Microeconomic Uncertainty, International Trade, and Aggregate Fluctuations*

George Alessandria†
Federal Reserve Bank of Philadelphia

Horag Choi
Monash University

Joseph P. Kaboski
University of Notre Dame and NBER

Virgiliu Midrigan
NYU and NBER

Draft: March 2014

VERY PRELIMINARY: DO NOT CITE

Abstract
We study empirically and theoretically the source of fluctuations in the dispersion of producer level sales and production over the business cycle. We verify that forward looking volatility of trade growth is highly countercyclical. On the theoretical side, we study the effect of exogenous shocks to producer level dispersion in a two-country DSGE model with heterogenous producers and endogenous export participation. We also study the ability of aggregate shocks to generate endogenous fluctuations in producer level dispersion through a channel of international reallocation. We find empirical evidence that international reallocation is indeed important for understanding cross-industry variation in cyclical patterns of measured dispersion.

JEL classifications: E31, F12.
Keywords: Sunk cost, fixed cost, establishment heterogeneity, tariff, welfare.

*We thank the audience at Ohio State Uinversity for helpful comments. The views expressed here are those of the authors and do not necessarily reflect the views of the Federal Reserve Bank of Philadelphia or the Federal Reserve System. This paper is available free of charge at www.philadelphiafed.org/research-and-data/publications/working-papers/.

†Corresponding author: george.alessandria@gmail.com, Ten Independence Mall, Philadelphia, PA 19106.

1 Introduction

A growing literature attributes an important fraction of cyclical fluctuation in output to changes in the distribution of idiosyncratic shocks hitting heterogenous producers. This literature shows in a range of closed economy models that more volatile producer-specific shocks can generate a downturn in economic activity. A primary example is the Great Recession, during which there was substantial increase in dispersion across establishments. Still, understanding the extent to which volatility leads to recessions or recessions lead to volatility remains an important task.[1] In this paper we revisit the relationship between idiosyncratic volatility and business cycles empirically and theoretically. We do so within an open economy, and in context of a model with nonconvex trade participation decisions across heterogenous producers. The role of uncertainty on international trade patterns is of independent interest, but trade models and data also constitute a natural laboratory for examining the role of uncertainty, since the selection behavior is well understood.

We start by confirming that trade looks much like other production: the volatility of growth of either imports or exports is strongly countercyclical. Whereas earlier work has used data on firms, but lacked data on products, we lack firm level data but utilize highly disaggregate product level data. Using U.S. monthly trade flow data, we construct 12-month, forward-looking growth volatility measures for the value of imports and exports of high disaggregate commodities. The forward-looking variance of quarterly exports (import) sales growth volatility is roughly 20 percent (35 percent) higher in recessions and is negatively correlated with GDP growth.

On the theoretical side, we follow Bloom et. al (2013) and Arellano, et al (2012) and consider the effect of exogenous shocks to producer level volatility. Unlike the previous work, though, we study these shocks in a two-country RBC with producer heterogeneity

[1] Bloom (2009) and Bloom et al (2013) argue that volatility leads to recessions. In Bachmann and Moscarini (2012), recessions lead to experimentation and thus micro volatility. Bloom (2013) gives an excellent review of the literature.

and realistic entry and exit from the export market based on Alessandria and Choi (2007). This model captures the well-known features that (i) not all producers export, (ii) those that do are relatively large, and (iii) exporting is quite persistent. Contrary to the closed economy literature, we find a country-specific shock to producer level dispersion has a small positive effect on output but an order of magnitude larger effect on international trade, as higher dispersion allows exporting firms to export more. Thus, the trade to GDP ratio rises. Given that it is well known that trade fell substantially more than output in the Great Recession, this constitutes a puzzle for the model.

We next use the model to simulate the effect of country-specific shocks to productivity on aggregate output and measured dispersion. Here we find that a country-specific productivity shock will generally an increase the dispersion in sales across heterogenous producers through two channels. First, there is a direct cost channel. A country-specific shock affects the relative costs of imported and domestic goods. This leads to a reallocation of market share between imported and domestic goods and thus leads to an increase in the dispersion of consumer purchases. Second, there is a market participation channel as domestic producers differ in their export participation. A country-specific shock will affect non-exporters differently from exporters leading to a reallocation of production across these heterogenous producers. We show these two affects can generate plausible fluctuations in dispersion in response to country-specific shocks. We also show the first channel will increase in importance when producers use greater shares of imported and domestic intermediates in production as in the data.

To evaluate the importance of country-specific shocks empirically, we examine the role of reallocation from international trade as a source of the increase in dispersion measured by Bloom et al (2013). At the aggregate level, we find that find that trade measures are as strongly related to fluctuations in uncertainty as GDP growth is. Across a wide range of industries, we find that international reallocation is an important source of fluctuations in

industry level dispersion over time. Focusing narrowly on the period 2007 to 2009, we find that the industries with the largest increase in dispersion are more open and experienced larger international reallocation using various measures of the change in industry level net exports.

Finally, we look within a particular industry, using automobiles as a case study. The automobile industry is an important industry that had a large and persistent decline in economic activity. It is also extremely well measured, allowing us to look at product level variation as well as firms both within and outside of the U.S. We find that an important share of the increased dispersion in sales and production from 2008 to 2011 can be attributed to reallocation between the Big 3 firms and Japanese firms. This reallocation is driven by identifiable shocks: a spike in oil prices that has relatively stronger impact on the Big 3, the pre-bankruptcy crisis and post-bankruptcy recovery of the Big 3, and the Japanese Tsunami, which hurt Japanese sales.

In Section 2, we present evidence on the cyclicality of disaggregate trade volatility. Section 3 develops and calibrates a two-country model of heterogenous producers with an endogenous export decision. In Section 4, we present the model experiments about the effect of first and second moment shocks. Section 5 presents evidence on the relationship between industry volatility and trade reallocation both across across industries and within a case study industry: automobiles. Section 6 concludes.

2 Volatility of Trade

We begin by evaluating the level of micro volatility in the trade data to see whether product level import and export data behave in a similar fashion to firm level sales data. That is, the growth in firm sales is more volatile in recessions (Bloom et al, 2013); is the growth in the value of trade of different commodities also more volatile in recessions?

We start with monthly use U.S. data on the value of imports and exports by 10-digit Harmonized System commodity, 1996-2010. We aggregate the monthly data to quarterly and the aggregate across destination country (source country) to obtain total exports (imports) of a particular commodity within a quarter. [2] We then compute quarterly volatility measures as the log of the forward looking standard deviation of quarterly growth in exports (imports) over a one year forward looking window. That is, for commodity i in quarter q, we define volatility V_{iq}:

$$V_{i,q} = \frac{1}{2} ln \left(\sum_{n=1}^{12} \left(g_{i,q+n} - \frac{1}{12} \left(\sum_{k=1}^{12} g_{i,q+k} \right) \right)^2 \right).$$

This measure captures the *time-series* volatility of growth of exports (imports) *within* a particular commodity, but it doesn't capture the *cross-sectional* variance in growth rates (e.g., across producers) that are typically used as a measure of volatility. To better capture this, we calculate an alternative measure within 4-digit Harmonized System commodities by examining the variance in growth rates in quarter q over all 10-digit i commodities within a 4-digit commodity category. [3]

We then regress these data on two measures capturing recession dynamics. First, we construct a forward-looking moving average of a recession dummy (the average number of months in recession over the next year inclusive of the current quarter).[4] Second, we use

[2] That is, we view each commodity, rather than a commodity-source or commodity-destination combination, as an overall market.

