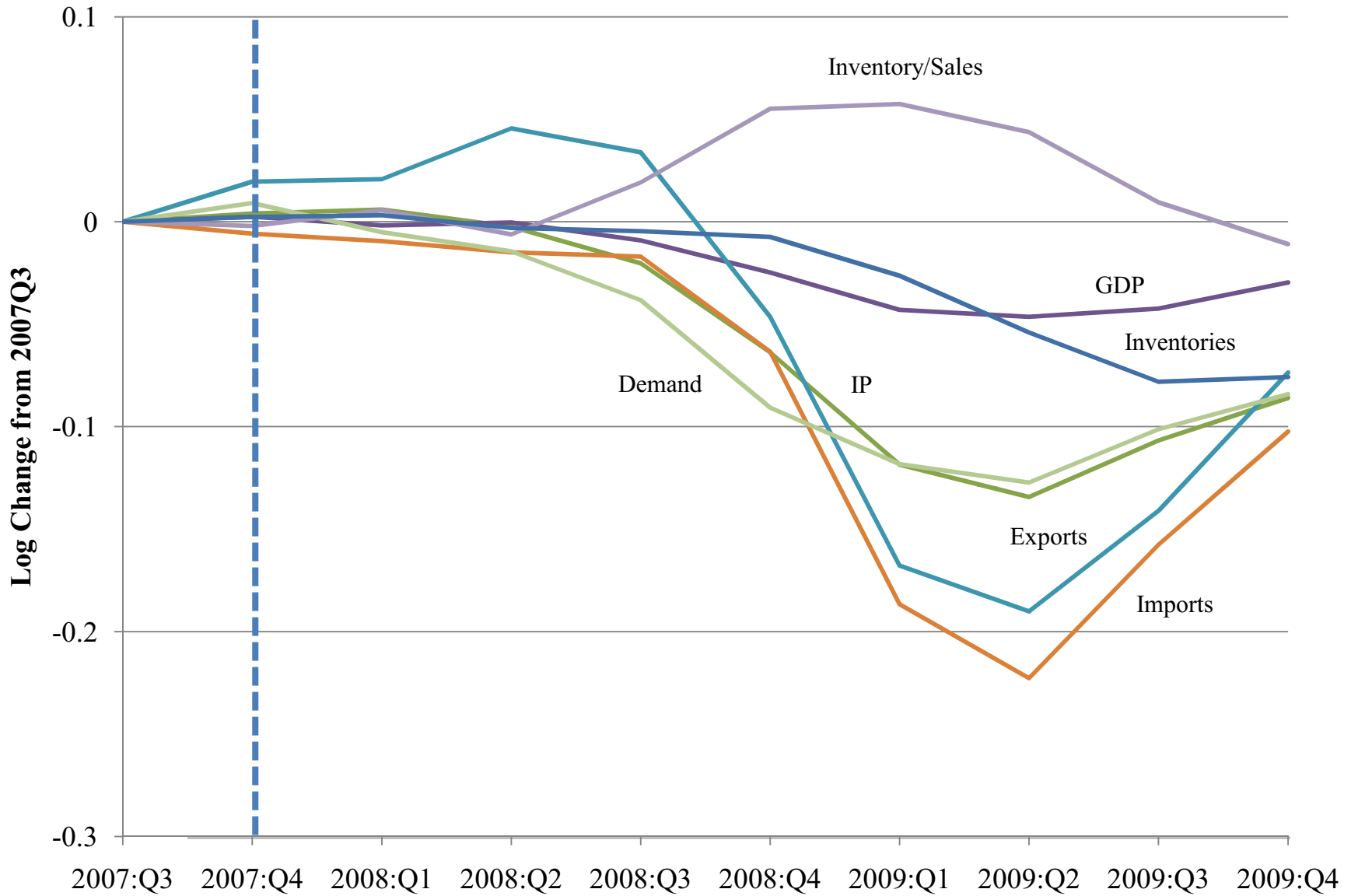
Figure 2A: US Real Imports (SA, $2005)
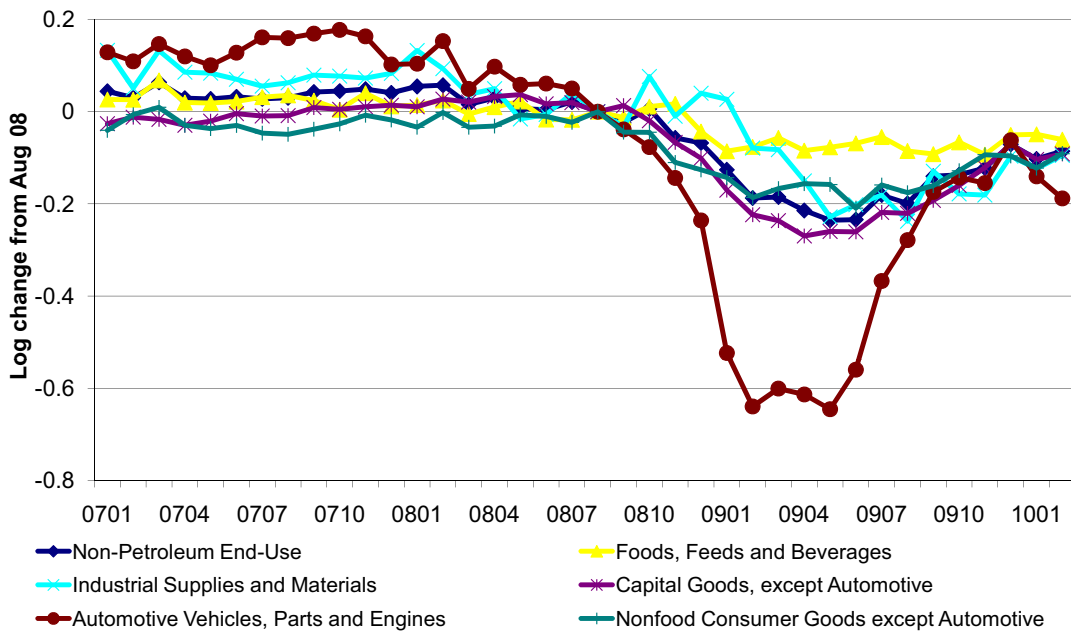
Figure 2B: US Real Exports (SA, $2005)
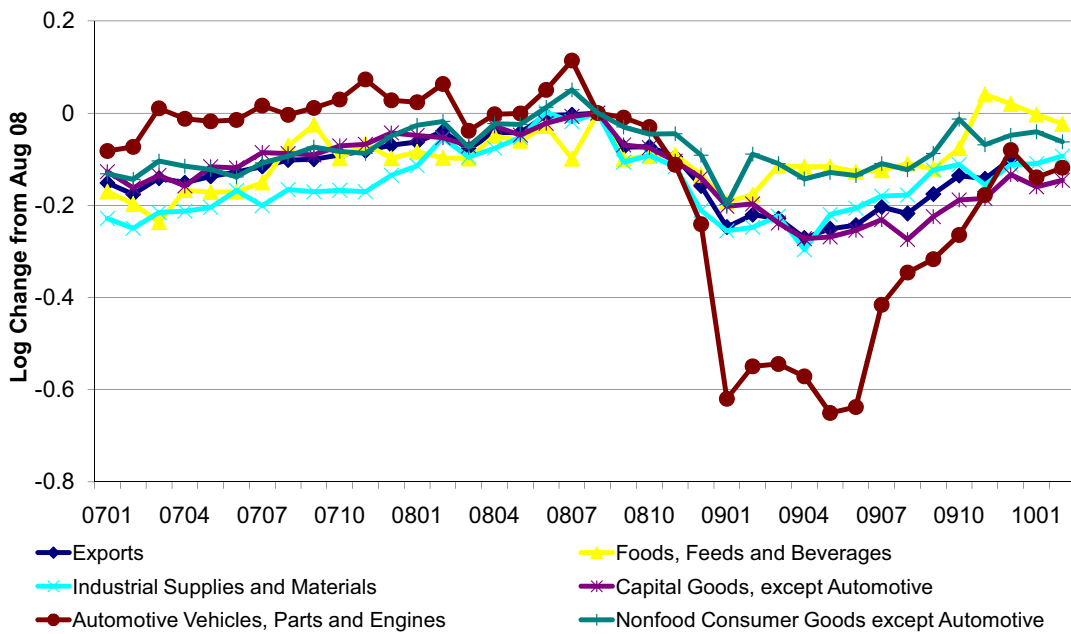
Figure 3: Dynamics of Imported Autos
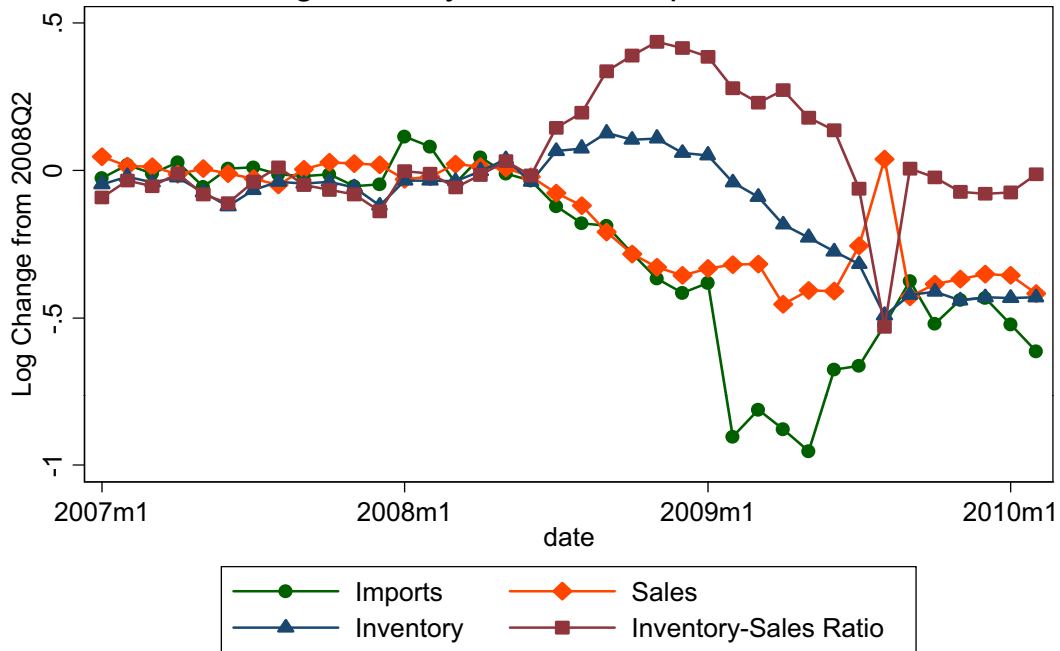
