US Trade and Inventory Dynamics *

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Our goal is to understand the substantial drop and rebound in international trade by the US[1] in the period 2008 to 2010. Relative to the movements in either production or absorption of traded goods, changes in trade flows in this period were quite large. For instance, from July 2008 to February 2009 US real imports and exports fell by about 24 percent while manufacturing production fell 12 percent. The rebound was equally impressive, with imports and exports expanding 23 percent between May 2009 and May 2010 while manufacturing production rebounded only by about 10 percent. Moreover, 90 percent of the drop in trade and over 100 percent of the recovery are explained by the extensive margin, i.e., the number of orders of disaggregate goods, with the balance accounted for by the size of these orders.[2] This suggests that importers' decisions of whether or not to order played an important role in the dynamics of trade over the crisis.

The hypothesis we explore here and in a companion paper (Alessandria, Kaboski, Midrigan, 2010a) is that the magnified movements in international trade and the extensive

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[1] Our focus here is on US trade dynamics. Bems, Johnson, and Yi (2010) and Eaton, Kortum, Neiman, and Romalis (2010) focus more on global trade flows.

[2] This is based on monthly ten-digit Harmonized System data where the total number of cards reflect the number of orders.

margin reflect a severe adjustment of inventory holdings of firms. Since our aim is to understand the large *excess* drop in trade relative to either sales or domestic production, we emphasize that these adjustments are larger for firms involved in international transactions compared to those involved in domestic transactions. We have argued, in Alessandria, Kaboski and Midrigan (2010b), that the frictions involved in international transactions - namely delivery lags and economies of scale in transaction costs - are more severe than for domestic transactions. Since these frictions lead firms to hold inventories, firms involved in international trade hold a much larger stock of inventories, a fact that we also document in our earlier work. Following a persistent negative shock to costs or demand, firms find themselves with too much inventory on hand and thus cut back sharply on ordering, selling out of the existing stock. This mechanism is stronger for international transactions because inventory levels are larger. Intuitively, since by definition, imports (production) are equal to sales plus inventory investment, and both sales and inventory investment decline during a recession, imports (production) are more volatile than sales. Moreover, since importers hold larger stocks of inventories than domestic firms, the response of imports is much larger than that of production.

In Alessandria, Kaboski and Midrigan (2010a) we study a general equilibrium two-country model of international trade in which firms face fixed costs of exporting and a stockout-avoidance motive for holding inventories. The model, when parameterized to match the evidence on the inventory holding premium of importers, is capable of accounting for the salient features of the dynamics of trade in the recent recession. In particular, the model predicts a response of imports that is much larger than that of domestic sales or production.

Our goal in this paper is to present additional empirical evidence suggesting that the magnified dynamics of trade flows is, to a large extent, shaped by inventories. In particular, we show that the response of trade in the current recession was not unusual relative to the size of the response of other macroeconomic variables. This calls for an explanation of the recent trade collapse that is about the nature of trade, and not the source of the business cycle.[3] A particular sector, autos, for which data on inventories is readily available, illustrates the role of inventories.[4] Using these data we show that inventory investment accounts for a sizable fraction of the decline in imports in the auto sector. We then present evidence that inventories matter for aggregate trade flows, emphasizing the importance of inventories for aggregate import demand estimation, and finally we show that, although aggregate trade wedges are often interpreted as trade barriers, a sizable fraction of their movements in the recent recession, are accounted for by inventories.

1. Response of trade in recent recession was not unusual

Figure 1 reports the behavior of imports, exports and several other macroeconomic variables using quarterly NIPA data. The figure shows that from the fourth quarter of 2007 to the second quarter of 2009 GDP (Y) had fallen by about 5 percent relative to trend, while industrial production (IP) and a trade-weighted measure of expenditure on goods ($Demand$) each fell by about 13 percent. In contrast, the collapse in trade was much more severe: exports and imports fell by around 20 percent. Although these numbers are striking, we argue below that the recent decline in trade (relative to the decline in other macroeconomic aggregates) was not unusual relative to past recessions. Table 1 reports the elasticity of trade to our measures of aggregate activity (GDP, industrial production, and a trade-weighted measure

[3] An alternative or perhaps complementary explanation views the drop in trade as being financially driven, e.g., Chor and Manova, 2010, and Amiti and Weinstein, 2009.