[3] An example of a 4-digit Harmonized System commodity is "Gloves, Mittens and Mitts", whereas a 10-digit commodity is "Ice/Field Hockey Gloves, Knit, Covered with Plastic or Rubber".

[4] Two alternative measures of recessions are (i) a balanced window moving average (the fraction of months in recession over the current quarter, previous two quarters and next quarter) and (ii) a current value measure (the fraction of months in a recession of the current quarter). The benchmark gives higher weight to months early in the recession, while these alternatives give higher weight to quarters inn the middle of the recession or equal weight to all quarters in the recession, respectively. The results are qualitatively quite similar across these specifications, although the coefficients are nearly 50 percent (30 percent) larger for exports (imports) using the balanced window alternative, indicating that forward looking volatility in trade is largest mid recession.

the growth rate of real GDP.

We run the following regressions:

$$V_{i,q} = \beta recession + \delta q + \phi_i + \epsilon_{i,q}$$

where δq is a time trend in volatility, ϕ_i indicates commodity i-specific fixed effects, and β is the coefficient of interest. We weight the regressions at the commodity level by the by the total value of the commodity exported (imported) over the sample.

Table 1 below presents the estimates of β for several specifications and both exports and imports. The first column shows that the log volatility of export and import growth are substantially higher in recessions. These results are largely robust to the inclusion or exclusion of commodity fixed effects. The volatility measures are also countercyclical, when real GDP growth is the measure of cyclicality. We omit standard errors because given the extremely large sample sizes, these are highly precise point estimates.

Table 1: Cyclicality of Sales Growth Volatility

	Benchmark	**No FEs**	**GDP Growth**	**Cross-Sectional Variance**
Exports	0.187***	0.187***	-0.031***	-0.016***
Imports	0.359***	0.363***	-0.050***	-0.020***

*** indicate significance at the 1 percent level, respectively.

The final column shows that the counter cyclicality of trade growth volatility disappears when measuring volatility using the log of the cross-sectional variance of export and import growth, i.e., the variance of growth in 10-digit commodities across 4-digit commodity groups. Indeed, the signs, though small, indicate a slightly pro cyclical relationship. It appears that although sales growth varies substantially over time in recessions, these move largely in parallel within 4-digit commodity groups.

We make two further points. First, if we divide the sample by the end use of the good,

we find a significant countercyclical pattern across food, industrial supplies, capital goods, automotive goods, and consumer goods. However, the patterns are strongest for the export of automotive goods, the import of capital, and the export and import of industrial supplies. Second, we can construct analogous measure for monthly growth volatility and regress this against an analogous monthly recession variable. Here we again find countercylical estimates, but the coefficients are just over one-third of the quarterly coefficients. This indicates that growth in trade at the monthly level is largely persistent.

In summary, our results for the behavior of time volatility of traded goods over the business cycle is quite similar to the research on other measures of volatility and uncertainty for firms. The cross-sectional volatility does not, however.

Since volatility appears to affect traded goods in a cyclical fashion, we develop a business cycle model with trade and export dynamics and idiosyncratic uncertainty.

3 Model

In this section, we describe and calibrate a modified version of the model of Alessandria and Choi (2007), augmented to allow for idiosyncratic volatility with time-varying dispersion. Specifically, we model two symmetric countries Home (H) and Foreign (F), each with a unit mass of heterogeneous producers producing differentiated intermediate goods. Intermediate producers differ not only by the variety they produce, but also by their productivity, and endogenously by their capital and exporter status. Exporting requires both fixed and sunk costs. In each country, competitive firms producer final goods by according to an Armington aggregator between Home and Foreign goods. The domestic good is an aggregate of the full range of domestic intermediates, while the other good aggregates only the subset of the other country's intermediate goods that are exported.

3.1 Intermediate Good Producers

In each country, a unit mass of monopolistically competitive intermediate goods producers indexed by $i \in [0,1]$ behave as monopolistic competitors. They produce output for the domestic market (y_H for Home), and potentially an export market (y_H^* for Home) using a constant returns to scale, Cobb-Douglas production technology, but they vary in their productivity z:

$$(1) \quad y_H(i) + m'(i)y_H(i)^* = y(i) = e^{z(i)}e^A k(i)^\alpha l(i)^{1-\alpha}.$$

Here A indicates a (stochastic) aggregate productivity parameter, and z is an idiosyncratic productivity parameter. We denote whether or not a firm is exporting using the indicator function $m(i)'$, which equals 1 if the firm decides to export in the current period and 0 otherwise.

In addition to this exporting decision, intermediate firms accumulate capital, hire labor, and set prices. Given inverse demand functions $p(y_H)$ and $p^*(y_H^*)$, within period profits π productivity, accumulated capital, and the choice of export status:

$$(2) \quad \pi(z,k;m') \;=\; \max_l p(y_H)y_H + m'p^*(y_H^*)y_H^* - W_t l \quad \text{s.t.} \quad (1)$$

The export and capital investment decisions, x and m, are dynamic. Capital depreciates at a rate δ and must be purchased in the prior period. Exporting status m' is chosen contemporaneously, but it entails a cost that depends on whether the firm exported in the previous period, m. Specifically, the cost, $f(m)$ is in units of labor and depends on the firm's past export status, m, with $f(0) \geq f(1) > 0$. That is, $f(0) - f(1)$ is a one-time

(sunk) cost of entering the export market, while $f(1)$ is a per-period fixed cost of exporting.

Discounting future cash flows at a rate Q, intermediate firms solve the following dynamic recursive problem:

$$\begin{aligned} V(m,z,k;\Omega) &= \max_{m',x} \pi(z,k;m') - W_t m' f(m) - x \\ &\quad + QE'V(m',z',x+(1-\delta)k;\Omega'). \end{aligned}$$

Here we denote the aggregate state as Ω. Qe assume that $E(z'|z)$ is weakly increasing in z. The dynamic process for idiosyncratic productivity, z, is where we will introduce stochastic idiosyncratic volatility shocks.

The optimal exporting decision is to export if $zge\bar{z}(m,k)$, where $\bar{z}(m,k)$ is decreasing in both m and k. The optimal law of motion for capital also depends on the exporting decision m', satisfying:

$$(3) \quad 1 = EQ'\left[V_k'(m',z',k';\omega) - (1-\delta)\right].$$

3.2 Final Good Producers

The demand that intermediate goods producers face comes from the producers of the final goods. There exists a single final good in each country which can be used for either consumption or investment. A representative competitive final goods producer in each country aggregates intermediates goods into final goods consumption according to an Armington aggregator with a nested constant elasticity substitution aggregator. For the Home final good producer, the available varieties of intermediates include all domestic varieties, but only the varieties of Foreign intermediates of firms who choose to export.