Figure 4: Dynamics of Imported Autos (70s)
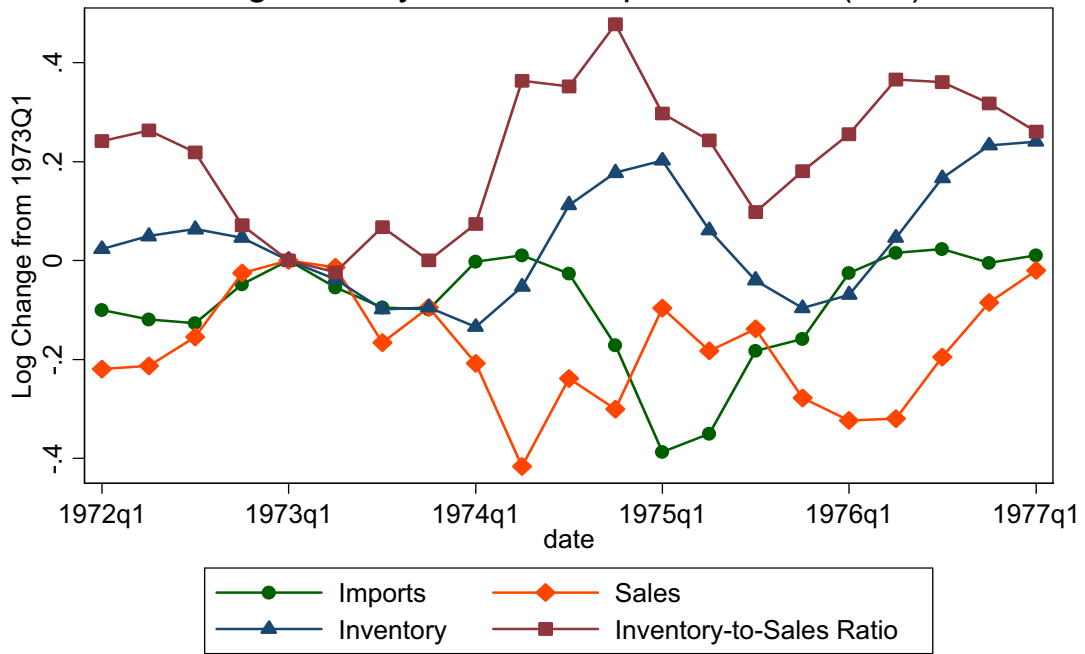
Figure 5: Capital Goods
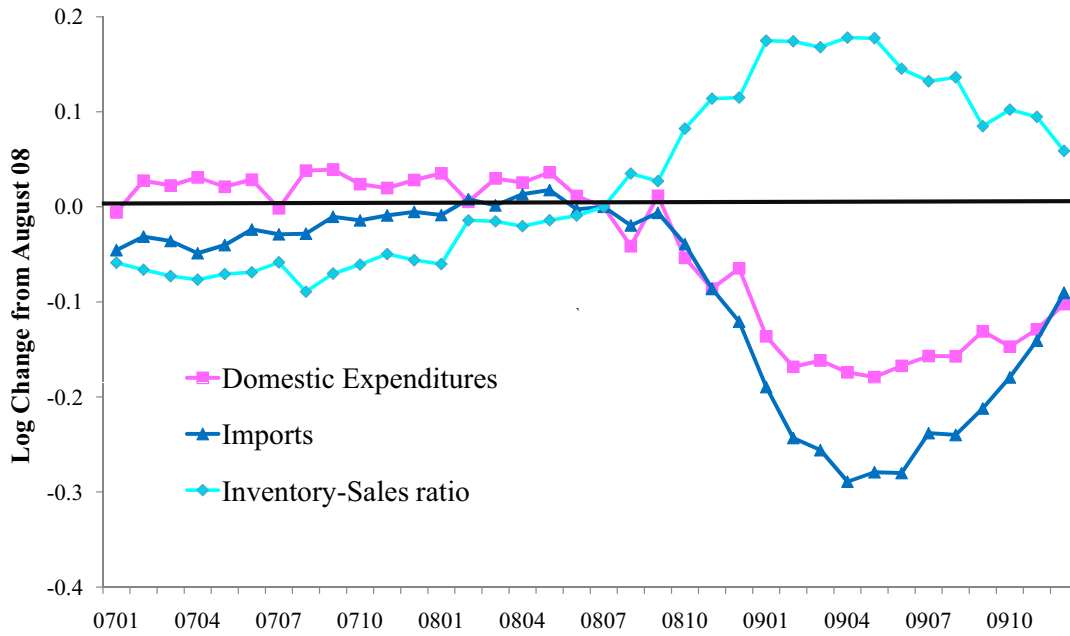
Figure 6: Consumer Goods (Non-Autos)
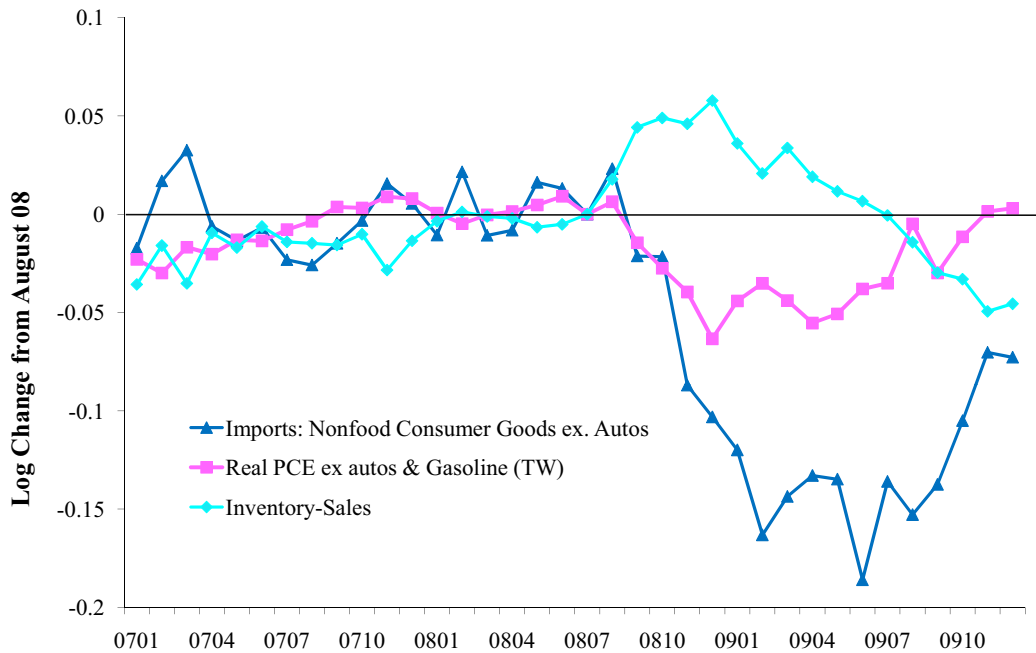
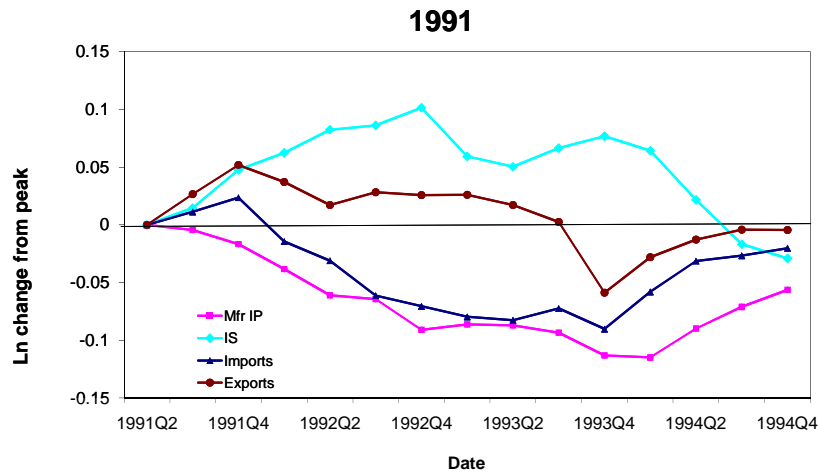# Figure 7: Agggregate Dynamics in Japanese Downturns