[4] Chor and Manova (2009) also study US trade flows at bilateral-industry level finding an important role for credit conditions in the change in trade flows in this period.

of expenditures) in the current and previous recessions. We compute the elasticity as the change in the log of imports or exports relative to the change in the log of each respective variable. The change is computed from peak to trough. The different panels of the Table report several different methods to detrend the data: an HP or linear trend, as well as the raw data.

The table shows that imports are about 5 times more volatile than GDP, twice as volatile as expenditures on tradeable goods and about 60 percent more volatile than industrial production. Most importantly, compared to the median US recession the fall in imports in the current (2009Q2 column) recession does not look unusual. We obtain similar conclusions when focusing on exports, rather than imports, and when detrending the data using alternative methods.

Table 2 shows that our conclusions are not driven by our focus on recessions, rather than business cycle fluctuations in general. In particular, the table presents the cyclical properties of these and several other aggregate time-series, filtered using a Hodrick-Prescott (1600) filter. We note that exports and imports are roughly 50 and 65 percent more volatile than industrial production,[5] around 3.5 times more volatile than GDP, and around 60 and 80 percent more volatile than expenditure on tradables. Finally, exports and imports are more volatile than consumption, as well as consumption of durable goods (exports and imports are 1.2 and 1.4 times more volatile than durable goods consumption). We thus conclude that the excess volatility of international trade does not simply reflect the fact that trade is more

[5] We also construed a trade-weighted measure of industrial production using durable, non-durable, and motor vehicle trade weights from the period 2003 to 2007. The standard deviation of this trade-weighted measure is about 10 percent higher than manufacturing industrial production. Even more narrowly, looking within the industry motor vehicles and parts, we find that exports and imports are about 30 percent more volatile than industrial production, 50 percent more volatile than manufacturer's shipments and 2.5 times as volatile as retail sales.

intensive in durable goods.[6] As we document in Tables 1 and 2, trade is more volatile than expenditures on tradeable goods, as well as more volatile than durable goods spending.

2. Evidence for auto industry

The challenge in disentangling the role of inventories in the dynamics of international trade flows is the lack of data on inventories of imported goods at either the industry or aggregate level. The auto industry is an exception as data exists in the US on inventories, sales, and imports of foreign produced autos. We use this data to show that inventory adjustment was indeed an important determinant of the collapse of international trade in autos. These data also alleviate concerns that the fall in trade relative to expenditures or production is entirely due to measurement.

The evidence on autos is, we argue, important in its own right, since autos are an important traded good, accounting for 18 percent of US non-petroleum imports. Moreover, the drop in auto imports was much more pronounced than that for other goods: the decline in auto imports alone thus account for about 1/3 of the overall collapse of U.S. imports in this episode. We therefore believe that any explanation of the recent trade collapse must also be able to explain autos to have a chance to explain aggregates more generally.

Figure 2 presents the evolution of imports and sales, as well as the stock of inventories for autos produced outside North America during the recent recession. At its worst, in the period of 7 months from August 2009 to February, real imports had dropped 77 log points, while sales had only fallen 30 log points, relative to their 2008Q2 averages. Thus for imported cars, the drop in trade over this period was over 2.5 times more than the drop in sales. Since,

[6] Boileau (1999) and Engel and Wang (2007) argue that the volatility of trade is entirely due to trade being intensive in cyclical goods like capital equipment or durables. Bems, Johnson and Yi (2010) and Eaton, Kortum, Neiman and Romalis (2010) show that a large part of the fall in trade relative to GDP arise because of the different composition of trade from production.

by definition, imports are equal to sales plus inventory investment, the evidence in Figure 2 suggests that inventory adjustment is responsible for roughly two-thirds of the drop in imports. These import and sale dynamics are similar for other countries and during previous recessions (see Alessandria, Kaboski and Midrigan, 2010), and provide very strong evidence for a high elasticity of imports relative to absorption, since these data do not suffer from a compositional mismatch between our measure of imports and absorption.

3. Aggregate evidence: import demand regressions

We next provide some evidence that inventories are an important determinant of trade flows in the aggregate. Since we lack data on inventories of imported goods in the aggregate, we proxy for these using data on the aggregate stock of U.S. inventories, and thus rely on the hypothesis that the aggregate stock tracks the stock of imported goods in inventories well.