It is convenient to define the domestic (i.e., Home) and imported (i.e., Foreign) aggre-

gates, Y_H and Y_F. separately as follows:

$$(4) \quad Y_H = \left(\sum_{m=\{0,1\}} \int y_H^d \left(m,z,k\right)^{\frac{\theta-1}{\theta}} \psi\left(m,z,k\right) \right)^{\frac{\theta}{\theta-1}}$$

and

$$(5) \quad Y_F = \left(\int y_F^d(1,z,k)^{\frac{\theta-1}{\theta}} \psi^*(1,z,k) \right)^{\frac{\theta}{\theta-1}}$$

where $\psi(m,z,k)$ and $\psi^*(m,z,k)$ denote the measure of Home and Foreign intermediate good firms, respectively.

These are then aggregated in Armington fashion,

$$(6) \quad C + \int x(m,z,k) d\psi(m,z,k) = Y = \left(Y_H^{\frac{\gamma-1}{\gamma}} + \omega^{\frac{1}{\gamma}} Y_F^{\frac{\gamma-1}{\gamma}} \right)^{\frac{\gamma}{\gamma-1}}$$

where $\omega < 1$ produces a bias for domestically produced goods.

Taking the price of final goods, P, intermediate prices $p_H(m,z,k)$, $p_H^*(m,z,k)$, and the measures of intermediate firms as given, the static profit maximization of final goods producers yields isoelastic demand functions for intermediate producers of the form:

$$\begin{aligned} y_H\left(i\right) &= \left(\frac{p_H\left(i\right)}{P_H} \right)^{-\theta} \left(\frac{P_H}{P} \right)^{-\gamma} Y \\ y_H^*\left(i\right) &= \omega \left(\frac{p_H^*\left(i\right)}{P_H^*} \right)^{-\theta} \left(\frac{P_H^*}{P^*} \right)^{-\gamma} Y^* \end{aligned}$$

and the following equilibrium price formulas:

$$\begin{aligned} P &= \left(P_H^{1-\gamma} + \omega P_F^{1-\gamma}\right)^{\frac{1}{1-\gamma}} \\ P_H &= \left(\sum_{m=\{0,1\}} \int p_H(z,m,k)^{1-\theta} \psi(m,z,k)\right)^{\frac{1}{1-\theta}} \\ P_H^* &= \left(\int p_H^*(z,1,k)^{1-\theta} \psi(1,z,k)\right)^{\frac{1}{1-\theta}} \end{aligned}$$

Given isoelastic demand, the intermediate goods producers charge a constant markup over marginal cost:

$$p_H(i) = p_H^*(i) = \frac{\theta}{\theta - 1} mc(i)$$

3.3 Consumer's Problem

The representative consumer in both countries is infinitely lived. Given the symmetry, we develop the Home consumer's problem, and the analogous problem for Foreign is denoted with an asterisk. The Home consumer chooses sequences of consumption C_t, labor L_t, and future capital K_t and nominal bond holdings B_t, to maximize expected utility:

$$V_{C,0} = \max_{\{C_t, N_t, B_t, K_{t+1}\}} \sum_{t=0}^{\infty} \beta^t U(C_t, N_t),$$

subject to the sequence of budget constraints,

$$C_t + K_t + Q_t \frac{B_t}{P_t} \leq W_t L_t + B_{t-1} + \Pi_t,$$

where P_t ,W_t, and R_t denote the price level, real wage, and rental rate on capital, respec-

tively, and Π_t is the sum of profits (net of export costs and capital investment) of the home country's intermediate good producers.

Although money has no role in the economy, we use the domestic currency as a unit of account. The nominal bond B_t pays one unit of the Home country's currency in period $t+1$ and its price in period t is Q_t. An analogous bond exists for Foreign. The Euler equation is therefore:

$$Q_t = \beta E_t \frac{U_{C,t+1}}{U_{C,t}} \frac{P_t}{P_{t+1}}.$$

3.4 Equilibrium and Computation

The equilibrium definition largely follows that in Alessandria and Choi (2007). The distribution of producers by country over export status, capital, and productivity in each country is part of the state of the economy $(\psi(m,z,k), \psi^*(m,z,k))$. Bond holdings, shocks to the level of TFP, and the variance of idiosyncratic shocks are also included in the aggregate state:

$$\Omega = (B, A, A^*, \sigma_\varepsilon, \sigma_\varepsilon^*, \psi, \psi^*)$$

The presence of two distribution makes this a challenging problem to solve. To make the model tractable, we allow producer productivity to have a persistent (z_p) and an idiosyncratic component (ε_z). The persistent component is Markovian so that $\phi\left(z_p'|z_p\right)$ is the probability that the persistent component tomorrow is $z_p^{'}$ given it is z_p today. The iid component is log normally distributed with standard deviation, σ_z. Producer level productivity then equals $z = z_p + \varepsilon_z$.

3.5 Calibration

To perform quantitative simulations, we need to calibrate the utility function, technologies, and exogenous stochastic processes for aggregate and idiosyncratic productivity. Our calibration again closely follows that of Alessandria and Choi (2007), with the exception of shock process to idiosyncratic productivity z, which here allows for stochastic idiosyncratic volatility.

We use a constant intertemporal elasticity of substitution utility function that is Cobb-Douglas in consumption and leisure. Normalizing the time endowment to one, we have

$$U(C,N) = \frac{\left(C^{\eta}(1-N)^{1-\eta}\right)^{1-\sigma}}{1-\sigma}$$

We choose standard values for the preference parameters: the discount factor $\beta = 0.99$ with a period equaling a quarter, consistent with an annual return to capital of 4 percent; and inverse intertemporal elasticity of substitution of $\sigma = 2$, widely used in the international business cycle literature (e.g., Backus, Kehoe, and Kydland, 1994, Stockman and Tesar, 1995, and Kehoe and Perri, 2002) ; and the share of consumption in utility, $\eta = 1/4$, dictating that one-quarter of nonsleep time is spent working.

For the Cobb-Douglas production intermediate good production functions, we assign $\alpha = 0.36$, consistent with standard measures of capital's share in income. We assign $\delta = 0.025$, as a quarterly depreciation rate of capital, which is consistent with a steady state capital output ratio of 2.5. In the final goods aggregators, we choose an Armington elasticity $\gamma = 1.5$, in the midrange of estimates of the elasticity between domestic and imported goods in the U.S. (Gallaway, McDaniel, and Rivera, 2003). The elasticity of substitution between varieties is set to 3, so $\theta = 2/3$, and implies a markup of 50 percent over marginal cost. This structure implies that goods from the same country are better

substitutes than goods from different countries and is necessary to have some chance of generating reasonable international business cycles.[5]

The standard deviation for idiosyncratic productivity (σ), export costs ($f(0), f(1)$) and the home bias parameter (ω) jointly determine trade flows, export participation, exporter entry and exit, and the size of exporters relative to non-exporters. To make things simple, we assume that z is iid over time and producers, and is drawn from log normal distribution with log mean of zero and a standard deviation, σ_ε.[6] Given the iid structure of idiosyncratic shocks and the persistent export decision, there will be two different capital stocks. We target a trade to GDP ratio of 20 percent, 20 percent of US producers exporting, and an annualized exit rate from exporting of about 12 percent. We choose the standard deviation of shocks so that exporters are on average 2.3 times larger than non-exporters in terms of sales. This exporter premium comes about because of the selection into exporting leading to a productivity premium and the additional sales from exporting. This exporter premium is a bit low based on the US Census of Manufacturers (the exporter premium is closer to 4.5), but given we abstract from other sources of productivity differences, this is a good starting point. This calibration yields $\sigma_\varepsilon = 0.3$, a startup export cost, $f(0) = 0.371$, and a continuing export cost of $f(1) = 0.162$. The up-front cost is about 2.3 times the continuation cost. This is a bit low relative to previous estimates in the literature in models with persistent idiosyncratic shocks (see Das, Roberts, and Tybout, 2007, or Alessandria and Choi, 2011). Table 1 below summarizes our parameter values.