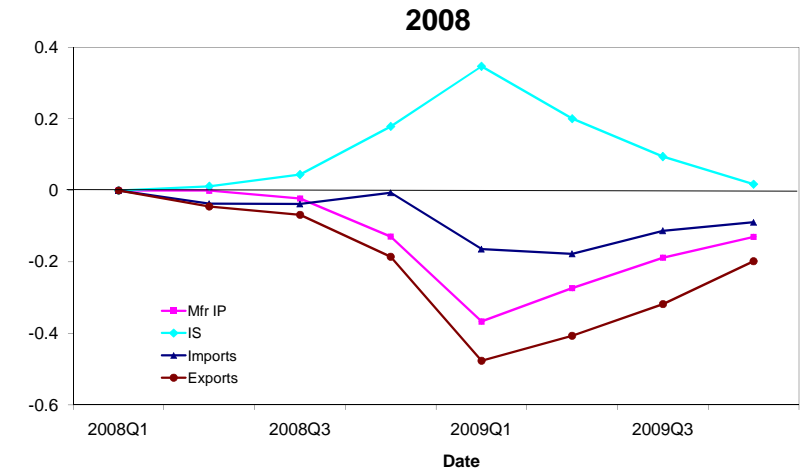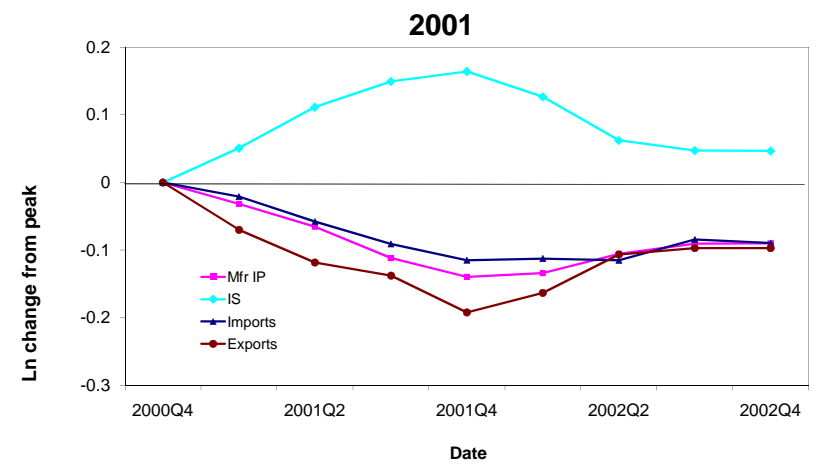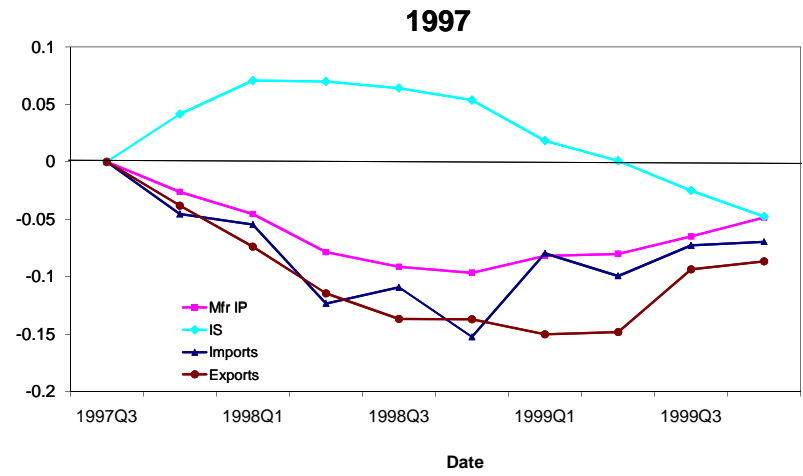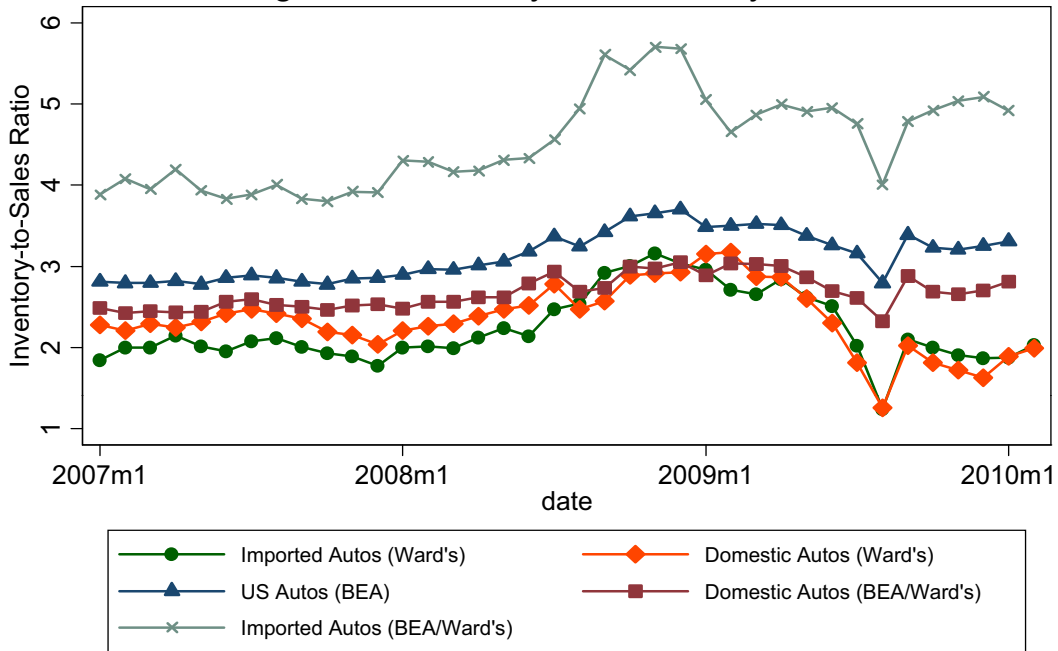
Figure 8: Inventory Measures by Source
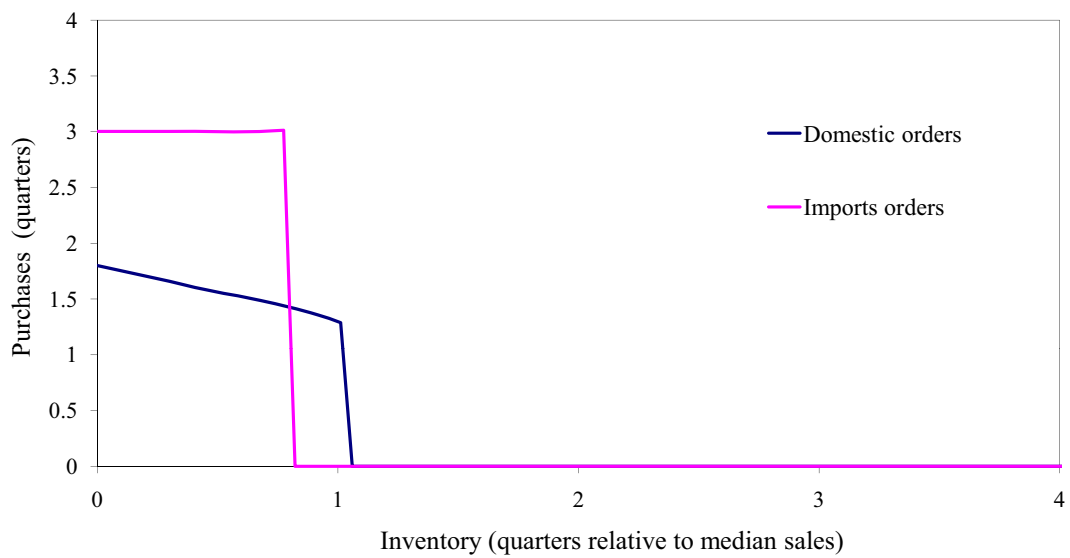