To motivate our analysis, consider the following accounting identity:

$$M_t = S_t + X_t, \tag{1}$$

where M are imports, S are sales and X is inventory investment, $X_t = I_t - I_{t-1}$, where I_t is the stock of inventories. We also assume a constant elasticity demand for imported goods:

$$S_t = P_t^{-\gamma} C_t, \tag{2}$$

where P is the relative price of imports and C is aggregate expenditure. Equation (1) is an accounting identity, while (2) characterizes a large class of models of international trade.

We assume that in the long run sales equals imports, $\bar{M} = \bar{S}$, so that inventory investment, is zero ($\bar{X} = 0$). Then we have:

$$\frac{M_t - \bar{M}}{\bar{M}} = \frac{S_t - \bar{S}}{\bar{S}} + \frac{\bar{I}}{\bar{S}} \frac{X_t}{\bar{I}}, \tag{3}$$

where $\bar{I}$ is the long-run stock of inventories and $\bar{I}/\bar{S}$ is the inventory to sales ratio. For small deviations, we have for any variable z:

$$\frac{z_t - \bar{z}}{\bar{z}} \approx \log \frac{z_t}{\bar{z}},$$

which then, letting a lower-case variable denote the log-deviation from the trend, gives, together with the import demand equation:

$$(4) \qquad m_t = -\gamma p_t + c_t + \frac{\bar{I}}{\bar{S}} x_t$$

where $x_t = \frac{X_t}{I_t}$.

Import demand regressions are typically run in differences for reasons of stationarity (see Gallaway, McDaniel, and Rivera, 2003, for example). Motivated by the above expression, we estimate an equation of the form:

$$(5) \qquad \Delta m_t = -\gamma \Delta p_t + \alpha \Delta c_t + \beta \Delta x_t,$$

Our measure of the relative price of imported goods is the import price index relative to the producer price index. Our measure of aggregate consumption expenditure, C_t, is domestic shipments by domestic manufacturers. Finally, our measure of inventories is the entire stock of inventories in the U.S. economy.[7] In Table 3 we present two sets of evidence, for monthly and quarterly data. We focus on the sample from 1997 to 2010. Columns I and II of both panels present the results of the specification above. Column II is the unrestricted equation, while in column I we eliminate the inventory term. As the table indicates, adding inventories raises the R^2 measure from 7.6 percent to 9.8 percent in the much noisier monthly data. Similarly, adding inventories raises the R^2 from 0.48 to 0.50 when focusing on the

[7] We have redone our analysis for alternative measures of expenditures (including imports) and inventories (wholesale) and have found very similar results.

quarterly data. The contribution of inventories is fairly small thus here, partly reflecting, we conjecture, the imperfect measure of inventories we use.

Columns III and IV of Table 3 report estimates of an error-correction model in which we also include lagged values of all variables. The idea here is to capture the gradual response of imports, maybe due to adjustment costs or lags between orders and deliveries of goods. Notice here that in this specification the role of inventories is much more pronounced. In the case of monthly data the R^2 increases from 0.21 to 0.31. In the case of quarterly data the R^2 increases from 0.55 to 0.72. In this sense inventory dynamics accounts for a sizable fraction of the dynamics of imports in the data. Clearly, these results understate the role of inventories, since we have used aggregate inventories to proxy for the stock of imported goods' inventories, an admittedly imperfect proxy.

4. Aggregate evidence: trade wedges

One can instead use theory to discipline a simplified aggregate import demand equation, calibrate an import elasticity, and measure deviations from predicted imports. Taking this approach, recent authors (e.g., Levchenko, Lewis, Tesar, 2010) document large deviations in trade flows, m_t, from the predictions of the theory, $\hat{m}_t$. They call these deviations from theory wedges and these wedges have been interpreted as changes in trade barriers. We show next that inventory adjustment is important for the interpretation of these wedges.