Table 2: **Parameter Values**

α	β	δ	σ	f_0	f_1	$\omega^{\frac{1}{\gamma}}$	θ	γ	v	η
0.36	0.99	0.025	0.30	0.372	0.161	0.25	2/3	1.5	2	0.25

We discuss the calibration of the stochastic processes for aggregate shocks to TFP and

[5]Having domestic and foreign varieties be equally substitutable leads to business cycles that are not very synchronized.

[6]Adding persistence to the z process requires recalibrating the export costs in order to match the persistence of exporter behavior but has small impacts on the overall results after recalibration.

the standard deviation of idiosyncratic volatility in the following experiments.

Figure 1 shows how trade interacts with idiosyncratic productivity shocks to determine the size distribution. With iid shocks, productivity is log normally distributed. The left panel shows the distribution of domestic shipments and overall shipments of domestic producers. Domestic shipments are close to log normally distributed (although there are some differences owing to the different capital stocks of exporters and nonexporters). The distribution of overall shipments though has a fatter right tail than domestic shipments as more productive producers are more likely to export and hence have larger sales. The panel to the right shows the distribution of purchases by domestic producers. The distribution of domestic shipments is the same as before. In addition, there is a distribution of imports. The typical importer sells more than the typical domestic producers. When these distributions are put together again the distribution of consumer purchases has a fat right tail. Changes in export participation by domestic and foreign producers will affect the sales and production distributions.

4 Model Experiments

The benchmark calibrated model is a steady state model with no aggregate uncertainty. Into this model we introduce two experiments. First, we consider the impact of shocks to idiosyncratic uncertainty, σ_t. We study the impact of a global shock. Second, we consider the impact of a country-specific negative shock to aggregate productivity, A_t.

4.1 Global Shock to Idiosyncratic Uncertainty

We first consider the effect of a changes in producer-level idiosyncratic volatility on aggregate fluctuations. In this experiment we consider a global increase in idiosyncratic uncertainty. As is well known, increasing dispersion will generally increase output in mod-

els with heterogeneous producers (Oi-Hartman-Abel effect). We undo this effect by putting the aggregate TFP shock that undoes this effect in the closed economy. It is assumed that autoregressive process for $\sigma_{\varepsilon,t}$ is

$$\begin{aligned}\sigma_{\varepsilon,t+1} &= \rho_\sigma \sigma_{\varepsilon,t} + \varepsilon_t \\ \sigma^*_{\varepsilon,t+1} &= \rho_\sigma \sigma^*_{\varepsilon,t} + \varepsilon^*_t\end{aligned}$$

The persistence is set to $\rho_\sigma = 0.9$ and we assume there is an unanticipated shock to $\varepsilon_t = \varepsilon^*_t$ of a magnitude of ten percent of steady state σ.

(The impulse responses are close to linear in the size of the shock.) We simulate these for two variants of the model: (i) the benchmark model in which $f(0) > f(1)$, so that entry requires a sunk cost , and (ii) an alternative model with no sunk cost, i.e., $f(0) = f(1)$. For this alternative model, we recalibrate the costs to match the fraction exporting, but we do not attempt to match the persistence of exporting decisions.

The results for Home are presented below in Figure 1. (Given the symmetry and a global shock, the results for Foreign are identical.) The ten percent increase in firm-level dispersion causes two clear impacts.

First, the increase in dispersion creates a very small aggregate boom. As the upper panels show, production and consumption go up by about 0.2 percent, and the impact is somewhat larger and more persistent in the model with no sunk cost. Employment rises in the very short run for the sunk cost model but is largely unaffected in the model without sunk costs.

The small aggregate boom is drive by a trade-specific Oi-Hartman-Abel effect: variation increases output if firms can respond by reallocating resources toward firms in the right tail. Although we use the standard correction that eliminates this effect in the closed economy model, trade introduces an additional channel through exporting decisions. That is, the

endogenous responses of the decision of whether and how much to export create an additional channel by which resources can be reallocated toward more productive intermediate firms.

Second, the increase in dispersion leads to large changes in exporting behavior. The lower panels show an increase in exports of about 2.5 percent on impact. That is, this impact on trade is much larger than the impact on output (and, indeed, it is robust to eliminating the aggregate impact on output with a compensating negative productivity shock). The economy also shows an increase in turnover, particularly in the model with sunk costs, as entry increase by 50 percent and exit increases by 100 percent. Overall the number of exporters falls by 2 to 4 percent.[7]

The reason for higher turnover stems directly from the higher dispersion in productivity. Firms with larger positive shocks enter. Entry requires labor, however, which drives up labor supply and wages. Similarly, entry lowers the aggregate price level. These general equilibrium effects lower the profitability of exporting, *ceteris paribus*, which causes many existing exporters with marginal productivity to exit.

The increase in exports comes from greater selection into exporting. Although there are fewer exporters, the average productivity of those firms that do export increases with greater dispersion. Thus the quantity of exports also increases and fairly dramatically.

The central finding here is this relatively large increase in exports, which is much larger than the increase in output. Unfortunately, such an increase is counterfactual to measured business cycle patterns. These patterns show that measured firm-level volatility is high in recessions, but trade pro cyclical with aggregate trade much more volatile then output. In recessions, with the Great Recession as a chief example, trade falls and does so precipitously. This apparent discord between model and empirics constitutes a puzzle for dynamic

[7]The scale of entry and exit in the sunk cost model mask the fact that entry decrease in the sunk cost model while exit decreases slightly in percentage terms. Because the rates of entry and exit are much higher in the model without sunk costs, these small changes nonetheless result in a comparably-sized decline in the number of exporters.

business cycle models with extensive export decisions.

4.2 Country-Specific Shock to Aggregate Productivity

Our second experiment considers a country-specific shock to aggregate productivity. For this experiment, we return to the benchmark steady state model with constant dispersion in idiosyncratic productivity. We then introduce stochastic aggregate productivity that follows an autoregressive form into Home, while keeping productivity constant in Foreign. That is, we assume

$$\begin{aligned} A_{t+1} &= \rho_A A_t + \varepsilon_{A,t} \\ A^*_{t+1} &= A^*_t \end{aligned}$$

We again assume a persistence of $\rho_A = 0.9$, and then we introduce a negative productivity shock to $\varepsilon_{A,t}$, i.e., Home's aggregate productivity, equivalent to a drop of 5 percent relative to steady state A.

The responses of aggregates (e.g., labor, consumption, investment) to productivity shocks in the international RBC model are well-known. Alessandria and Choi (2007) show that producer heterogeneity and endogenous export participation do not noticeable change these properties. Instead, we examine the impacts of a first moment shock on measured dispersion across producers in an open economy. We choose two measures:. (i) the log variance of total sales (i.e., $p_H(i)y_H(i) + p_F(i)y_F(i)$) across Home producers, and (ii) the log variance of the value total purchases of Home consumer's across both domestic (i.e., $p_H(i)y_H(i)$) and imported goods (i.e., $p_F(i)y_F(i)$). We refer to the first as production dispersion, and the the latter as sales dispersion.

