Multinational Firms and International Business Cycle Transmission *

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Abstract

We investigate how multinational firms contribute to the transmission of shocks across countries using a large firm-level dataset that contains ownership information for 8 million firms in 34 countries. We use these data to document two novel empirical patterns. First, foreign affiliate and headquarter sales exhibit strong positive comovements: a 10% growth in the sales of the headquarter is associated with a 2% growth in the sales of the affiliate. Second, shocks to the source country account for a significant fraction of the variation in sales growth at the source-destination level. We propose a parsimonious quantitative model to interpret these findings and to evaluate the role of multinational firms for international business cycle transmission. For the typical country, the impact of foreign shocks transmitted by all foreign multinationals combined is non-negligible, accounting for about 10% of aggregate productivity shocks. On the other hand, since bilateral multinational production shares are small, interdependence between most individual country pairs is minimal. Our results do reveal substantial heterogeneity in the strength of this mechanism, with the most integrated countries significantly more affected by foreign shocks.

Keywords: international business cycle comovement, multinational firms

JEL Codes: F23, F44

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1 Introduction

Multinational firms are a first-order feature of the world economy: about a quarter of gross output in many developed countries is produced by multinationals (see Alviarez, 2013). Because multinationals by construction involve production facilities owned and operated by the same firm in multiple countries, a natural conjecture is that the rapid rise of multinationals in recent decades has had an impact on how shocks are transmitted across countries.

This paper uses novel firm level data and a quantitative multi-country model to examine the role of multinational firms in aggregate business cycle transmission. Our data come from ORBIS, a firm-level database that covers more than 8 million firms operating in 34 countries over the period 2004-2012. The key feature of the dataset is that it contains information on domestic and foreign ownership. Hence, for the first time in this context, the operations of parents and affiliates are observed in the same dataset as well as through time. We exploit this feature to study comovements between parents and affiliates and between firms from the same source country. We then develop a conceptual framework to interpret these comovements and to evaluate how much they contribute to aggregate business cycle synchronization.

We start by documenting comovements between multinational affiliates and their parents, and between firms from the same source country that operate in different destinations. There is a strong positive correlation between the growth rate of parents and their affiliates; a 10% growth in the sales of the parent is associated with a 2% growth in the sales of the affiliate. This correlation is computed after controlling for sectoral and aggregate trends using source-sector-destination-sector-year fixed effects. We further evaluate whether these comovements are driven solely by vertical production linkages, by splitting the sample into sectors that differ in their intermediate input intensities. The results hold for multinationals operating in both the manufacturing and the service sector, although the elasticities in the manufacturing sector are higher, on the order of 30%. We show the correlation between parent and affiliate's growth is also present when we use value added to measure firms' growth, and is highly significant and robust to different samples, fixed effects, and aggregation methods.

We next aggregate multinational sales to the source-destination level (i.e., combined sales of all US multinational affiliates operating in the UK), and estimate whether the variation in source-destination growth rates is driven by source-specific or destination-specific factors. We find that source-specific shocks are an important determinant of bilateral growth rates, accounting for about 10% of the variation in growth rates, compared to 20% accounted for by destination-specific shocks. We interpret this result as evidence that shocks to the source country are important for the variation in total sales.

Our empirical results thus demonstrate strong interdependence between source countries and their foreign affiliates. This interdependence is detectable both at the firm and the source-destination level. In order to assess the quantitative importance of this phenomenon for aggregate business cycle transmission, we develop a multi-country quantitative framework that can be implemented on the data. In the model, each country produces a final good by aggregating the output of intermediate producers. These intermediate producers may be local firms or foreign multinational affiliates. We introduce comovement between multinational firms and their foreign affiliates by assuming that the productivity of the affiliates is in part affected by the productivity of the parent.[1] In particular, the productivity of foreign affiliates is a combination of a source-specific and destination-specific component. The relative importance of the source vs. the destination component is governed by a crucial parameter that we discipline with the ORBIS data.

The model illustrates that the extent to which multinationals contribute to the transmission of shocks across countries is driven by: (i) what share of the firm's technology shock originates in the source vs. the destination country; (ii) the distribution of bilateral multinational shares in the economy; and (iii) general equilibrium effects. We use the model's structural equations to interpret our empirical results, and to calibrate the extent to which shocks in the source country are transmitted by multinationals. We estimate that between 20 and 40 percent of the firms' shocks originate in the source country. The multinational production shares are taken directly from the data. Finally, the magnitude of the general equilibrium effects depends on a composite parameter that combines the elasticity of substitution across intermediates and the Frisch labor supply elasticity. We benchmark this parameters using micro estimates of these elasticities, and check the sensitivity of the results to alternative values.

We use the calibrated model to conduct three quantitative exercises to measure the importance of multinationals for the transmission of shocks across countries. First, we simulate impulse responses to country and firm-level productivity shocks in each source country, and track the propagation of these shocks across countries. For the majority of country pairs, the role of multinationals in the transmission of shocks is essentially nil, since bilateral multinational shares tend to be small. Multinationals can be important fot the transmission of shocks between some country pairs in which multinationals account

[1]This is a common approach in the literature on multinational production, see, among many others, Helpman [1984], Markusen [1984], Helpman et al. [2004] and more recently McGrattan and Prescott [2009, 2010], Burstein and Monge-Naranjo [2009], Keller and Yeaple [2013], Ramondo and Rodríguez-Clare [2013], Ramondo [2014], Alviarez [2013].

for a large share of the economy. At the extreme, a productivity shock in the US that increases US GDP by 1% increases Ireland's GDP by 0.17%. We also examine the combined impact of all foreign productivity shocks on a country's productivity. For the median country foreign shocks can account for 11% of productivity shocks. There are some countries, however, in which foreign shocks are more significant; up to 35% in Ireland, 25% in the Netherlands, and 22% in Slovakia.[2]

Second, we use the model structure, observed bilateral multinational production shares, and our estimates of how foreign affiliates are affected by shocks in their source country to compute the business cycle correlation between each pair of countries when the primitive productivity shocks are uncorrelated. This exercise is an assessment of how much correlation can be generated purely by propagation of shocks through multinationals under observed levels of multinational activity. It turns out that multinationals as they stand today can generate almost no business cycle correlation: the mean correlation in our sample of country pairs is 0.01. This is of course much too low to account for a non-trivial share of international business cycle comovement observed in the data. As in our previous excersise, multinationals also can generate non-negligible correlations across some country pairs that are heavily integrated, the maximum correlation in our sample of country pairs is 0.25.

Third, we conduct two counterfactual exercises in which we change the shares of multinational firms in the world economy, and study the cross-country dispersion of growth rates under these scenarios. In the first counterfactual, we consider a world with no multinational firms operating in foreign destinations. The counterfactual cross-country dispersion in growth rates is 10% larger in this scenario than in our benchmark calibration. In the second counterfactual, we simulate a "full integration" equilibrium, in which multinationals from any source country operate with the same intensity in all destinations (that is, we eliminate the home bias in multinational production seen in the data). We show that the counterfactual cross-country dispersion in growth rates is 35% smaller than in our benchmark calibration.

Our main takeaway from these exercises is that the combined impact of all foreign multinationals in the median country is small but significant, accounting for about 10% of the productivity shocks. On the other hand, since bilateral shares are small, interdependence between most individual country pairs is minimal. Our results do reveal substantial heterogeneity in the strength of this mechanism, with the most integrated countries

[2]The large values for Ireland and the Netherlands reflect their importance as host countries for multinational firms, which may be due in part to their role as tax shelters. None of the empirical or quantitative results in the paper are driven by these countries.

significantly more affected by foreign shocks.

While the driving mechanism in our model is that productivity shocks are directly transferred across countries by multinational firms, our setup can be interpreted more broadly as a reduced form for other types of interdependencies, such as shocks to demand for the firms' product or as intermediate input linkages (see Appendix A.3). It has not (yet) been established empirically that the transmission of shocks through input trade by multinationals is a quantitatively important phenomenon. Ramondo et al. [2014] show that US multinational affiliates abroad sell mostly in the local market, with the median affiliate having no shipments to the parent. In a non-international context, Atalay et al. [2014] show that most vertical ownership is not primarily motivated by input linkages within the firm. In our own results, the correlation between affiliate and parent sales occurs even among service sector firms, for which input linkages are likely to be much weaker. While our setup is flexible enough to capture this alternative interpretation, our empirical results show that intermediate input linkages are unlikely to be the sole determinant of parent-affiliate comovement.

This paper contributes to three strands of the literature. The first is the research agenda on the role of multinational firms in the transmission of international business cycles [see, e.g., Burstein et al., 2008, Contessi, 2010, Zlate, 2012].[3] This literature has focused mainly on the role of within-multinational trade and vertical integration for business cycle synchronization, and has predominantly employed 2-country models. In contrast, we develop a parsimonious multi-country quantitative framework that can be directly taken to the firm-level data.

