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# Globalization and aggregate fluctuations: The role of international trade and large firms

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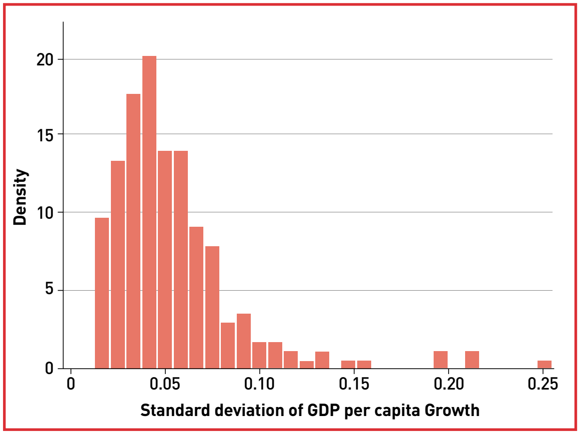
## 1. Introduction and motivation

The impact of international trade on the macroeconomy has become more pronounced over time, as the exponential growth of trade has led countries' fortunes to become more intertwined with each other. Along with the potential benefits that trade integration brings, such as greater economic growth, there are also potential costs. One risk is that by opening its economy to trade, a country will be exposed to more economic shocks, which leads to greater aggregate fluctuations of the domestic economy, such as increased output volatility (Rodrik, 1997).

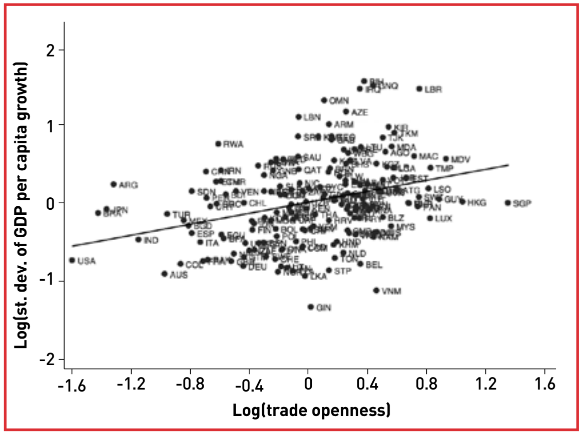
There are indeed large differences in macroeconomic volatility across countries as can be seen in Figure 1, which plots the distribution of the standard deviation of GDP per capita for all countries in the world. Understanding the source of these differences is important, given the potential costs of macroeconomic volatility —particularly for developing and emerging countries, where the welfare costs of volatility can be high (Pallage and Robe, 2003).

**Figure 1.** **Cross-country dispersion of GDP per capita volatility**




*Notes: This figure reports the histogram of cross-country macroeconomic volatility, calculated as the standard deviation of GDP per capita growth over 1960–2013. Source: World Development Indicators, World Bank.*

**Figure 2.** **GDP per capita volatility vs. trade openness**




*Notes: This figure reports the partial correlation between trade openness and macroeconomic volatility, after controlling for average per capita income. Volatility is calculated using annual growth rates over 1960–2013 for per-capita GDP, and trade openness is the average of imports plus exports divided by GDP over the same period. Source: World Development Indicators, World Bank.*

One robust empirical fact that has been highlighted by researchers is that these differences in macroeconomic volatility are positively correlated with countries' trade openness. Figure 2 plots a strong positive relationship between trade openness, defined as a country's [Exports+Imports]/GDP, and GDP volatility.[1]

The purpose of this *opuscle* is to answer the following question: what explains this positive relationship between aggregate volatility and trade? In particular, is this relationship causal? And, if so, what are the potential channels that underlie this relationship? This *opuscle* will provide answers to these questions by focusing on the production side of the economy, and by discussing the state-of-the art research, which studies both international trade and macroeconomic fluctuations.

I will draw insights from two separate but related literatures to help explain the link between trade and aggregate volatility observed across countries. Both literatures focus on the importance of *large firms*. On the one hand, such firms are important contributors to international trade, as they dominate the export market, and have been a focal point of study of the recent trade literature. On the other hand, the importance of *idiosyncratic* shocks to these firms in driving aggregate fluctuations has also been highlighted in recent research.[2]

The *opuscle* proceeds as follows. Section 2 reviews the literature on the relationship between trade and macroeconomic volatility, and argues that there exists a causal relationship between the two. Furthermore, the section will discuss the different channels underlying the observed bivariate relationship in Figure 2, and provide quantitative evidence on the importance of the different channels. Section 3 introduces why large firms are important in international trade, and for aggregate fluctuations. Section 4 discusses the relationship between trade, firms and aggregate volatility. Section 5 concludes.

## 2. Trade and macroeconomic volatility: Aggregate relationships

### 2.1 Cross-country evidence

A country's openness to both trade and finance plays a potentially important role in transmitting shocks originating from abroad, and the importance of such *linkages* and *spillovers* has been an area of recent interest given the financial crisis of 2007–08, which had global effects. Work by both academics and researchers in policy institutions have tried to quantify the importance of international linkages in transmitting the effects of recent crisis across countries (e.g., IMF, 2013).

More generally, research has pointed to a positive relationship between openness —whether it is in financial instruments or goods trade— and macroeconomic volatility across countries over long periods of time. Some studies (e.g., Easterly, Islam, and J. E. Stiglitz, 2001; and Kose, Prasad, and Terrones, 2003) have extended the basic analysis of Figure 2, and estimated how trade openness, among other factors, can affect GDP volatilities. Those studies confirm a positive relationship between openness and the volatility of GDP. Furthermore, Kose et al. (2003) and Bekaert, Harvey and Lundblad (2006) also find that greater trade openness increases the volatility of consumption growth, suggesting that the increase in output volatility due to trade is not fully insured away.[3] Rodrik (1998) also finds that measures of external risk —which depend on trade openness and on the volatility of import and export prices— are positively associated with consumption and income volatility.

These studies, and others like them, provide careful empirical analysis in order to argue that there exists a positive *correlation* between trade openness and volatility. However, this evidence is not enough to establish that trade openness causes higher volatility. For example, a low-income country may open to trade to grow faster, but this higher growth may initially also lead to greater GDP volatility as the country develops. Therefore, it is not trade openness per se that generates greater GDP volatility. Furthermore, cross-country regressions often remain silent on the potential channels through which international trade can impact aggregate volatility. Fortunately, these concerns can be addressed empirically by examining more detailed data, and using more structure to better understand the channels underlying the trade-volatility correlation.

### 2.2 The underlying channels of the trade-volatility relationship: Sector-level evidence

Di Giovanni and Levchenko (2009) provide a novel approach to address both concerns. They first study the relationship between trade openness and volatility for individual sectors (e.g., textiles, machinery, etc.). The estimates for individual sectors are then combined to quantify the effects of trade openness for a country as a whole.

The sector-level data are used to test three hypotheses of the impact of trade on volatility put forth in the theoretical literature. First, does greater trade openness lead to higher volatility of individual sectors? Answering this question directly tests whether opening an economy to international trade will make a country's industry more vulnerable to supply and demand shocks from the rest of the world. In theory, the industry will then face a world price for their goods, and will thus have to adjust output when hit by a shock from abroad (e.g., demand for the domestic economy's goods), as shown by Newbery and Stiglitz (1984).

Second, how does greater trade openness impact comovement between sectors within the economy? One possibility is that when a sector is very open to trade, it will depend more on global shocks to the industry, and less on the domestic cycle, which leads to a fall in the comovement between sectors of the economy. This fall in comovement implies a decline in aggregate volatility. To understand why a change in comovement impacts aggregate volatility, consider an economy with only two sectors and only sector-level shocks. Initially, assume that the correlation of shocks hitting the two sectors is zero, so the comovement of sector-level output is also zero. In this case, the overall movement, and thus volatility, of aggregate output will only depend on the volatility of the shocks hitting the individual sectors. Now, allow the correlation of shocks (thus comovement) of the two sectors to become negative, say due to trade opening. In this case, when one sector experiences a good shock, so that its output goes up, the opposite will hold for the other sector. Therefore, in the aggregate the increase in output of one sector will cancel out with the decline of output in the other sector (at least to some degree), so that swings to aggregate output are dampened relative to those of an economy with zero correlation of shocks across sectors. Overall, this implies that the volatility of aggregate output also declines.

