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ABSTRACT

This paper investigates the role of individual firms in international business cycle comovement using data covering the universe of French firm-level value added, bilateral imports and exports, and cross-border ownership over the period 1993-2007. At the micro level, controlling for firm and country effects, trade in goods with a particular foreign country is associated with a significantly higher correlation between a firm and that foreign country. In addition, foreign multinational affiliates operating in France are significantly more correlated with the source economy. The impact of direct trade and multinational linkages on comovement at the micro level has significant macro implications. Because internationally connected firms are systematically larger than non- internationally connected firms, the firms directly linked to foreign countries represent only 8% of all firms, but 56% of all value added, and account for 75% of the observed aggregate comovement. Without those linkages the correlation between France and foreign countries would fall by about 0.091, or one-third of the observed average business cycle correlation of 0.29 in our sample of partner countries. These results are evidence of transmission of business cycle shocks through direct trade and multinational ownership linkages at the firm level.

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1 Introduction

Countries that exhibit greater bilateral trade and multinational production linkages have more correlated business cycles (Frankel and Rose, 1998; Kleinert et al., 2015). While the empirical literature has repeatedly confirmed the trade-comovement relationship in the data, its meaning is not well-understood, either empirically or quantitatively. Taken at face value, the positive association between bilateral trade and multinational linkages and comovement is often interpreted as evidence of transmission of shocks across countries through those linkages.

The empirical literature has faced two related challenges. The first is the critique by Imbs (2004) that countries that trade more with each other are similar in other ways, and thus subject to common shocks. Under an extreme version of this view, the trade linkage variable in the Frankel-Rose specification does not reflect the intensity of transmission of shocks, but rather is simply a stand-in for the prevalence of common shocks. The second is that even if one accepts the transmission of shocks interpretation of the Frankel-Rose result, the coarse nature of the cross-country setting makes it difficult to learn about the micro underpinnings of the trade-comovement relationship. This lack of understanding is reinforced by the quantitative literature, which has struggled to capture the trade-comovement relationship. Kose and Yi (2006) and Johnson (2014) show that even quite sophisticated IRBC models fail to generate the observed positive association, dubbing it the "trade-comovement puzzle."[1]

Until now the properties of international comovement at the firm level, or its aggregate implications, have by and large not been studied. This paper provides a forensic account of international comovement at both the micro and macro levels using data covering the universe of French firm-level value-added, destination-specific imports and exports, and cross-border ownership over the period 1993-2007. Examining cross-border comovement at the firm level has two advantages relative to the traditional approach of looking directly at GDP correlations. First, at the micro level, the data allow for precise measurement of trade and multinational linkages – by firm×country – and to control for common shocks using appropriate fixed effects. This overcomes the common shocks critique and lets us establish much more firmly that the positive trade-comovement relationship is due at least in part

[1]The literature on multinationals and international business cycle comovement is more limited, but shares this feature. Kleinert et al. (2015) show that French regions that contain more multinationals from a particular foreign country are more correlated with that country. However, Cravino and Levchenko (2015) show that the observed multinational presence alone cannot generate the level of positive comovement found in the data. Liao and Santacreu (2015) develop a model in which technology shocks are transmitted between countries through changes in the mix of imported inputs, and show that allowing for the extensive margin of trade yields more promising results.

to transmission of shocks at the firm level.

Second, at the macro level, our approach allows us to capture the aggregate comovement implications of heterogeneity across firms in both size and the extent of international linkages. Larger firms are disproportionately more likely to trade internationally and own affiliates in foreign countries. Indeed, in most countries international trade flows are dominated by only a handful of large firms. An emerging research agenda in closed-economy macro has argued convincingly that modeling and measuring shocks at the micro level (to firms and sectors), and linkages between them, is essential for understanding aggregate fluctuations.[2] If large firms and firm-to-firm linkages matter for aggregate fluctuations, a natural conjecture is that they will matter as much if not more for cross-border comovement.

We begin by estimating a specification inspired by Frankel and Rose (1998), that relates the correlation of firm total value added growth with foreign GDP growth to firm-level direct linkages to that country. The data contain, for each firm and potential partner country, four types of direct linkages: (i) importing from it, (ii) exporting to it, (iii) being a France-based affiliate of a multinational firm headquartered in that country; (iv) being a French firm with a foreign affiliate in that country. Because the sample includes many firms and countries, estimation controls for both firm and country effects. Country effects in particular absorb the common aggregate shocks affecting France and each foreign country.

In a sample of firm-level correlations with 10 large trading partners of France, trade linkages at the firm level are significantly associated with increased comovement between an individual firm and the country with which it trades. An import link increases the correlation by 0.012, and an export link by 0.005. This is large relative to the average correlation between an individual firm and foreign GDP, which is 0.024 for directly connected firms, and essentially zero for non-directly connected ones. By a similar token, affiliates of foreign multinationals operating in France have a 0.01 higher correlation with their source countries.

At the same time, the empirical exercise reveals the importance of common shocks in the data. In a specification that omits the 10 country fixed effects but still includes the $\sim$1 million firm effects, the coefficients on the direct linkages variables are 2-5 times larger in magnitude and all strongly statistically significant. This underscores both the empirical

[2] Gabaix (2011), di Giovanni and Levchenko (2012), and Carvalho and Grassi (2015) develop models in which aggregate fluctuations arise from shocks to individual firms, because the firm-size distribution is extremely fat-tailed (Zipf's Law). Acemoglu et al. (2012) and Carvalho and Gabaix (2013) argue that sectoral shocks lead to aggregate fluctuations through interconnections between sectors. Di Giovanni et al. (2014) and Atalay (2014) provide corresponding empirical evidence on the role of shocks to firms and sectors in aggregate fluctuations.

relevance of common shocks, and how important it is to control for them in "gravity-macro" analyses of the effects of bilateral trade and capital flows linkages on aggregate outcomes. Nonetheless, the results when controlling for common shocks still provide clear evidence of transmission through direct linkages at the firm level.

We then use the sector-level Input-Output table together with firm-level information on input purchases and domestic sales to construct proxies for indirect linkages between French firms and foreign markets. The measures, inspired by the "network effect" propagation terms in Acemoglu et al. (2015), capture the intensity with which a French firm interacts with internationally connected firms. The downstream indicator reflects whether a firm buys intermediate inputs from firms that import from a particular country. The upstream indicator captures whether a firm sells its output to firms that export to a particular country. Both of these measures are firm- *and* foreign country-specific. We augment the main specification with these indirect linkage terms, and show that the downstream indirect linkages do matter significantly for firm-level comovement with foreign markets. Firms that buy inputs from importers from a particular country are more correlated with that country. The evidence on upstream linkages is more mixed, with coefficients differing in sign and significance depending on specification.

The second half of the analysis examines the macro implications of the micro-level findings. We start with the observation that the aggregate business cycle correlation between France and another country is simply an appropriately weighted sum of the correlations of firm-level total value added with that country. The aggregate business cycle correlation between France and each country can thus be written as a sum of two terms: the part due to the directly connected firms, and the part due to the not directly connected firms. For the 10 large trading partners of France in our sample, we show that the large directly connected firms are important in accounting for aggregate comovement. For a typical foreign partner country, the directly connected firms represent only about 8% of all firms in our dataset, but account for 56% of total value added. The directly connected firms are also unconditionally more correlated with the foreign country. Together these two facts imply that the directly connected firms account for 75% of the aggregate business cycle correlation observed in the data for the median country.

We then use the conditional relationship between direct linkages and firm-level correlations to compute the change in the aggregate correlation between France and each foreign country that would occur if direct linkages at the firm level disappeared. The aggregation exercise combines information on the change in the correlation at the firm level from the

regression estimates with firm-level weights. If direct linkages at the firm level were severed, the aggregate correlation would fall by 0.091 on average in our sample of 10 partner countries. This is a non-negligible change relative to the observed correlations between France and its main trading partners of 0.29 on average over this period. Since our data allow us to estimate the coefficients on trade and multinational links separately, we can also check which ones matter more for generating aggregate comovement. It turns out that the trade linkages are about 9 times more important in generating aggregate comovement than multinational linkages, accounting for 0.083 of the overall 0.091 effect.

Augmenting the aggregate impact with the indirect linkage estimates, we show that indirect linkages are quantitatively important as well. Accounting for indirect linkages implies that aggregate correlation would fall by 0.13 on average in the whole economy if links to the foreign country were severed. Thus, direct and indirect linkages together can account for nearly half of the average 0.29 observed aggregate correlation. The results are even stronger in manufacturing. Direct and indirect linkages produce a correlation of 0.414 between French manufacturing and foreign GDP, accounting for the bulk of the 0.484 average correlation in the data. Indirect linkages have a much larger impact in the manufacturing sector compared to the whole economy, alone accounting for 0.343 of the 0.414 total impact, more than 80%.

To summarize, on the one hand the data point clearly to the presence of common shocks, implying that it is imperative to control for them in the empirical exercise. On the other hand, even after controlling for common shocks, there is still substantial evidence of transmission of shocks through trade and multinational linkages. Among those linkages, trade linkages appear to matter more than multinational ones, especially in aggregate. Downstream indirect input linkages are both statistically robust and quantitatively important as well.

Our paper contributes to the empirical literature on international business cycle comovement. Studies building on Frankel and Rose (1998) have confirmed the positive association between trade and comovement and examined how it differs across types of goods trade and sub-samples of countries (see, e.g. Baxter and Kouparitsas, 2005; Calderon et al., 2007; Ng, 2010; Blonigen et al., 2014; Liao and Santacreu, 2015). While the existing empirical literature has almost exclusively used aggregate GDP correlations as the outcome variable, there has been comparatively little work on international comovement at more disaggregated levels. Di Giovanni and Levchenko (2010) estimate the relationship between bilateral trade, input linkages, and sector-level correlations. This paper's contribution is to examine the

trade-comovement relationship at the firm level, and to derive the aggregate implications based on micro-level estimates. In this respect, it shares some features with recent papers such as Kurz and Senses (2015), Boehm et al. (2014), and Cravino and Levchenko (2015), who perform related exercises.

An important research agenda, going back to Backus et al. (1995), attempts to understand the positive GDP correlation across countries using representative firm models in which all shocks are aggregate. Later developments in this literature explored the role of the production structure, such as input-output linkages (Burstein et al., 2008; Arkolakis and Ramanarayanan, 2009), or firm heterogeneity (Ghironi and Melitz, 2005; Alessandria and Choi, 2007) but have similarly been confined to considering only the role of aggregate productivity shocks in generating cross-country business cycle comovement. Our results suggest that to fully understand the impact of transmission of shocks for aggregate comovement, a quantitative framework must feature a realistic micro-structure that combines granularity in the firm size distribution and systematic heterogeneity among firms in trade and multinational linkages.

The rest of the paper is organized as follows. Section 2 lays out the conceptual framework and the empirical exercises performed in the paper. Section 3 describes the data, and Section 4 the results. Section 5 concludes.