Second, we contribute to the empirical literature on multinationals and comovement. A number of papers [e.g., Budd et al., 2005, Desai and Foley, 2006, Desai et al., 2009] explore whether parents and affiliates are correlated.[4] These papers make no attempt to go from their estimates to business cycle comovement between countries. Buch and Lipponer [2005] and Kleinert et al. [2012] use sectoral and regional data to study whether greater multinational presence is associated with greater comovement. All of these papers feature only one source, or only one destination country, and frequently the information on either the parent or the affiliate is limited. Our work is the first to study aggregate

[3]Also related is the literature that explores the role of cross-border vertical production linkages in the international business cycle transmission [see, e.g., Kose and Yi, 2001, Arkolakis and Ramanarayanan, 2009, Johnson, 2013], though this line of research is not explicit on whether the production linkages take place within firms. Some recent papers have focused how liquidity shocks are transmitted through international banks, see for example Acharya and Schnabl [2010], Cetorelli and Goldberg [2011], Schnabl [2012].

[4]A related paper is Alfaro and Chen [2012], who study how how the affiliates of multinational firms responded to the recent financial crisis relative to local establishments. Their focus is not, however, on parent and affiliate comovements.

comovement with multi-country data in which parents and affiliates are observed within the same dataset. In addition, we develop a quantitative framework to interpret the empirical findings.

Finally, there is a large theoretical literature on multinationals and technology transfers [see, among many others, McGrattan and Prescott, 2009, Ramondo and Rappoport, 2010, Keller and Yeaple, 2013]. In addition, an extensive empirical literature has studied the effects of FDI on productivity.[5] In contrast, our empirical contribution is to use firm level data to quantitfy the extent to which parent's and affiliates are affected by common shocks at the business cycle frequency.

The rest of this paper is organized as follows. Section 2 describes the data and presents the basic summary statistics on multinationals' presence. Section 3 documents bilateral and firm-level comovements between multinational firms. Section 4 derives a structural framework to interpret our empirical results and to study the aggregate implications of multinationals for business cycle comovements and for the transmission of shocks. Section 5 describes the quantitative results from the model and counterfactuals, and Section 6 concludes.

2 Data and summary statistics

The data come from ORBIS, a large cross-country database maintained by Bureau van Dijk. The ORBIS database includes information on both listed and unlisted firms collected from various country-specific sources, such as national registries and annual reports. Importantly, it contains information on the "global ultimate owner" of each firm in the database. This information enables us to build links between affiliates of the same firm, including cases in which affiliates and the parent are in different countries. We specify that a parent should direclty own at least 50% of an affiliate to identify an ownership link between the two firms. Currently, the data are available for the period 2004-2012. The main variable used in the analysis is the total sales (turnover) of each firm.

ORBIS contains data on more than 100 countries, although coverage is extremely uneven, with most of those countries reporting information on very few firms. In addition, in order to analyze multinationals we must use the "unconsolidated" accounts of each firm, since the "consolidated" accounts include operating revenue of the foreign affiliates. After extensive checking of the data, we focus on a sample of 34 countries for which the coverage and data quality are sufficiently good. In particular, we focus on the set of countries for which the raw data satisfies the following criteria: First, we focus on

[5] See for example Javorcik [2004], Guadalupe et al. [2012], Fons-Rosen et al. [2013].

countries with data on more that 750 firms on the avarage year (as noted below, most countries in our sample are well above this threshold, the median country contains data on 100,000 firms in the average year). Second, we focus on countries for which the aggregate revenues in ORBIS are at least 40% of aggregate output as reported by Eurostat (for EU countries) or by the UN SNA data (for non-EU countries). Third, we focus countries for which the correlation between the growth rate of aggregate revenues in ORBIS and GDP as reported in the WDI exceeds 50%.[6]

Table 1 presents the resulting sample of countries along with some summary statistics and checks on the quality of the data. The sample is dominated by European countries, but includes both developed and developing countries, as well as countries outside of Europe. Column 1 reports the total number of firms in the average year for each country. The mean number of firms is about 180,000, and the median is about 100,000. There is a wide range of firm coverage even in our restricted sample of countries: the country with the smallest number, Australia, has only 766 firms in the average year. Column 2 reports the number of multinational firms in each country, the sample covers about 2300 multinational firms in the median country.

Column 3 presents the correlation between the country's GDP growth rate and the growth rate of aggregate sales of all the continuing firms in ORBIS. We can see that the aggregate growth rate implied by ORBIS mimics the GDP growth quite well: the mean correlation between aggregate growth in ORBIS and GDP growth from the national accounts is 0.81, and the median is 0.83. This suggests that business cycles features are well captured in the ORBIS data. Column 4 reports the ratio of the total sales of firms in ORBIS to the gross output as reported in other sources. We use two data sources for this consistency check. For EU countries, the best source of gross output data is EUROSTAT. For countries outside of the EU, we take gross output data from the UN System of National Accounts. In this sample of countries, the ORBIS data captures the bulk of aggregate output as reported by national statistical agencies.

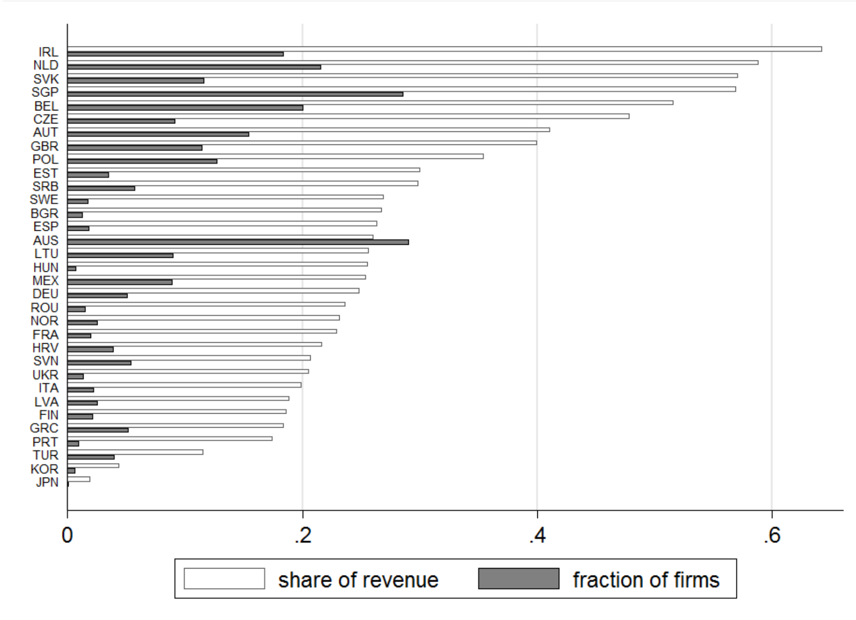
[6]Bosnia-Herzegovina and the Phillipines were dropped from the sample in spite of satisfying the three criteria due to poor data quality. Mexico was mantained in the sample despite having a correlation with GDP that is slightly below our threshold (0.49). Finally, ORBIS data for the US predominantly has consolidated accounts, which implies that the aggregate unconsolidated revenues in ORBIS are a low share of total revenues as reported by the UN. We maintained the US in the sample in spite of this issue due to its importance as a source country of multinational affiliates present in other countries, as well as its overall importance in the world economy. The data in ORBIS are collected in each destination country, which means that we have extensive information of the foreign operations of US based multinationals even when data on their US operations is missing. The introducion of the US as a destination country does not affect our quantitative results in Section 5 for the remaining countries. .

Table 1: Sample and summary statistics

Country	Number of Firms	Number of Multinationals	Correlation between ORBIS growth and GDP growth	Ratio of ORBIS revenue to total revenue	Country	Number of Firms	Number of Multinationals	Correlation between ORBIS growth and GDP growth	Ratio of ORBIS revenue to total revenue
Austria	15,300	2,202	0.83	0.63	Lithuania	7,473	631	0.96	0.53
Australia	766	208	0.60		Latvia	43,887	1,093	0.91	0.59
Belgium	18,362	3,606	0.91	0.70	Mexico	6,102	485	0.49	0.93
Bulgaria	120,520	1,444	0.92	0.71	Netherlands	10,061	2,163	0.81	0.40
Czech Republic	85,422	7,007	0.86	0.81	Norway	148,599	3,708	0.80	0.81
Germany	224,395	10,010	0.89	0.69	Poland	56,414	6,780	0.82	0.68
Estonia	47,132	1,537	0.96	0.71	Portugal	212,761	2,047	0.89	0.93
Spain	519,129	9,034	0.82	1.07	Romania	319,347	4,700	0.86	0.55
Finland	106,222	2,301	0.93	0.93	Serbia	48,083	2,428	0.62	0.74
France	751,859	14,581	0.96	0.81	Sweden	222,882	3,942	0.79	0.93
United Kingdom	194,711	22,459	0.59	0.69	Singapore	1,249	351	0.64	
Greece	24,639	1,262	0.74	0.54	Slovenia	29,868	559	0.90	0.77
Croatia	60,527	2,293	0.96	0.75	Slovak Rep.	30,377	3,004	0.75	0.88
Hungary	174,795	822	0.99	0.76	Turkey	7,975	286	0.77	
Ireland	14,131	2,579	0.56	1.03	Ukraine	218,489	2,489	0.79	0.80
Italy	556,874	12,640	0.96	0.79	United States	97,378	605	0.84	0.09
Japan	217,024	282	0.81	0.84	**Mean**	179,273	5,270	0.83	0.78
Korea, Rep.	95,112	598	0.68	0.78	**Median**	100,667	2,297	0.87	0.76

Notes: This table reports the sample of countries used in the analysis. It reports the total number of firms and total number of multinationals in each country, the correlation between the growth rates of aggregate sales in ORBIS and GDP growth over the period for which ORBIS data are available (2004-2012), and the ratio of combined sales in ORBIS to total gross output reported in EUROSTAT (for EU countries) or UN SNA data (for non-EU countries).