Using equation (4) but setting inventory adjustment to zero yields a standard Armington demand equation:

$$\hat{m}_t = -\gamma p_t + c_t \tag{6}$$

Assuming a conventional value of the Armington elasticity of $\gamma = 1.0$, we can contrast the time-series of U.S. imports with those predicted by the theory and define the implied trade wedge $\hat{\omega}_t$ as the difference between the two:

$$(7) \qquad \hat{\omega}_t = m_t - \hat{m}_t$$

Figure 3 plots the evolution of this wedge over time. We note that the wedge declines by about 12 percent, and thus accounts for about 1/2 of the drop in trade in the past recession. We refer to this wedge, $\hat{\omega}_t$, as the wedge without inventory adjustment. Accounting for inventory adjustment, however, equation (4) implies that the actual wedge, ω_t, is related to $\hat{\omega}_t$, according to:

$$(8) \qquad \hat{\omega}_t = \omega_t + \frac{\bar{I}}{\bar{S}} x_t$$

We next argue that inventory investment accounts for a sizable fraction of the trade wedge that ignores inventory adjustment. In Table 4 we use quarterly data to construct the two wedges and report the fraction of variance of $\hat{\omega}_t$ accounted for by inventory investment. We assume an inventory-to-sales ratio for importers, $\frac{\bar{I}}{\bar{S}}$, equal to 1.12 and 2.25, the latter consistent with the evidence in Alessandria, Kaboski and Midrigan (2010b), and report results for several different values of the Armington elasticity, γ. As Table 4 shows, when we assume an importer-specific inventory-sales ratio of 2.25, the inventory-sales ratio of importers in the Chilean data we study in an earlier paper, we find that the inventory term accounts for 35-38 percent of the trade wedge that comes out of the Armington import demand equation. This is substantial, since this result is likely biased downward due to our imperfect measure of importer's inventories. When we lower the inventory-sales ratio to an economy-wide 1.12, the value for the U.S. firms (mainly reflecting domestic firms), the contribution of inventories declines somewhat, to about 0.25 but is nevertheless significant.

5. Conclusions

We have presented evidence that international trade fluctuated more than economic activity in the recent recession, and that inventories appear to have played an important role in this fluctuations. While we have focused on the recent recession, these empirical phenomena appear relevant more generally, both across U.S. recessions and across countries. Our monthly data show that the ordering decision margin plays a similar role across imports from and exports to a variety of countries. Alessandria, Kaboski, and Midrigan (2010b) have shown their importance for large devaluation episodes in developing countries.

Our results have implications for future work. With the magnified response of trade they generate, inventory considerations for storable goods may also matter for the international transmission of business cycles. For example, the massive drop in U.S. auto sales together with large inventory holdings lead to a sharp contraction in the production of exports for the U.S. in Japan, roughly 2.5 times the drop in sales. Foreign inventories may therefore have contributed to the severity of the downturn in Japan.[8] We are currently exploring how the nature of trade frictions affect the propagation of business cycles in Alessandria, Kaboski, and Midrigan (2011). We have further emphasized the importance of inventories for future import demand estimation and wedge analyses. On the micro side, the growing availability of plant- and transaction-level datasets should enable detailed and precise examination of how inventory considerations affect the timing and level of trade, especially international trade. In a more globally integrated world, with inputs from and sales to distant markets, managing inventories is becoming an ever more critical element in the production process.

[8] Indeed over this same period, production of autos fell 38 percent while exports fell 53 percent and domestic sales fell only 17 percent.