2 Conceptual Framework

Total value added X_t by all French firms in year t is by definition given by: $X_t \equiv \sum_{f \in I_t} x_{ft}$, where x_{ft} is defined as the value added of firm f in year t, and I_t is the set of firms f operating at t. The growth rate of aggregate value added is then defined simply as $\gamma_{At} = X_t/X_{t-1} - 1$, where we assume that X_{t-1} and X_t are the aggregate value added of all firms that exist both at $t-1$ and t, i.e. we restrict attention to the *intensive margin* of aggregate value added growth. Appendix A develops a complete decomposition of the total value added growth into extensive and intensive margins, and presents the results for the relative contributions of the extensive and intensive margins to aggregate comovement between France and its main trade partners. The main result is that the large majority of aggregate comovement is accounted for by the intensive margin, with the extensive margin playing only a minor role.[3]

[3]These results are not inconsistent with the empirical findings in Liao and Santacreu (2015), who show that the extensive margin of trade is positively correlated with bilateral comovement. Those results relate the cross-sectional variation in the number of products traded between country pairs to bilateral business cycle comovement. Our extensive margin is the aggregate contribution of entry and exit of French firms

The growth rate of aggregate value added can be written as a function of individual firm growth rates and firm shares:

$$\gamma_{At} = \sum_f w_{ft-1}\gamma_{ft}, \tag{1}$$

where γ_{ft} is the growth rate of value added of firm f, and w_{ft-1} is the share of f's value added in total French value added.

The object of interest is the correlation between French aggregate growth and foreign GDP growth. Let $\gamma_{\mathcal{C}t}$ be the GDP growth of a foreign country $\mathcal{C}$ between $t-1$ and t. This correlation is given by:

$$\rho\left(\gamma_{At}, \gamma_{\mathcal{C}t}\right) = \frac{\text{Cov}\left(\gamma_{At}, \gamma_{\mathcal{C}t}\right)}{\sigma_A \sigma_{\mathcal{C}}}, \tag{2}$$

where $\sigma_{\mathcal{C}}$ is the standard deviation of country $\mathcal{C}$ growth.

Combining (1) and (2), the correlation between France and $\mathcal{C}$ at time t can be written as

$$\begin{aligned} \rho\left(\gamma_{At}, \gamma_{\mathcal{C}t}\right) &= \frac{\text{Cov}\left(\sum_f w_{ft-1}\gamma_{ft}, \gamma_{\mathcal{C}t}\right)}{\sigma_A \sigma_{\mathcal{C}}} \\ &= \sum_f w_{ft-1}\frac{\sigma_f}{\sigma_A}\rho\left(\gamma_{ft}, \gamma_{\mathcal{C}t}\right), \end{aligned} \tag{3}$$

where σ_f is the standard deviation of γ_{ft}.

While simply an identity, Equation (3) states the key premise of the paper: the aggregate correlation between the French economy and another country is an appropriately weighted sum of the firm-level correlations. The substantial literature on international comovement has studied empirically and theoretically the left-hand side of this equation – the aggregate business cycle comovement. This paper provides a picture of aggregate comovement by examining instead the components of the right-hand side. We proceed by analyzing first the properties of the individual firm-level correlations $\rho\left(\gamma_{ft}, \gamma_{\mathcal{C}t}\right)$, and then the consequences of aggregation across firms.

2.1 Micro Evidence

Equation (3) emphasizes that the aggregate business cycle correlation between the French economy and foreign countries is a function of the individual firm-level correlations and these firms' weights in the total French economy. We start by establishing whether the

from year to year, an object that has no close relationship to the cross-country differences in the number of traded varieties.

direct trade and multinational linkages at the firm level to a particular foreign country are associated with a higher correlation between the firm and that foreign country. To that end, we estimate the following specification:

$$\rho\left(\gamma_{ft}, \gamma_{\mathcal{C}t}\right) = \alpha + \beta_1 EX_{f,\mathcal{C}} + \beta_2 IM_{f,\mathcal{C}} + \beta_3 AFF_{f,\mathcal{C}} + \beta_4 HQ_{f,\mathcal{C}} + \delta_f + \delta_{\mathcal{C}} + \eta_{f,\mathcal{C}}. \quad (4)$$

In equation (4), the correlation between a firm and a foreign market $\mathcal{C}$ is related to binary indicators of whether the firm exports to there ($EX_{f,\mathcal{C}}$), imports from there ($IM_{f,\mathcal{C}}$), is a French multinational with affiliates in $\mathcal{C}$ ($HQ_{f,\mathcal{C}}$), or is an affiliate of a foreign multinational headquartered in $\mathcal{C}$ ($AFF_{f,\mathcal{C}}$). Importantly, the specification admits both firm and country effects, allowing for a precise identification of transmission of shocks through direct linkages.

The specification is inspired by Frankel and Rose (1998), who were the first to establish the robust empirical benchmark in this literature: country pairs that trade more with each other exhibit higher business cycle correlation. However, the interpretation of this stylized fact and the mechanisms responsible for generating it are still not well-understood. Taken at face value, the positive association between trade intensity and comovement suggests transmission of shocks through international trade linkages. However, as argued by Imbs (2004), an alternative interpretation is that countries that trade more with each other are similar in other ways, and thus subject to common shocks. Under an extreme version of this view, the trade linkage variable in the Frankel-Rose specification does not reflect the intensity of transmission of shocks, but rather is simply a stand-in for similarity between countries. In addition, even if one accepts the transmission of shocks interpretation of the Frankel-Rose result, the coarse nature of the cross-country setting makes it difficult to learn about the micro underpinnings of the trade-comovement relationship.[4]

Our firm-level specification leads to qualitatively new insights relative to the traditional cross-country empirical model. First, comparing firms within the same country and including country and firm fixed effects addresses the Imbs (2004) common shock critique. Since all firms in this specification are in France, country effects will absorb the common shocks affecting France and country $\mathcal{C}$. As a result, we can establish convincingly that trade and multinational linkages are indeed a source of transmission of shocks, rather than simply a stand-in for the presence of common shocks. Di Giovanni and Levchenko (2010) adopt a related strategy and use data on sector-level trade and comovement together with country-pair effects that control for common aggregate shocks. At the industry level, a link between

[4]These difficulties in interpreting the cross-country relationship are underscored by the finding that traditional international business cycle models have trouble reproducing it quantitatively (Kose and Yi, 2006; Johnson, 2014).

sectoral correlation and sectoral trade intensity does not have a tight interpretation, since it is not clear that exports from one of the sector-countries in the pair are used by the other sector-country. Extending this approach to firm-level data is a significant improvement in measurement, since we observe exactly which firms have direct links with which countries. While the country effects are useful at absorbing the macro common shocks, the firm effects allow us to control for heterogeneity at the firm level that varies by firm but not partner country: size, primary industry of operation, capital or skill intensity, access to external finance, R&D intensity, and so on.

Second, estimation at the firm level reveals the micro underpinnings of the aggregate relationship. Observing cross-border links at the firm level allows us to establish with forensic precision the role of each type of trade and multinational relationship in international comovement. With very few exceptions (e.g. Kleinert et al., 2015), existing papers do not combine information on both trade and multinational linkages in the same specification. This may be important: if both types of linkages potentially matter, not including them will lead to omitted variable bias. Information at the firm level paired with firm effects also enables us to control for heterogeneity across firms in volatility and comovement, as well as for forces that shape a firm's average comovement with the rest of the world (such as its domestic linkages, for instance).

2.1.1 Indirect Linkages

It may be that even firms not directly connected to a particular foreign country comove with that country through indirect linkages, that is, interactions inside the French economy induced by the directly connected firms. A complete account of all indirect linkages is not possible in this empirical setting, as those linkages can take a variety of forms, from purchases/sales of intermediate inputs by the directly connected firms to changes in factor and goods prices in general equilibrium. Nonetheless, we attempt to capture one type of indirect linkage, that can be potentially measured: indirect linkages through input-output relationships inside the French economy. To that end, we construct the following firm-specific indices of indirect linkages:

$$DS_{f,j,\mathcal{C}} = INPUTINT_f \sum_i IO_{ij} \frac{NIM_{i,\mathcal{C}}}{N_i} \tag{5}$$

$$US_{f,j,\mathcal{C}} = DOMINT_f \sum_i IO_{ji} \frac{NEX_{i,\mathcal{C}}}{N_i}. \tag{6}$$

In these expressions, i and j index sectors, and firm f belongs to sector j. IO_{ij} is the

domestic direct requirement coefficient of the 1995 French Input-Output matrix, defined as the share of spending on domestically-produced sector i inputs in production in sector j. $NIM_{i,\mathcal{C}}$ is the number of French firms in sector i that import from $\mathcal{C}$, $NEX_{i,\mathcal{C}}$ is the number of French firms in sector i that export to $\mathcal{C}$, and N_i is the total number of firms in sector i. Each of these numbers is computed excluding firm f itself (which is obviously only relevant if $i = j$), and thus are in that sense firm-specific, but we suppress the dependence of those values on f to economize on notation. Finally, $INPUTINT_f$ is the firm's total input usage intensity, defined as the total material input spending divided by material input spending plus wage bill, averaged across years. $DOMINT_f$ is the domestic sales intensity, defined as the share of firm f sales that goes to the domestic market, averaged across years.

These indices are heuristic, but inspired by the formulation of the "network effect" propagation of terms in Acemoglu et al. (2015). The $DS_{f,j,\mathcal{C}}$ indicator, short for "downstream," is meant to capture the fact that firms in sector j buy inputs from other sectors i in the economy. To the extent that sector i is populated by firms that import from country $\mathcal{C}$, country $\mathcal{C}$ shocks will propagate to input-buying firms in j through their input purchases of i. For any individual sector i, the term in the summation, $IO_{ij}\frac{NIM_{i,\mathcal{C}}}{N_i}$, will be high either if j uses a lot of sector i inputs (IO_{ij} is high), or if a high fraction of sector i firms import from $\mathcal{C}$. The summation aggregates this information across all the input-supplying sectors of j, and multiplies it by the firm-specific input intensity, since the importance of downstream linkages will be higher for firms that spend a lot on inputs.

The $US_{f,j,\mathcal{C}}$ ("upstream") indicator is meant to capture the fact that firms in sector j supply inputs to other sectors i, and thus will be affected by whether the sector i buying its inputs has a large population of directly connected firms. Export opportunities in sector i to country $\mathcal{C}$ will propagate to sector j as an increase in exports from i to $\mathcal{C}$ will raise demand for sector j inputs. For an individual output sector i, the term $IO_{ji}\frac{NEX_{i,\mathcal{C}}}{N_i}$ will be high if either i uses a lot of j inputs, or if a large share of firms in i export to $\mathcal{C}$. The summation across sectors is multiplied by the share of firm f's sales in the domestic market, since if f does not sell much of its output in France, by construction it must be a relatively unimportant supplier of inputs to the French market.

The indices are constructed using sector-level information by necessity, as there is yet no firm-level Input-Output matrix available for France. If we had firm-level information, these indices would have a much simpler form, and would exploit information on whether firm f sources inputs from directly connected firms, or supplies inputs to directly connected

firms.[5]

Note that while these formulations appear the most natural to us, one can think of other transmission mechanisms that might be at work. For example, one can build an alternative DS indicator that instead of counting the number of importing firms in the input-supplying sector, counts the number of exporting firms. This indicator would be relevant if there are capacity constraints, and thus greater export opportunities in the input-supplying sector i reduce those firms' domestic supply of inputs. We view those alternative indicators as less compelling and most likely second-order relative to those set out above. An additional question is whether we should also build propagation indices for multinationals and affiliates. In this case, it is also unclear in which way do shocks to multinationals propagate to non-directly connected firms. To avoid a proliferation of regressors, we favor a more parsimonious specification with only the two indices (5)-(6).