Figure 9: Policy Rules: Orders
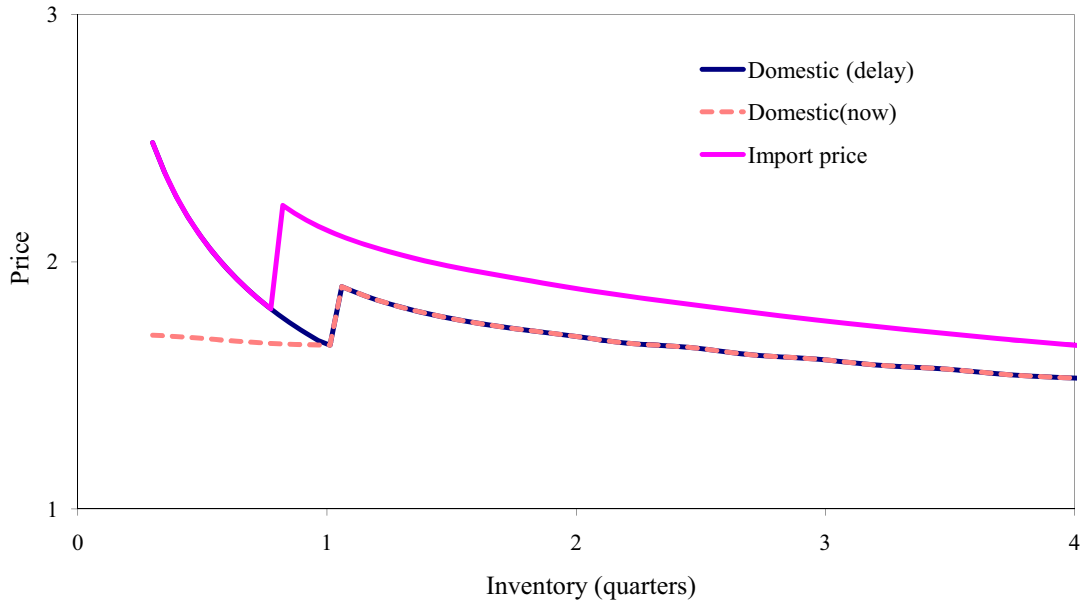
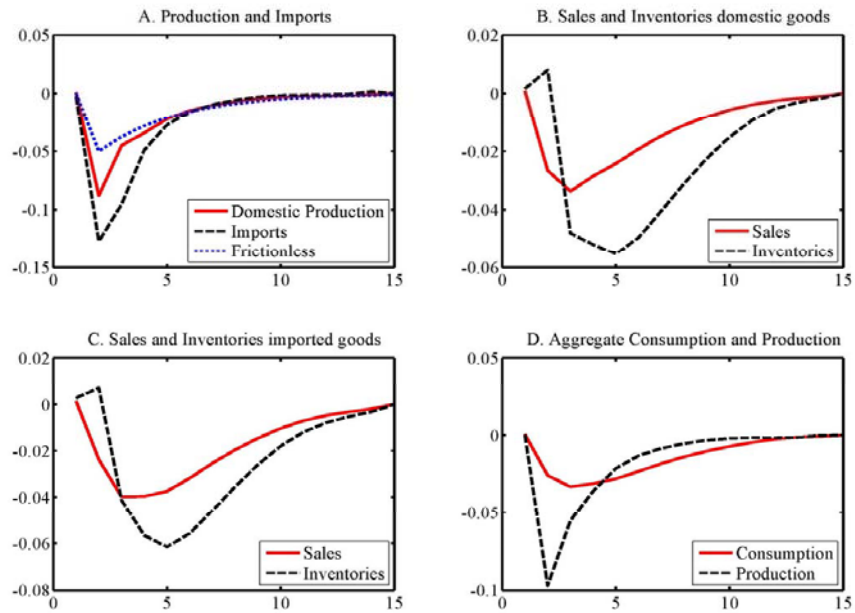# Figure 10: Policy Rules: Prices