Figure 1: The importance of multinationals



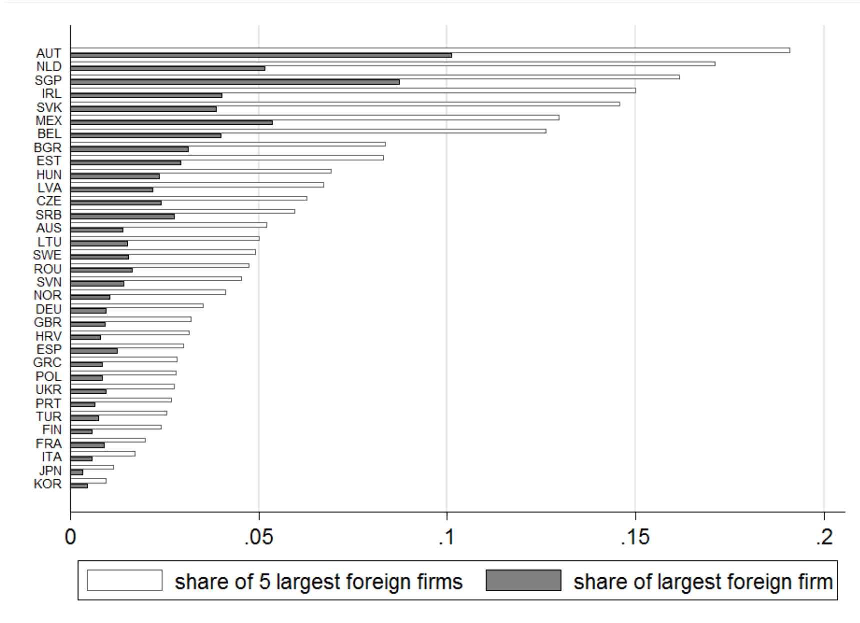
Notes: This figure reports, for each country, the share of multinationals in total revenue (light bars) and the total number of firms (dark bars).

Figure 1 shows the relative importance of multinationals in the countries in our sample for the average year. In the average country, about 7.5% of all firms are multinationals, ranging from 0.1% in Japan to 29% in Australia. Multinational affiliates tend to be larger than domestically-owned firms, so they comprise higher shares of total revenue, 29% on average. Once again there is a wide range, from 2% for Japan to 64% for Ireland. Indeed, in a number of countries – Belgium, Netherlands, Singapore, Slovakia, Czech Republic, Austria and the UK – multinational affiliates account for 40% or more of total sales in our data.

It could be that multinational firms affect aggregate comovement through the "granular" channel [Gabaix, 2011]: idiosyncratic shocks to individual multinationals will appear in aggregate comovement if those multinationals are sufficiently large relative to the aggregate. Figure 2 reports the shares of the largest one and five multinational firms in each country. As expected, multinationals are granular: the top foreign multinational affiliate accounts for 2.2% of total sales on average, and as much as 10.1%. Indeed, in 13 out of 34 countries, a foreign multinational affiliate is the single largest firm in the economy.

Appendix Table A1 presents the matrix of bilateral multinational shares. It displays, in percent, the share of aggregate revenue in the country in the row that is taken up by the firms owned by the country in the column. Thus the diagonal terms, for example, cor-

Figure 2: Top Foreign Multinational Firms



Notes: This figure reports, for each country, the share of largest 5 multinationals (light bars) and the share of the single largest multinationals (dark bars) in total sales in each country.

respond to the share of aggregate revenue that is taken up by domestically-owned firms. The salient feature of the table, important for the results below, is that bilateral multinational shares are small. In the square matrix of 34 sources and destinations, the mean cross-border revenue share is 0.7%, and the median is 0.025%. These low averages are driven partly by the fact that many countries in the sample (such as the small peripheral European countries) do not have many of their own multinationals. However, even in the G-7 economies, the average outward bilateral shares tend to be small. The largest source country, the US, accounts on average for 5.5% of revenue in a foreign destination country, followed by Germany (3.7%), the UK (2.9%), and France (2.3%). All of the other source countries have average foreign shares of under 1.5%.

Finally, Appendix Table A2 presents the distribution of firms and of foreign multinationals across 2-digit NACE sectors that we use in our empirical analysis below. The table shows the largest sectors in our sample are wholesale and retail trade respectively. The last column of the table shows that foreign multinationals represent an important share of revenues in various sectors, both within manufacturing and services categories.

3 Empirical results

This section uses the ORBIS data to estimate how the growth rates of affiliates are related to the growth rates of parents, both at the firm level and at the source-destination level. Throughout the analysis below, we use growth rates and shares in the form suggested by Davis et al. [1996]: for any variable x_j and time periods t and $t-1$, the growth rate is defined as $\gamma_{j,t} \equiv 2\left(\frac{x_{j,t}-x_{j,t-1}}{x_{j,t}+x_{j,t-1}}\right)$. That is, the denominator is the average of the beginning and end period levels, rather than the beginning period level. Davis et al. [1996] recommend using this growth rate because it has a number of attractive properties: it is bounded between -2 and 2, is symmetric around zero, and lends itself to aggregation. If $x_t = \sum_j x_{j,t}$, the aggregate growth of x_t, γ_t, can be written as the weighted sum of the disaggregated growth rates, $\gamma_t = \sum \omega_{j,t}\gamma_{j,t}$, with weights that are defined as $\omega_{j,t} = \frac{x_{j,t}+x_{j,t-1}}{\sum_j(x_{j,t}+x_{j,t-1})}$.

3.1 Firm level comovements

We first use the firm level data to estimate how the growth rates of affiliates are related to the growth rates of parents. In particular, we run the following regression:

$$\gamma_{in,t}(f) \quad = \quad \phi\gamma_{ii,t}(f) + \bar{a}_{inss',t} + \epsilon_{in,t}(f). \tag{1}$$

Here $\gamma_{in,t}(f)$ is the sales growth rate of the firms from multinational group f from source country i, operating in destination country n, $\gamma_{ii,t}(f)$ is the growth rate of firm multinational group f's parent firm in the source country i.[7] The specifications include source × destination × affiliate sector × parent sector × year fixed effects $\bar{a}_{inss',t}$, that control for comovements arising from country-specific sectoral and aggregate trends. We run equation (1) on the sample of firms that are foreign affiliates (so that the growth rate of the parent, $\gamma_{ii,t}(f)$ exists), pooling observations across years. Standard errors are clustered at the parent level.

The results are presented in Table 2. It reports results from a simple bivariate regression with no fixed effects, as well as the results with the fixed effects. The first panel of the table shows the results for a sample consisting of the universe of firms, while the next two panels focus on a sample of firms in which both the parent and the affiliate are either in the manufacturing or in the service sector. There is a strong positive and highly significant

[7] To compute the growth rate of the multinational group in a (source or destination) country, $\gamma_{in,t}(f)$, we aggregate the sales of all the firms belonging to multinational f that operate in the country in the two consecutive years on which the growth rate is computed. This ensures that changes in the composition of the multinational group (i.e. by the acquisition of a new firm in a particular destination) are not reflected in the growth rate.

correlation between affiliates and parents across all the specifications. Our benchmark estimate of ϕ using the full sample and controlling for fixed effects is 0.227. The estimated correlation is larger for firms in the manufacturing sector, although the last panel shows there is a strong positive correlation for service sector firms as well.

Robustness

We conduct a series of robustness checks on these results in Appendix Tables A3-A5. Table A3 evaluates, in different ways, whether the results are driven by input linkages. To isolate whether our estimated correlation is driven exclusively by input-output linkages, in Table 2 we already restricted attention to parent-affiliate pairs that operate in the service sector. However, it could be that many firms in the service sector sample in fact have manufacturing facilities. Column 1 in Table A3 reports the results of restricting the sample to cases in which both the parent firm(s) and all the affiliates are in the service sector, and are both in the same sector (thus ruling out manufacturing affiliates on both sides of the border). Columns 2 and 3 present the results excluding firms whose primary activity is listed as wholesale and retail trade respectively. These specifications verify that our results are not driven by firms that may be simply re-selling the output of their foreign counterparts. Columns 4-6 repeat our baseline regression with fixed effects using value added rather than sales data to calculate the growth rates in equation (1). Value added information is only available for less than half of the observations in the sample. We find a strong positive correlation in the value added growth of parents and affiliates. This robustness check rules out a mechanical relationship that can occur with sales, if the parent sells some products to the affiliate, and the affiliate resells them in the local market.