We add these two variables to the baseline specification (4). Thus, we include the indirect linkage indicators alongside the direct linkage indicators and country and firm fixed effects:

$$\begin{aligned}\rho\left(\gamma_{ft},\gamma_{\mathcal{C}t}\right) &= \alpha+\beta_1 EX_{f,\mathcal{C}}+\beta_2 IM_{f,\mathcal{C}}+\beta_3 AFF_{f,\mathcal{C}}+\beta_4 HQ_{f,\mathcal{C}}+\\ &\quad+\beta_5 DS_{f,j,\mathcal{C}}+\beta_6 US_{f,j,\mathcal{C}}+\delta_f+\delta_{\mathcal{C}}+\eta_{f,\mathcal{C}}. \qquad (7)\end{aligned}$$

2.2 From Micro to Macro

Next, we investigate the macroeconomic implications of these micro findings. The aggregate correlation as written in (3) is additive in the individual firm-level correlations with foreign GDP, and thus can be decomposed easily into the various components. Since we are interested in the impact of individual firms on aggregate correlations, we can decompose the aggregate growth rate into the contribution of two sets of firms: the directly connected and the not directly connected to a particular country:

$$\gamma_{At}=\sum_f w_{ft-1}\gamma_{ft}=\sum_{f\in I_{\mathcal{C}}} w_{ft-1}\gamma_{ft}+\sum_{f\in I_{\mathcal{C}}^c} w_{ft-1}\gamma_{ft},$$

where $I_{\mathcal{C}}$ is the set of firms that satisfy at least one of the four criteria included in estimating equation (4): (i) export to $\mathcal{C}$; (ii) import from $\mathcal{C}$; (iii) is a French affiliate of a multinational based in $\mathcal{C}$; or (iv) is part of a French multinational that has affiliates in $\mathcal{C}$. Correspondingly,

[5] If we had a firm-to-firm IO matrix, we could construct the simple index $DS^*_{f,\mathcal{C}}=\sum_g IO_{gf}IM_{g,\mathcal{C}}$, where IO_{gf} if the share of spending by firm f on inputs supplied by firm g in f's total output (the firm-to-firm direct requirement coefficient), and $IM_{g,\mathcal{C}}$ is, as defined above, the indicator for whether g imports from $\mathcal{C}$. The "ideal" index $DS^*_{f,\mathcal{C}}$ would be a precise measure of whether firm f sources inputs from directly connected firms or not. In the absence of firm-to-firm IO information, $INPUTINT_f IO_{ij}$ is our best guess for IO_{gf}, and $\frac{NIM_{i,\mathcal{C}}}{N_i}$ is an estimate for how likely it is that $IM_{g,\mathcal{C}}=1$.

$I_{\mathcal{C}}^c$ is the complement of that set of firms. Then, the aggregate comovement decomposes additively into two components, one due to the directly connected firms, and the other due to the rest:

$$\rho\left(\gamma_{At}, \gamma_{\mathcal{C}t}\right) = \frac{\sigma_{I_{\mathcal{C}}}}{\sigma_A}\rho\left(\sum_{f\in I_{\mathcal{C}}} w_{ft-1}\gamma_{ft}, \gamma_{\mathcal{C}t}\right) + \frac{\sigma_{I_{\mathcal{C}}^c}}{\sigma_A}\rho\left(\sum_{f\in I_{\mathcal{C}}^c} w_{ft-1}\gamma_{ft}, \gamma_{\mathcal{C}t}\right), \tag{8}$$

where $\sigma_{I_{\mathcal{C}}}^2 = \text{Var}\left(\sum_{f\in I_{\mathcal{C}}} w_{ft-1}\gamma_{ft}\right)$ is the variance of the combined value added of the directly connected terms, and similarly for $\sigma_{I_{\mathcal{C}}^c}^2$.

By bringing in information on firm weights w_{ft-1}, this additive decomposition will provide the first glimpse of whether the directly connected firms combined are a large enough segment of the economy to play an appreciable role in aggregate comovement. Of course, this decomposition yields only part of the answer: the direct component can be large either because the directly connected firms are large, or because they are more correlated. Estimates of equation (4) provide the means of separating the two.

For each directly connected firm, we can compute the predicted change in its correlation with country $\mathcal{C}$ if it were no longer connected with $\mathcal{C}$:

$$\widehat{\Delta\rho}\left(\gamma_{ft}, \gamma_{\mathcal{C}t}\right) = -\widehat{\beta}_1\mathbb{1}\left(EX_{f,\mathcal{C}}=1\right) - \widehat{\beta}_2\mathbb{1}\left(IM_{f,\mathcal{C}}=1\right) - \widehat{\beta}_3\mathbb{1}\left(AFF_{f,\mathcal{C}}=1\right) - \widehat{\beta}_4\mathbb{1}\left(HQ_{f,\mathcal{C}}=1\right). \tag{9}$$

As an example, if firm f only exported to $\mathcal{C}$ and had no other links, the predicted change in the correlation between f and $\mathcal{C}$ is simply $-\widehat{\beta}_1$. The formulation (9) allows for every combination of different types of direct links, and turns off all the existing ones at the same time.

Combining (9) with (3), the predicted change in the aggregate business cycle correlation between France and $\mathcal{C}$ if all cross-border links were severed is:

$$\widehat{\Delta\rho}\left(\gamma_{At}, \gamma_{\mathcal{C}t}\right) = \sum_f w_{ft-1}\frac{\sigma_f}{\sigma_A}\widehat{\Delta\rho}\left(\gamma_{ft}, \gamma_{\mathcal{C}t}\right). \tag{10}$$

For simplicity, this calculation assumes that the severing of the direct links does not have an impact on volatilities either at the firm or the aggregate level, or on firm weights. Since in the data the weights differ across years, below we report the values of $\widehat{\Delta\rho}\left(\gamma_{At}, \gamma_{\mathcal{C}t}\right)$ averaged across the sample years.

We next account for the impact of indirect linkages in a similar way. If all the direct linkages between country $\mathcal{C}$ and France were severed, the $NIM_{i,\mathcal{C}}$ and $NEX_{i,\mathcal{C}}$ terms in (5)-(6) become zero, and as a result in this comparative static, $DS_{f,j,\mathcal{C}} = US_{f,j,\mathcal{C}} = 0\ \forall\ f$.

This means that at the firm level, the change in correlation following elimination of links with country $\mathcal{C}$ is:

$$\begin{aligned}\widehat{\Delta\rho}\left(\gamma_{ft},\gamma_{\mathcal{C}t}\right) &= -\widehat{\beta}_1\mathbb{1}\left(EX_{f,\mathcal{C}}=1\right)-\widehat{\beta}_2\mathbb{1}\left(IM_{f,\mathcal{C}}=1\right)-\widehat{\beta}_3\mathbb{1}\left(AFF_{f,\mathcal{C}}=1\right)\\ &\quad -\widehat{\beta}_4\mathbb{1}\left(HQ_{f,\mathcal{C}}=1\right)-\widehat{\beta}_5 DS_{f,j,\mathcal{C}}-\widehat{\beta}_6 US_{f,j,\mathcal{C}}, \qquad (11)\end{aligned}$$

and the change in aggregate correlation is still given by (10). Note that in this formulation, correlation of a firm with $\mathcal{C}$ will change even if it has no direct connections to $\mathcal{C}$. By a similar token, even directly connected firms will also exhibit indirect connections to $\mathcal{C}$, and thus the impact in (11) is additive.

3 Data and Basic Patterns

The empirical analysis relies on several firm-level databases. The main object of interest is the correlation between French and foreign GDP growth. At the most disaggregated level, it is measured using a database that covers the universe of French firm sales and value added over the period 1993-2007. The dataset is described in detail in di Giovanni et al. (2014). Importantly, it covers the entire French economy, manufacturing and non-manufacturing sectors included. We augment it with information on each firm's direct trade and multinational linkages, disaggregated by foreign partner country. Namely, we use Customs data to recover bilateral export and import flows, at the level of each individual firm. Finally, information on the firm ownership linkages is taken from the *LIaisons FInancieres* (LIFI) database, an administrative dataset that provides information about the ownership and nationality of the parent company of firms located in France. Together, these two datasets provide firm-level information on all possible direct links to each individual foreign country, whether through cross-border trade or multinational production. Finally, note that we do not have any information at the plant level.

The value added data, as well as additional variables, come from the balance sheet information collected from firms' tax forms. The original dataset is quasi-exhaustive. However, the amount of information that has to be provided to the fiscal administration differs according to the firm's size. Namely, the French tax system distinguishes three different regimes, the "normal" regime (called BRN for *Bénéfice Réel Normal*), the "simplified" regime (called RSI for *Régime Simplifié d'Imposition*) that is restricted to smaller firms, and the "micro-BIC" regime for entrepreneurs.[6] Throughout the exercise, "micro-BIC"

[6]Under some conditions, firms can choose their tax regime. In 2010, an individual entrepreneur can

and "RSI" firms are excluded. We do not have enough information for "micro-BIC" firms. We also exclude "RSI" firms, both because their weight in annual sales is negligible and because it is difficult to harmonize these data with the rest of the sample. In 2007, those firms represented less than 4% of total sales and about 11% of total employment. Thus, our sample represents the bulk of the aggregate French economy. In this sample, it is possible to classify firms according to the sector in which they operate, using information on their NAF code.[7]

The information collected by the tax authorities is combined with the firm-level export and import data from the French customs authorities. The datasets can be merged using a unique firm identifier, called SIREN. On top of the firm dimension, the customs data also detail trade flows by their country of destination (for exports) or the country of origin (for imports). This information makes it possible to investigate the heterogeneity of trade linkages within firm across different foreign countries. The customs data are also quasi-exhaustive. There is a declaration threshold of 1,000 euros for annual exports to and annual imports from any given destination outside the European Union. Below the threshold, the customs declaration is not compulsory. Since 1993, intra-EU trade is no longer liable for any tariff, and as a consequence firms are no longer required to submit the regular customs form. A new form has however been created that tracks intra-EU trade. Unfortunately, the declaration threshold for this kind of trade flows in much higher, around 150,000 euros per year in 2010. A number of firms continue declaring intra-EU trade flows below the threshold however, either because they don't know ex ante that they will not reach the 150,000 Euro limit in a given fiscal year, because they apply the same customs procedure for all export markets they serve, or because they delegate the customs-related tasks to a third party (e.g., a transport firm) that systematically fills out the customs form. Below-cutoff trade flows missing from customs data imply that we might underestimate the contribution of direct trade linkages as a driver of aggregate comovement.[8]

decide to enroll in the "micro-BIC" regime if its annual sales are below 80,300 euros. Likewise, a firm can choose to participate in the RSI rather than the BRN regime if its annual sales are below 766,000 euros (231,000 euros in services). Those thresholds are adjusted over time, but marginally so.

[7] "NAF", *Nomenclature d'Activités Française*, is the French industrial classification. Our baseline analysis considers the level of aggregation with 114 sectors. This corresponds to the 3-digit ISIC (Revision 3) nomenclature. We drop NAF sectors 95 (domestic services), and 99 (activities outside France). We also have to neglect the banking sector due to important restructuring at the beginning of the 2000s that makes it difficult to follow individual firms.

[8] We can judge how many exports we are missing by comparing exports declared on tax forms to exports declared to customs. It appears that the problem is relatively minor. In 10% of firm-year observations, the tax form reports exports but the customs data do not. These observations account for 7% of overall exports. On average, the total exports reported in the tax form but missing from customs (413,000 euros per year) are an order of magnitude smaller than average exports in the whole sample, which are 3,056,000.