Kraay and Ventura (2007) present a theoretical model that generates this result, where countries differ in their comparative advantage in producing high and low technology goods. The two sectors differ in either (a) the price elasticity of demand for their final good, or (b) the type of labor used —low vs. high skilled, where the elasticity of supply is greater for high skilled labor. Either channel (a) or (b) implies that the low and high quality goods' sectors will not comove perfectly when hit by an aggregate shock, and this channel is amplified when the economy opens to trade.



Third, does a change in trade openness change the pattern of industrial specialization, as one might expect given classical trade theory? If trade leads to a less diversified production structure, aggregate volatility will increase, and vice versa.

The main empirical results using sector-level data are the following. First, sectors more open to international trade are more volatile. Second, more trade in a sector is accompanied by a lower correlation between growth in that sector and aggregate growth, an effect that leads to a reduction in aggregate volatility, all else equal. Third, countries that are more open exhibit greater specialization, which works as a channel for creating increased volatility.

In sum, the quantitative impact of these channels implies that opening to trade will significantly increase aggregate volatility. For example, moving from the $25^{th}$ to the $75^{th}$ percentile in the distribution of trade openness —equivalent to a movement in the trade-to-output ratio of about 60 percentage points (i.e., from the average sector openness of India to that of Norway)— implies an increase in aggregate volatility of about 17.3% of the average aggregate variance observed in the data. This change is both statistically and economically significant.

These channels can also be examined across different country sub-samples and over time. Interestingly, the impact of trade openness is five times larger for developing than developed countries, and that the impact of all three channels increases over time when comparing the impact of openness on volatility on the 1970s vs. the 1990s. Therefore, as international trade increased over time, it would also appear that countries, particularly poorer ones, became more susceptible to macroeconomic volatility associated with increased trade integration.

## 2.3 Specialization and risk

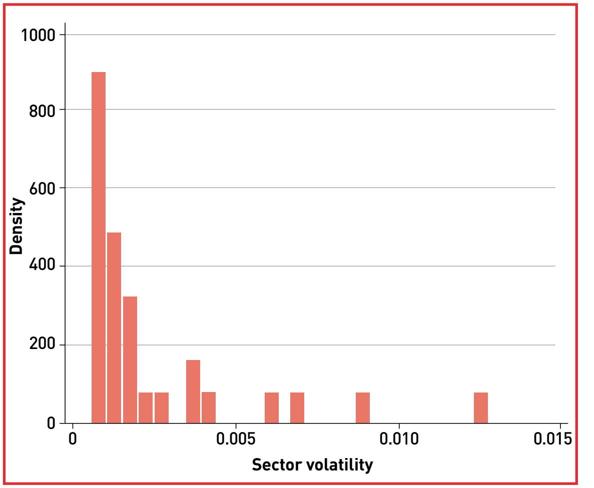
An important question to consider is why specialization impacts volatility —or riskiness— of a country. One reason is that countries specializing in fewer sectors should have more volatile exports given the lack of diversification. However, one must also take into account how risky the sectors that a country specializes are in order to have a more complete picture of what drives the riskiness of a country's exports. To that end it is possible to construct a measure of a country's export riskiness as in di Giovanni and Levchenko (2012b), which they call the risk content of exports (RCX), that takes into account both a country's specialization pattern across sectors, as well as how risky sectors are.

The RCX is constructed by combining a global variance-covariance matrix of sector-level productivities for 28 manufacturing sectors, as well as the agricultural and mining sector, with countries' export shares in given sectors. The risk matrix does not vary across countries (see Koren and Tenreyro, 2007) so all time series and cross-country variation in RCX is due to countries' patterns of export specialization.

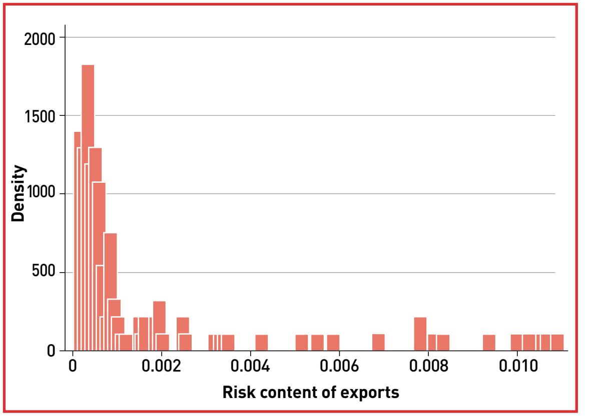
Figure 3a plots sector-level volatility for thirty sectors of the underlying risk matrix, while Figure 3b plots the 30-year average RCX for the 131 countries in the sample. As one can see in Figure 3a there is some dispersion in the sector-level volatility measures, with the global sector-level output growth variances ranging from 0.0006 (Wearing apparel, except footwear) to 0.013 (Mining), with an average of 0.002. It is also important to note that this histogram excludes the cross-sector covariance terms, which are used to compute the final RCX measure. There is also quite a bit of heterogeneity across countries' measures of RCX in Figure 3b, ranging from 0.00017 (China) to 0.0109 (Nigeria), with a mean value of 0.002.

**Figure 3. Distributions of sector risk and the risk content of exports**

**(a) Sector risk**




**(b) Risk content of exports across countries**



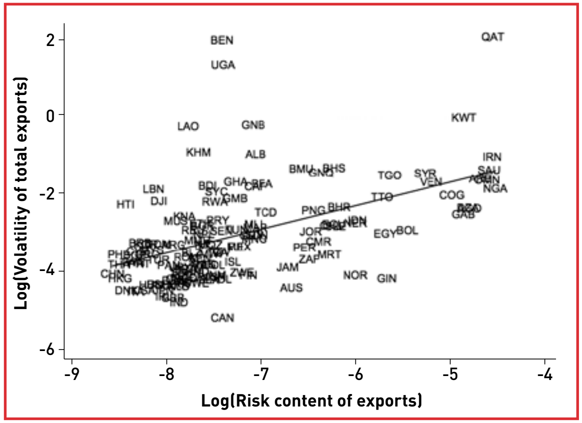

*Notes: The sector risk measure is the the global volatilty of sector-level output growth rates computed following the methodology of Koren and Tenreyo (2007) using data over 1970–99. The Risk Content of Exports is measured as the 30-year mean for 131 countries, computed using data over 1970–99. These measures are computed using sector-level data for 28 manufacturing sectors, as well as the Agriculture and Mining sectors.*

Armed with over one hundred countries' RCXs, it is possible to investigate whether the RCX is related to macroeconomic volatility across countries. In order to study such relationships, one may first study cross-country patterns by examining how the thirty-year mean of countries' RCXs correlate with the standard deviation of different macroeconomic aggregates. Figure 4a plots the (log) volatility of total exports against the (log mean) RCX across countries. As one can see, there is a strong positive relationship between the two variables. Therefore, countries that have risky export structures due to the sectors they are specializing in also have more volatile exports overall. Though this result may not be surprising given the construction of RCX, it is still important to see such a relationship hold in the data if one believes that RCX is a useful statistic for indicating macroeconomic volatility. Figure 4b next plots the (log) volatility of real GDP per capita against RCX. Again there is a strong positive relationship. Therefore, countries with more risky export structures also tend to be more volatile overall. However, the RCX does not correlate with any of the "usual suspects," such as a country's income per capita, trade openness, or financial openness. Therefore, it is not obvious why some countries specialize in risky sectors, while others do not.