Table A4 evaluates alternative channels that can induce correlation between affiliate and parent sales growth. First, we check whether comovement in sales growth is driven mainly by multinational firms shifting profits across markets for tax purposes. Column 1 evaluates this hypothesis by repeating our baseline estimation excluding the two countries typically associated with tax sheltering behavior: Ireland and Netherlands. The table shows that the coefficient in our baseline regression is unchanged when excluding these countries. Next, we check whether comovement in sales growth is a special consequence of the 2008 financial crisis. Column 2 shows that the estimates are similar when restricting the sample to non-crisis years. Finally, Column 3 includes an interaction between the regressor of interest and a dummy variable indicating whether the destination country is a high income country, to evaluate the extent to which the correlation arises exclusively between parents and affiliates operating in high-income countries. The table shows that there is a strongly significant, although lower, positive correlation between parents and affiliates even when affiliates are not in high -income countries.

All of the above results were on the combined sales of the parent and affiliates in each country. That is, the parent observation was the growth rate of the combined sales of all the firms that the parent owns in the home country, and the affiliate observation was the combined sales of all the firms that the parent owns in a particular destination country. To establish that the results are not driven by this approach, Table A5 repeats the exercise on individual firms, rather than combined sales. In this specification, domestic affiliates of the parent firm are also included in the sample.[8] Column 1 shows the estimated regression on the entire sample, column 2 further restricts the sample of individual firms to the service sector, and column 3 restricts both the parent and the affiliate to be in the same sector. The last two columns estimate the regression using value added data. Throughout these specifications, we continue to find a strong positive and significant correlation between affiliates and parents growth. We prefer the specifications that aggregate affiliate sales of the same firm in each country for two reasons. First, the home country shock need not originate in the headquarter firm only: some shocks may be transmitted directly from the source country affiliates to the destination country affiliates. Combining all the affiliates of a given firm in the home country yields a composite of all the shocks hitting the home operations of a multinational. Second, taking the combined sales of firms in each country averages out some of the noise in the sales growth data, especially in smaller constituent firms.

Finally, the finding of a strong positive comovement between parent's and affiliate's growth is robust to a variety of additional checks: estimation year-by-year instead of pooling years, including and excluding domestic affiliates and different configurations of fixed effects. We do not report those robustness checks to conserve space, but they are available upon request.

3.2 Bilateral comovements

The results above reveal strong interdependence at the firm level. It may be that this interdependence is driven by transmission of idiosyncratic shocks within firms, that averages out on aggregate. Figure 2 provides an indication that even these idiosyncratic shocks are unlikely to average out, given the granular nature of multinational activity. Nonetheless, we would like to establish that there is a common component to the combined overall sales of multinationals from a particular country. We thus estimate the contribution of

[8] We checked whether the coefficient of interest is different between the parent and a domestic affiliate compared to a foreign affiliate. There was no economically meaningful or statistically significant difference.

Table 2: Affiliate-Parent Comovement

	All		Manufacturing		Services	
ϕ	0.278***	0.228***	0.402***	0.299***	0.233***	0.213***
	(0.00524)	(0.0117)	(0.0137)	(0.0394)	(0.00628)	(0.0131)
Obs.	181978	181978	19756	19756	105774	105774
N. mult.	18881	18881	2470	2470	12419	12419
R^2	0.047	0.724	0.102	0.789	0.032	0.674
FE	No	Yes	No	Yes	No	Yes

Notes: Standard errors clustered at the parent level in parentheses. ***: significant at the 1% level. This table presents the results of estimating equation (1). "FE" refers to source × destination × affiliate sector × parent sector × year fixed effects. Sectors are defined at the 2 digits of the NACE classification.

source and destination specific shocks to the variation in the bilateral growth rates:

$$\gamma_{in,t} = \quad s_{i,t} + d_{n,t} + a_{in,t}. \tag{2}$$

Equation (2) writes the growth rate $\gamma_{in,t}$ of total sales of firms owned by country i operating in country n (i.e., the growth rate of the total sales of all i =US multinationals operating in n =UK) as a function of the source effect $s_{i,t}$ that is common to all firms owned by i worldwide, the destination effect $d_{n,t}$ that is common to all firms from all countries selling in market n, and an idiosyncratic term $a_{in,t}$. This decomposition of a cross-section of data into different types of shocks draws on a common approach in macroeconomics [see, e.g., Stockman, 1988, and the literature that followed], but to our knowledge has never been applied to foreign multinational operations to establish the existence of a source country shock.

The empirical model (2) is estimated by regressing observed growth rates $\gamma_{in,t}$ on source and destination fixed effects (when carried out year-by-year), or source-year and destination-year effects (when carried out in a pooled sample of years). The regression for the pooled sample of years also includes non-time-varying source-destination fixed effects. There is a large amount of variation in the size of source-destination pairs. Smaller in pairs tend to have fewer firms and thus tend to be more volatile. To account for this fact, we employ a Generalized Least Squares estimation in which the observations are weighted by the inverse of the Herfindahl index of sales shares in an in pair.[9] This ap-

[9] Let the variance of the residual of an individual firm's growth rate be $\sigma^2(f)$, and let $\tilde{\omega}_{in,t}(f)$ be the share of firm f in the total sales of firms from source i in destination n. Then the variance of the residual of the source-destination level observation is equal to $Var(\alpha_{in,t}) = \sigma^2(f)\sum_{f\in\Omega_{in}}\tilde{\omega}^2_{in,t}(f) \equiv \sigma^2(f)Herf_{in,t}$, where Ω_{in} is the set of firms from i selling in n. The GLS estimator weights the observations by the inverse

Table 3: Importance of source and destination effects

	Source			Destination		
	Part. R^2	F-stat.	p-val.	Partial R^2	F-stat	p-val.
2005	0.09	2.02	0.000	0.14	4.83	0.000
2006	0.08	2.02	0.000	0.14	4.99	0.000
2007	0.06	1.55	0.012	0.14	5.16	0.000
2008	0.15	4.09	0.000	0.24	10.29	0.000
2009	0.08	2.20	0.000	0.19	7.62	0.000
2010	0.12	3.41	0.000	0.23	9.91	0.000
2011	0.10	2.70	0.000	0.19	7.52	0.000
2012	0.09	2.36	0.000	0.23	8.96	0.000
Mean	**0.10**	**2.54**	**0.002**	**0.19**	**7.41**	**0.000**
Median	**0.09**	**2.28**	**0.000**	**0.19**	**7.57**	**0.000**
Pooled	0.10	6.82	0.000	0.17	8.40	0.000

Notes: This table reports the results of estimating equation (2). The first column reports the partial R^2 associated with the source and destination effect. The second column reports the F-statistic associated with the hypothesis that all of the source/destination effects are zero, and the third column reports the p-value associated with that hypothesis test. The results are reported year-by-year as well as pooled across years. In the pooled estimation uses source-year and destination-year effects.

proach underscores the usefulness of firm-level data even for the estimation of source- or destination-level outcomes, as they are used to model the heteroskedasticity in the source-destination data.

Table 3 reports the results. Source effects account for about 10% of the variation in the cross-section of source-destination growth rates, compared to 19% for the destination shocks. The table reports the F-statistics and p-values associated with the hypothesis that the source effects as a group are zero. As a group, they are highly significant in explaining the variation in the data.

3.2.1 Implications for aggregate growth rates

We now provide a decomposition of country-level growth rates to understand the contribution of source vs. destination shocks to the dispersion in aggregate growth rates. We

of the variance of the error term, which in this case is proportional to the Herfindahl index of firm sales shares.

can write the aggregate growth rate in country n as:

$$\gamma_{n,t} \;\; = \textstyle\sum_i \omega_{in,t} \gamma_{in,t} = \displaystyle\sum_i \omega_{in,t} \left[a_{in,t} + s_{i,t} \right] + d_{n,t}, \tag{3}$$

where $\omega_{in,t}$ denotes the share of country $n's$ revenues generated by firms from country i. We can express country n's growth rate relative to the average growth rate as:

$$\gamma_{n,t} - \bar{\gamma}_t \;\; = \;\; \mathcal{A}_{n,t} + \mathcal{S}_{n,t} + \mathcal{D}_{n,t} \tag{4}$$

where $\mathcal{A}_{n,t} \equiv \sum_i \omega_{in,t} a_{in,t} - \frac{1}{N} \sum_n \sum_i \omega_{in,t} a_{in,t}$ is the aggregation of all of the idiosyncratic shocks; $\mathcal{S}_{n,t} \equiv \sum_i \omega_{in,t} \left[s_{i,t} - \bar{s}_{i,t} \right] - \frac{1}{N_n} \sum_n \sum_i \omega_{in,t} \left[s_{i,t} - \bar{s}_{i,t} \right]$ is the aggregation of all the source shocks, and $\mathcal{D}_{n,t} \equiv d_{n,t} - \bar{d}_t$ is the destination effect. In these expressions, we denote by $\bar{x}_t \equiv \frac{1}{N} \sum x_{n,t}$ the average of a variable across all destinations.