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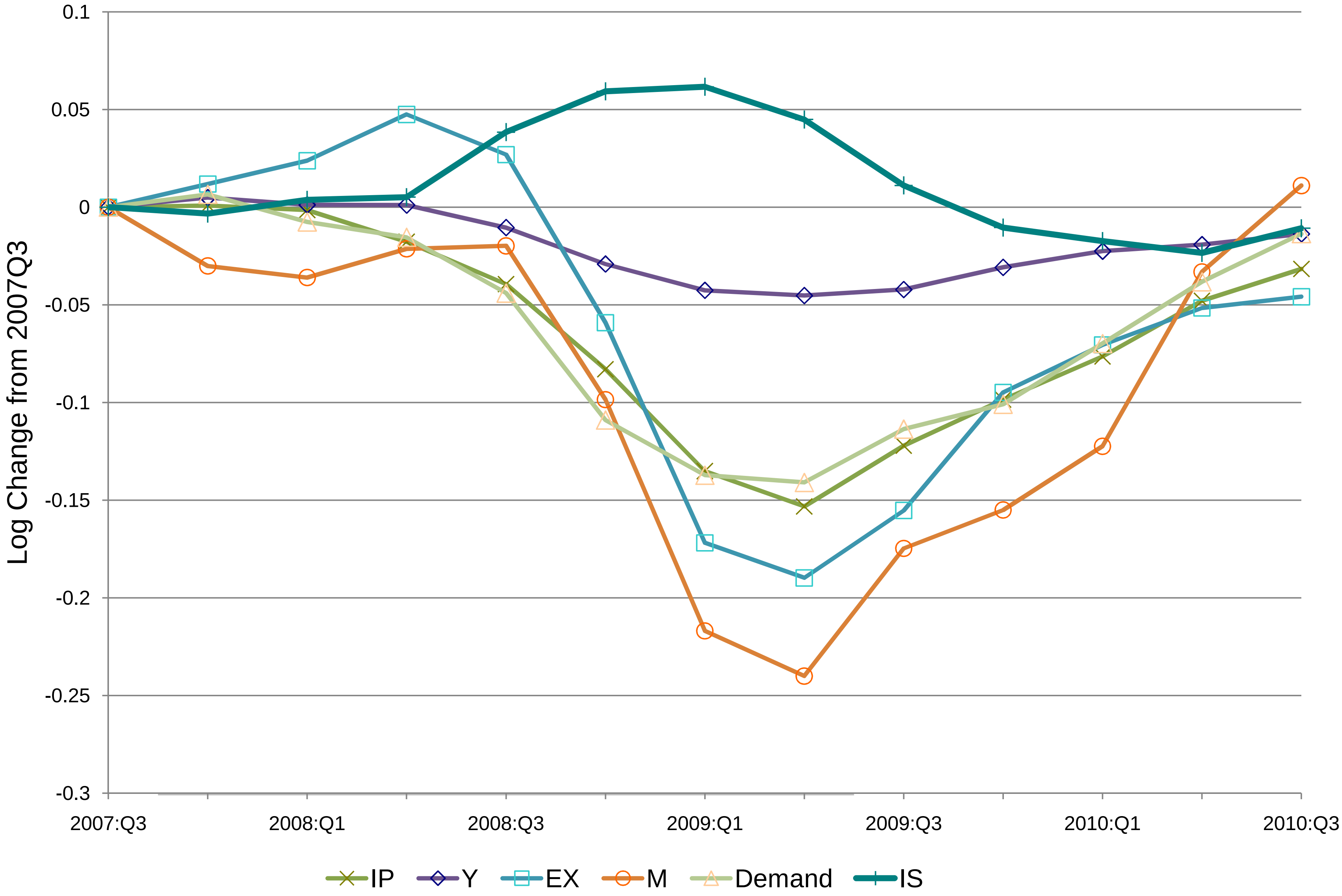
Figure 1: 2007 Recession