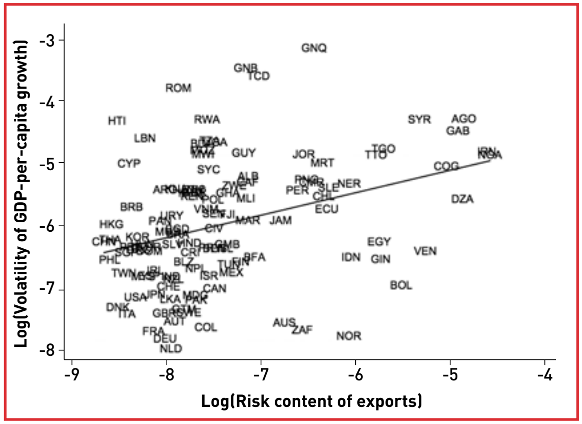
To better understand the riskiness patterns observed in the data we turn to Turnovsky (1974)'s early contribution, which incorporates risky production into a standard international trade model based on Ricardian comparative advantage.[4] In this model, absent international risk sharing, countries may no longer completely specialize in the sector that they have a comparative advantage in, which would otherwise be predicted to occur in the standard Ricardian model without risk. The intuition for this result is the following. As long as consumers are risk averse, volatile production (thus income risk) will be welfare reducing. Therefore,

**Figure 4. The risk content of exports and macroeconomic volatility**

**(a) RCX and export volatility**




**(b) RCX and GDP volatility**




*Notes: Export and GDP-per-capita volatility are calculated over 1970–99 using Penn World Tables data. The Risk Content of Exports (RCX) is constructed using the average trade shares for the period 1970–99.*

the introduction of volatile production may lead to specialization in production (thus exporting) to be welfare reducing, since the standard gains in trade from specialization may be out-weighted by the losses that the consumer faces from volatile output if the sector the economy has a comparative advantage in is very volatile. Therefore, a country may choose to diversify its production structure.[5]

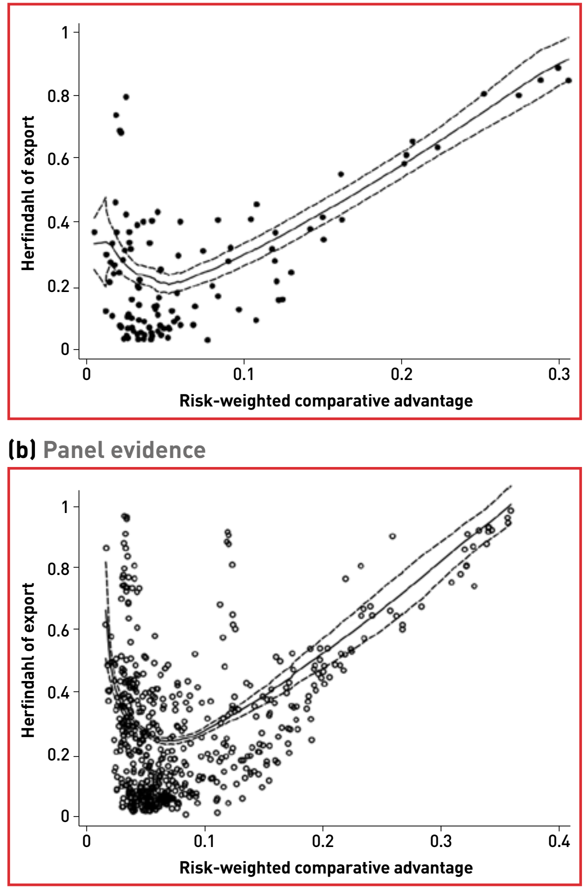
A key prediction from this model then is that countries with very strong comparative advantages in given sectors, whether they be “safe” or “risky,” will move towards high levels of specialization, while countries with only moderate comparative advantage across different sectors will not fully specialize. Therefore, it is possible to find countries that specialize in either very safe or very risky sectors.

Given that the underlying sectoral productivities that govern countries’ comparative advantages are unobservable, one must rely on proxies constructed using data, such as Balassa (1963)’s measure of “revealed comparative advantage” to measure countries’ comparative advantage. This measure is constructed by comparing a country’s exports across sectors relative to total world exports in those sectors in the world. Intuitively, after controlling for a country’s size, one would expect that a country that has a comparative advantage in a given sector, say textiles, would export more in this sector that the world on average. Next, we can combine measures of sector-level risk with measures of a country’s revealed comparative advantage in order to construct a “risk-weighted comparative advantage” (RiskCA) measure. According to the simple theory posited by Turnovsky, one would expect to see a U-shape relationship between RiskCA and a measure of a country’s export specialization, such as its Herfindahl index of exports, which can be easily constructed. The export Herfindhal index is constructed using export shares, and ranges from 0 to 1. A country that is diversified across all sectors will have a Herfindahl index closer to 0, while a country that exports in only one sector will have a Herfindahl index equal to 1.

**Figure 5. The risk-weighted comparative advantage and the Herfindahl of exports**

**(a) Cross-sectional evidence**

**(b) Panel evidence**




*Notes: These graphs present semi-parametric estimates of the relationship between the Herfindahl of Exports (Herfx) and the Risk-Weighted Comparative Advantage (RiskCA) for cross-sectional (109 obs.) and five-year panels (579 obs.) data. The solid line is estimated Herfx, and the ‘– –’ lines represent ± two-standard deviation (95 percent) confidence bands, which are calculated by bootstrapping with 10,000 replications.*

Figures 5a and 5b plot the relationship between the Herfindahl of exports and the RiskCA. The dashed lines represented two standard error confidence bands. As can be seen in both figures, the U-shape relationship predicted by theory is born out in the data. In particular, countries with high RiskCA values due to either a strong comparative advantage in safe sectors (small values of RiskCA) or risky sectors (large values of RiskCA) also tend to specialize in exports (large values of the Herfindahl index). Meanwhile, countries with intermediate values of RiskCA tend to diversify, and thus have lower Herfindahl indices of exports. Therefore, countries' specialization patterns are indeed influenced by the risk characteristics of the sectors in which they have a comparative advantage.

### 2.4 The next steps in understanding the trade-volatility relationship

All this sector-level evidence helps provide evidence that the trade-volatility relationship is not simply a correlation. Further, it points to the importance of studying the underlying microeconomics of the production structure of the economy. This research has recently been extended to analyze the impact of trade on *firm-level volatility*. This work is still in its embryonic stage, and results are thus far ambiguous on whether trade openness leads to greater firm-level volatility or not (Buch, Döpke and Strotmann, 2009; Kurz and Senses, 2013; Vannoorenberghe, 2012). The importance of the distribution of sector size within a country (i.e., the level of specialization) can also be extended to analyzing the impact of the *firm-size distribution* on aggregate volatility, in both a closed- and open-economy setting. In particular, recent research in both macroeconomics and international trade points to the importance of firms, and particularly large ones, in explaining aggregate outcomes.



## 3. The importance of large firms

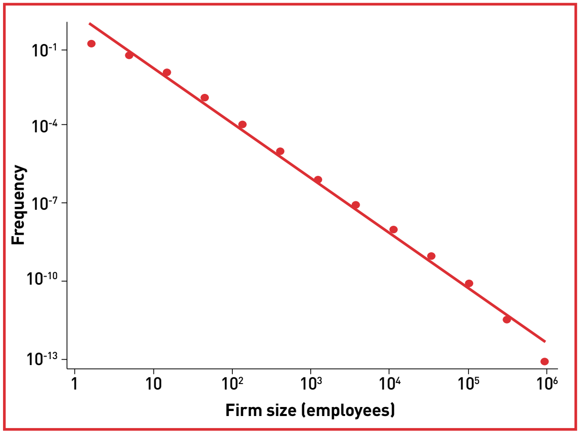
### 3.1 The distribution of firm size

Large firms produce the majority of countries' exports. For example, Bernard, Redding and Schott (2007) document that only a small fraction of U.S. firms are exporters, and that these firms are very large. Of 5.5 million firms operating in the United States in 2000, just 4 percent were exporters. Furthermore, the top 10 percent of exporters accounted for 96 percent of total U.S. exports. Similar patterns hold across other countries (e.g., see Eaton, Kortum and Kramarz, 2011, for France).

This observation on the firm-size distribution for exports led to the firm playing a central role in the "new-new" trade theory, which has taken off since the seminal work of Melitz (2003). Melitz models firms that have heterogenous levels of productivity, and that must overcome fixed costs in order to both produce for the domestic market, as well as to export. More productive firms are more likely to sell at home as well as export, and are therefore also larger in size (e.g., measured by total sales).[6] In particular, the assumptions in the model lead to a skewed distribution of firm sizes, where the largest firms dominate the export market. A crucial prediction from this theory, which I shall return to below, is that trade opening (e.g., a fall in tariffs or transport costs) will lead to large firms growing even larger (given economies of scale), while the least-productive domestic firms are driven out of business given entry by new foreign (productive) competitors.