Equation (4) states that differences in the growth rate of country n relative to the world average are driven by: (i) differences in the origin of the firms operating in country n vs. the rest of the world, $\mathcal{S}_{n,t}$; (ii) differences in the destination shock in country n vs the rest of the world, $\mathcal{D}_{n,t}$; or (iii) differences in the country pair shocks between pairs that include country n vs the average pair, $\mathcal{A}_{n,t}$. We now use the decomposition in equation (4) to write the cross sectional variance of growth rates in any year t as:

$$\begin{aligned} \sigma^2_{\gamma_{n,t}} &= \sum_n \left(\gamma_{n,t} - \bar{\gamma}_t \right)^2 \\ &= \sigma^2_{\mathcal{S}_{n,t}} + \sigma^2_{\mathcal{D}_{n,t}} + \sigma^2_{\mathcal{A}_{n,t}} + 2 \sum_n \left(\mathcal{S}_{n,t} \mathcal{A}_{n,t} + \mathcal{D}_{n,t} \mathcal{A}_{n,t} + \mathcal{D}_{n,t} \mathcal{S}_{n,t} \right). \end{aligned} \tag{5}$$

This cross-sectional variance is a measure of business cycle comovement between countries: a low variance implies a high level of synchronization, and vice versa. This measure of dispersion can be decomposed additively into the dispersion due to source shocks $\sigma^2_{\mathcal{S}_{n,t}} = \sum_n \mathcal{S}^2_{n,t}$, due to destination shocks $\sigma^2_{\mathcal{D}_{n,t}} = \sum_n \mathcal{D}^2_{n,t}$, due to idiosyncratic shocks $\sigma^2_{\mathcal{A}_{n,t}} = \sum_n \mathcal{A}^2_{n,t}$, and all the combined covariance terms.

The results of this variance decomposition are presented in Table 4. Most of the cross-sectional variance in growth rates is driven by the cross-sectional variance of the destination-specific shocks. This is not surprising: examining (3), it is immediate that the destination shock applies to all the firms operating in n, whereas the source and idiosyncratic shocks are "diversified" across all the source countries. Note, however, that for the median year, a quarter of the cross-sectional variance in growth rates is accounted for the cross-sectional variance of $\mathcal{S}_{n,t}$. This shows that differences in the origin of the firms operating in different destination countries is an important source of cross-country dis-

Table 4: Decomposition of cross-sectional variance of aggregate growth rates

Year	$\sigma^2_{\gamma_{n,t}}$	$\sigma^2_{\mathcal{S}_{n,t}}$	$\sigma^2_{\mathcal{D}_{n,t}}$	$\sigma^2_{\mathcal{A}_{n,t}}$	Covariances
2005	0.0015	0.0005	0.0011	0.0005	-0.0006
2006	0.0007	0.0003	0.0009	0.0002	-0.0007
2007	0.0005	0.0001	0.0007	0.0001	-0.0004
2008	0.0027	0.0006	0.0022	0.0005	-0.0006
2009	0.0031	0.0004	0.0020	0.0003	0.0003
2010	0.0022	0.0005	0.0018	0.0002	-0.0002
2011	0.0017	0.0003	0.0013	0.0002	-0.0001
2012	0.0010	0.0003	0.0015	0.0002	-0.0010
Mean	**0.0017**	**0.0004**	**0.0014**	**0.0003**	**-0.0004**
Median	**0.0016**	**0.0004**	**0.0014**	**0.0002**	**-0.0005**

Notes: This table reports the results of decomposition (5). The first column reports cross-sectional variance of the aggregate growth rates. The rest of the columns report the components due to source, destination, and idiosyncratic variances, and the covariance terms.

persion in growth. Note that while the cross-country variation in growth rates increased during the financial crisis, the increase is mainly accounted for by the variance of the destination-specific shocks.

The contribution of $S_{n,t}$ to the variance can be small if either: (i) the source shocks $s_{i,t}$ do not differ across countries, or; (ii) the source shocks $s_{i,t}$ do differ across countries, but the sets of firms operating in each country is similar – that is, the same multinationals account for a large share of sales in different countries. We come back to this point in the next section when we use this decomposition to evaluate how multinational affect the dispersion of growth rates across countries.

4 A structural framework for interpreting the data

The preceding empirical results underscore two key features of the data. First, there is significant comovement between multinational parents and their foreign affiliates. This comovement is detectable in overall source-destination sales. Second, there is a large amount of heterogeneity across sources, destinations, and country pairs in the extent of multinational presence. This suggests that the impact of multinational firms on business cycle comovement may differ significantly across country pairs. These two features of the data inform the design of the quantitative multi-country model that we use to study the implications of the empirical findings for aggregate cross-country comovements. After setting up the theoretical framework, we circle back to the empirical results in Section 3 and interpret them through the lens of the model.

4.1 Model

Preliminaries We consider a world economy with multiple countries indexed by i and n. Each country produces a homogeneous final good using intermediate inputs. In each country, intermediate producers from different countries produce differentiated goods that are combined into the final good by a CES aggregator. The output of the intermediate producers cannot be traded internationally. We focus on the model's predictions for aggregate output and productivity, which, as we explain below, are independent of the international asset market structure.

Technologies and market structure The production function of the final good in each country n is given by:

$$Q_{n,t} = \left[\sum_i A_{in,t}^{\frac{1}{\rho}} Q_{in,t}^{\frac{\rho-1}{\rho}} \right]^{\frac{\rho}{\rho-1}}, \tag{6}$$

where $Q_{in,t}$ is a bundle of the output produced by firms from source country i that operate in country n, and ρ denotes the elasticity of substitution across goods produced by firms from different source countries. $A_{in,t}$ is a source-destination specific productivity parameter, normalized such that $\sum_i A_{in,t} = 1$ for each n. Thus, the production function is an Armington aggregator of goods produced by firms owned by various countries, including domestically owned and operated firms.

Cost minimization by final good producers implies:

$$Q_{in,t} = \frac{A_{in,t} P_{in,t}^{-\rho}}{P_{n,t}^{-\rho}} \quad Q_{n,t}, \tag{7}$$

where $P_{in,t}$ is the price index in country n for the bundle of goods produced by firms from source country i, and

$$P_{n,t} = \left[\sum_i A_{in,t} P_{in,t}^{1-\rho} \right]^{\frac{1}{1-\rho}} \tag{8}$$

is the aggregate price index in country n.

In turn, the intermediate output bundle $Q_{in,t}$ aggregates the output of all the firms from source country i operating in n:

$$Q_{in,t} = \left[\sum_{f\in\Omega_i} Q_{in,t}(f)^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}},$$

where Ω_i is the set of firms from country i and $Q_{in,t}(f)$ is the output of firm f from country i in the destination country n. It follows that the price index for the intermediate input bundle is

$$P_{in,t} = \left[\sum_{f\in\Omega_i} P_{in,t}^{1-\rho}(f)\right]^{\frac{1}{1-\rho}}. \tag{9}$$

Each firm operates a linear technology that uses labor in the destination country as the only input of production. Following the literature on multinational production and technology transfers, we assume that the multinational's technology can be partially shared across all destination countries.[10] In particular, the output of the firm is given by:

$$Q_{in,t}(f) = Z_{in,t}(f)\, L_{in,t}(f), \tag{10}$$

where $Z_{in,t}(f) = Z_{i,t}^{\phi}(f)\, Z_{n,t}^{1-\phi}(f)$ is a firm-destination specific productivity component.[11]

This production function implies that a fraction $(1-\phi)$ of the productivity of the firm is specific to a particular destination in which the firm operates, while the remaining ϕ is shared across destinations.[12] This is the only potential endogenous source of aggregate comovement in the model. The demand for firm's f product is given by:

$$Q_{in,t}(f) = \frac{P_{in,t}^{-\rho}(f)}{P_{in,t}^{-\rho}} Q_{in,t}. \tag{11}$$

Firms are monopolistically competitive, so profit maximization implies a constant markup

[10]See for example McGrattan and Prescott [2009, 2010], Ramondo and Rappoport [2010], Keller and Yeaple [2013], Ramondo [2014].

[11]Our model is isomorphic to a model in which affiliate-parent comovements are driven by shocks to demand for the firms' product. In particular, the firm-level productivity differences $Z_{in,t}(f)$ would come out of equation (10), and firm-level demand differences would enter as $Z_{in,t}(f)^{\frac{1}{\rho}}$ in equation (9). Our results can be reinterpreted in a version of the model in which the transmission of shocks is driven by intermediate input linkages. Appendix A.3 presents this alternative model.