Figure 11: Benchmark Model
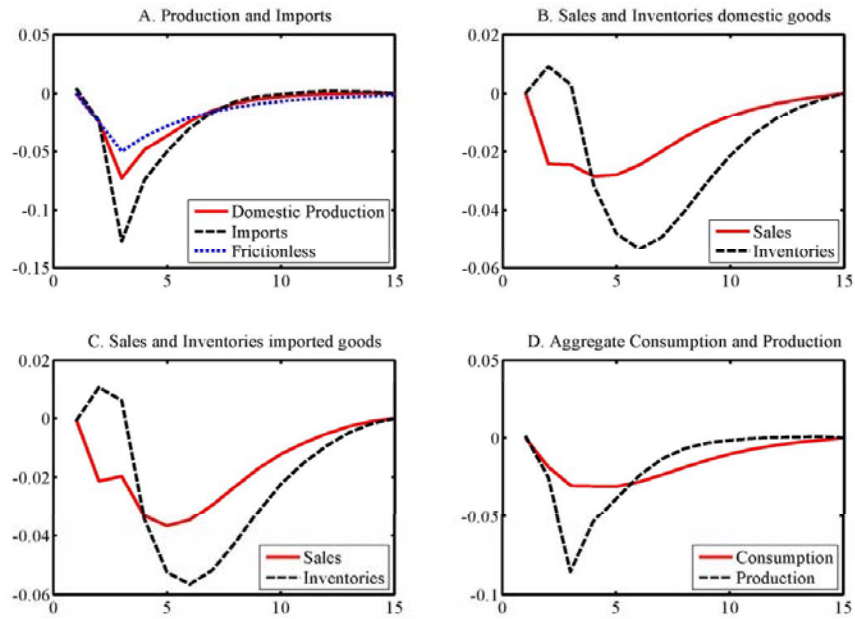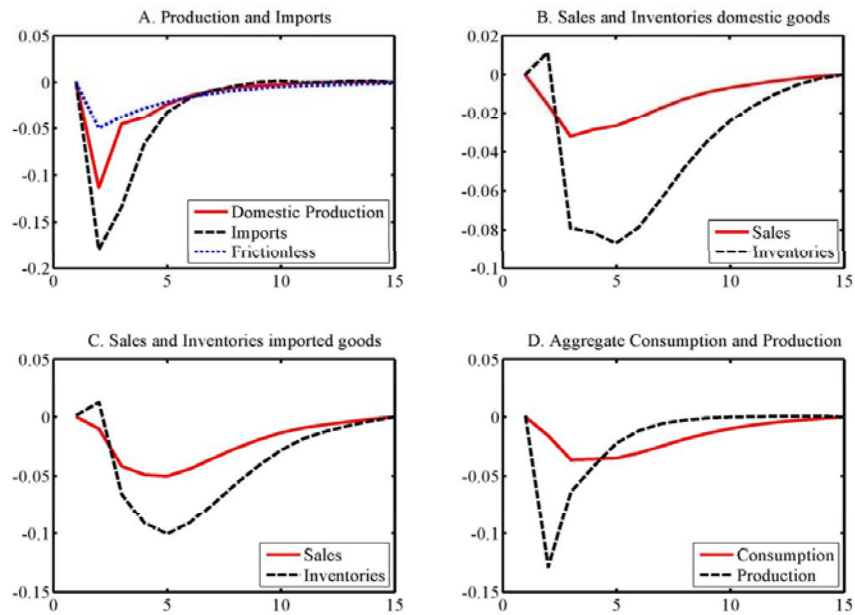
Figure 12: Benchmark Model Gradual Shock