The firm-size distribution is not only skewed when looking at export sales, but also for overall size (either measured by employment, sales, or assets, for example). One well-known paper that points to the dominance of large firms in the econ-

**Figure 6. The distribution of firm size in the U.S.**




*Notes: This figure plots the histogram of U.S. firm sizes, by employees. The data are from U.S. Census Bureau for 1997, and are tabulated in bins having width increasing in powers of three. The solid line is the OLS regression line through the data, and it has a slope of 2.059 (standard error = 0.054; adjusted $R^2$ = 0.992), meaning that a power law coefficient of 1.059. Source: Axtell (2001).*

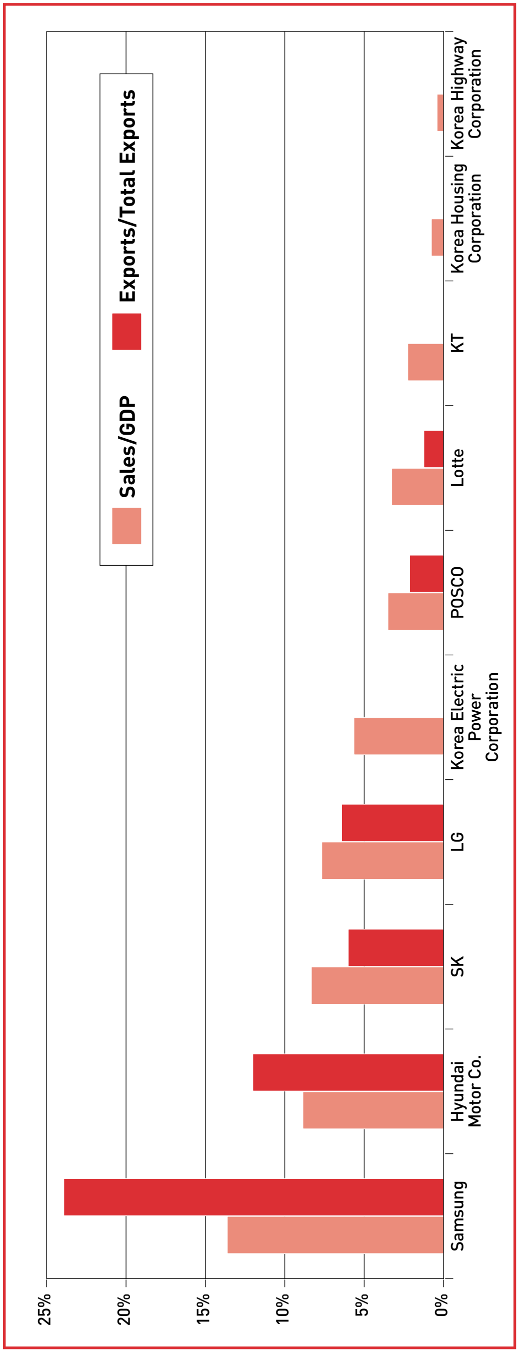
omy is Axtell (2001), who uses U.S. census data on firm employment to study the firm-size distribution. Figure 6 reproduces Axtell's figure that summarizes the U.S. distribution of firm size. The figure plots (bins of) firm size on the x-axis, and the frequency (probability) of observing this size on the y-axis. In looking at the bottom right-hand corner of the figure, one notes that the probability of observing a few large firms is small, while the converse holds in looking at the upper-left hand corner: there are many small firms. Therefore, the distribution of firm size is very skewed, and more specifically, it follows a *power law* with a coefficient near 1 (1.06 to be precise), which implies that the distribution of firm size can be approximated by Zipf's Law (Zipf, 1949). Power laws have useful statistical properties that can be applied in economic models, and have been observed in various areas of study, such as international trade, or the wealth distribution.[7]

There are many examples of the importance of large firms in various countries. For example, the New Zealand firm Fonterra is responsible for a full one-third of global dairy exports (it is the world's single largest exporter of dairy products). Fonterra accounts for 20% of New Zealand's overall exports, and 7% of its GDP. The firm is highly dependent on international trade: 95% of its sales are exports, and it also dominates the dairy industry within New Zealand —the second largest producer of dairy products in New Zealand is 1.3% the size of Fonterra. Large firms also play important roles in other sectors of the economy. For example, Nokia is a huge firm whose activities contribute significantly to Finland's GDP; and in Korea, the 10 largest business groups account for 54% of GDP, and 51% of total exports (Korean Development Institute). Even within this top 10, the distribution of firm size is very skewed, as can be seen in Figure 7. In particular, Samsung is responsible for 23% of exports and 14% of GDP. Similar conclusions are also valid for France (see di Giovanni, Levchenko and Rancière, 2011) and for a large pool of countries (see di Giovanni and Levchenko, 2013).

## 3.2 Large firms and macroeconomic volatility

Given that large firms play important roles throughout the economy, it is natural to ask what would happen if such firms were hit by a positive or negative shock. For example, what would happen to U.S. GDP if autoworkers went on strike in Detroit? Or, what happens when Apple introduces its latest innovation? The U.S. is a large and diversified economy, but such "shocks" to large firms can potentially have a significant impact on overall output. Indeed, in 2012, JP Morgan estimated that sales of Apple's new device (the iPhone5) could add as much as half a percentage point to U.S. fourth quarter GDP (CNBC, Sept. 17, 2012). This contribution to aggregate output is quantitatively

**Figure 7.** **Korean large firms**




*Notes: This figure reports the 2006 sales of the top 10 Korean business groups, as a share of Korean GDP (light bars) and total Korean exports (dark bars). Source: Korean Development Institute.*



important, and is an example of how the fortunes of large firms can impact aggregate fluctuations.

Such anecdotes are enticing, and may naturally lead one to ask whether economists should spend time focusing on the activity of large firms when formulating forecasts of economic activity. However, what does theory predict? And, is there rigorous empirical evidence beyond anecdotes to motivate researchers turning their attention to large firms being important sources of macroeconomic fluctuations?

Arguably, the answer to these questions has been no until recently. Indeed, Lucas (1977), among others, argued that microeconomic shocks could not be the source of economy-wide fluctuations. Furthermore, macroeconomists have traditionally focused on aggregate variables as sources of business cycle fluctuations. Therefore, considerable research has concentrated on the role of monetary and fiscal policy, as well as total factor productivity (TFP) shocks in driving the aggregate economy. Some work has focused on the possibility of sector-level shocks being sources of aggregate fluctuations,[8] but only recently has Gabaix (2011) articulated under what conditions could firms be the source of aggregate fluctuations. In particular, Gabaix shows under which conditions *idiosyncratic* shocks to large firms can impact macroeconomic fluctuations.

Standard arguments against firms being the source of aggregate fluctuations assume that no one firm is very large relative to others in the economy. In particular, in a world with symmetric-sized firms (a similar argument can be made for sectors), the impact of idiosyncratic shocks to the firms on the macroeconomy will cancel out, as the number of firms grows large. This aggregation property is simply a result of the law of large numbers, which leads to the average impact of shocks at the microeconomic level canceling out on the aggregate.[9] To be precise, if shocks (e.g., productivity or demand) are uncorrelated across firms, the variance of GDP will converge to zero at the rate of square-root of N, where N is the number of firms in the economy.

But, what if the firm-size distribution is not symmetric, which indeed appears to be the case as the evidence above shows? In this case, the standard statistical theory, which is applied to show that idiosyncratic shocks cancel out in a symmetric world no longer works. Instead, Gabaix (2011) shows that now the variance of GDP will decline at a much slower rate, as the number of firms (N) increases. This rate of decay is in fact slow enough so that shocks to firms will have an impact on the aggregate economy, even as N grows very large. Gabaix coins the term "granular" to apply to cases where microeconomic shocks impacts aggregate volatility.

Given this theory, Gabaix estimates the importance of shocks to large firms in driving GDP fluctuations in the U.S. over time. In order to do so, he uses data for the 100 largest firms in the U.S. and estimates shocks to firms' productivity, by estimating a panel regression of productivity growth (measured as the sales-per-worker growth) on sector fixed effects and other firm characteristics. The residuals from this regression are taken to be the idiosyncratic shocks. Gabaix then aggregates these shocks using firm sales' shares as weights, to construct a "granular residual." He then regresses U.S. GDP growth on the granular residual, and other controls over time, such as measures of monetary policy and oil shocks, to estimate the contribution of the granular residual to aggregate fluctuations. He finds that the granular residual can explain up to one-third of U.S. GDP movements over time. Therefore, accounting for idiosyncratic shocks to large firms is quantitatively important for explaining aggregate fluctuations.



One useful result from Gabaix (2011), which I will return to below, is that assuming that the volatility of firm-level idiosyncratic shocks is identical, aggregate volatility will equal firm-level idiosyncratic volatility (measured as the standard deviation of idiosyncratic shocks) times the Herfindahl index of firm size, measured in terms of the share of firm sales to total GDP. Therefore, the degree of specialization is a sufficient statistic to measure the impact of microeconomic shocks on aggregate fluctuations. This result mirrors one of the findings of di Giovanni and Levchenko (2009), who show that trade openness increases industrial specialization, which in turn leads to higher output volatility. If greater trade openness also leads to a more skewed distribution of firm size (thus a large Herfindahl index), then granular volatility will also increase.