[12]The assumption that the productivity in the source and destination are combined by a Cobb-Douglas aggregator is not crucial. Appendix A derives the equations under CES aggregation of productivities, and shows they are the same to a first-order approximation.

over marginal cost:

$$P_{in,t}\left(f\right) \quad = \frac{\rho}{\rho-1}\frac{W_{n,t}}{Z_{in,t}(f)}. \tag{12}$$

Preferences Consumers in country n get utility from consumption and disutility from supplying labor according to the GHH preferences [Greenwood et al., 1988]:

$$u\left(C_{n,t}, L_{n,t}\right) \quad = \quad \sum_t \delta^t v\left(C_{n,t} - \frac{\psi_0}{\bar{\psi}} L_{n,t}^{\bar{\psi}}\right).$$

Utility maximization implies the following labor supply:

$$L_{n,t} \quad = \quad \left[\frac{W_{n,t}}{P_{n,t}}\right]^{\frac{1}{\bar{\psi}-1}}, \tag{13}$$

As is well known, under GHH preferences the labor supply is independent of wealth effects. We exploit this property to derive predictions for output that are independent of the international asset market structure.[13]

Equilibrium Combining equations (9) and (12) we can write the real wage as:

$$\frac{W_{n,t}}{P_{n,t}} \quad = \quad \frac{\rho-1}{\rho}\left[\sum_i \sum_{f\in\Omega_i} A_{in,t} Z_{in,t}\left(f\right)^{\rho-1}\right]^{\frac{1}{\rho-1}}, \tag{14}$$

where Ω_n is the set of firms that are active in country n. Profit maximization implies that aggregate revenues are proportional to total labor payments:

$$\sum_i P_{in,t} Q_{in,t} = P_{n,t} Q_{n,t} \quad = \quad \frac{\rho}{\rho-1} W_{n,t} L_{n,t}, \tag{15}$$

which in combination with (14) and (13) permits expressing the aggregate production function as:

$$Q_{n,t} \quad = \quad \left[\sum_i A_{in,t} Z_{in,t}\left(f\right)^{\rho-1}\right]^{\frac{\psi}{\rho-1}}, \tag{16}$$

where $\psi \equiv \frac{\bar{\psi}}{\bar{\psi}-1} > 1$.

[13] The assumption of GHH preferences makes the model highly tractable. Some of the quantitative results do not rely on this assumption,conditional on the spillover parameter ϕ . We discuss how this assumption affects the results in the following section.

For simplicity, we assume that the final good is homogeneous across countries and can be freely traded. We use the final good as the numeraire of the world economy and set its price equal to $P_t^W = P_{n,t} = 1 \quad \forall n$.[14] This impies that aggregate sales growth is equivalent to growth of real output $Q_{n,t}$. Aggregate growth in country n is given by:

$$\gamma_{n,t} \;\; = \psi \;\; \sum_i \sum_{f \in \Omega_i} \omega_{in,t}(f) \left[\frac{a_{in,t}}{\rho - 1} + z_{in,t}(f) \right]. \tag{17}$$

where lower-case variables to denote growth rates, and $\omega_{in,t}(f) \equiv \frac{P_{in,t}(f) Q_{in,t}(f)}{P_{n,t} Q_{n,t}} = \frac{A_{in,t} Z_{in,t}(f)^{(\rho-1)}}{\sum_i A_{in,t} Z_{in,t}(f)^{(\rho-1)}}$ denotes the share of country $n's$ revenues generated by firm f from source country i.

In the special case where the destination shock is common across firms, $z_{n,t}(f) = z_{n,t}$, equation (17) becomes:

$$\gamma_{n,t} \;\; = \;\; \frac{\psi}{\rho - 1} \sum_i \omega_{in,t} \left[a_{in,t} + \phi (\rho - 1) z_{i,t} \right] + \psi (1 - \phi) z_{n,t}, \tag{18}$$

where, $z_{i,t} = \sum_{f \in \Omega_i} \frac{\omega_{in,t}(f)}{\omega_{in,t}} z_{i,t}(f)$, and $\omega_{in,t} \equiv \frac{P_{in,t} Q_{in,t}}{P_{n,t} Q_{n,t}}$ denotes the share of country n's revenues generated by firms from source country i.

Equation (18) is the key equation that encapsulates the role of multinationals in business cycle comovement. It states that growth in country n depends on its own productivity shock, $z_{n,t}$, and a weighted average of the productivity shocks $z_{i,t}$ to all countries that have firms operating in country n. Because foreign multinational affiliates inherits part of the shock that hit the parent $z_{i,t}$, their presence implies that productivity and output of countries will be positively correlated even if the primitive productivity shocks $z_{n,t}$ are not. This equation connects our framework to the international business cycle literature in the tradition of Backus et al. [1995, henceforth BKK]. The canonical BKK model has no multinationals, but it typically must assume that TFP shocks across countries are correlated. Equation (18) provides a possible microfoundation for this correlation.

The equation illuminates the key parameters and quantities that will drive the strength of the shock transmission through multinationals. The first is the share of the affiliate productivity shock that originates in the source country, ϕ. The more foreign affiliates inherit the source country productivity, the more comovement there will be in the aggregate. The second is the multinational shares, $\omega_{in,t}$. Larger shares will imply more comovement, since more of the shocks are shared. Finally, the combination of parameters $\frac{\psi}{\rho-1}$

[14] The assumption that the final good is homogeneous is not crucial. Appendix A derives the equations under the assumption that country-specific goods are imperfect substitutes, and shows that the results go through.

captures the strength of general equilibrium effects that occur in response to a particular productivity shock $z_{i,t}$. It regulates how the rest of the economy responds to a shock in a particular country.

We now interpret the empirical results from Section 3 in light of this conceptual framework, and use these results to disentangle the different shocks and discipline the model.

4.2 Interpreting affiliate-parent comovements

The empirical results in Section 3.1 can be given a structural interpretation and used to estimate the share of the firm's technology that gets transferred across destinations, ϕ. Using equations (11) and (12), firm f sales in destination n can be written as:

$$P_{in,t}(f)\,Q_{in,t}(f) \;=\; \bar{A}_{in,t} Z_{in,t}^{\rho-1}(f)\,,$$

where $\bar{A}_{in,t} \equiv W_{n,t}^{1-\rho} P_{in,t}^{\rho} Q_{in,t}\left[\frac{\rho}{\rho-1}\right]^{1-\rho}$. Using the functional form for $Z_{in,t}(f)$ we can write this in growth rates as:

$$\gamma_{in,t}(f) \;=\; \bar{a}_{in,t} + (\rho-1)\,\phi z_{i,t}(f) + (\rho-1)(1-\phi)\,z_{n,t}(f)\,. \tag{19}$$

The growth rate of the firm in its home country is:

$$\gamma_{ii,t}(f) \;=\; \bar{a}_{ii,t} + (\rho-1)\,z_{i,t}(f)\,. \tag{20}$$

Substituting we obtain:

$$\gamma_{in,t}(f) \;=\; \tilde{a}_{in,t} + \phi\gamma_{ii,t}(f) + \epsilon_{in,t}(f)\,, \tag{21}$$

where $\bar{a}_{in,t} \equiv \tilde{a}_{in,t} - \phi\tilde{a}_{ii,t}$ and $\epsilon_{in,t}(f) \equiv (\rho-1)(1-\phi)\,z_{n,t}(f)$. Equation (21) states that, after controlling for source-destination-year effects, the coefficient on the parent's growth rate is can be interpreted as ϕ. Hence, our empirical results in Table 2 imply that the share of a firm's productivity that is transferred across countries is approximately 20% ($\phi \approx 0.2$).

4.3 Interpreting source and destination specific shocks

We now use the model's implications for aggregate source-destination growth rates $\gamma_{in,t}$ to interpret our empirical results in Section 3.2 under the assumption that destination shocks are common across firms (i.e. $z_{n,t}(f) = z_{n,t}$). Combining expressions (7), (12), (8), and (16) we can write the total revenues by multinationals from source country i operating in country n as:

$$P_{in,t}Q_{in,t} = A_{in,t}S_{i,t}D_{n,t},$$

where $S_{i,t} = Z_{i,t}^{\phi(\rho-1)}$ is a term common to all firms from source country i and $D_{n,t} = \left[\sum_i A_{in,t}Z_{i,t}^{\phi(\rho-1)}\right]^{\frac{\psi-\rho+1}{\rho-1}} Z_{n,t}^{\psi(1-\phi)}$ is a term common to all firms operating in destination country n. Expressed in growth rates, this is given by:

$$\gamma_{in,t} = s_{i,t} + d_{n,t} + \alpha_{in,t}, \tag{22}$$

which is identical to the decomposition (2) estimated in Section 3.2.