The customs data include only trade in goods, and thus firm-level information on trade in services is missing from our analysis. Data on services trade are not collected by customs authorities and are thus considerably more spotty. According to the OECD, in the later half of our sample period services trade accounted for about 20% of overall (goods plus services) French imports and exports. Note that our production, goods trade, and multinational indicator data include service sector *firms*, and our indirect transmission measures in (5) and (6) incorporate domestic service sector linkages. Nonetheless, if there are firms that trade services but not goods, the analysis below understates the extent of direct linkages to foreign countries, and thus the contribution of direct linkages to comovement.

Finally, the LIFI data are used to get information on i) whether each French firm is an affiliate of a company headquartered in a particular foreign country, or ii) whether each firm is, or belongs to, a French company that owns foreign affiliates in a particular foreign country. The LIFI database is constructed by the French statistical institute (INSEE). It is not exhaustive, but it has a good coverage. All firms with more than 500 employees or a turnover above 60 million euros, whatever their sector of activity, are included in the survey. Moreover, the information is complemented with two additional administrative sources that contain information on a large number of smaller groups. According to the French statistical institute, a firm is an affiliate of a group if the group has the (direct or indirect) majority of voting rights. Using this definition, INSEE identifies firms that own affiliates abroad, together with the nationalities of those affiliates. When the French firm is identified as an affiliate of a foreign company, the nationality of the parent group is recorded as well.

The firm-level correlation coefficients are measured using the time dimension of the value added data, at the firm level. On the other hand, the empirical strategy does not use the time variability of measures of each firm's direct links with each destination country. To construct the dummies for whether a firm exports ($EX_{f,C}$), imports ($IM_{f,C}$), has affiliates in the destination ($AFF_{f,C}$) or is an affiliate of a foreign multinational firm ($HQ_{f,C}$) the time dimension is thus collapsed. Namely, in the baseline analysis the dummy is set to 1 whenever the firm satisfies the corresponding condition over at least one year in the period of observation.[9] The numbers of firms in each sector that import and export used in the indirect linkage indicators, $NIM_{i,\mathcal{C}}$ and $NEX_{i,\mathcal{C}}$, are defined consistently with the direct linkage indicators and are simply sector-level summations of those, e.g. $NIM_{i,\mathcal{C}} = \sum_{f \in i} IM_{f,\mathcal{C}}$.

[9]The results are robust to instead defining the dummy to equal 1 whenever the firm is connected for at least 50% of the years it is present in the sample.

Figure 1 plots the growth rates of aggregate value added, exports, and imports, together with the growth rate of GDP from IMF's International Financial Statistics, and total exports and imports from IMF's Direction of Trade Statistics. The aggregates in our sample of firms mimic the aggregate data from standard sources quite well.

Figure 2 reports the scatterplot of the aggregate correlations with the 10 main trading partner countries implied by our data and the GDP correlations from standard sources, along with a 45-degree line. It is clear that our data capture both the levels and the variation in aggregate comovement extremely well. The correlation between the business cycle comovement implied by our data and by standard GDP data is 0.992.

Table 1 presents the basic stylized facts on the composition of the sample. Panel A reports the summary statistics for the whole economy, and Panel B for the manufacturing sector only. The first columns reports the number of firms in the dataset. There are about a million firms in total. The rest of the panel reports the summary statistics for exporters, importers, affiliates of foreign multinationals, and French firms with foreign affiliates. These four categories are of course not mutually exclusive. The table reports the total numbers of observations and firms, the mean and median value added in each category, and the percentage of total value added captured by each category of firms.

As expected, firms engaged in an international activity represent a small share of the population of French firms. Around 20% of French firms export or import at all. There are an order of magnitude more exporters and importers than multinational firms: about 200 thousand of importers and exporters, compared to 30 thousand affiliates of foreign multinationals, and 1786 French firms that have foreign affiliates. Each category of the internationally connected firms has larger average value added than purely domestic firms. The largest category on average is French multinationals with affiliates abroad.

More novel is the information in the last column that reports the share of total value added in France that is taken up by each category of firms. These statistics have not, to our knowledge, been previously reported. It turns out that importers account for 72% of total French value added, and exporters 71%. By contrast, multinational firms account for a smaller share of economic activity, with about 25% for foreign affiliates in France, and 14% for French-owned multinationals. Panel B reports the same statistics for the manufacturing sector. Not surprisingly, the shares of exporters and importers are even larger, at around 93%.

Table 2 reports the measures of connectedness and firm-level correlations with France's

10 major trading partner countries.[10] For each country, the table presents the number of directly connected firms, the combined share of those firms in total French value added, and the mean correlation between an individual firm and the GDP growth of that country. The last three columns report the same statistics for the not directly connected firms.

The table illustrates the extent to which the aggregate value added in France is dominated by directly connected firms, as those connected firms are on average an order of magnitude larger than non-connected firms. On average, and for most individual countries, there are an order of magnitude fewer directly connected firms than non-directly connected firms. At the mean, there are 77 thousand directly connected, and 890 thousand not directly connected firms. However, the directly connected firms take up on average 56% of total French value added. For every single partner country, the directly connected firms are more correlated with the foreign GDP, with an average difference in correlation of 0.029 between the directly connected and not connected firms in this set of countries.[11] The variation across countries is as expected. In the 4 countries most closely integrated with France – Belgium, Germany, the UK, and Italy – the directly connected firms account for about 60% of all French value added. At the other extreme, the firms directly connected to Brazil, China, and Japan account for 0.385, 0.489, and 0.478 of aggregate French value added, respectively.

Panel B reports the same statistics for the manufacturing sector. The role of the directly connected firms is greater in this sample. On average, the directly connected firms account for 80% of aggregate manufacturing value added, even though they comprise less than one-quarter of all the firms in this sample. The average correlations are slightly higher for manufacturing firms compared to the whole economy, but the difference is not large.

Table 3 further separates the directly connected firms into importers, exporters, and foreign and domestic multinationals. Once again, the categories are not mutually exclusive. There are large differences between the trading firms and the multinationals. Directly connected exporters and importers account for 45 and 51 percent of aggregate French value added for this set of foreign countries, or the large majority of the total value added of connected firms. By contrast, affiliates of foreign multinationals from an individual country

[10] These countries are 9 of the top 10 trading partners of France plus Brazil, which we included as a major emerging market to make the sample more diverse and less dominated by European countries.

[11] The reason that the absolute values of these firm-level correlations are quite small can be gleaned from Equation (3), which shows that aggregate correlation is a combination of firm-level correlations and the ratio of firm-level standard deviations to the aggregate standard deviation. Since firm-level standard deviations of value added growth are much larger than the aggregate (see, e.g. di Giovanni et al., 2014), the individual correlations must be small to be consistent with the observed aggregate correlations such as those reported in Figure 2.

take up 2.3% of aggregate value added. French firms with foreign affiliates account for 10.4% of aggregate value added. There are also many fewer multinational firms of both kinds than trading firms. The manufacturing sector (Panel B) yields similar results.

Table A1 presents the average standard deviations of firm growth rates across sectors, along with the shares of each sector in total value added. The raw volatility of value added growth varies across sectors, with the standard deviation ranging from a low of 0.2557 (Health and social work) to a high of 0.4157 (Research and development), and a cross-sectoral mean standard deviation of 0.3365. The wholesale and retail trade sector has by far the highest share in aggregate value added, at nearly 18% of the total. While the standard deviation of value added growth, at 0.3221, is quite typical of the rest of the economy, clearly wholesale and retail trade is quite special in other ways. To establish the robustness of the results, all of the analysis below is carried out both on the whole economy and on the manufacturing sector.

Throughout the analysis, we winsorize the firm-level growth rates to be bounded by $+100\%$ and -50% to reduce the impact of outliers.

4 Main Results

4.1 Firm-Level Linkages and Correlations

Table 4 reports the results of estimating Equation (4). The baseline sample includes all firms, and performs the analysis on the growth rates of value added. The standard errors are clustered at the firm level. The first column presents the basic estimation without any fixed effects. All four forms of connectedness are positive and strongly significant. The coefficient magnitudes are sizeable as well. Importing or exporting is associated with increases in the correlation of 0.030 and 0.036 respectively. Being a French multinational with affiliates in a particular country increases correlation with that country by 0.02. Foreign affiliates in France have a 0.030 higher correlation with the parent country. The next column adds firm fixed effects. In this specification, the coefficients are estimated from the variation within the same firm across the 10 partner countries. Some of the point estimates fall somewhat, but all four types of connectedness remain positive and strongly significant.

The next column adds country effects. Given that this specification adds only 10 dummy variables to a regression with nearly 9 million observations, it is remarkable how dramatically the coefficients change. The importer coefficient falls by a factor of 2, and the exporter coefficient by a factor of 4. Both multinational coefficients decrease and one of them ceases

to be statistically significant. This change in the coefficients is a stark illustration of the key tension in the Frankel-Rose type estimation: disentangling transmission of shocks through trade from common shocks.

Taken at face value, the Frankel and Rose (1998) result that countries with greater bilateral trade are more correlated appears to suggest that trade linkages transmit shocks across countries. However, as argued forcefully by Imbs (2004), trade intensity at the bilateral country level could simply be a proxy for a greater prevalence of common shocks (see also the discussion in di Giovanni and Levchenko, 2010). By using firm-level data, we can control much better for the common shocks that affect France and its trading partners. The contrast between the specifications with and without country effects shows why it is important to do so. Without country effects (and even after including firm effects), it looks like directly connected firms are strongly correlated with the markets with which they are linked. However, it is clear that a large part of these estimated coefficients is due to the fact that firms are more likely to establish direct links with more correlated markets. Adding country effects controls for the average correlation between French firms and each country, and reduces the estimated impact of direct connectedness considerably.

Nonetheless, column 3 shows that even after controlling for common shocks, direct linkages increase comovement between a firm and the foreign country. A direct importing link is associated with an increase in the firm-level correlation of 0.012, and an exporting link of 0.005. Foreign affiliates in France have 0.010 higher correlation with their parent country. Relative to the mean correlation of about 0.024 for the directly connected firms, these coefficients are still sizeable.

The rest of the table checks robustness of the results to alternative specifications. Column 4 checks whether the results are driven by omitted regional variation within France, by using foreign country×*département* effects instead of foreign country effects. A *département* is a relatively small French region: there are 96 *départements* in metropolitan France. These fixed effects control for any differences in correlation between firms in individual French regions and foreign countries. Column 5 instead adds foreign country×sector effects. These control for any differences between how individual French sectors are correlated with foreign countries. In both cases the results are virtually identical to the baseline. Column 6 uses the correlation of firm sales instead of value added. The results are stronger than in the baseline. Table 5 replicates all the results using the sample of manufacturing firms. All the patterns of significance and substantive conclusions are unchanged.

Table 6 presents the results of estimating Equation (7), that includes indirect linkages.