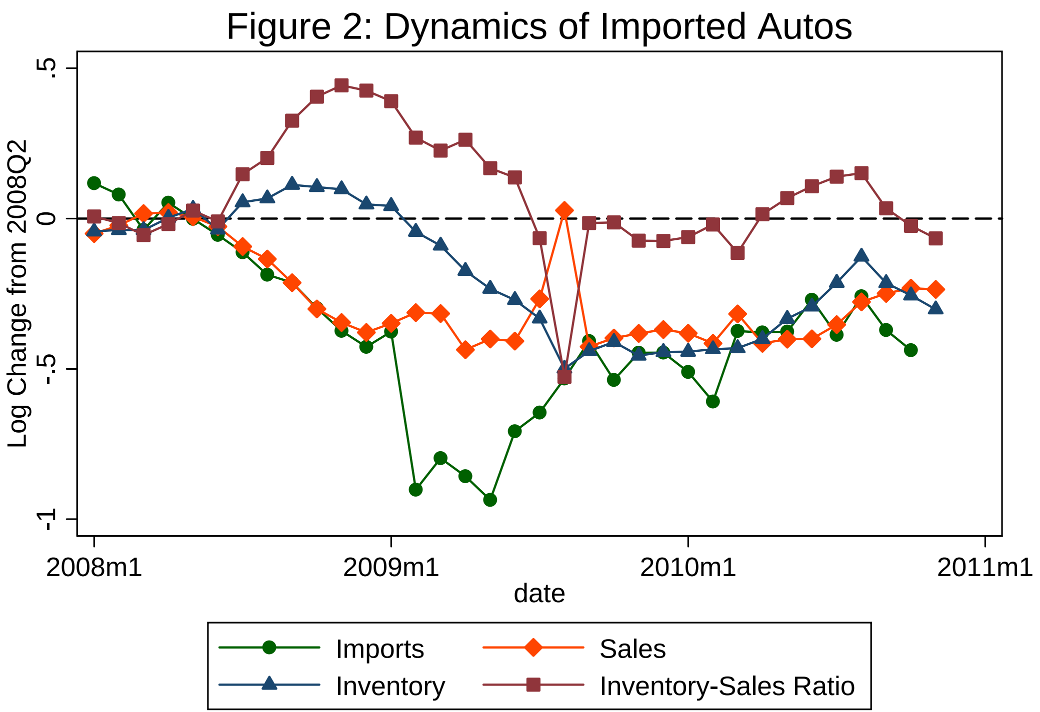


Figure 2: Dynamics of Imported Autos
Log Change from 2008Q2
.5
0
-.5
-1
2008m1
2009m1
2010m1
2011m1
date
Imports
Sales
Inventory
Inventory-Sales Ratio

Figure 3: Two Measures of the Import Wedge

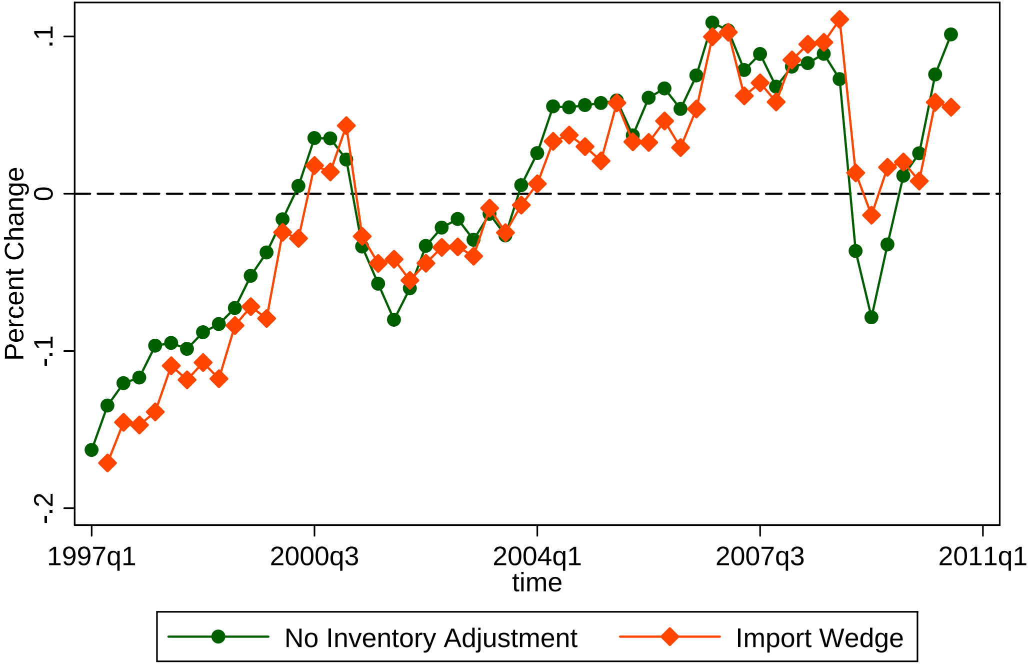


Table 1: Elasticity of Trade in Previous Recessions

	A. HP = 1600		B. Linear		C. HP = 10^5		D. Raw data	
Imports	Median	2009Q2	Median	2009Q2	Median	2009Q2	Median	2009Q2
GDP	4.67	5.31	4.62	4.62	4.33	4.33	3.19	7.56
Industrial Production	1.57	1.57	1.62	1.62	1.58	1.58	1.39	1.39
Expenditure on tradeables	2.39	1.70	2.29	1.60	2.14	1.67	1.74	1.74
Exports								
GDP	3.33	5.24	2.83	3.31	2.57	3.00	5.75	5.75
Industrial Production	1.53	1.55	0.98	1.16	0.99	1.10	0.88	1.06

Notes: Imports are measured from start of recession based on the NBER dates. Exports are measured as the change from the peak, which may be after the recession has started. Median denotes the median (across all recessions) response of the variable in question and 2009Q2 denotes the dynamics in the current recession. 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 paramter of 100000. Thus, all drops are measured relative to the trend. Raw data is the unfiltered data.