Equation (22) provides a structural interpretation for the source and destination dummies estimated in Section 3.2. The fact that a significant fraction of the variation of the bilateral growth rates is accounted for the source dummies, as reported in Table 3, implies a role for the transmission of technology from the source country, $\phi > 0$.

4.4 Calibrating comovements with source-destination data

We now use these structural equations together with the estimates for the source and destination specific shocks to pin down the spillover parameter ϕ. In particular, the model structure implies the destination-specific shock have the form:

$$d_{n,t} = \left[\frac{\psi}{\rho-1} - 1\right] \sum_i \omega_{in,t} \left[a_{in,t} + s_{i,t}\right] + \frac{\psi}{\rho-1}\frac{1-\phi}{\phi} s_{n,t}. \tag{23}$$

Foreign productivity shocks z_i affect the destination effect in country n through two different channels. On the one hand, these changes affect competitiveness in country n through $\left[\sum_i A_{in,t}Z_{i,t}^{\phi(\rho-1)}\right]^{-1}$ (i.e. in response to an increase in Z_i, firms from all other source countries i' will sell less in country n due to increased competition). On the other hand, these shocks affect the real wage (and real aggregate output) in country i through $\left[\sum_i A_{in,t}Z_{i,t}^{\phi(\rho-1)}\right]^{\frac{\psi}{\rho-1}}$ (i.e. in response to an increase in Z_i, aggregate demand in country n will increase, increasing the sales of all firms operating in country n). In the case of $\rho - 1 = \psi$ these two effects exactly offset each other, and the destination effect is independent of changes in foreign technologies.

We can use the relation between source and destination shocks in equation (23) to infer

ϕ. Using the notation from Section 3.2.1 we can write:

$$\mathcal{D}_{n,t} = \left[\frac{\psi}{\rho-1} - 1\right]\left[\mathcal{A}_{n,t} + \mathcal{S}_{n,t}\right] + \frac{\psi}{\rho-1}\frac{1-\phi}{\phi}\mathcal{S}^{own}_{n,t}, \tag{24}$$

where $\mathcal{S}^{own}_{n,t} \equiv \left[s_{n,t} - \frac{1}{N}\sum_n s_{n,t}\right]$ captures the deviation of country $n's$ source shock from the average source shock. In particular, note from equation (24) that the destination effect is linked to the source effect $\mathcal{S}^{own}_{n,t}$ through the parameter ϕ and a term capturing general equilibrium effects. Taking squares in equation (24), averaging across countries, and solving for ϕ we obtain:

$$\phi = \frac{\sigma_{s,t}}{\sigma_{s,t} + \sigma_{\Phi t}}, \tag{25}$$

where $\sigma^2_{\Phi t} \equiv \frac{1}{N}\sum_n \left[\frac{\rho-1}{\psi}\left(\mathcal{D}_{n,t} - \frac{\psi+1-\rho}{\rho-1}\left[\mathcal{A}_{n,t} + \mathcal{S}_{n,t}\right]\right)\right]^2$, and $\sigma^2_{s,t} \equiv \frac{1}{N}\sum_n \left(\mathcal{S}^{own}_{n,t}\right)^2$. Note that in the special case of $\rho - 1 = \psi$, obtain $\sigma^2_{\Phi t} = \sigma^2_{dt} = \frac{1}{N}\sum_n \mathcal{D}^2_{n,t}$.

Equations (24) and (25) use the model structure to connect observables – $s_{i,t}$, $d_{n,t}$, and $\alpha_{in,t}$ estimated in Section 3.2 – to the two key model parameters, $\psi/(\rho-1)$ and ϕ. For each value of $\psi/(\rho-1)$ we can thus use (24) and (25) and the estimated $s_{i,t}$, $d_{n,t}$, and $a_{in,t}$ to pin down ϕ.

The basic intuition for this appoach can be gleaned from (25). Ignoring the general equilibrium effects, it says that ϕ drives the relative variances of the estimated source and destination effects. In the world of no spillovers from source countries ($\phi = 0$), shocks to the source country do not affect bilateral growth rates, so that the variance of the source effects is zero. By contrast, high ϕ would manifest ifself in a high variability of the source effects. The variance of the source effects is benchmarked by the variance of the destination effects, since those are driven by the same productivity shock process as the source effects, but affect all the firms operating in each market.

Table 5 presents the implied ϕ for different values of $\frac{\psi}{\rho-1}$. We focus on the special case of $\frac{\psi}{\rho-1} = 1$, in which the general equilibrium effects cancel out, and the alternative cases of $\frac{\psi}{\rho-1} = 2$ (the effect of a positive foreign shocks on domestic income overcomes the effects on increased competition) and $\frac{\psi}{\rho-1} = 2/3$ (the increase in competition overcomes the effect of increased income).[15]

[15] The special case of $\psi = \rho - 1$ is not inconsitent with empirical estimates of the Frisch elasticity of labor supply and the elasticities of substitution across intermediate varieties used in the trade literature. In particular, estimates of the aggregate labor supply elasticity put it at about 0.5 [see Chetty et al., 2013], which implies a $\bar{\psi} = 3$ and $\psi = 1.5$. This implies that $\rho = 2.5$ – well within the range of estimates in Broda and Weinstein [2006]– is consitent with $\frac{\psi}{\rho-1} = 1$. Under an aggregate labor supply elasticity of about 0.5,

Table 5: Estimated ϕ based on source-destination data

Year	$\frac{\psi}{\rho-1}=1$	$\frac{\psi}{\rho-1}=2$	$\frac{\psi}{\rho-1}=\frac{2}{3}$
2005	0.470	0.552	0.375
2006	0.449	0.531	0.373
2007	0.390	0.472	0.319
2008	0.373	0.482	0.286
2009	0.395	0.532	0.294
2010	0.400	0.518	0.308
2011	0.379	0.491	0.289
2012	0.357	0.444	0.289
Mean	**0.401**	**0.503**	**0.317**
Median	**0.392**	**0.505**	**0.301**

Notes: This table reports estimates of ϕ using bilateral data following equation (25). Each column represents the estimate under an alternative value of the GE parameter $\frac{\psi}{\rho-1}$.

The estimates of ϕ range from 0.3 to 0.5, with a central tendency of about 0.4. This is higher than, but not too dissimilar from, the firm-level estimates in Section 4.2.

What are the relative merits of the firm-level based estimates of ϕ from Section 4.2 compared to the source-destination level estimates in this section? The firm-level estimates use stringent fixed effects, and thus represent the most convincing evidence that the correlation between parents and affiliates captures within-firm transmission of shocks rather than simply common shocks across countries and/or sectors. On the other hand, precisely because it nets out common shocks at the source-sector-destination-sector-year level, the firm-level estimation will omit the within-firm transmission of aggregate shocks. A shock that hits all the firms in the Chemicals sector in France may be transmitted from the French parent operating in the Chemicals sector to its subsidiaries in Spain. But the fixed effects in the firm-level specification net out the aggregate/sectoral shocks, and thus identify only the transmission of the idiosyncratic shock hitting the French Chemicals parent. By contrast, the source and destination effects will capture not only the transmission of firm-level, but also of aggregate shocks in the parent country to the foreign destinations.

$\frac{\psi}{\rho-1}=2$ (resp., $\frac{2}{3}$) is consistent with an elasticity of substitution of $\rho=\frac{7}{4}$ (resp., 3.25).

5 Quantitative results

We now have the theoretical structure, the estimates of the key parameter, and the data to carry out a quantitative assessment of multinationals' role in the international business cycle transmission. This section performs three exercises. The first is an "impulse response" exercise designed to answer the question, how much does a productivity shock in one country change output in another? The second is a counterfactual correlation exercise, that answers the question, if all the countries' productivity shocks were uncorrelated, how much correlation would the business cycles exhibit across countries under the current levels of multinational activity? And third, how much do multinationals contribute to observed dispersion in cross-country growth rates, and how much would that dispersion fall if integration increased further?