The two panels report estimates for the whole economy and the manufacturing sector, respectively. Columns 1 and 3 present the baseline specification with firm and country effects. The coefficients on the indirect linkage variables are strongly significant. The coefficient on $DS_{f,j,\mathcal{C}}$ ("Indirect importers") is positive in both samples, indicating that foreign shocks transmitted through the firm's input suppliers that import from abroad increase comovement. The coefficient on $US_{f,j,\mathcal{C}}$ ("Indirect exporters") is positive for the manufacturing sector, but actually negative (though small in magnitude) for the whole economy. To understand the results better, columns 2 and 4 report the estimates including country×sector effects. These will further absorb the variation across sectors, but are very demanding for the purposes of estimating the impact of $DS_{f,j,\mathcal{C}}$ and $US_{f,j,\mathcal{C}}$, since those indicators are constructed from largely sector-level variation. The coefficients in $DS_{f,j,\mathcal{C}}$ continue to be positive and significant, but fall considerably in magnitude. The coefficient on $US_{f,j,\mathcal{C}}$ flips sign and becomes positive and significant in the whole economy, but becomes insignificant in the manufacturing sample. We conclude that the impact of downstream indirect linkages is clearly detectable in the data and robustly positive. On the other hand, the importance of upstream linkages (i.e., supplying inputs to exporting firms) is less clear in the data, with the sign and significance sensitive to sample and fixed effects configuration. As a side note, including indirect linkages has virtually no impact on the size and pattern of significance of the direct linkage coefficients.

An interesting question is whether connectedness through trade and multinational links interact in important ways. One may conjecture, for instance, that firms that are part of the same multinational will comove more when they trade compared to firms that trade at arm's length. Table 7 checks this possibility. In order to avoid an excessively large set of interaction terms that is possible between 4 variables, we condense the set of indicators to two: whether the firm trades with a country and whether it is a part of a multinational with a presence in that country. Columns 1 and 3 check whether these coarser indicators significantly increase the correlation with the foreign GDP in the whole economy and the manufacturing samples, respectively. Columns 2 and 4 augment the specification with the interaction between the two. It seems that there is no *prima facie* evidence of an interaction effect: the coefficient is actually negative, but insignificant.

To summarize, direct connectedness through importing, exporting, and foreign parent firms is robustly positively associated with greater comovement between a firm and foreign GDP. This effect is identified from the variation across foreign countries within the firm (i.e., by comparing the firm's correlation with a country that it trades with to its correlation

with a country that it does not), and after controlling for common aggregate shocks. Thus, this result can be interpreted as robust evidence for transmission of shocks through trade and multinational links. In addition, indirect linkages to downstream firms are robustly positively associated with increased comovement at the firm level.

4.2 Aggregate Implications

Table 8 presents the decomposition in (8). For each country, it reports the aggregate correlation $\rho(\gamma_{At}, \gamma_{Ct})$, as well as the two components of the aggregate correlation on the right-hand side of Equation (8), namely those due to the directly and not directly connected firms. The top panel reports the results for the whole economy, and the bottom panel for the manufacturing sector only.

In the whole economy, at the median, 75% of the aggregate correlation is taken up by the directly connected firms. The shares are between zero and one in all but one case (the UK), implying that the direct and indirect components tend to have the same sign as the overall correlation. In the manufacturing sector, the observed correlations are on average higher, and the share taken up by the directly connected firms is larger, at 0.83 at the median.

This decomposition is merely suggestive that direct links are responsible for the observed aggregate comovement. Equation (8) shows that the direct component could be large both because the directly connected firms account for the large share of the economy, and/or because they exhibit larger correlations with the foreign country. Table 2 shows indeed that both of those things are true. However, the higher correlations reported for the directly connected firms in the table are not necessarily evidence of transmission of shocks. To isolate the role of the transmission of shocks, we next make use of the econometric estimation results.

We first compute, based on each firm's connectedness values, how much its correlation with each country would change if it were no longer connected to that country, as in (9). For all firms that are not connected at all to a particular country, this change is zero. We then aggregate according to Equation (10). This equation takes into account the interaction between relative firm sizes (w_f) and connectedness: the impact on aggregate comovement would be greater, all else equal, if the connected firms take up a larger share of aggregate value added.

Table 9 presents the results of computing the change in the aggregate correlation as in (10). It reports the actual correlation in the data, the predicted change in the correlation

if none of the firms were connected, and the standard error for that predicted change in correlation. On average correlation would decrease by about 0.091 if firms stopped being connected. By comparison, the mean actual observed correlation is about 0.29. In the manufacturing sector, the impact is larger, with the severing of direct linkages leading to a fall in correlation of 0.103 on average, relative to the mean observed correlation of 0.484.

An interesting question is whether the change in aggregate correlation is driven by trade in goods or multinational linkages. Examining (9), it is clear that the change in aggregate correlation is simply additive in the weighted contribution of trade links (captured by the EX and IM coefficients) and the multinational links. Of course, these are not mutually exclusive for each firm, as a single firm can be in up to 3 of these categories at the same time. However, the breakdown of the aggregate effect into those two components can still be suggestive of the relative importance of those effects.

Columns 4-7 of Table 9 separate the contribution of trade linkages (denoted by $\Delta\rho_A|Trade$), and of the multinational linkages ($\Delta\rho_A|MNE$) to aggregate comovement. It turns out that the bulk of the aggregate effect is due to trade. On average, trade linkages account for more than 90% of the total (0.083 out of 0.091). The conclusion is similar in the manufacturing sector.

Finally, we check to what extent the fact that the largest firms tend to be systematically more internationally connected contributes to the aggregate impact of direct linkages. To that end, we construct the change in the aggregate comovement that would obtain if all firms were of equal size: $w_f = 1/N \ \forall f$ in Equation (10), with N the total number of firms. The results are presented in columns 8-9 of Table 9, under $\Delta\rho_A|Eq.W$. The change in the aggregate correlation is substantially smaller, 0.022 for the whole economy, and 0.039 for the manufacturing sector. That is, the fact that the larger firms are systematically more likely to exhibit international linkages roughly quadruples the impact of direct linkages on international comovement.

Table 10 reports the change in aggregate correlation taking indirect linkages into account. The indirect linkages are incorporated using the coefficients in columns 1 and 3 of Table 6, and thus in the whole economy sample the impact of upstream linkages is actually modestly negative. The change in aggregate correlation, -0.13 for the whole economy and -0.414 for the manufacturing sector, is now larger, considerably more so in manufacturing. Indeed, the average change in correlation attributed to the regression estimates can account for the majority of the average observed correlation of the manufacturing sector with foreign economies, which is 0.484.

There is a pronounced difference between the whole economy and the manufacturing sector when it comes to the importance of indirect linkages. Columns 4-7 of Table 10 present the breakdown of the change in the aggregate correlation due to direct and indirect linkages. This exercise uses the direct linkage coefficients from Table 6, and thus column 4 of Table 10 does not match exactly column 2 of Table 9 (though it is close). For the whole economy, direct linkages account for the majority of the overall effect, an average of -0.074 of the -0.130 total effect. Indirect linkages contribute -0.057 on average.[12] By contrast, indirect linkages are overwhelmingly the most important component in the manufacturing sector, accounting for 0.343 of the total of 0.414, or more than 80% of the overall effect.

An important assumption underlying this aggregation exercise is that there are no other general equilibrium interactions that change firm-level correlations when France's openness changes. In particular, the calculation assumes that (i) the change in the correlation of all directly connected firms is given by (9); and (ii) the change in the correlation of all not directly connected firms is accounted for by our measures of indirect linkages through inputs. Thus, it ignores the possibility that a change in France's overall openness has feedback effects that move the firm-level correlations away from what is predicted by the micro-level regressions. These feedbacks are potentially interesting but there are no established intuitions or results that could even point to the direction of those effects. Clearly, general equilibrium feedbacks can only be analyzed within a full general equilibrium model structure, and are inaccessible to the regression estimation-type approach adopted here. Nonetheless, by combining micro results on changes in comovement at the firm level with information on the combined size of the connected firms, our results can be used to benchmark the size of the likely aggregate effect, evaluate the relative importance of trade and multinational ownership links, and demonstrate the role of the fact that directly connected firms are systematically larger.

5 Conclusion

In order to understand fluctuations at the macro level, we must understand micro-level behavior. This paper applies this principle to international business cycle comovement by analyzing this phenomenon at the firm level. Because the largest firms are the most likely to exhibit direct international linkages, we show that they account for nearly half of French aggregate value added. We next show that they are more correlated with the countries to

[12] The two effects do not add up exactly to the total due to rounding error in averaging. Within each country, they add up exactly.

which they are directly connected through trade. Combining the two, the directly connected firms account for two-thirds of the observed aggregate correlations between France and its major trading partners, and if these direct linkages were severed, the aggregate correlations would fall by about 0.09, or one-third of the observed aggregate correlations in the data. We provide evidence of downstream linkages as well: firms that buy inputs from French firms that import from foreign markets tend to be more correlated to those foreign markets. Direct and indirect linkages combined can account for nearly half of the observed aggregate comovement between the overall French economy and its trading partners, and for nearly all the observed comovement between French manufacturing value added and foreign GDP.

Appendix A Intensive and Extensive Margins

This appendix decomposes the growth rate of aggregate value added into the intensive and extensive components, and shows that the bulk of the aggregate business cycle comovement between France and its main trading partners is accounted for by the intensive margin. The intensive component at date t is defined as the growth rate of value added of firms that had positive value added in both year t and year $t-1$. The extensive margin is defined as the contribution to total value added of the appearance and disappearance of firms. The log-difference growth rate of total value added can be manipulated to obtain an (exact) decomposition into intensive and extensive components:

$$\begin{aligned}\tilde{\gamma}_{At} &\equiv \ln \sum_{f\in I_t} x_{ft} - \ln \sum_{f\in I_{t-1}} x_{ft-1} \\ &= \ln \frac{\sum_{f\in I_{t/t-1}} x_{ft}}{\sum_{f\in I_{t/t-1}} x_{ft-1}} - \left(\ln \frac{\sum_{f\in I_{t/t-1}} x_{ft}}{\sum_{f\in I_t} x_{ft}} - \ln \frac{\sum_{f\in I_{t/t-1}} x_{ft-1}}{\sum_{f\in I_{t-1}} x_{ft-1}} \right) \\ &= \underbrace{\gamma_{At}}_{Intensive\ margin} - \underbrace{\ln \frac{\pi_{t,t}}{\pi_{t,t-1}}}_{Extensive\ margin},\end{aligned} \tag{A.1}$$

where $I_{t/t-1}$ is the set of firms active in both t and $t-1$ and $\pi_{t,t}$ ($\pi_{t,t-1}$) is the share of output produced by this intensive sub-sample of firms in period t ($t-1$). Entrants have a positive impact on growth while exiters push the growth rate down, and the net impact is proportional to the share of entrants'/exiters' value added in aggregate value added.[13]

Using equation (A.1), aggregate correlation between France and $\mathcal{C}$ can be written as

$$\tilde{\rho}\left(\gamma_{At}, \gamma_{\mathcal{C}t}\right) = \frac{\sigma_A}{\tilde{\sigma}_A}\rho\left(\gamma_{At}, \gamma_{\mathcal{C}t}\right) + \frac{\sigma_\pi}{\tilde{\sigma}_A}\rho\left(\ln \frac{\pi_{t,t}}{\pi_{t,t-1}}, \gamma_{\mathcal{C}t}\right), \tag{A.2}$$

where σ_π is the standard deviation of the extensive margin component of equation (A.1), σ_A is the standard deviation of the intensive margin growth rate γ_{At}, and $\tilde{\sigma}_A$ is the standard deviation of the overall growth rate $\tilde{\gamma}_{At}$.