Figure 2 presents these results. The left panel shows the impact in the benchmark open

economy, while the right panel shows the impact in an effectively closed economy – where the trade share approaches zero. Aggregate GDP declines in Home as expected, producing a very slight decline in aggregate output in Foreign in the open economy and no impact on Foreign in the closed economy. That is, the model produces very little endogenous comovement, with or without trade.

In the benchmark open economy, both measures of dispersion increase in response to the country-specific shock, with sales dispersion increasing by 3 to 4 percent and production dispersion increasing by slightly less (in log changes). The (effectively) closed economy exhibits (effectively) no increase in dispersion. The increase in dispersion is clearly tied to the importance of trade. Sales dispersion increases more because the aggregate of the change in relative prices between domestic and foreign producers. Production dispersion rises because the shock affects exporters differently from non-exporters.

To examine in greater detail the effect of the country specific shock on production dispersion we examine the same shock in a variation of the economy with 1/2 the dispersion in productivity keeping the calibration targets constant. This case reduces the exporter premium by less than 2 percent (from 2.3 to 2.26) and reduces the sunk cost aspect (f(0)/f(1) falls to 1.45 from 2.3) as it takes less to convince exporters to stay in the market. With less dispersion, a country-specific shock has a larger effect on sales and production dispersion. Sales dispersion now increases by almost 12 percent in the second quarter after the shock and remains elevated for some time. Production dispersion also rises by almost twice as much. The increase in sales and production dispersion in the low dispersion calibration occurs because this puts more producers at the margin for exporting. Indeed, it is well known that in heterogeneous plant models that the variance of productivity is negatively related to the trade elasticity. With more producers at the margin, there is greater reallocation in activity across countries in response to a country specific aggregate shock. This increased reallocation shows up with larger swings in net exports (in the right panel of Figure 3)

5 Empirical Evidence

The country-specific shock experiment in Section 3.2 suggests that reallocations stemming from country-specific first moment shocks may lead to increases in the dispersion of firm growth rates. We now examine whether their is evidence for such mechanisms. We begin by examining whether the dynamics of changes in industry dispersion measures are associated with aggregate international reallocations, measured as the absolute value of the change in the net export ratio. We then ask whether the variation in openness across industries explains the cross-industry variation in the dynamics of dispersion. Finally, using detailed data from on particular industry, automobiles, we examine whether the composition of output within an industry is important in explaining the variation in measured dispersion over time.

5.1 All industries

Our starting point for industry-level analysis is the NBER Industry Uncertainty Data from Bloom et al(2014), which gives a cross-sectional measure of annual growth rate variation across 4-digit SIC industries in the U.S.[8] The data are an annual panel. Bloom et al (2013) use various industry-level measures, none of which are able to significantly explain cross-industry variation, so the determinants of cross-industry variation are an open question. We focus on the sample from 1989-2012, since these are the available years for our international industry-specific data that we will utilize.

We begin by examining whether the time-variation in industry-level volatility is associated with measures associated with international reallocation, namely, absolute changes in the real exchange rate and net exports. the absolute change in normalized net exports, an aggregate measure. We use the absolute values, since the theory indicates that any change

[8]These data include the NBER CES manufacturing database.

in reallocation will have heterogeneous effects on firms, regardless of its sign. For the real exchange rate, we use the real "effective" (i.e., trade-weighted by country) exchange rate for the U.S. from the Bank of International Settlements. We look at a one-year lag since trade is slower to respond to changes in the real exchange rate, and we construct percentage changes as $\Delta RER_t = (RER_t - RER_{t-1})/RER_{t-1}$. For net exports, That is, using current nominal values, the absolute change in net exports at time is constructed as:

$$\Delta NX_t = \left| \left(\frac{X_{t+1} - M_{t+1}}{Y_{t+1}} \right) - \left(\frac{X_t - M_t}{Y_t} \right) \right|$$

We regress the log of the NBER industry sales volatility measure for industry j at time t on a time trend, industry fixed effects, and an aggregate predictor of volatility (X, where X represents ΔRER_t, ΔNX_t, and/or, for comparison, real GDP growth at time t):

$$V_{salesgrowth,j,t} = \beta X + \delta t + \phi_j + \epsilon_{j,t}$$

We cluster the standard errors by industry. Here the estimate of β is of interest.

The results are presented below in Table 3.

Table 3: **Industry-Level Dispersion and Aggregate Reallocation Measures**

	GDP Growth	**Δ RER**	**Δ Net Exports**	**All 3**
GDP Growth	-0.005***	.	.	-0.005***
SE	0.002	.	.	0.002
Δ RER	.	0.265**	.	0.247**
SE	.	.113	.	.113
Δ Net Exports	.	.	1.296***	0.841*
SE	.	.	0.512	0.486
R^2	0.61	0.61	0.61	0.61
Observations	5088	5088	5088	5088

*, **, and *** indicate significance at the 10, 5, and 1 percent level, respectively.

Consistent with the theory, in the univariate regressions, the absolute changes in both

the real exchange rate and the net export ratio are associated with increased measured dispersion in sales growth, and significant at the one percent level. The R^2 values indicate that the explanatory power of these regressors are comparable to the explanatory power of real GDP growth, the more standard explanatory variable for cyclical behavior. (The R^2 values are relatively high, but much of this comes from the industry fixed effects and the linear time trend.) In the regression that combines all three, GDP growth is the most significant, but the change in the real exchange rate is still significant at the 5 percent level, and the change in net exports is marginally significant at the 10 percent level. Thus, the trade variables seem to have some additional explanatory power beyond that of GDP growth alone.

We next examine whether we can explain cross-industry variation in the cyclicality of dispersion measures using measures of openness and trade. Recall, that trade-driven dispersion depended critically on the openness of the economy. As an analog here, we examine the openness of particular industries. We start by constructing these measures of industry openness by using annualized import and export data by HS-code from 1989-2012 from Schott (2008) aggregating to the 4-digit SIC level, and combining with industry shipment data from Bloom et al (2013), we define the following measures of openness for

4-digit industry j at time t: [9]

$$
\begin{aligned}
Open_{j,t}^{Overall} &= \frac{exports_{j,t} + imports_{j,t}}{shipments_{j.t}} \\
Open_{j,t}^{Import} &= \frac{imports_{j,t}}{(shipments_{j,t} - exports_{j,t}) + imports_{j,t}} \\
Open_{j,t}^{Exports} &= \frac{exports_{j,t}}{shipments_{j,t}}.
\end{aligned}
$$

We start by focusing on the recent recession. Our motivation is the fact that the recession was large and was associated with a large collapse and recovery in trade. The size of the recession is likely to swamp other potential industry-specific trends, and so our specification can be quite simple.[10] and technology shocks alone We look at whether the absolute change in industry-specific sales volatility from 2009-2007 is correlated with our measures of openness. Note this is the drop in the cross-sectional variance of sales growth, not the drop in average sales. Table 4 presents the regressions below. The coefficients on industry openness is presented in the first row, but the exact measure of industry openness varies by column.