Figure 13: Financial Shock

Appendix 1: Data summary

Here we describe the data series used in constructing our figures and tables. We also report some robustness to using alternate series.

Table 1 and 2
Most data are downloaded through Haver. The data series are

- Industrial Production: Mfr [SIC] (SA, 2002=100), IPMFG@USECON ;
- Real Gross Domestic Product (SAAR, Bil.Chn. 2005$), GDPH@USECON;
- Real PCE: Goods (SA, Bil.Chn. 2005.$), CTGH@USECON;
- Real PCE: Durable Goods (SAAR, Bil.Chn. 2005$), CDH@USECON;
- Real PCE: Nondurable Goods (SAAR, Bil.Chn. 2005$), CNH@USECON;
- Real Private Nonresidential Investment: Equipment & Software(SAAR,Bil.Chn. 2005$), FNEH@USECON;
- Real Private Investment: Software (SAAR,Bil.Chn. 2005$), FNENSH@USECON;
- Real Change in Private Farm Inventories (SAAR, Bil.Chn. 2005$), VFH@USECON;
- Real Exports of Goods (SAAR, Bil.Chn. 2005$), XMH@USECON;
- Real Imports of Goods (SAAR, Bil.Chn. 2005$), MMH@USECON;
- Real Mfr & Trade Inventories: All Industries (EOP, SA, 2005$), TITH@USECON;
- Real Mfr & Trade Sales: All Industries (SA, 2005$), TSTH@USECON;

We measure final expenditures, $Y_t^T = \alpha \left(I_{EQ,t} + C_{D,t} \right) + (1 - \alpha) C_{ND,t}$ where $I_{EQ,t} = I_{EQS,t} - I_S$ and I_{EQ} =Investment in Equipment, I_{EQS} =Investment in Equipment and Software, I_{EQ} =Investment in Software, C_D =Consumption of Durables, C_{ND} =Consumption of Nondurables and α is share of durables in total nonpetroleum imports and is measured as the average share from 2003 to 07, or

$$\alpha = \frac{1}{5} \sum_{t=2003}^{2007} M_t^D / M_t = 0.70,$$

where M^D is annual real imports of durables and M_t is annual real non-petroleum imports (from the BEA table 4.2.6, $2005). Note, relative to all imports (including petroleum) the durable share is approximately 0.60.

To evaluate the role of filtering on our finding that the declines in trade in 2008-09 are not unusual, in Table A1 we report the elasticity of trade under alternative filtering methods. In particular, we use the HP filter with a smoothing parameter of 10^5 and we also remove a linear trend from each data series. These detrending methods remove very low frequency trends from each data series and generate quite similar results. In the final two columns, we report the results on the raw, unfiltered data. Here, we find that the decline in trade in the current recession is indeed unusual particularly for imports with respect to income (an elasticity of 8.49 vs 3.19). Exports also seem to have fallen by more than usual. Given that the rising importance of trade is often attributed to factors outside of growth in income or production, say falling trade barriers, we believe the appropriate way to analyze the data is to detrend it. Moreover, this detrending allows us to compare mild and severe recessions.

The volatility of trade is substantially less volatile when compared to industrial production rather than GDP. Obviously, this reflects in part the fact that the industry composition of trade is more similar to industrial production than GDP. One might still be concerned that the relatively high volatility of trade relative to industrial production may also reflect compositional differences. To account for this, we construct a measure of industrial production that more closely matches the composition of trade. In particular, we construct a measure of trade-weighted industrial production as

$$IP_t^{TW} = \alpha_{D\_exMV} IP_t^{D\_exMV} + \alpha_{autos} IP_t^{MV} + \left(1 - \alpha_{D\_exMV} - \alpha_{MV}\right) IP_t^{ND}$$

The data for these series are availabel from 1972M1 to 2010M2. Based on the 2003-07 shares of each good in non-petroleum imports we set $\alpha_{D\_exMV} = 0.55, \alpha_{MV} = 0.15, \alpha_{ND} = 0.30$. These shares overstate the importance of durables and motor vehicles in trade since they are based on trade shares excluding petroleum for imports. Table A2 panel A shows that this trade-weighted measure of industrial production that places a larger weight on durables and motor vehicles is approximately 10 percent more volatile than US manufacturing production, suggesting that only a small part of the high volatility of trade can be attributed to the different composition of industrial production from trade.

The data for these calculations are:

- IP: Durable Goods Mfg Ex. Motor Vehicles/Parts (SA, 2002=100), IPMDXMV@USECON;
- IP: Motor Vehicles and Parts (SA, 2002=100), IPG61T3@USECON;
- IP: Nondurable Mfr (SA, 2002=100), IPMND@USECON.

One might be still concerned that our trade-weighted measure of industrial production is not disaggregated enough. To consider this, we examine the cyclical properties at the industry level, focusing on motor vehicles. Due to data limits (we would like a real series of motor vehicle trade and shipments), we consider monthly data from 1997:01 to 2010:01. Panel B of Table A2 shows that trade is more volatile than producton and even more volatile than shipments. Thus, it appears clear that trade is more volatile than production and domestic shipments even once we control for industry composition. The data series considered are:

- IP: Motor Vehicles and Parts (SA, 2002=100), IPG61T3@USECON;
- Exports: Autos, Parts and Engines (SA, Mil.Chn.2005$), TMXEAVH@USECON;
- Imports: Autos, Parts, and Engines (SA, Mil.Chn.2005$), TMMEAVH@USECON;
- Real Sales: Mfg: Motor Vehicles & Parts (SA, Mil.Chn.2005$), TSMG6MH@USECON.

Table 3
All analysis is conducted at the SIC 4 digit level from 1989 to 2001.

- US industry data (http://www.nber.org/data/nbprod2005.html).
- US trade data (http://www.som.yale.edu/faculty/pks4/sub_international.htm.)
- Chilean plant level data is described in AKM

Figure 2A and 2B:

- Exports, f.a.s. (SA, Mil.Chn.2005$) TMXAH@USECON
- Exports: Non-Petroleum End-Use Commodity Category (SA, Mil.Chn.2005$) TMX-ENPH@USECON
- Exports: Foods, Feeds and Beverages (SA, Mil.Chn.2005$) TMXEFBH@USECON
- Exports: Industrial Supplies and Materials (SA, Mil.Chn.2005$) TMXEIMH@USECON
- Exports: Capital Goods, except Automotive (SA, Mil.Chn.2005$) TMXECGH@USECON
- Exports: Autos, Parts and Engines (SA, Mil.Chn.2005$) TMXEAVH@USECON
- Exports: Nonfood Consumer Goods except Automotive (SA, Mil.Chn.2005$) TMX-ECNH@USECON
- Imports: Non-petroleum Products (SA, Mil.Chn.2005$) TMMENPH@USINT
- Imports: Food, Feeds and Beverages (SA, Mil.Chn.2005$) TMMEFBH@USECON
- Imports: Industrial Supplies and Materials (SA, Mil.Chn.2005$) TMMEIMH@USECON
- Imports: Capital Goods except Automotives (SA, Mil.Chn.2005$) TMMECGH@USECON
- Imports: Autos, Parts, and Engines (SA, Mil.Chn.2005$) TMMEAVH@USECON
- Imports: Non-food Consumer Goods except Automotive (SA, Mil.Chn.2005$) TM-MECNH@USECON

Figure 3.
Here we plot dynamics of imports, sales, and inventory of imported autos.