Thus, aggregate comovement is simply additive in the correlations of the intensive and the extensive margins. Table A2 presents the decomposition. On average, the intensive margin accounts for about 90% the overall correlation. Figure A1 plots the aggregate correlations against the intensive and the extensive margin components, together with the 45-degree line in each case. It is clear that the variation in the business cycle correlation between France and its trading partners is much better accounted for by the intensive

[13] This decomposition follows the same logic as the decomposition of price indices proposed by Feenstra (1994).

margin component. The cross-sectional correlation between the overall and intensive margins (Figure A1a) is 0.96. By contrast, the variation in the extensive margin correlation across countries is much smaller, and does not explain nearly as well the cross-section of comovement between France and other countries (Figure A1b).

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Table 1. Summary Statistics

	Panel A: Whole Economy			
	No. firms	Value Added		
		Mean	Median	Share in total
All Firms	998,504	1,165	211	1.00
Importers	189,852	3,516	515	0.72
Exporters	200,725	3,220	477	0.71
Affiliates of foreign multinationals	30,651	7,061	1,335	0.25
Firms with foreign affiliates	1,786	65,833	2,279	0.14
	Panel B: Manufacturing Sector			
	No. firms	Value Added		
		Mean	Median	Share in total
All Firms	145,594	2,367	382	1.00
Importers	60,402	4444	872	0.93
Exporters	66,536	40523	754	0.93
Affiliates of foreign mutinationals	8,370	11993	2938	0.38
Firms with foreign affiliates	378	34787	6993	0.06

Notes: This table reports the summary statistics for the whole economy and the manufacturing sectors. It reports the number of distinct firms, mean and median value added, and the share of a particular type of firm in total value added. Value added is reported in millions of euros. The categories of firms are not mutually exclusive.

Table 2. Directly Connected and Not Directly Connected Firms

Panel A: Whole Economy

Country	Directly Connected			Not Directly Connected		
	No. firms	Combined share	Mean $\rho(\gamma_{ft}, \gamma_{Ct})$	No. firms	Combined share	Mean $\rho(\gamma_{ft}, \gamma_{Ct})$
Belgium	113,470	0.626	0.047	853,793	0.374	0.007
Brazil	19,966	0.385	-0.013	947,297	0.615	-0.035
China	46,929	0.489	-0.064	920,334	0.511	-0.066
Germany	108,659	0.627	0.039	858,604	0.373	-0.006
Italy	105,518	0.607	0.065	861,745	0.393	0.027
Japan	39,500	0.478	-0.042	927,763	0.522	-0.059
Netherlands	82,372	0.590	0.065	884,891	0.410	0.013
Spain	93,179	0.590	0.065	874,084	0.414	0.001
United Kingdom	84,369	0.604	0.046	882,894	0.396	0.021
United States	80,817	0.604	0.063	886,446	0.396	0.044
Average	77,478	0.560	0.024	889,785	0.440	-0.005

Panel B: Manufacturing Sector

Country	Directly Connected			Not Directly Connected		
	No. firms	Combined share	Mean $\rho(\gamma_{ft}, \gamma_{Ct})$	No. firms	Combined share	Mean $\rho(\gamma_{ft}, \gamma_{Ct})$
Belgium	43,277	0.887	0.068	96,799	0.113	0.031
Brazil	9,854	0.601	0.000	130,222	0.399	-0.016
China	17,447	0.689	-0.051	122,629	0.311	-0.049
Germany	42,431	0.889	0.060	97,645	0.111	0.024
Italy	40,416	0.874	0.082	99,660	0.126	0.060
Japan	16,784	0.697	-0.036	123,292	0.303	-0.043
Netherlands	31,852	0.847	0.083	108,224	0.153	0.051
Spain	36,665	0.857	0.035	103,411	0.143	0.016
United Kingdom	33,372	0.854	0.057	106,704	0.146	0.033
United States	29,695	0.810	0.065	110,381	0.190	0.047
Average	30,179	0.800	0.036	109,897	0.200	0.015

Notes: This table reports the features of directly connected and not directly connected firms for each partner country. The columns report the number of firms, their combined share in aggregate value added (averaged across years), and the mean correlation between firm value added growth and the foreign country's GDP growth.

Table 3. Directly Connected Firms: by Connection Type

Panel A: Whole Economy

Country	Exporters			Importers			Affiliates of multinationals			Firms with foreign affiliates		
	No. firms	Combined share	Mean $\rho(\gamma_{ft}, \gamma_{Ct})$	No. firms	Combined share	Mean $\rho(\gamma_{ft}, \gamma_{Ct})$	No. firms	Combined share	Mean $\rho(\gamma_{ft}, \gamma_{Ct})$	No. firms	Combined share	Mean $\rho(\gamma_{ft}, \gamma_{Ct})$
Belgium	68,453	0.514	0.054	87,971	0.591	0.047	3,527	0.016	0.039	396	0.097	0.064
Brazil	12,761	0.317	-0.007	9,888	0.278	-0.014	4	0.000	-0.016	121	0.072	0.018
China	16,562	0.372	-0.050	39,154	0.445	-0.069	89	0.000	-0.110	203	0.100	-0.056
Germany	57,198	0.493	0.050	91,183	0.603	0.040	4,485	0.035	0.052	437	0.124	0.058
Italy	51,903	0.471	0.073	90,359	0.583	0.066	1,849	0.014	0.068	374	0.124	0.035
Japan	25,071	0.401	-0.042	22,960	0.413	-0.036	644	0.006	-0.038	105	0.066	-0.073
Netherlands	42,239	0.451	0.076	63,577	0.551	0.063	4,195	0.039	0.061	141	0.081	0.088
Spain	52,171	0.477	0.031	72,540	0.543	0.029	957	0.006	0.039	524	0.128	0.044
United Kingdom	46,790	0.471	0.055	64,160	0.567	0.046	5,142	0.040	0.036	405	0.125	0.059
United States	46,876	0.496	0.068	56,914	0.563	0.061	5,522	0.071	0.078	430	0.123	0.091
Average	42,002	0.446	0.031	59,871	0.514	0.023	2,641	0.023	0.021	314	0.104	0.033

Panel B: Manufacturing Sector

Country	Exporters			Importers			Affiliates of multinationals			Firms with foreign affiliates		
	No. firms	Combined share	Mean $\rho(\gamma_{ft}, \gamma_{Ct})$	No. firms	Combined share	Mean $\rho(\gamma_{ft}, \gamma_{Ct})$	No. firms	Combined share	Mean $\rho(\gamma_{ft}, \gamma_{Ct})$	No. firms	Combined share	Mean $\rho(\gamma_{ft}, \gamma_{Ct})$
Belgium	33,266	0.823	0.070	32,929	0.851	0.069	1,065	0.020	0.069	79	0.036	0.061
Brazil	7,644	0.541	0.001	4,080	0.429	0.003				40	0.032	0.019
China	9,424	0.578	-0.044	13,240	0.613	-0.055	16	0.001	-0.076	59	0.013	-0.045
Germany	29,131	0.809	0.064	35,926	0.869	0.060	1,375	0.057	0.064	115	0.039	0.092
Italy	25,988	0.787	0.087	34,401	0.849	0.081	608	0.031	0.064	91	0.037	0.045
Japan	12,547	0.608	-0.037	9,230	0.603	-0.026	168	0.009	0.007	36	0.011	-0.060
Netherlands	21,776	0.750	0.088	23,931	0.804	0.081	1,084	0.066	0.065	34	0.030	0.102
Spain	26,706	0.788	0.039	27,679	0.805	0.033	270	0.009	0.027	122	0.044	0.053
United Kingdom	24,222	0.776	0.060	25,535	0.817	0.058	1,101	0.050	0.064	96	0.038	0.115
United States	21,298	0.721	0.067	20,117	0.753	0.066	1,655	0.121	0.073	145	0.043	0.141
Average	21,200	0.718	0.039	22,706	0.739	0.037	816	0.036	0.040	82	0.032	0.052

Notes: This table reports the features of different types of directly connected firms. The columns report the number of firms, their combined share in aggregate value added (averaged across years), and the mean correlation between firm value added growth and the foreign country's GDP growth.

Table 4. Main Estimation Results, Whole Economy

	(1) Baseline	(2) Baseline	(3) Baseline	(4) Baseline	(5) Baseline	(6) Sales
Dep. Var: $\rho(\gamma_{ft}, \gamma_{ct})$						
Importer	0.030^a	0.024^a	0.012^a	0.012^a	0.011^a	0.017^a
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Exporter	0.036^a	0.020^a	0.005^a	0.005^a	0.006^a	0.011^a
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
French Multinational	0.024^b	0.022^b	0.009	0.009	0.009	0.018^c
	(0.010)	(0.009)	(0.009)	(0.008)	(0.008)	(0.008)
Affiliate of a Foreign MNE	0.030^a	0.028^a	0.010^a	0.010^a	0.009^a	0.014^a
	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Observations	8,687,772	8,687,772	8,687,772	8,687,770	8,687,772	9,272,135
Adjusted R^2	0.001	0.294	0.300	0.375	0.376	0.298
Firm FE	No	Yes	Yes	Yes	Yes	Yes
Country FE	No	No	Yes	No	No	Yes
Country×Region FE	No	No	No	Yes	No	No
Country×Sector FE	No	No	No	No	Yes	No
# of Xing links	407,266	407,266	407,266	407,266	407,266	422,620
# of Ming links	579,787	579,787	579,787	579,785	579,787	599,579
# of Affiliates	25,646	25,646	25,646	25,646	25,646	28,053
# of HQ links	3,070	3,070	3,070	3,070	3,070	3,646
# of Firm FEs		934,021	934,021	934,019	934,021	996,365
# of Country FEs			10			10
# of Country×Region FEs				980		
# of Country×Sector FEs					1,110	

Notes: Standard errors clustered at the firm level. ^{a}: significant at the 1% level; ^{b}: significant at the 5% level; ^{c}: significant at the 10% level. This table reports the results of estimating Equation (4) for the whole economy. The independent variables are binary indicators for whether the firm imports from a country, exports to it, is an affiliate of a multinational firm from that country, or is a French multinational with affiliates in that country.

Table 5. Main Estimation Results, Manufacturing Sector

	(1) Baseline	(2) Baseline	(3) Baseline	(4) Baseline	(5) Baseline	(6) Sales
Dep. Var: $\rho(\gamma_{ft}, \gamma_{\mathcal{C}t})$						
Importer	0.023^a	0.030^a	0.011^a	0.011^a	0.008^a	0.018^a
	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)
Exporter	0.026^a	0.021^a	0.005^a	0.005^a	0.005^a	0.011^a
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
French Multinational	0.008	0.009	0.002	0.002	0.006	0.015
	(0.018)	(0.014)	(0.013)	(0.013)	(0.013)	(0.014)
Affiliate of a Foreign MNE	0.016^a	0.026^a	0.013^a	0.014^a	0.012^a	0.010^b
	(0.005)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Observations	1,275,031	1,275,031	1,275,031	1,275,031	1,275,031	1,324,962
Adjusted R^2	0.001	0.297	0.301	0.376	0.378	0.302
Firm FE	No	Yes	Yes	Yes	Yes	Yes
Country FE	No	No	Yes	No	No	Yes
Country×Region FE	No	No	No	Yes	No	No
Country×Sector FE	No	No	No	No	Yes	No
# of Xing links	204,722	204,722	204,722	204,722	204,722	209,160
# of Ming links	219,066	219,066	219,066	219,066	219,066	223,463
# of Affiliates	7,163	7,163	7,163	7,163	7,163	7,453
# of HQ links	815	815	815	815	815	839
# of Firm FEs		135,756	135,756	135,756	135,756	141,185
# of Country FEs			10			10
# of Country×Region FEs				980		
# of Country×Sector FEs					610	

Notes: Standard errors clustered at the firm level. ^{a}: significant at the 1% level; ^{b}: significant at the 5% level; ^{c}: significant at the 10% level. This table reports the results of estimating Equation (4) for the manufacturing sector. The independent variables are binary indicators for whether the firm imports from a country, exports to it, is an affiliate of a multinational firm from that country, or is a French multinational with affiliates in that country.