The coefficients on all three measures of openness are positive and significant, indicating that openness was associated with larger increases in uncertainty. Since we use the log of the uncertainty measure, the coefficient on export openness, for example, indicates that uncertainty is four percent higher in an industry that exports all of its shipments relative

[9] Our monthly data from Section 1 begin in 1996. Schott (2008)'s annual data therefore allow for a longer time series. Merging at the industry, we lose data at several levels. First, the trade data include agricultural goods, but these are not included in the NBER data. Second, the concordance between HS and SIC is not perfect, and we lose many manufacturing industries. Even a cursory examination indicates that this is not because these industries have zero trade, but is a result of an imperfect concordance. Reconstructing a correspondence goes beyond the task of this analysis. Third, the NBER Industry Uncertainty Data has fewer industries for reasons unknown. The NBER CES manufacturing database has 459 industries, whereas the NBER Industry Uncertainty Data include 320 to 390 over the years. Schott's data has 402 to 447 sectors.

[10] One potential criticism, especially as relates to our model, is that while the sources of the Great Recession are not fully understood, there appears to have been a substantial global element to it. Nonetheless, we believe our mechanism is more general, in that international reallocation caused by differences in a broader range of aggregate shocks hitting countries differently, should lead to greater dispersion. It is this aspect of the mechanism that we evaluate.

Table 4: **Industry-Level Dispersion and Industry Openness**

	$Open_{j,t}^{Overall}$	$Open_{j,t}^{Import}$	$Open_{j,t}^{Export}$
Industry Openness	0.034***	0.040***	0.014***
SE	0.011	0.011	0.005
R^2	0.05	0.07	0.03
Observations	195	193	195

*** indicate significance at the 1 percent level.

to a hypothetical industry that exports none. The magnitude and explanatory power is substantially larger for export and overall openness than for import openness. The R^2 values are not large for any of the three, but they are comparable to partial R^2 of the aggregate measures in Table 3.

We now return to the role of the absolute changes in the real exchange rate and net exports in explaining changes in industry-specific uncertainty in the broader time series. The dependent variable is again the log of the cross-sectional volatility of sales growth in industry j in year t. However, since we now use industry-specific measures, rather than using overall GDP growth as a benchmark, we use the industry-specific growth in shipments. This is shown in the first column of Table 4 below. Total shipment growth, i.e., the first moment, is highly significant. (Although the R^2 is high, most of this comes the industry-specific fixed effects and the time trend.)

The second column through fourth columns show that industry openness alonw is not a significant predictor of volatility in the overall time series as it was in the crisis. This may be because both the numerator and denominator of openness change over time and cyclically. When we add the aggregate RER in the third column and interact it with the industry-specific measure of openness, however, we get a positive and significant coefficient. That is, an absolute change in the real exchange rate seems to be associated with an increase in cross-sectional volatility, but especially in open industries, i.e., industries where trade is sizable. Similarly, the fourth column shows that the absolute change in net exports to GDP

Table 5: **Industry-Level Dispersion, Reallocation, and Openness**

	ΔIndustry Shipment	**Industry Openness**	**ΔRER Interact**	**ΔNX Interact**
ΔShipment	-0.236***	.	.	.
SE	0.028	.	.	.
Openness	.	0.010	0.006	0.007
SE	.	0.011	0.012	0.011
ΔRER	.	.	.	2.392***
SE	.	.	.	0.756
ΔRER x Open	.	.	.	0.773**
SE	.	.	.	0.375
Δ NX	.	.	0.549***	.
SE	.	.	0.164	.
Δ NX x Open	.	.	0.135*	.
SE	.	.	0.071	.
R^2	0.64	0.63	0.63	0.63
Observations	4840	4840	4840	4840

***, * indicate significance at the 10 and 1 percent level, respectively.

is again associated with an increase in cross-sectional volatility. The interaction indicates that this is especially true in industries that are open, but this term is only marginally significant (at the ten percent level).

In sum, the results are consistent with the model's prediction where (i) country-specific shocks lead to increased dispersion because changes in exports and imports leads to reallocation of production, but (ii) this happens only when trade plays a quantitatively important role.

5.2 Autos

Having shown suggestive evidence consistent with the model at the economy-wide and cross-industry level, we know examine the determinants of measured dispersion within a particular industry. Similar to Bloom et al. (2013) we find that dispersion is high when activity is low, but consistent with our model, this seems to come in large part from

reallocation between domestic and foreign producers rather than among all producers.[11] Such reallocation is consistent with our theoretical finding from country-specific shocks.

Data are available on production, y_t, and sales, s_t, of autos in the US at the monthly level. The data are from Autonews and IHS automotive and are quite disaggregate (by company, trim, brand, and product). For each producer a measure of production and sales growth is constructed as

$$\Delta x_{it} = \ln\left(x_{it}/x_{it-1}\right).$$

The standard deviation of this variable, $\sigma\left(\Delta x_{it}\right)$ is weighted by each firm's current period share of the variable.[12] This measure of dispersion is then logged and seasonally adjusted using a month dummy. Thus, the dispersion measures can be thought of the log change in volatility. Quarterly measures are an average of the monthly measure.

Figure 4 plots the level and volatility of sales and production in a 7-year period that includes the Great Recession. As is already well known, sales are a bit smoother than production and fall by less (see Alessandria, Kaboski, and Midrigan, 2013). Indeed the drop in production is almost twice that of sales in the first two quarters of 2009, when economic activity was contracting at a fast pace. Figure 4 also plots the change in the standard deviation of sales and production growth. These two dispersion measures increase quite substantially as economic activity starts to stagnate in late 2007 (prior to the start of the recession.) Production dispersion rises by more initially and surges in 2009. By mid 2010, both measures of volatility have returned to normal levels while the level of activity remains quite low. Volatility picks up again at the start of 2011. The increase in volatility

[11] Aggregation bias is also a clear driver of rising dispersion as dispersion increases 1) more at the company level than product level (i.e. split between truck/SUV and cars); 2) more at the quarterly level than the monthly level. These sources of aggregation bias are studied in the appendix.

[12] Unweighted measures are strongly influenced by exit and entry decisions of producers. The appendix shows some of the biases from these measures.

coincides with another country specific shock - the Japanese Tsunami.

To clarify the role of reallocation across countries we consider the reallocation between the Big 3 and Japanese producers. Specifically, let

$$\Delta ms = \left(10 \left(\frac{x_t^{Big3} - x_t^{Japan}}{X_t} - \frac{x_{t-1}^{Big3} - x_{t-1}^{Japan}}{X_{t-1}} \right) \right)^2,$$

where X_t is the total production or sales. This tells us how much market share is being reallocated in a way that is related to the country of ownership. Obviously, holding reallocation between groups constant, more reallocation between the groups will increase the dispersion measure. Figure 5A and 5B plot these dispersion measures for production and sales. The non-seasonally adjusted data is plotted. This measure helps to clarify that an important source of the rise in dispersion is predictable and due to the two types of plants having a different timing of production. Specifically, at the end of the year and the middle of the year, there are recurring increases in growth dispersion. These spikes correspond to the establishments shutting down for different lengths at these periods. Once the factories are up and running there is very little dispersion in growth in these other periods. This point is particularly important since the spike in volatility in 2009m1 to 2009m7 is larger and more persistent than the rest of the period. This seems to correspond to GM and Chrysler having prolonged shutdowns as they re-organized in early 2009. The monthly sales data tell a similar story, increases in sales growth dispersion tend to be associated with reallocation between the Big 3 and Japaneses brands rather than within these brands. Comparing reallocation between Big 3 and Japanese producers, we also see that there are much larger swings in production reallocation than sales reallocation at the monthly level.