- Sales = from Ward's automotive: US: Imported Car Sales ex Canada & Mexico (NSA, Units) + US: Imported Light Truck Sales ex Canada & Mexico (NSA, Units). The Sales series is seasonally adjusted using the Board of Governors Combined Seasonal, Trading-day Factor for Imported Auto Sales.
- Imports = downloaded from the USITC based on select Harmonized codes for passenger cars and light trucks from the Census. Measured as total imports minus imports from Mexico and Canada. Seasonally adjusted using the X-12.
- Inventory = from Ward's automotive: US: Imported Light Vehicle Inventory ex Canada & Mexico (NSA, Units). Seasonally adjusted using the X-12.
- Inventory Sales Ratio = Inventory SA/Sales SA.

Figure 4 Dynamics of Imported Autos in 70s.
This figure was constructed using the following two series

- Imported Retail Auto Sales (SAAR, Mil.Units) BEA (AFS@USECON)
- Real Imports of Automotive vehicles, engines, and parts, BEA (Table 4.2.3 line 35) Quantity Indexes, 2005=100, SA

To convert the Import series into units series, each observation was scaled by the ratio of real imports to retail sales on a centered period (i.e. $M_t^U = M_t^R * \sum_{t-10}^{t+10} S_t / \sum_{t-10}^{t+10} M_t^R$).To construct an inventory series it was assumed that in 1970:Q4 there were 2.5 months of inventory of imported autos ($I_{t=1970Q4} = 2.5 * S_t$). From there on, we used the law of motion to construct inventory as $I_t = I_{t-1} + M_t^U - S_t$. The nature of the series is robust to our scaling and our assumption about the initial inventory-to-sales ratio.

Figure 5: Capital Goods: The three series in this figure are constructed as

- Domestic Expenditure = [Manufacturers Shipments Capital Goods (SA Mil $) + Imports: Capital Goods except Automotives (SA, Mil.$) - Exports: Capital Goods, except Automotive (SA, Mil.$)]/PPI: Capital Equipment: Mfr Industries (SA, 1982=100)
- Imports = Imports: Capital Goods except Automotives (SA, Mil.Chn.2005$)
- Inventory-to-Sales Ratio = Manufacturers' Inventories: Capital Goods (EOP, SA, Mil.$)/ Manufacturers' Shipments: Capital Goods (SA, Mil.$)

The raw data series are downloaded from Haver.

- Manufacturers' Shipments: Capital Goods (SA, Mil.$) NMSCG@USECON
- Manufacturers' Inventories: Capital Goods (EOP, SA, Mil.$) NMICG@USECON
- PPI: Capital Equipment: Mfr Industries (SA, 1982=100) SP3210@USECON
- Imports: Capital Goods except Automotives (SA, Mil.Chn.2005$) TMMECGH@USECON
- Exports: Capital Goods, except Automotive (SA, Mil.Chn.2005$) TMXECGH@USECON
- Imports: Capital Goods except Automotives (SA, Mil.$) TMMECGAC@USECON
- Exports: Capital Goods, except Automotive (SA, Mil.$) TMXECGA@USECON

Figure 6 - Consumer Goods

- Imports: Nonfood Consumer Goods except Automotive (SA, Mil.Chn.2005$) - TM-MECNH@USECON
- Expenditures = $\alpha*$Durable PCE ex autos + $(1-\alpha)*$Nondurable ex Gasoline

Durable PCE ex autos = CDBHM@USECON Real Personal Consumption Expenditures: Durable Goods (SAAR, Bil.Chn.2005$) - real auto expenditures

- Real Auto Expenditures = [NRSI1@USECON Retail Sales: Motor Vehicle & Parts Dealers (SA, Mil.$)/ PCUTV@USECON CPI-U: New and Used Motor Vehicles (SA, Dec-97=100)]*Scaling factor
- Scaling Factor = Share of MV in DURABLE PCE in 2008Q2 from Quarterly NIPA * Average Expenditure on Durable PCE in Monthly Data in 2008Q2/Average Real Auto Expenditures in 2008Q2
- Nondurable ex Gasoline = Nundurable PCE - Real Gasoline Expenditures
- Real Personal Consumption Expenditures: Nondurable Goods (SAAR, Bil.Chn.2005$) CNBHM@USECON
- Real Gasoline Expenditures = (1/Scaling Factor Gasoline)*NRSI7@USECON Retail Sales: Gasoline Stations (SA, Mil.$)/ CPI-U: Motor Fuel (SA, 1982-84=100) PCUTPM @USECON
- Scaling Factor Gasoline = Real PCE: Gasoline, Fuel Oil & Other Energy Goods (SAAR, Bil.Chn.2005$) CNEH@USECON in 2008Q2/2008Q2 Real Gasoline Expenditures

Retail Inventory measured as retail and wholesale industries for related industries (EOP,SA, Mil.$):

- Retail Inventories: Furniture/Home Furnish/Electron/Appl Stores NRII2T3@USECON
- Retail Inventories: Building Mat., Garden Equip & Supply Stores NRII4@USECON

43

- Retail Inventories: Clothing & Accessory Stores NRII8@USECON
- Retail Inventories: Gen Merchandise Stores NRIJ2@USECON
- Merchant Whole: Inventories: Furniture NWIH12@USECON
- Merchant Whole: Inventories: Lumber NWIH13@USECON
- Merchant Whole: Inventories: Professional Equipment NWIH14@USECON
- Merchant Whole: Inventories: Electrical NWIH16@USECON
- Merchant Whole: Inventories: Hardware NWIH17@USECON
- Merchant Whole: Inventories: Machinery NWIH18@USECON
- Merchant Whole: Inventories: Misc. Durable Goods NWIH19@USECON
- Merchant Whole: Inventories: Apparel NWIH23@USECON

Retail Sales measured as (SA, Mil.$):

- Retail Sales: Funiture/Home Furnishings & Elect/Appliance Stores NRSI2T3@USECON
- Retail Sales: Building Materials, Garden Equipment & Supply Dealers NRSI4@USECON
- Retail Sales: Clothing & Accessory Stores NRSI8@USECON
- Retail Sales: General Merchandise Stores NRSJ2@USECON
- Retail Inventories: Total Excl Motor Vehicle & Parts Dealers (EOP) NRIXM@USECON

Figure 7 (Japanese data);