## 3.3 Large firms and linkages

The granular results of Gabaix (2011) have been extended to better understand business cycle dynamics across countries by focusing on sectors as well as firms (for example, see Carvalho and Gabaix, 2013). Crucially, the firm (or sector) size distribution will ultimately govern how important shocks at the microeconomic level translate into macroeconomic effects.

However, shocks to large firms may play an important role for the macroeconomy beyond simply the effect generated from the observed distribution of firm size —i.e., the direct "granularity" result of Gabaix (2011). In particular, firms (and sectors) are linked across the economy due to production and financial linkages. For example, a firm may provide crucial inputs to firms *downstream*, and if the *upstream* firm is hit by a bad shock, it may have to cut back on supply to its customers, which in turn could set off a rippled effect across the economy, as well as abroad potentially

—for example, the effects of the 2011 Japanese earthquake and nuclear disaster were felt around the world given the impact on the global supply chain.[10]

Therefore, not only the size of a firm, but its importance in the supply chain plays an important role for how microeconomic shocks impact aggregate fluctuations. A recent contribution by Acemoglu et al. (2012) applies tools, developed in graphical network theory, to an economy where production across sectors features input-output linkages (the same methodology could be applied to firms, but input-output data currently only exist at the sector level). Among its several interesting theoretical results, the paper also provides a microfoundation, based on input-output linkages, for the power laws in sector or firm size that are observed in the data; thus, providing a microfoundation for why shocks to large firms may have aggregate effects.

# 4. Firms, trade, and aggregate volatility

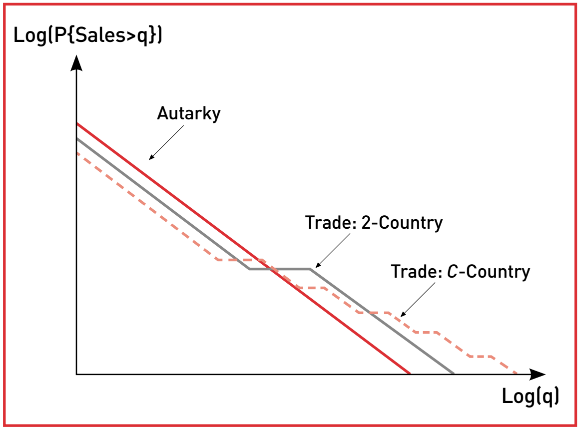
## 4.1 Melitz (2003) meets Gabaix (2011)

As the previous section highlighted, large firms play crucial roles in both international trade (Melitz, 2003), as well as potentially generating macroeconomic fluctuations (Gabaix, 2011). What do these two facts imply about the role of large firms for macroeconomic volatility in an open economy setting? In particular, underlying both these results is the distribution of firm size that exists in the economy. Does this observation have implications for whether idiosyncratic shocks to large firms impact economies differently given their relative openness to trade?

The answer to this question is yes, and can be easily understood intuitively when considering the mechanisms underlying the Melitz model. In particular, as discussed in Section 3.1, a central prediction from the Melitz model is that, given a fixed set of potential entrepreneurs (each who start a unique firm), as an economy opens to international trade, the largest firms will grow larger as their costs to access foreign markets fall, while smaller, less productive domestic-only producing firms may be driven out of production all together given increased competition from abroad. Thus, the economy will effectively become more granular, thus increasing the impact of a large firm's idiosyncratic shock on the macroeconomy following the logic of Gabaix (2011).

The impact of trade on the distribution of firm size as the economy moves from autarky to trading with more and more countries is depicted in Figure 8. The red solid line measures the firm-size distribution in autarky. As the economy moves from autarky to trade with another country (black line), the probability of observing a small firm falls, while the probability of observing a very large firm increases. This is precisely the "Melitz effect" of trade opening, and implies that the economy becomes more granular, as large firms increase their share of sales relative to total sales in the economy. The red dashed line considers the case of trade opening in a $C$-country world, where $C$ is greater than two. The distribution of firm size becomes more skewed as the economy becomes more granular. Therefore, there is the potential that idiosyncratic shocks to large firms will play a greater role in generating aggregate fluctuations as a country opens to international trade.

**Figure 8. The impact of trade on the distribution of firm size**




*Notes: This figure depicts the distribution of firm size, measured by sales, and how it changes as it moves from Autarky to a 2-Country Trade equilibrium, and finally to a* C*-Country Trade equilibrium. In the two-country case, there is a single productivity cutoff, above which firms export abroad. Compared to autarky, there is a higher probability of finding larger firms above this cutoff. In the* C*-Country case, with multiple export markets there will be cutoffs for each market, with progressively more productive firms exporting to more and more markets and growing larger and larger relative to domestic GDP.*

## 4.2 Quantifying the impact of trade openness on granular volatility

The Melitz-Gabaix channel linking firm shocks to macroeconomic volatility in an open economy seems to match nicely with some of the anecdotal evidence discussed in Section 3.1, such as the case of Fonterra, which is a firm highly dependent on international trade for sales, as well as being a major contributor to the New Zealand economy. However, to move beyond simple examples, and to provide quantitative evidence on the channel, it is necessary to construct a theoretical model to examine the impact of trade openness on the distribution of firm size across countries, since there does not exist sufficient panel data of firm size across countries and over time.



Di Giovanni and Levchenko (2012a) develop a theoretical and quantitative framework to study the consequences of the Melitz-Gabaix channel in a large cross section of countries. The study highlights two key ingredients in linking firm shocks to aggregate volatility in a multi-country world: (1) how open a country is to trade, and (2) how large the country is. In particular, a crucial insight is *that opening to trade will have a larger impact on aggregate volatility for smaller countries.* Furthermore, the model allows for counterfactual analysis, such as examining how much aggregate volatility changes by moving the economy from trade autarky to the current level of trade openness. Measuring this change is not possible using data, since no data on aggregate volatility exist for the counterfactual autarkic world.

To provide a quantitative analysis the paper builds a canonical multi-country model with heterogeneous firms in the spirit of Melitz (2003) and Eaton et al. (2011), which is implemented on the 50 largest economies in the world. In order to study the impact of large firms on aggregate fluctuations, the equilibrium total number of firms is determined endogenously in the model, and the parameters are calibrated to match the observed firm size distribution (i.e., a power law with a coefficient of 1.06, as found by Axtell, 2001).

The model also incorporates many features of the economy to be as realistic as possible.[11] These features, as well as the multi-country scale of the model requires the solution to be implemented numerically, where the quantitative solution of the model procedure targets the key aggregate country characteristics —GDPs and average trade volumes.

The model is successful in matching a number of non-targeted features of the micro data, such as the share of firms that export and the relative size

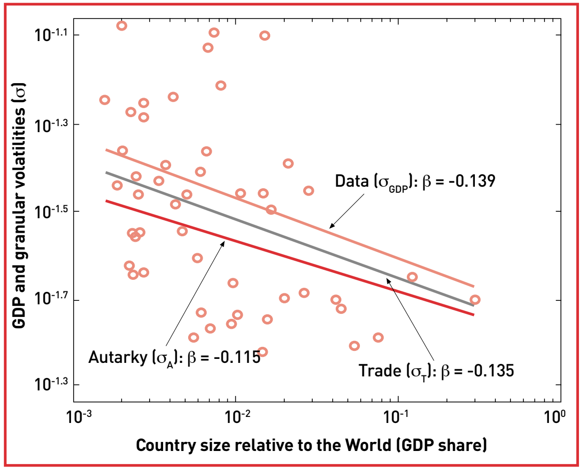
**Table 1. Export participation: Data and model predictions for whole economy and tradeable sector**

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | Model | | Data | |
| Country | Total | Tradeable | Total | Tradeable |
| United States | 0.010 | 0.018 | 0.040 | 0.150 |
| Germany | 0.111 | 0.238 | 0.100 | ... |
| France | 0.029 | 0.065 | 0.040 | 0.090 |
| Argentina | 0.112 | 0.352 | ... | 0.422 |
| Colombia | 0.148 | 0.548 | ... | 0.363 |
| Ireland | 0.332 | 1.000 | ... | 0.740 |
| Chile | 0.095 | 0.335 | 0.105 | ... |
| New Zealand | 0.062 | 0.189 | 0.051 | 0.135 |