To further explore the idea that a rise in dispersion of sales growth reflects reallocations that from country or country-industry shocks, Figure 6 plots the quarterly sales growth dispersion against log change in market share of trucks, imports, Big 3, and Japan firms

(all measured as averages of the monthly numbers). The data is not seasonally adjusted. Clearly the increase in dispersion in 2008 is accounted for by a shift away from trucks and the Big 3 toward cars, imports, and Japanese firms. There are two clear phases to this reallocation in 2008 and 2009. In 2011, sales growth dispersion rises sharply again. This rise reflects a shift away from sales of Japanese cars (produced in the US or imported) as the Tsunami in Japan had a much larger effect on Japanese firms sales of US and Japanese produced cars.

6 Conclusions

Using quantitative theory and data, we have examined both the impact of stochastic microlevel volatility on the cyclical patterns of international trade and output, and the impact of aggregate international shocks on measured microlevel volatility or dispersion through the channel of international trade.

Examination of the first channel uncovered a puzzle for the standard business cycle model used to understand microlevel trade dynamics: increases in firm-level dispersion lead to large increases in trade rather than the steep declines typically observed in recessions. Examination of the second channel, in contrast, uncovered a potentially important source of measured cyclicality in firm-level dispersion, shocks to international trade patterns increase uncertainty. The model indicates that such a channel could be quantitatively important, and our empirical evidence shows that industry volatility measures are indeed associated with measures of trade reallocation shocks and measures of openness. Moreover, within the auto industry, through careful examination, we have confirmed importance of such country-to-country reallocation at the firm-level.

This second channel we have uncovered motivates several avenues for future research. First, although cars are an important industry, it would be informative to examine whether

other industries behave in similar fashion. This would require access to Census level data, however.

Secondly, trade-induced reallocation appears to be an important channel, it seems unlikely that this could be the entire story. For example, neither the VXO data on the implied volatility of a 30 day option, that Bloom (2009) nor the differences in aggregate predictions nor the greater dispersion in firm-level forecast errors documented by Bachmann, Elstner, and Sims (2013) could likely be explained by country-specific shocks alone, since these patterns would presumably be predictable. These may primarily reflect aggregate uncertainty. In any case, a quantitative decomposition of the fraction of cyclical changes in dispersion that can be explained by trade reallocations therefore remains to be done.

Finally, aggregate uncertainty in trade policy, may itself be important to business cycle and trade dynamics. A quantitative analysis of this channel is the subject of our current ongoing work.

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Table 1: Parameter Values

α	β	δ	σ	f_0	f_1	$\omega^{\frac{1}{\gamma}}$	θ	γ	v	η
0.36	0.99	0.025	0.30	0.372	0.161	0.25	2/3	1.5	2	0.25

Figure 1: Distributions 20% trade

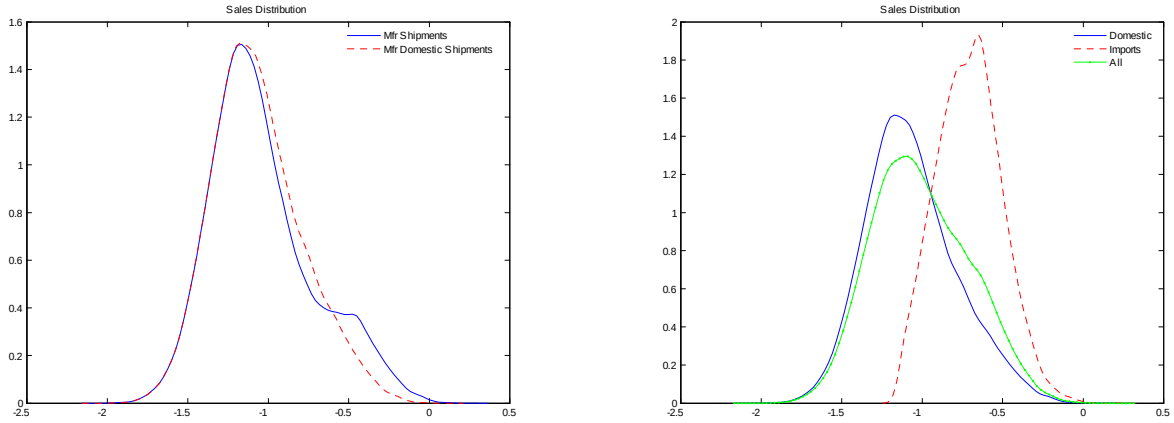


Figure 2: Negative Home productivity shock - 20% trade (left) and closed (right)

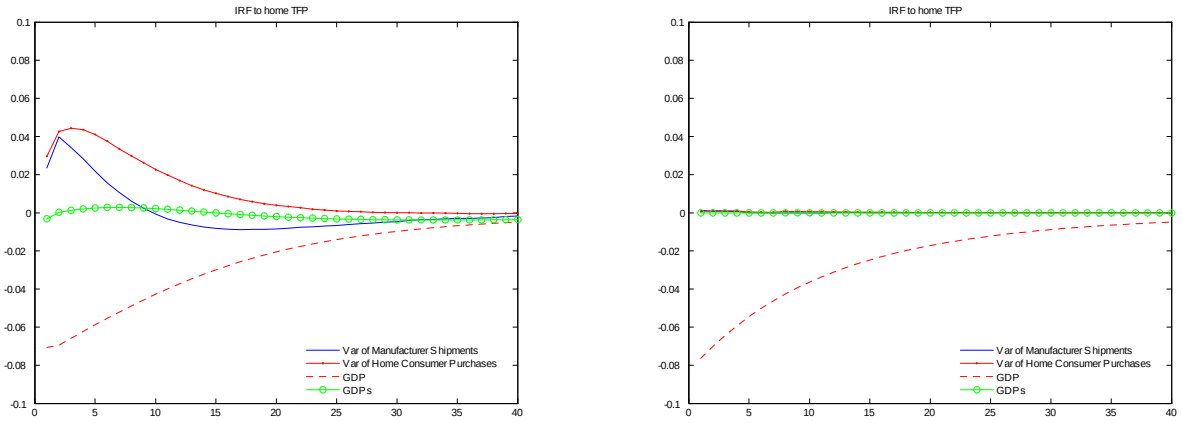


Figure 3: Negative Home productivity shock - 20% trade less productivity dispersion