Table 6. Estimation Results, Taking Indirect Linkages into Account

	(1)	(2)	(3)	(4)
	Panel A: Whole Economy		**Panel B: Manufacturing Sector**	
Dep. Var: $\rho(\gamma_{ft}, \gamma_{\mathcal{C}t})$				
Importer	0.010^a	0.011^a	0.008^a	0.007^a
	(0.001)	(0.001)	(0.002)	(0.001)
Exporter	0.003^a	0.006^a	0.003^b	0.005^a
	(0.001)	(0.001)	(0.002)	(0.002)
French Multinational	0.010	0.009	0.002	0.006
	(0.009)	(0.008)	(0.013)	(0.013)
Affiliate of a Foreign MNE	0.011^a	0.010^a	0.012^a	0.012^a
	(0.002)	(0.002)	(0.004)	(0.004)
Indirect importers	0.204^a	0.052^b	0.226^a	0.098^a
	(0.016)	(0.022)	(0.028)	(0.033)
Indirect exporters	-0.025^a	0.037^b	0.311^a	0.120
	(0.006)	(0.015)	(0.033)	(0.077)
Observations	8,146,907	8,146,907	1,263,024	1,263,024
Adjusted R^2	0.300	0.376	0.302	0.378
Firm FE	Yes	Yes	Yes	Yes
Country FE	Yes	No	Yes	No
Country×Sector FE	No	Yes	No	Yes
# of Xing links	405,689	405,705	204,575	204,575
# of Ming links	577,705	577,526	218,931	218,931
# of Affiliates	24,313	24,313	7,134	7,134
# of HQ links	3,043	3,043	815	815
# of Firm FEs	871,741	871,741	134,308	134,308
# of Country FEs	10		10	
# of Country×Sector FEs		1,110		610

Notes: Standard errors clustered at the firm level. ^{a}: significant at the 1% level; ^{b}: significant at the 5% level; ^{c}: significant at the 10% level. This table reports the results of estimating Equation (7) for the whole economy in Panel A and for the manufacturing sector in Panel B. The independent variables are binary indicators for whether the firm imports from a country, exports to it, is an affiliate of a multinational firm from that country, or is a French multinational with affiliates in that country. "Indirect importers" is the downstream indirect linkage indicator $DS_{f,j,\mathcal{C}}$ defined in (5). "Indirect Exporters" is the upstream indirect linkage indicator $US_{f,j,\mathcal{C}}$ defined in (6).

Table 7. Estimation Results: Interaction Terms

	(1)	(2)	(3)	(4)
	Panel A: Whole Economy		**Panel B: Manufacturing Sector**	
Dep. Var: $\rho(\gamma_{ft}, \gamma_{Ct})$				
Trade dummy (Importer+Exporter≥1)	0.010[a]	0.010[a]	0.009[a]	0.009[a]
	(0.001)	(0.001)	(0.002)	(0.002)
MNE Dummy (French multinational + Affiliate≥1)	0.012[a]	0.012[a]	0.014[a]	0.020[c]
	(0.002)	(0.004)	(0.004)	(0.012)
Trade×MNE Dummy		-0.000		-0.009
		(0.005)		(0.012)
Observations	8,687,727	8,687,727	1,275,031	1,275,031
R^2	0.300	0.300	0.301	0.301
Firm FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
# of Trade links	735,715	735,715	289,006	289,006
# of MNE links	28,658	28,658	7,966	7,966
# of Firm FEs	934,021	934,021	135,756	135,756
# of Country FEs	10	10	10	10

Notes: Standard errors clustered at the firm level. [a]: significant at the 1% level; [b]: significant at the 5% level; [c]: significant at the 10% level. This table reports the results of estimating Equation (4), adding an interaction between trade and multinational status. The independent variables are binary indicators for whether the firm trades with a country (imports from it or exports to it), has any multinational links with a country (is an affiliate of a multinational firm from that country, or is a French multinational with affiliates in that country), and the interactions.

Table 8. Aggregate Correlations: Contributions of Direct and Indirect Terms

Country	ρ_A (observed)	Directly Connected	Not Directly Connected
	Panel A: Whole Economy		
Belgium	0.758	0.542	0.216
Brazil	-0.269	-0.184	-0.085
China	-0.545	-0.389	-0.157
Germany	0.643	0.445	0.198
Italy	0.630	0.464	0.166
Japan	-0.183	-0.152	-0.032
Netherlands	0.618	0.442	0.176
Spain	0.876	0.588	0.288
United Kingdom	0.010	0.128	-0.119
United States	0.372	0.327	0.045
Average	0.291	0.221	0.070
	Panel B: Manufacturing Sector		
Country	ρ_A (observed)	Directly Connected	Not Directly Connected
Belgium	0.935	0.828	0.107
Brazil	0.177	0.153	0.025
China	-0.190	-0.164	-0.026
Germany	0.695	0.596	0.098
Italy	0.718	0.620	0.098
Japan	0.166	0.138	0.028
Netherlands	0.718	0.622	0.096
Spain	0.673	0.587	0.087
United Kingdom	0.435	0.428	0.007
United States	0.509	0.464	0.045
Average	0.484	0.427	0.056

Notes: This table reports the results of decomposition in Equation (8). The first column reports the actual correlation in the data.

Table 9. Changes in Aggregate Correlations

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
					Panel A: Whole Economy				
Country	ρ_A	$\Delta\rho_A$	$s.e.(\Delta\rho_A)$	$\Delta\rho_A\|Trade$	$s.e.(\Delta\rho_A\|Trade)$	$\Delta\rho_A\|MNE$	$s.e.(\Delta\rho_A\|MNE)$	$\Delta\rho_A\|Eq.W$	$s.e.(\Delta\rho_A\|Eq.W)$
Belgium	0.758	-0.104	0.016	-0.096	0.010	-0.008	0.013	-0.032	0.002
Brazil	-0.269	-0.049	0.011	-0.045	0.006	-0.004	0.010	-0.004	0.000
China	-0.545	-0.074	0.015	-0.068	0.008	-0.005	0.013	-0.013	0.001
Germany	0.643	-0.109	0.019	-0.097	0.010	-0.011	0.017	-0.032	0.002
Italy	0.630	-0.102	0.019	-0.093	0.010	-0.009	0.017	-0.030	0.002
Japan	-0.183	-0.071	0.012	-0.067	0.008	-0.004	0.009	-0.010	0.001
Netherlands	0.618	-0.097	0.014	-0.087	0.009	-0.010	0.011	-0.023	0.002
Spain	0.876	-0.095	0.020	-0.087	0.010	-0.008	0.017	-0.026	0.002
United Kingdom	0.010	-0.103	0.019	-0.091	0.010	-0.012	0.017	-0.024	0.002
United States	0.372	-0.109	0.019	-0.092	0.010	-0.016	0.017	-0.023	0.002
Average	0.291	-0.091		-0.083		-0.009		-0.022	
					Panel B: Manufacturing Sector				
Country	ρ_A	$\Delta\rho_A$	$s.e.(\Delta\rho_A)$	$\Delta\rho_A\|Trade$	$s.e.(\Delta\rho_A\|Trade)$	$\Delta\rho_A\|MNE$	$s.e.(\Delta\rho_A\|MNE)$	$\Delta\rho_A\|Eq.W$	$s.e.(\Delta\rho_A\|Eq.W)$
Belgium	0.935	-0.116	0.019	-0.113	0.018	-0.003	0.005	-0.058	0.008
Brazil	0.177	-0.062	0.012	-0.061	0.011	-0.001	0.004	-0.009	0.002
China	-0.190	-0.080	0.013	-0.080	0.013	0.000	0.002	-0.022	0.003
Germany	0.695	-0.121	0.019	-0.114	0.018	-0.007	0.006	-0.059	0.008
Italy	0.718	-0.116	0.019	-0.111	0.018	-0.004	0.005	-0.055	0.008
Japan	0.166	-0.083	0.013	-0.082	0.013	-0.001	0.002	-0.019	0.003
Netherlands	0.718	-0.115	0.018	-0.105	0.017	-0.009	0.005	-0.042	0.006
Spain	0.673	-0.108	0.019	-0.107	0.018	-0.002	0.006	-0.048	0.007
United Kingdom	0.435	-0.114	0.018	-0.108	0.018	-0.006	0.006	-0.045	0.006
United States	0.509	-0.115	0.018	-0.100	0.016	-0.015	0.008	-0.039	0.005
Average	0.484	-0.103		-0.098		-0.005		-0.040	

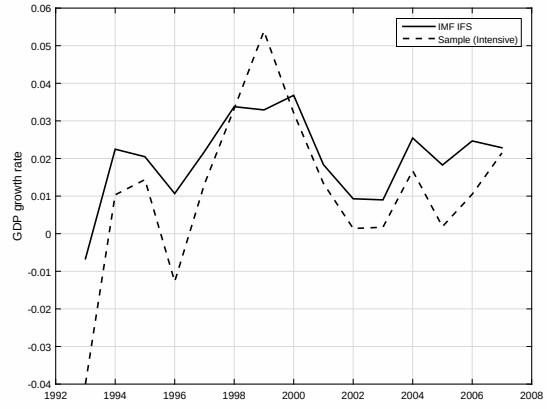
Notes: This table reports the results of the aggregation exercise in Equation (10). The column labeled $s.e.(\Delta\rho_A)$ reports the standard error associated with the estimated change in aggregate correlation. Columns 4-7 present the change in the correlation due to severing of trade linkages and multinational linkages separately, along with corresponding standard errors. Columns 8-9 present the change in the correlation due to severing of direct linkages assuming that all firms have equal size, along with corresponding standard errors.