*Notes: This table compares, for selected countries, the share of exporters among all firms in the model (column 1) and the share of exporters among the tradeable sector firms in the model (column 2) with available estimates of corresponding shares in existing literature. Since for some countries, data are reported relative to all the firms in the economy, while for other countries it is reported relative to all the firms in the traded sector, column 3 (data) should be compared to column 1 (model), and column 4 (data) should be compared to column 2 (model). For the United States, data are imputed based on publicly available U.S. Economic Census data on the numbers of firms by sector, together with the summary statistics for the numbers of exporters reported in Bernard et al. (2007). Data for France is based on authors' calculations using the French Census data in di Giovanni, et al. (2011). Data for Germany are from Arndt, Buch and Mattes (2009), Table A2. Data for Argentina come from Bustos (2011), Table D.1. For New Zealand, data come from Fabling and Sanderson (2008), Table 4. Data on Ireland come from Fitzgerald and Haller (2010), Table 1. Data for Chile come from private communication with Miguel Fuentes at the Central Bank of Chile. Data for Colombia come from private communication with Jorge Tovar at the Universidad de los Andes.*

of the largest firms across countries. For example, Table 1 presents the actual and model-predicted shares of firms exporting viz. either the total number of firms in (a) the whole economy, or (b) the tradeable sector. As can be seen in Table 1, the calibrated model does a relatively good job at matching export participation for a variety of countries, particularly small open ones such as Chile, Ireland, and New Zealand.

**Figure 9. Volatility and country size: Data and model predictions**




*Notes: This figure plots the relationship between country size and aggregate volatility implied by the data (conditioning on per capita GDP), the model under trade, and the model in autarky. The dots represent actual observations of volatility. Note that the data points and regression line are shifted by a constant for ease of visual comparability with the model regressions lines. Source: World Development Indicators, World Bank.*

Model-based generated distributions of firm sizes show that the model is able to reproduce key facts that are found in the data. The two main results are summarized in Figure 9, which plots the standard deviation of real GDP in the data, as well as the model-implied granular analogs in the autarky and trade equilibriums, against country size, which is measured as a country's GDP relative to world GDP. Note that the figure is in log-log scale. As can be seen by the ligh red line, there is a strong negative relationship between GDP volatility and country size in the data, with an elasticity of –0.139. Does this relationship hold in the model-generated GDP (granular) volatilities? Furthermore, how does the relationship change as one moves from autarky to the trade equilibrium?[12]

First, the model endogenously generates a negative relationship between country size and aggregate volatility, as seen in both autarky (dark red line), and the trade equilibrium (grey line). The reason for this finding is that smaller countries will have a smaller equilibrium number of firms (as implied by many models since at least Krugman, 1980), and thus shocks to the largest firms will matter more for aggregate volatility. In effect, smaller economies are less diversified, when diversification is measured at the firm level. The model matches this relationship not only qualitatively, but also quantitatively: in the trade equilibrium, the rate at which volatility decreases in country size in the model is very similar to what is observed in the data. Both in the model and in the data, a typical country that accounts for 0.5% of world GDP (such as Poland or South Africa) has aggregate volatility that is 2 times higher than the largest economy in the world —the United States.

Second, trade openness increases volatility by making the economy more granular: the volatility-size elasticity is –0.119 in *autarky* vs. –0.135 in the *trade* equilibrium. This result follows from the basic logic underlying the Melitz effect: when a country opens to trade, only the largest and most productive firms export, while some of smaller firms disappear. This effect implies that after opening, the biggest firms become even larger relative to the size of the economy, thus contributing more to aggregate output fluctuations. In the counterfactual exercise, aggregate volatility in an autarkic world is computed and compared to the volatility under the current trade regime. It turns out that at the levels of trade openness observed today, international trade increases volatility relative to autarky in every country. The importance of trade for aggregate volatility varies greatly depending on country characteristics, and in particular country size: opening trade has a larger impact on smaller countries. For example, in the largest economies like Japan or the U.S., aggregate volatility is only 1.5–3.5% higher than it would have been in complete autarky. While in small, remote economies such as South Africa or New Zealand, trade raises volatility by about 10% compared to autarky. Finally, in small, highly integrated economies such as Denmark or Romania, international trade raises aggregate volatility by some 15–20%.

These results provide evidence that a country's openness to trade and firm-specific shocks must be considered when thinking about aggregate volatility. Work by Canals et al. (2007) also highlights the importance of granularity in an open economy context. These authors analyze sector- and firm-level export data and demonstrate that exports are highly undiversified, both across firms and sectors, and across destinations. Furthermore, they show that this feature of export baskets can explain why aggregate macroeconomic variables cannot account for much of the movements in the current account.

### 4.3 Measuring firm-specific shocks and their impact on aggregate fluctuations

The work on granularity, and the importance of microeconomics underpinnings of aggregate fluctuations in general, has opened up new avenues of research. This work has also been of interest given the role of a few large players in the systemic nature of the recent financial crisis. However, very little empirical evidence measuring the importance of firm shocks on aggregate volatility exists. Note that Gabaix (2011) relies on data for only the 100 largest firms in the U.S. economy, and therefore by not including the universe of firms, his estimation strategy may omit some important information. Furthermore, di Giovanni and Levchenko (2012a) take the volatility of firm-specific shocks as given, and seek to explain cross-country differences in aggregate volatility arising from granular fluctuations.

Di Giovanni, Levchenko and Méjean (2014) take a step further in understanding the quantitative importance of firm shocks on aggregate fluctuations by constructing a novel French database, which combines fiscal data on firm-level characteristics and customs data over 1990–2007. The resulting dataset covers the universe of French firms' annual domestic sales and destination-specific exports, and therefore is not subject to sampling concerns.

In order to extract a firm-specific shock we setup a simple multi-sector model of heterogeneous firms, which draws inspiration from the work of Melitz (2003) and Eaton et al. (2011). The beauty of the setup is that it provides a simple framework to breakdown the annual of *firm-destination* sales additively into (i) a macroeconomic shock, which is defined by the common contribution to sales to all firms in a given destination each year; (ii) a sector-level shock, which is defined by the common contribution to sales to all firms in a given sector each year; and (iii) an idiosyncratic component, which captures the unique firm-destination component of annual sales growth —this is defined to be the "firm-specific" shock. The resulting estimating strategy to extract the firm shocks is a panel regression with the firms' annual growth of destination-specific sales as the dependent variable, and sector×destination×year fixed effects, which are inclusive of the macroeconomic and sector-level shocks. Crucially, the heterogeneity across markets also allows for the estimation strategy to identify the firm-specific shocks affecting a firm's sales to all markets it serves from shocks particular to individual markets. The residuals from the regression thus capture firms' idiosyncratic shocks.

Not surprisingly, given the large dataset (several million observations), the firm-specific shocks account for the overwhelming majority (98.7%) of the variation in sales growth rates across firms. In addition, about half of the variation in the firm-specific component is explained by variation in that component across destinations, which can be interpreted as destination-specific demand shocks in the conceptual framework laid out in the paper.

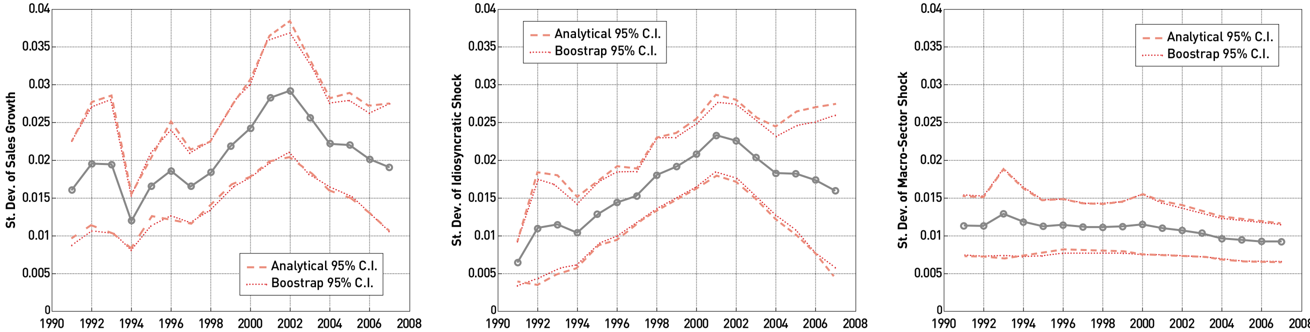
However, the firm-specific shocks need not explain much of the variance of the aggregate sales growth. In particular, recalling the work by Gabaix (2011) discussed above, if the French firm-destination sales' shares (viz. total sales) are equal, the impact of firm-destination shocks will cancel out on the aggregate. We therefore derive a decomposition of aggregate volatility in the economy into the contributions of macroeconomic-sectoral (simply "macroeconomic" in the following) and firm-specific shocks, and quantify the importance of the latter for aggregate volatility.