- Japan: Producers Shipments: Mfr (SA, 2005=100) S158TSM@G10;
- Japan: Producers Inventories: Mining & Mfr (SA, 2005=100) S158TI@G10;
- Japan: Export Price Index: All Commodities (SA, 2005=100) F158PFXI@G10;
- Japan: Import Price Index: All Commodities (SA, 2005=100) F158PFMI@G10;
- Japan: Imports of Goods (SA, Bil.Yen) S158IM@G10;
- Japan: Exports of Goods (SA, Bil.Yen) S158IX@G10; Japan:
- Industrial Production: Mining and Mfr (SA, 2005=100) S158DMN@G10;
- Japan: Industrial Production: Mfr (SA, 2005=100) S158DM@G10;

Figure 8

In addition to the Ward's data on foreign inventory and sales from Figure 3, we used Ward's data on US sales and inventory of North American-made autos and data from the Census/BEA. Specifically,

- US: Vehicle Inventory made in North America (NSA, Units) UINA@WARDS
- US: Vehicle Sales made in North America (NSA, Units) USNA@WARDS
- Real Inventories: Retail Trade: Motor Vehicle/Parts Dlrs (EOP, SA, 2005$) TIRI1H@USECON
- Real Inventories: Merch Whole: Motor Vehicles (EOP, SA, 2005$) TIWH11H@USECON
- Real Inventories: Mfg: Motor Vehicles & Parts (EOP, SA, 2005$) TIMG6MH@USECON
- Real Sales: Retail Trade: Motor Vehicle & Parts Dlrs (SA, 2005$) TSRI1H@USECON

We then constructed Imported Autos (BEA/Ward's) as $\alpha_t = \frac{\text{Foreign Inventory (Ward's)}_t}{\text{Retail Inventory (Ward's)}_t}$, $\gamma_t = \frac{\text{Foreign Sales (Ward's)}_t}{\text{Retail Sales (Ward's)}_t}$ and then

$$\widetilde{IS}_t^M = \frac{\alpha_t * \text{Real Retail Inventory (Census)}_t + \text{Real Wholesale Inventory (Census)}_t}{\gamma_t * \text{Real Sales (Census)}_t}$$

$$\widetilde{IS}_t = \frac{(1-\alpha_t) * \text{Real Retail Inventory (Census)}_t + \text{Real Mfg Inventory (Census)}_t}{(1-\gamma_t) * \text{Real Sales (Census)}_t}$$

Calibration

We measure the trade share in manufacturing as

$$tr = \frac{1}{5} \sum_{t=2003}^{2007} \frac{1/2 \left(\text{Mfrs Exports}_t + \text{Mfrs Imports}_t \right)}{\text{Mfrs Shipments}_t}$$

where

- Mfrs' Shipments: All Mfr Industries (SA, Mil.\$) NMS@USECON
- Imports for Consumption: Mfr, Total (Customs Value, Mil.\$), TMME0@USECON
- Exports: Mfr, Total (f.a.s. Value, Mil.\$), TMXE0@USECON

Inventory Sales Ratio

$$IS = \frac{1}{10} \sum_{t=1998}^{2007} \frac{\text{Inventory}_t}{\text{Private Expenditures on Goods}}$$

where

- Inventory_t = Average private business inventory over year t (series tbivu from the January 2010 Census Manufacturing and Trade Inventories and Sales report)
- Private Expenditure$_t$ = Personal consumption expenditures on Goods (line 3) + Gross private domestic investment on Equipment and software (line 11) from BEA NIPA Table 1.1.5. Gross Domestic Product.

Table A1 : Trade Dynamics Under Alternative Detrending Methods

	HP = 1600		Linear		HP = 10^5		Raw data	
IMPORTS	Median	2009Q2	Median	2009Q2	Median	2009Q2	Median	2009Q2
Y	4.67	4.81	4.72	4.72	4.54	4.54	3.19	8.49
IP	1.64	1.66	1.75	1.76	1.70	1.71	1.41	1.54
Demand	2.38	1.70	2.28	1.64	2.13	1.73	1.83	1.83
EXPORTS								
Y	2.54	4.10	1.74	2.80	1.31	2.87	-0.97	4.28
IP	1.41	1.41	0.89	1.04	0.74	1.08	-0.17	0.78
Demand	1.45	1.45	0.97	0.97	0.77	1.09	-0.36	0.92
EXPORTS (peak to trough)								
Y	3.33	5.09	2.83	3.33	2.53	3.19	6.08	6.54
IP	1.53	1.75	0.97	1.24	0.97	1.20	0.86	1.19
Demand	1.80	1.80	1.19	1.16	1.21	1.21	0.61	1.41
Inventory-Sales Ratio								
IP	-0.56	-0.49	-0.47	-0.47	-0.48	-0.42	-0.75	-0.55

Notes: Measured from start of recession based on the NBER dates. The third panel measures the difference in exports between the peak and trough, where the peak is either the start of the recession if exports fall immediately. Three seperate detrending methods were used. HP=1600 stands for data HP filtered with a smoothing parameter of 1600; Linear stands for removing a linear trend; and HP=10^5 stands for HP filtered with a smoothing parameter of 10^5. Thus, all drops are measured relative to the trend. Raw data are the unfiltered data.

Table A2: Alternative Measures of Trade Volatility

A. Adjusting Trade Weights for Durables and Motor Vehicles (Quarterly)*

		Correlation with				
	SD (rel to IP TW)	IP	IP TW	Exports	Imports	Autocorr.
Industrial Production	0.91	1.00	0.99	0.58	0.86	0.89
Industrial Production (TW)	1.00	0.99	1.00	0.51	0.89	0.88
Exports	1.34	0.58	0.51	1.00	0.33	0.85
Imports	1.48	0.86	0.89	0.33	1.00	0.84

B. Industry Analysis of Motor Vehicles and Parts (Monthly, 94M1 to 10M1)**

		Correlation with				
	SD (rel to IP)	IP	Exports	Imports	Shipments	Autocorr.
Industrial Production (IP)	1.00	1.00	0.84	0.85	0.80	0.76
Exports	1.33	0.84	1.00	0.91	0.58	0.84
Imports	1.35	0.85	0.91	1.00	0.63	0.88
Shipments	0.82	0.80	0.58	0.63	1.00	0.68

Notes: * Based on quarterly data from 72Q1 to 09Q4. HP filtered with a smoothing paramter of 1600. IPTW uses 2003 to 2007 trade weights on Durables excluding motor vehicles, motor vehicles, and nondurables.

 ** Based on monthly data from 94M1 to 10M1. HP filtered with a smoothing paramter of 14400. Industrial Production: Motor Vehicles and Parts (SA, 2002=100); Exports: Automotive Vehicles, Parts and Engines (SA, Mil.Chn.2005$); Imports: Automotive Vehicles, Parts, and Engines (SA, Mil.Chn.2005$) Real Sales: Mfg: Motor Vehicles & Parts (SA, Mil.Chn.2005$).

Figure A1: Aggregate Dynamics in US Recessions