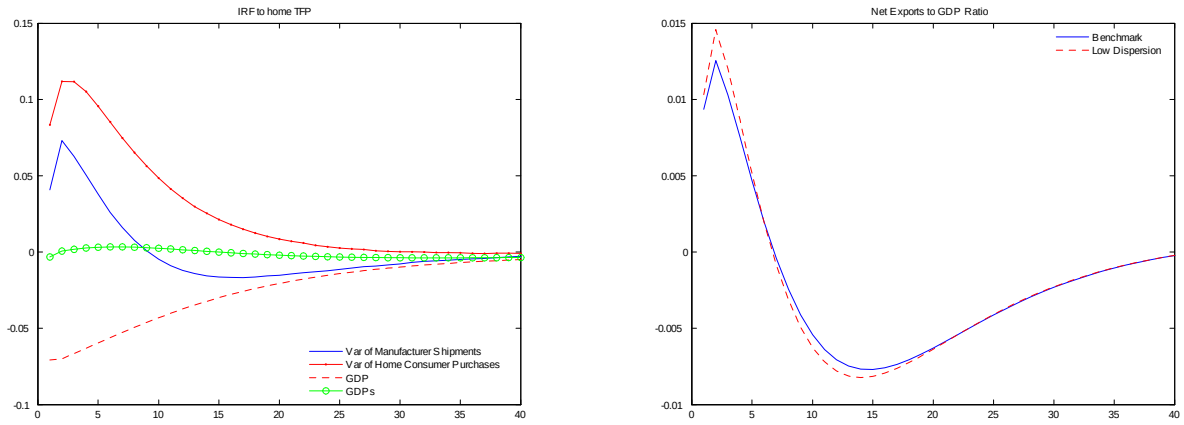


Figure 4: Volatility and Level of Activity (Sales and Production of Autos)

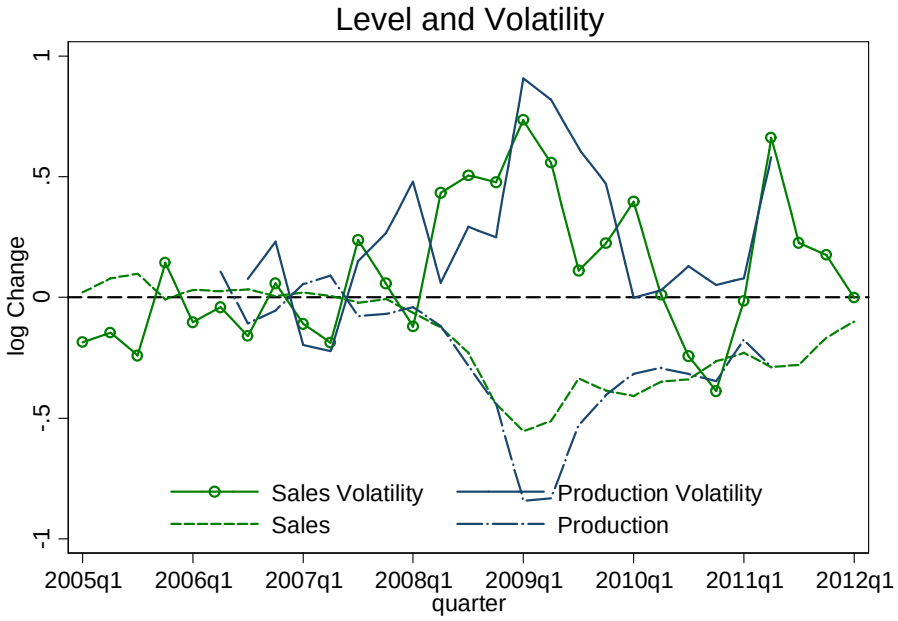
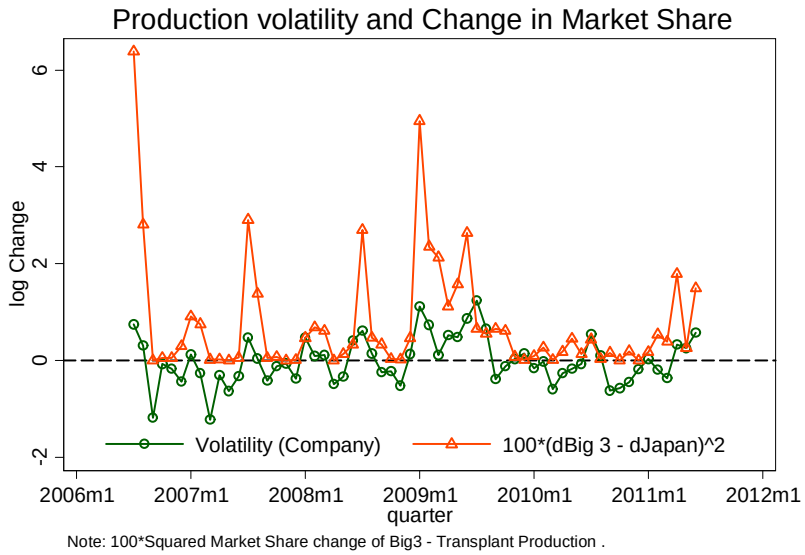


Figure 5: Volatility and Reallocation by Country Ownership



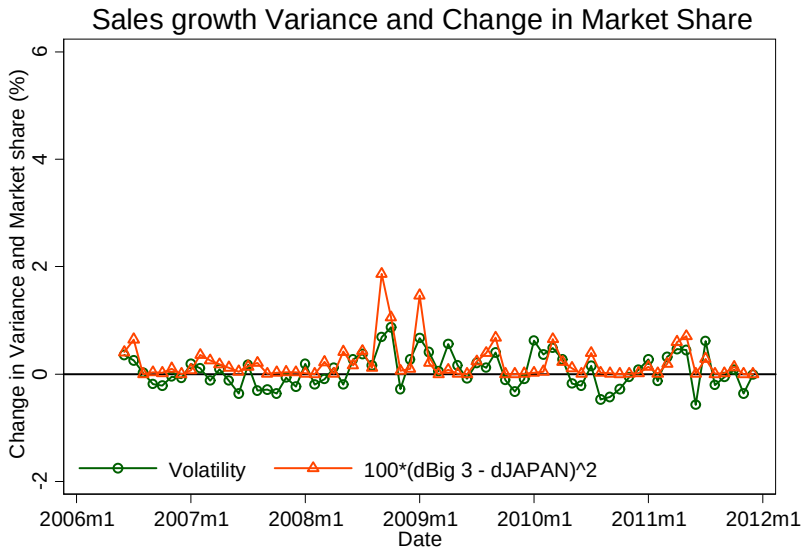
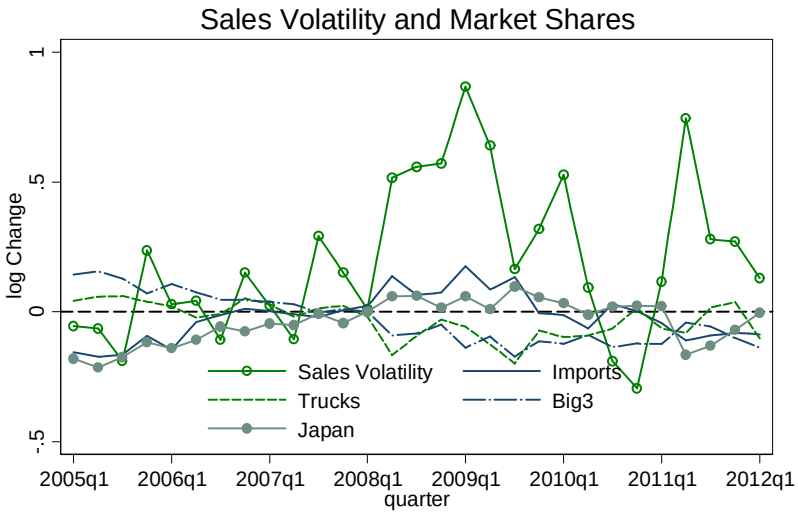


Figure 6: Sales Volatility and Market Shares



Note: Not Seasonally adjusted.
Market shares are log deviations from pre recession mean.