The decomposition shows that the firm-specific components contribute substantially to aggregate fluctuations. The standard deviation of the firm-specific shocks' contribution to aggregate sales growth amounts to 80% of the standard deviation of aggregate sales growth in the whole economy, and 69% in the manufacturing sector over the sample period. This contribution is similar in magnitude to the combined effect of all macroeconomic shocks. The standard deviation of the macroeconomic shocks' contribution to aggregate sales growth is 53% of the standard deviation of aggregate sales growth for the overall economy, and 64% for the manufacturing sector.

Figure 10 plots the volatility of the (i) aggregate sales growth, (ii) aggregate macroeconomic component, and (iii) aggregate idiosyncratic component for the whole economy and manufacturing sector, respectively. Note that the time variation in the standard deviation of these shocks is due to the time-varying firm-destination sales'

**Figure 10.** Volatility of sales growth and its components

**(I) Whole economy**

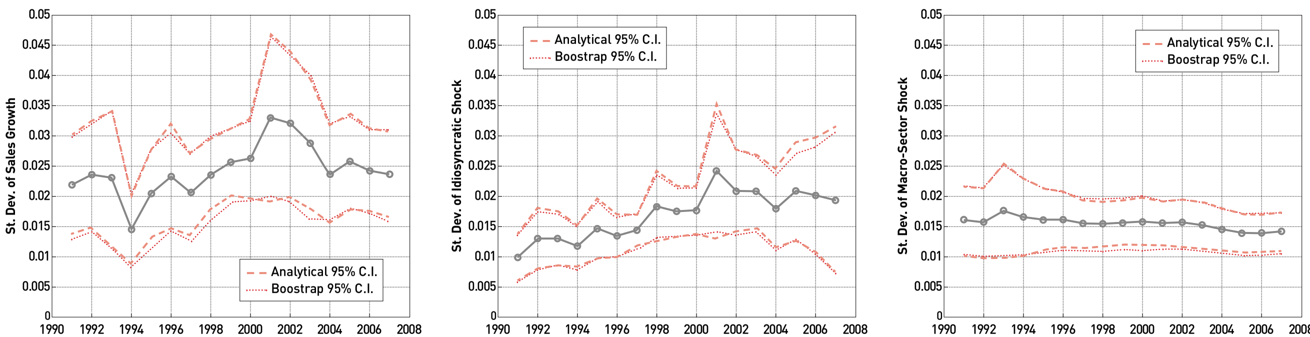



(a) Sales

(b) Idiosyncratic

(c) Macroeconomic

**(II) Manufacturing sector**




(a) Sales

(b) Idiosyncratic

(c) Macroeconomic

*Notes: This figure presents the estimated standard deviations of aggregate sales, idiosyncratic shock, and macroeconomic shocks for the whole economy (Panel I) and the manufacturing sector (Panel II), along with both analytical and bootstrap 95% confidence intervals.*

shares, which are used to identify firm-destination components over time. As can be seen for both the whole economy (panel I) and manufacturing sector (panel II), the volatility of total sales and the idiosyncratic components increases over time into the early 2000s, before dropping. Meanwhile, the volatility of the macroeconomic component is quite stable. One explanation for these patterns is that the economy became more granular in terms of the firm-destination component of sales, while the sector-destination shares did not vary greatly over time. Therefore, idiosyncratic shocks played a greater role into the early 2000s, and generally drove the time variation of aggregate sales. This is what we would expect to see if microeconomic shocks played an important role in explaining aggregate fluctuations, and mirrors what Carvalho and Gabaix (2013) find for the U.S. using sector-level data over a longer time series.

Next, we can investigate whether there are any systematic differences between the behaviors of domestic and export sales. Recall that only a small percentage of firms export, therefore one might expect that the idiosyncratic component will play a larger role in explaining the volatility of aggregate exports. Indeed, the firm-specific component contributes more to the volatility of exports compared to both total and domestic sales. This result holds for the whole economy, as well as only the manufacturing sector sub-sample, where exporting is more prevalent. But, the firm-specific shocks are also important contributors to domestic sales volatility as well.

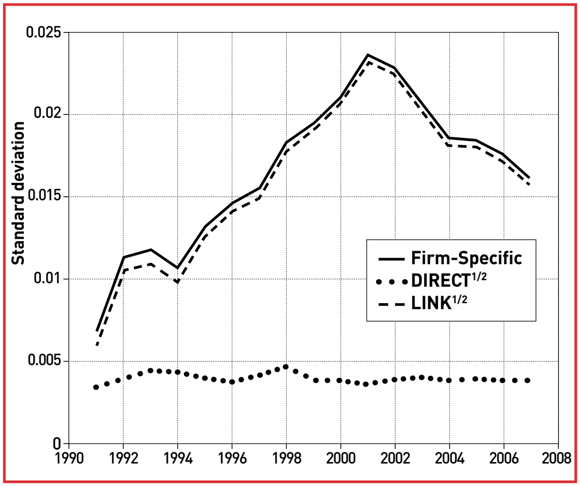
It is also possible to investigate different channels through which the firm shocks may be driving aggregate volatility. As the discussion in Section 3.3 notes, large firms may matter for aggregate fluctuations because of the "direct" granular effect (referred to as DIRECT in what follows) proposed by Gabaix (2011), and because of their important role in "linkages" of production across the economy (referred to as LINK in what follows) as modeled by Acemoglu et al. (2012), and others, which would lead to comovement of firm-specific growth rates given a shock to one firm.

To investigate how important the contributions of the DIRECT and LINK channels are to aggregate fluctuations, we can next decompose the overall contribution of firm-specific shocks to aggregate volatility into two terms: (i) a weighted sum of all the variances of firm-specific shocks (i.e., DIRECT), and (ii) a weighted sum of all the covariances between the firm-specific shocks (i.e., LINK). Though both channels matter quantitatively, the majority of the contribution of firm-specific shocks to the aggregate variance is accounted for by the LINK term —the covariances of the firm-specific components of the sales growth rates. The relative contributions of the different components can be seen in Figure 11, which plots the overall firm-specific component, and the contributions of the DIRECT and LINK for the whole economy and manufacturing sector, respectively. As one can see, the LINK component (the dashed line) tracks the overall firm-specific component very closely in both sub-figures.

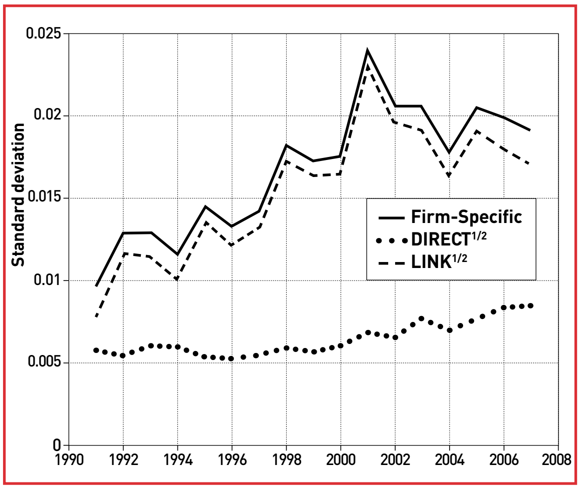
The analysis can further exploit cross-sector level heterogeneity in order to test more explicitly the importance of the granular channel and the role of input-output linkages in explaining the observed DIRECT and LINK components. First, Figure 12 plots the DIRECT component, calculated at the sector-level rather than for the aggregate economy, against the Herfindahl index of firm sales within a given sector for whole economy and the manufacture sector, respectively. As the granular channel would predict, firm-specific shocks in more concentrated industries —such as transport, petroleum, and motor vehicles— contribute more to aggregate volatility than firm-specific shocks in