Table 2: Summary Statistics on US Business Cycles

	Standard Deviation (relative to IP)	Correlation with IP	Autocorrelation
Industrial Production (%)	3.6%	1.00	0.89
Exports	1.48	0.52	0.74
Imports	1.65	0.81	0.75
GDP	0.43	0.90	0.87
Expenditures on tradeables	0.91	0.87	0.87
Consumption on Goods	0.56	0.75	0.84
Consumption Durables	1.20	0.71	0.77
Consumption non-durables	0.33	0.71	0.84
Investment on Equipment	1.53	0.89	0.90

Notes: Based on quarterly NIPA data from 67:1 to 10:3. Data are HP filtered with a smoothing parameter of 1600.

Table 3: Import Demand Regressions

A. Monthly (1997:01) to 2010:10)

	I	II	III	IV
Δc(t)	0.72	0.75	0.70	0.59
	3.9	4.1	3.9	3.5
Δp(t)	-0.20	-0.17	-0.10	-0.13
	-0.9	-0.8	-0.5	-0.7
x(t)		0.68		1.19
		2.3		4.0
m(t-1)			-0.24	-0.31
			-5.4	-6.8
c(t-1)			0.43	0.47
			5.0	5.8
p(t-1)			-0.26	-0.42
			-4.3	-6.2
x(t-1)				1.52
				4.7
# obs.	165	165	165	165
R^2	0.076	0.098	0.21	0.31

B. Quarterly (1997:I) to 2010:III)

	I	II	III	IV
Δc(t)	1.81	1.67	1.60	0.89
	6.4	6.0	5.2	3.2
Δp(t)	-0.70	-0.59	-0.60	-0.70
	-2.3	-1.9	-2.0	-2.8
x(t)		0.87		1.36
		2.0		3.5
m(t-1)			-0.39	-0.56
			-3.2	-5.3
c(t-1)			0.67	0.76
			2.9	4.1
p(t-1)			-0.45	-0.85
			-3.1	-5.6
x(t-1)			-0.26	2.06
			-4.3	5.2
# obs.	54	53	54	53
R^2	0.48	0.5	0.55	0.72

Note: t-stats below point estimates
Inventory are measured as Real Manufacturing & Trade Inventories: All Industries (EOP, SA, Mil.Chn.2005$); Sales are measured as the sum of real manufacturers shipments, wholesale shipments, and retail sales minus US exports (SA, Mil.Chn.2005$). The terms of trade is measured as the Import Price Index: Nonpetroleum Imports/PPI: Manufacturing (Dec-84=100).

Table 4: Fraction of import wedge accounted for by inventory adjustment

	I/S, inventory-sales ratio	
	1.12	2.25
γ, Armington Elasticity		
0	0.24	0.37
1	0.25	0.38
2	0.24	0.35

Note: Using quarterly data from 1997:q1 to 2010:q3.

Table A: Alternate Measures of Trade Volatility

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

	SD (rel to IP)	Correlation with IP	IP TW	Exports	Imports	Autocorrelation
Industrial Production	3.6%	1.00	0.98	0.58	0.86	0.89
Industrial Production (TW)	1.10	0.98	1.00	0.48	0.90	0.87
Exports	1.46	0.58	0.48	1.00	0.34	0.85
Imports	1.63	0.86	0.90	0.34	1.00	0.84

B. Industry Analysis of Motor Vehicles and Parts (Monthly, 94M1 to 10M10)**

	SD (rel to IP)	Correlation with IP	Exports	Imports	Shipments	Autocorrelation
Industrial Production (IP)	8.2%	1.00	0.82	0.86	0.88	0.82
Exports	1.20	0.82	1.00	0.91	0.69	0.88
Imports	1.27	0.86	0.91	1.00	0.76	0.90
Mfr Shipments	0.83	0.88	0.69	0.76	1.00	0.75
Retail Sales	0.51	0.55	0.48	0.58	0.52	0.64

Notes: * Based on quarterly data from 72Q1 to 10Q3. HP filtered with a smoothing paramter of 1600. IPTW uses 2003 to 2007 tradeweights on Durables excluding motor vehicles, motor vehicles, and nondurables.

** Based on monthly data from 94M1 to 10M10. 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$). Real Sales: Retail Trade: Motor Vehicle & Parts Dlrs (SA, Mil.Chn.2005$)