Table 10. Changes in Aggregate Correlations, Including Indirect Effects

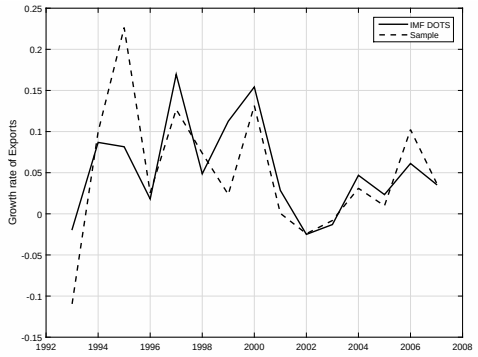
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Panel A: Whole Economy						
Country	ρ_A	$\Delta\rho_A$	$s.e.(\Delta\rho_A)$	$\Delta\rho_A \vert Direct$	$s.e.(\Delta\rho_A \vert Direct)$	$\Delta\rho_A \vert Indirect$	$s.e.(\Delta\rho_A \vert Indirect)$
Belgium	0.758	-0.161	0.027	-0.083	0.017	-0.078	0.023
Brazil	-0.269	-0.044	0.012	-0.038	0.011	-0.006	0.005
China	-0.545	-0.096	0.017	-0.058	0.015	-0.037	0.009
Germany	0.643	-0.178	0.029	-0.088	0.020	-0.090	0.022
Italy	0.630	-0.168	0.027	-0.082	0.019	-0.086	0.021
Japan	-0.183	-0.078	0.014	-0.056	0.012	-0.022	0.009
Netherlands	0.618	-0.143	0.021	-0.079	0.014	-0.064	0.017
Spain	0.876	-0.137	0.026	-0.076	0.020	-0.061	0.019
United Kingdom	0.010	-0.149	0.026	-0.084	0.019	-0.065	0.018
United States	0.372	-0.148	0.025	-0.089	0.019	-0.059	0.017
Average	0.291	-0.130		-0.073		-0.057	
	Panel B: Manufacturing Sector						
Country	ρ_A	$\Delta\rho_A$	$s.e.(\Delta\rho_A)$	$\Delta\rho_A \vert Direct$	$s.e.(\Delta\rho_A \vert Direct)$	$\Delta\rho_A \vert Indirect$	$s.e.(\Delta\rho_A \vert Indirect)$
Belgium	0.935	-0.576	0.045	-0.080	0.019	-0.496	0.044
Brazil	0.177	-0.150	0.015	-0.042	0.012	-0.108	0.010
China	-0.190	-0.246	0.020	-0.055	0.013	-0.191	0.017
Germany	0.695	-0.570	0.045	-0.084	0.020	-0.486	0.044
Italy	0.718	-0.528	0.042	-0.080	0.019	-0.448	0.041
Japan	0.166	-0.238	0.019	-0.057	0.014	-0.181	0.016
Netherlands	0.718	-0.445	0.035	-0.081	0.018	-0.364	0.033
Spain	0.673	-0.478	0.038	-0.074	0.019	-0.404	0.036
United Kingdom	0.435	-0.473	0.037	-0.080	0.019	-0.393	0.035
United States	0.509	-0.436	0.034	-0.082	0.018	-0.354	0.031
Average	0.484	-0.414		-0.071		-0.343	

Notes: This table reports the results of the aggregation exercise in Equation (10), augmented with indirect linkages. The column labeled $s.e.(\Delta\rho_A)$ reports the standard error associated with the estimated change in aggregate correlation. The last 4 columns present the change in the correlation due to severing of direct linkages and indirect linkages separately, along with corresponding standard errors.

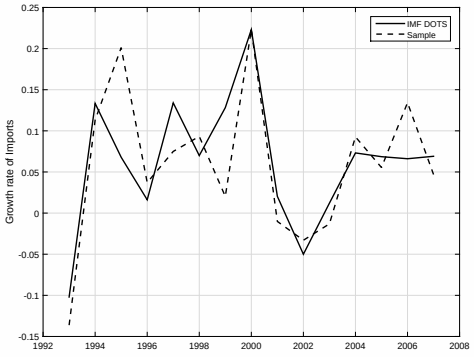
Figure 1. Comparison with Aggregates, Growth Rates



(a) Aggregate Value Added and GDP



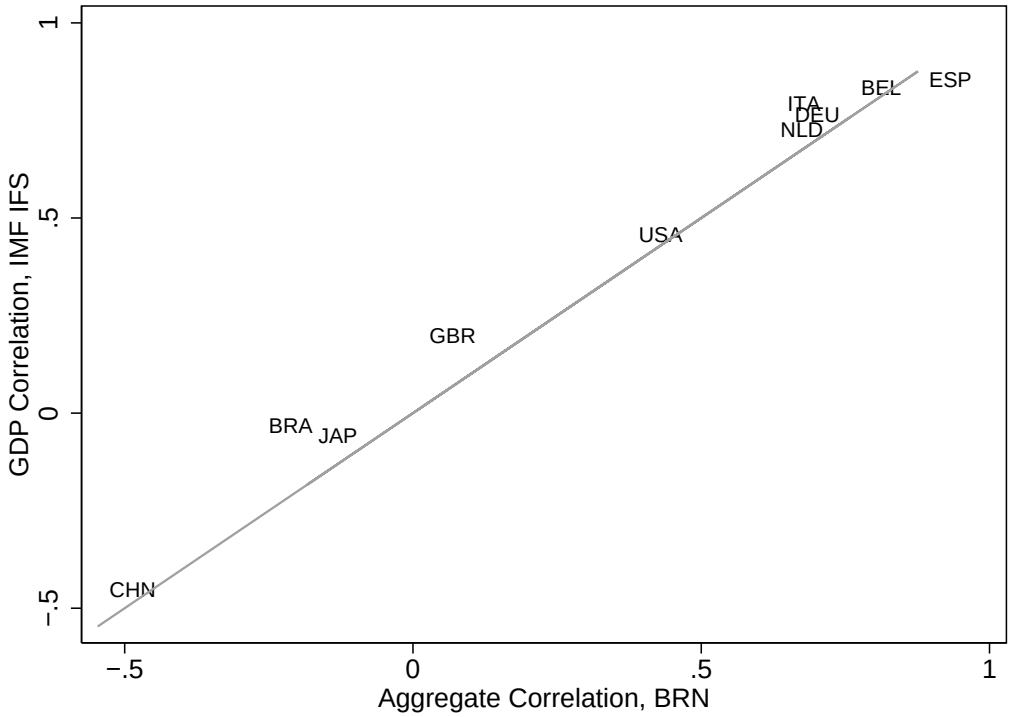
(b) Exports



(c) Imports

Notes: The top panel presents the time series of the growth rates of total before-tax value added in our data and GDP sourced from the IMF International Financial Statistics. The bottom two panels present the growth rates of total exports and imports, respectively, in our sample and sourced from IMF's Direction of Trade Statistics.

Figure 2. Aggregate Correlations: Comparison to Standard Sources



Notes: This Figure presents the scatterplot of the aggregate correlations implied by our data and the correlations in GDP from IMF International Financial Statistics, along with a 45-degree line.

Table A1. Firm-Level Volatility by Sector

NAF	Sector	St. Dev.	Share	NAF	Sector	St. Dev.	Share
01-05	Agriculture, forestry and fishing	0.3378	0.0069	35	Other transport equipment	0.3461	0.0138
10-14	Mining and quarrying	0.3381	0.0049	36-37	Manufacturing n.e.c.	0.3311	0.0099
15-16	Food and tobacco	0.2808	0.0405	40-41	Electricity, gas, water supply	0.3910	0.0409
17-19	Textile, wearing apparel and leather	0.3296	0.0144	45	Construction	0.3067	0.0606
20	Wood products	0.2853	0.0050	50-52	Wholesale and retail trade	0.3221	0.1793
21-22	Paper products, publishing	0.3383	0.0259	55	Hotels and restaurants	0.3058	0.0233
23	Coke, refined petroleum, nuclear fuel	0.3402	0.0077	60-63	Transport	0.3179	0.0745
24	Chemical industry	0.3381	0.0411	64	Post and telecommunications	0.4078	0.0529
25	Rubber and plastics	0.3102	0.0170	70	Real estate activities	0.4106	0.0379
26	Mineral products	0.2875	0.0136	71	Rental without operator	0.3804	0.0139
27	Basic metals	0.3074	0.0111	72	Computer services	0.4096	0.0267
28	Metal products	0.2859	0.0284	73	Research and development	0.4157	0.0028
29	Machinery and equipment	0.3112	0.0256	74	Other business services	0.3813	0.1144
30	Office machinery	0.3879	0.0045	75	Public administration	0.3403	0.0006
31	Electrical equipment	0.3058	0.0130	80	Education	0.3651	0.0030
32	Radio, TV and communication	0.3475	0.0122	85	Health and social work	0.2557	0.0146
33	Medical and optical instruments	0.3090	0.0114	90-93	Personal services	0.3519	0.0291
34	Motor vehicles	0.2985	0.0189				

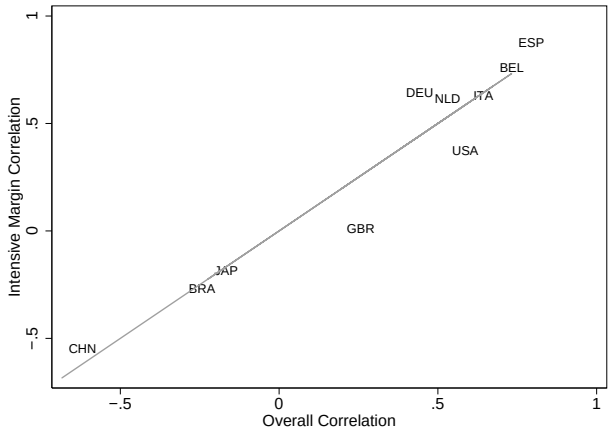
Notes: This table presents the standard deviations of firm growth rates broken down by sector over 1993–2007. "Share" is the share of the sector in total value added. The manufacturing sector covers NAF sectors 15 to 37.

Table A2. Contribution of Intensive and Extensive Margins to Overall Aggregate Correlation

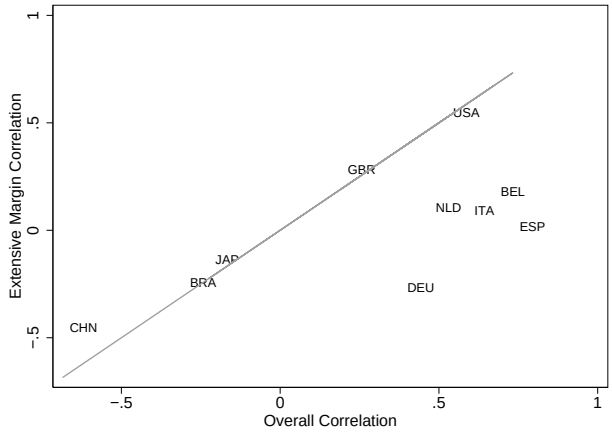
Country	$\tilde{\rho}_A$ (observed)	Intensive (share)	Extensive (share)
Panel A: Whole Economy			
Belgium	0.674	1.030	-0.030
Brazil	-0.305	0.808	0.192
China	-0.684	0.731	0.269
Germany	0.379	1.552	-0.552
Italy	0.591	0.977	0.023
Japan	-0.224	0.749	0.251
Netherlands	0.469	1.206	-0.206
Spain	0.733	1.094	-0.094
United Kingdom	0.193	0.045	0.955
United States	0.524	0.651	0.349
Average	0.235	0.884	0.116
Panel B: Manufacturing Sector			
Belgium	0.882	0.937	0.063
Brazil	0.136	1.149	-0.149
China	-0.291	0.578	0.422
Germany	0.556	1.105	-0.105
Italy	0.720	0.881	0.119
Japan	0.133	1.105	-0.105
Netherlands	0.649	0.977	0.023
Spain	0.584	1.020	-0.020
United Kingdom	0.547	0.704	0.296
United States	0.597	0.754	0.246
Average	0.451	0.921	0.079

Notes: This table presents the correlation of combined aggregate value added (intensive plus extensive margins), and the share of aggregate correlation due to the intensive and the extensive margins.

Figure A1. Overall Correlations and the Intensive and Extensive Margins



(a) Intensive



(b) Extensive

Notes: The top panel presents the scatterplot of the overall (intensive plus extensive) correlation against the intensive margin correlation. The bottom panel presents the scatterplot of overall and the extensive margins. The 45-degree line is added to both plots.