**Figure 11. Contribution of individual volatilities and covariance terms to firm-specific fluctuations**

**(a) Whole economy**



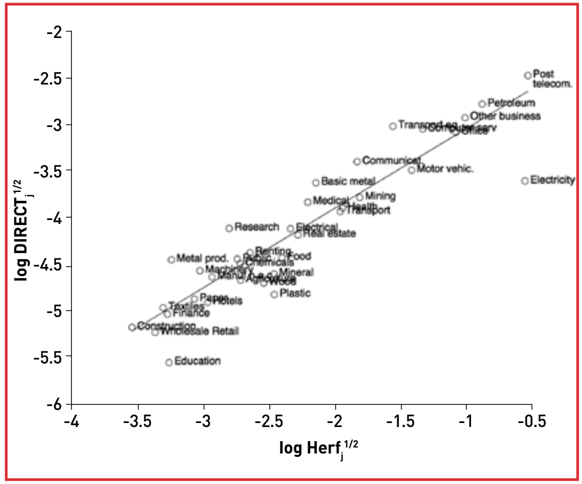

**(b) Manufacturing sector**



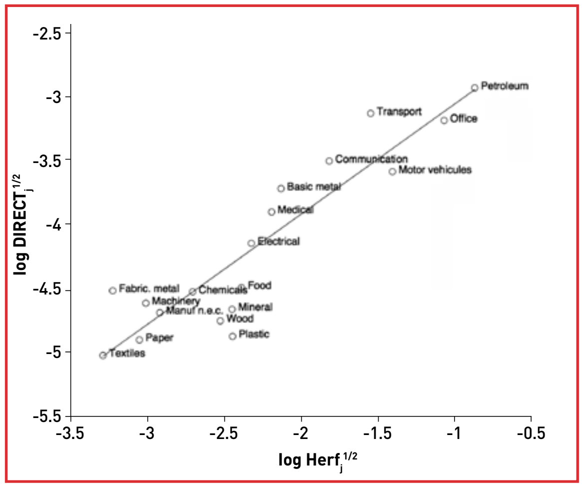

*Notes: This figure presents a decomposition of the Firm-Specific aggregate variance into two components that measure the contribution of firm-specific variances (DIRECT), and of covariances across firms (LINK).*

**Figure 12. Firm-specific volatility aggregated at the sector-level and the sectoral mean Herfindahl Index**

**(a) Whole economy**




**(b) Manufacturing sector**




*Notes: This figure plots the time average of the sectoral ($DIRECT_j$) component against the square root of the sectoral mean Herfindahl index. The correlation between time average ($DIRECT_j$) and $Herf_j$ is 0.86 for the whole economy and 0.93 for the manufacturing sector.*

less concentrated sectors such as metal products or publishing —i.e., sectors with higher Herfindahl indices also have higher DIRECT measures.

Second, Figure 13 compares the covariances of the firm-specific shocks aggregated to the sector level to a measure of sectoral linkages taken from the Input-Output Tables. Assuming that firms in a given sector have the same input-output coefficient as the sector as a whole, we should expect that sectors with stronger input-output linkages will exhibit significantly greater correlation of firm-specific shocks – this relationship is born out in the data, as can be seen in Figure 13, for the whole economy and the manufacturing sector. Thus, the evidence presented in Figures 12 and 13 provide direct corroboration in the data for the mechanisms behind both the DIRECT and the LINK effects.

## 5. Conclusion

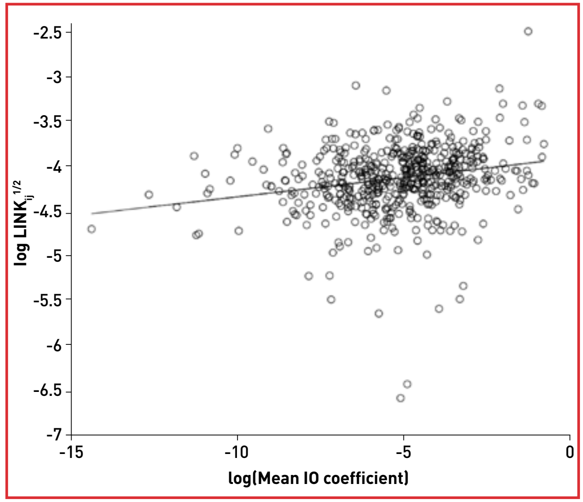
I began this article by asking a very simple question: does greater trade openness lead to higher macroeconomic volatility? By delving "under the hood" of countries' production structures using better and more disaggregated data, as well as exploring new channels that link trade openness and output volatility, the evidence points to an affirmative answer to the original question posed.

Furthermore, research has moved beyond relying on simple cross-country correlations. Given the importance of large firms highlighted in recent work in both international trade and macroeconomics, there are now rich theories that place firms, as well as production linkages within and across the economies, at center stage in order to better understand how shocks are propagated and

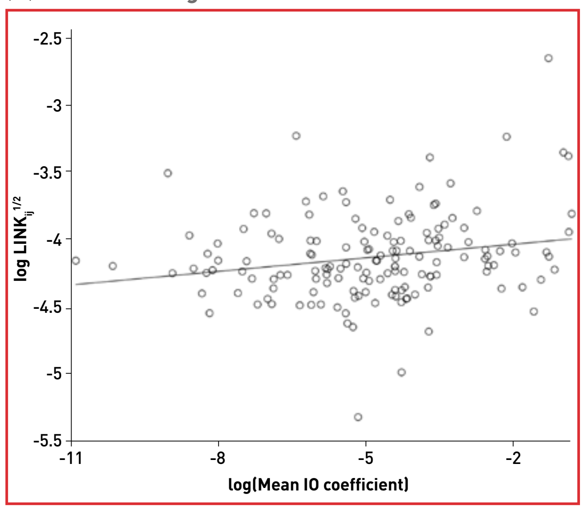


**Figure 13. Covariances of firm-specific shocks across sectors and their input-output linkages**

**(a) Whole economy**




**(b) Manufacturing sector**




*Notes: This figure plots the time average of the sector-pair LINK$_{ij}$ component against the mean IO linkage (share of intermediate inputs in total costs times the share of the upstream sector in intermediate consumption between sectors i and j). The correlation between the time average LINK$_{ij}$ and the IO linkages is 0.29 for the whole economy and 0.34 for the manufacturing sector.*

their ultimate impact on aggregate fluctuations. These empirical and theoretical contributions have potentially important policy implications. For example, they point to the necessity of not only monitoring macroeconomic aggregates during risk surveillance exercises, but also the activity and health of large firms, with particular emphasis on ones that play important roles in the production chain, both domestically and abroad.



## Notes

*(*) This* opuscle *draws heavily on joint work undertaken over the past several years with Andrei Levchenko, who I am grateful to for being a fantastic co-author as we have developed our research agenda over time. I would like to thank an anonymous referee for thoughtful comments, which helped improve the paper. I would also like to thank the Marie Curie International Incoming Fellowship FP7-PEOPLE-2013-IIF for financial support under Grant Agreement 622959.*

*(1) The fitted line controls for countries' income per capita, since poor countries may experience higher output volatility as they grow.*

*(2) An* idiosyncratic *shock refers to an event impacting a firm independently from other firms in the economy.*

*(3) In theory, a country can insure against output volatility if international financial integration is perfect, so all idiosyncratic country risk can be insured away via financial trade with other economies.*

*(4) A country has a comparative advantage over another in producing a particular good if it can produce that good at a lower relative opportunity cost or autarky price (i.e., at a lower relative marginal cost prior to trade). Opening to trade will lead to a country specializing in the goods it has a comparative advantage in, and thus becoming a net exporter of these goods.*

*(5) Note that this argument crucially depends on the lack of international risk sharing, which would allow consumers to smooth their consumption stream across states of nature. Even before the most recent financial crisis, economic research pointed towards the presence of imperfect international risk sharing.*

*(6) The model extends Krugman (1980)'s original insights on increasing returns and varieties.*

*(7) See Gabaix (2009) on power laws in economics.*

*(8) For example, the pioneering work of Long and Plosser (1983), and the contributions that followed by Dupor (1999), Horvarth (1998, 2000), Foerster, Sarte and Watson (2011), and Acemoglu et al. (2012) among others.*

*(9) The same logic underlies standard diversification strategies to minimize the variance of a financial portfolio in basic risk management theory.*

*(10) See http://www.voxeu.org/article/japans-earthquake-and-tsunami-global-supply-chain-impacts for examples of the effects that were passed through via trade, such as the impact on a French car manufacturer that was being supplied by Japan.*

*(11) For example, the model has both tradeable and non-tradeable sectors, intermediate goods in production, numerous entry costs to production and exporting markets, as well as transport costs.*

*(12) Note that the trade equilibrium is solved for to match the trade patterns observed the data.*



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## Julian di Giovanni

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