5.1 Transmission of shocks across countries

5.1.1 Country-level

We now use our parameterized model to evaluate how productivity shocks to any source country spread across countries. From 18, the response of output to a productivity shock in any source country i is given by:

$$\frac{\partial \gamma_n}{\partial z_i} = \psi \left[\omega_{in} \phi + (1-\phi) \mathbb{I}_{i=n} \right] \tag{26}$$

where $\mathbb{I}_{n=n'}$ is an indicator function that equals 1 if $n = n'$ and 0 otherwise. We can express the response in country n as a fraction of the effect of the shock in the source country i as:

$$\frac{\partial \gamma_n}{\partial z_i} / \frac{\partial \gamma_i}{\partial z_i} = \frac{\omega_{in}\phi}{\omega_{ii}\phi + (1-\phi)} \quad n \neq i. \tag{27}$$

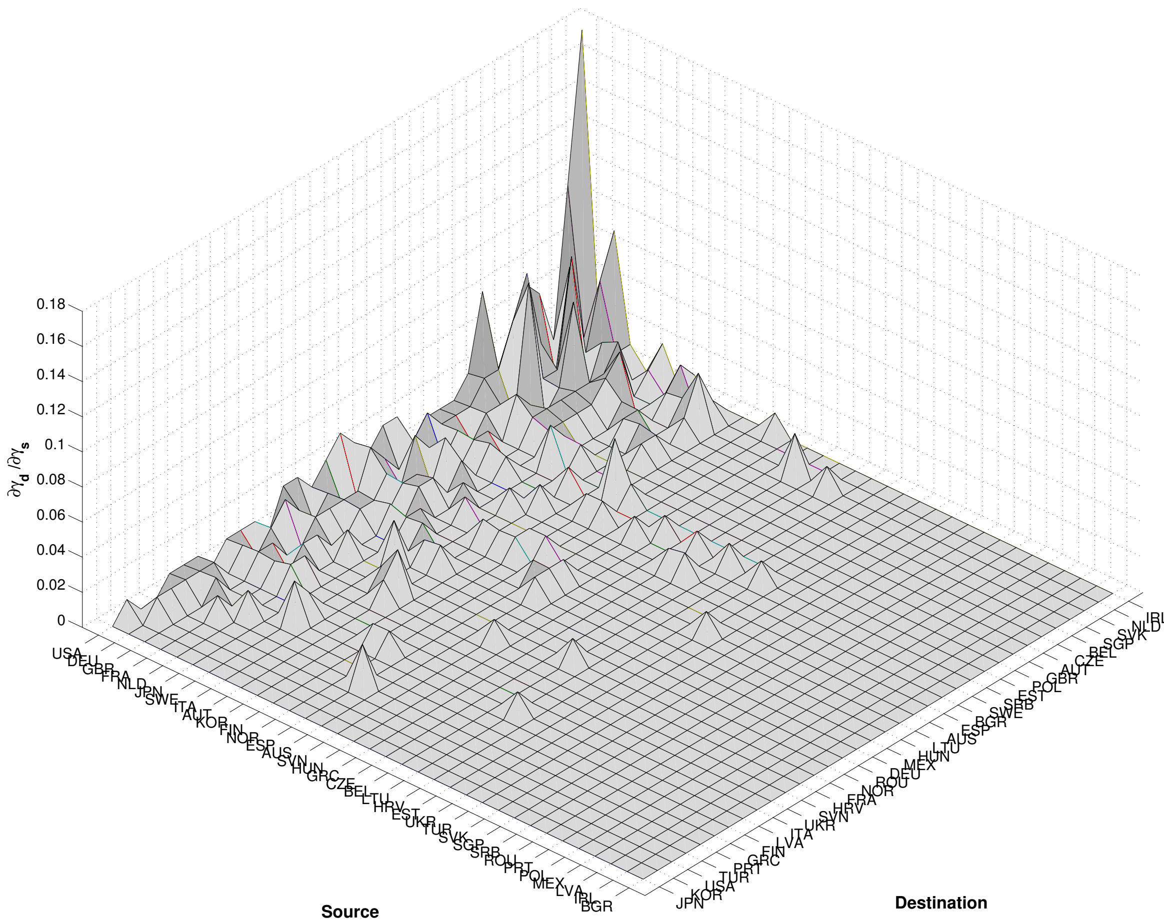
Equation (3) answers the question, how much does aggregate output in country n change when output in country i goes up by 1? It is immediate that the answer depends on two key quantities: the magnitude of the spillover ϕ, and the extent of country i's multinational presence in n, ω_{in}. If either of these is large, there will be more interdependence between i and n. In contrast, note that given these parameters, this impulse response does not depend on the value of the general equilibrium parameter $\frac{\psi}{\rho-1}$. There is no simulation required to compute these impulse responses. Instead, they are computed directly from the data on ω_{in} and estimated ϕ. Since there are 34 countries in the sample, there are 34×33 cross-border impulse responses.

Figure 3 shows the impulse responses to source specific shocks for all possible country pairs. We use $\phi = 0.4$ and ω_{in}'s for 2011 to construct the figure. Each square in the figure represents the impulse response in destination n to a shock to productivity in source country i, z_i, relative to the response in the source country, as in (27). We can interpret each square of the figure as the percent change in country n GDP to a shock that increases GDP in country i by one percent. We rank countries in the x and y axes according to their importance as a source or as a destination, respectively. We omit the ii entries (they are all tautologically 1) to facilitate the presentation.

The figure shows that shocks to the productivity of most source countries do not have big aggregate consequence in most destinations. This reflects the fact that the bilateral shares ω_{in} in equation (27) are small for most country pairs. In more than half of all source-destination pairs, the impact is exactly zero, reflecting the absence of multinationals from most sources in most destinations. Among the nonzero pairs, the mean and median impact is about 0.006, that is, an increase in a source country output of 1% changes foreign output by less than one-hundredth of that amount. However, this low amount of transmission on average masks a number of outliers. US, Germany, and UK have the highest average outward impact, at 0.022, 0.014, and 0.013 respectively. About 16 country pairs have impulse response coefficients of above 0.03, with the maximum coefficient of 0.17 between US and Ireland.

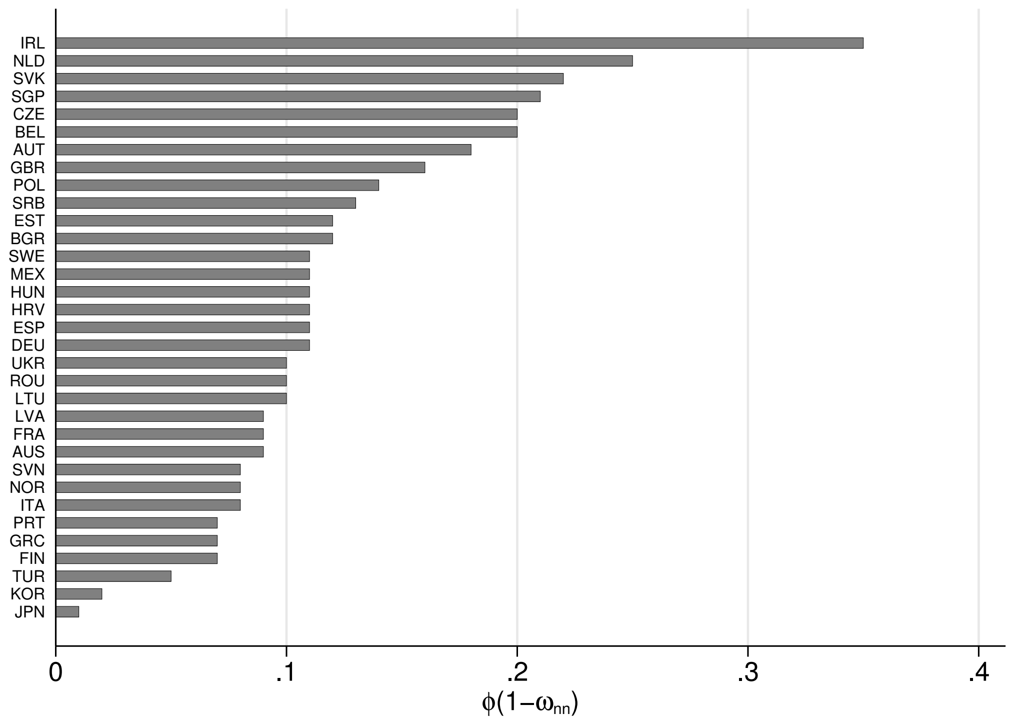
This section so far considered the transmission of shocks from one individual country to another. A distinct but related question is what is the total impact of all foreign productivity shocks on a country's productivity. One way to gauge the importance of all foreign shocks combined is to consider the impact of a 1% change in all foreign productivities simultaneously. The impact on destination n's productivity in this experiment is given by $\phi(1 - \omega_{nn})$. Figure 4 displays the results. In our sample of 34 countries, the mean value of this combination of parameters is 0.12, with the median of 0.11. This suggests that loosely speaking, foreign shocks can account for 11% of productivity shocks in the median country, or alternatively, foreign shocks are about one-ninth as important as domestic productivity shocks. There are some countries, however, in which foreign shocks are more significant. At the extreme, the value of this combination of parameters is 0.35 in Ireland, 0.25 in the Netherlands, and 0.22 in Slovakia.

Figure 3: Response (in %) to a source shock that raises source country output by 1%



Notes: This figure displays the change in aggregate output of each destination that accompanies a change in source output equal to 1.

Figure 4: Response (in %) to a 1% shock in all foreign countries simultaneously



Notes: This figure displays the change in productivity in each destination that accompanies a change in productivity in every foreign source country (i.e. $i \neq n$) equal to 1.

5.1.2 Firm-level

Above we established that a few top multinationals often comprise a large share of output in both the source and destination countries. This section analyzes the extent to which shocks to the largest multinational firms spread across countries. The response of country n's aggregate output to a productivity shock to firm f is given by

$$\frac{\partial \gamma_n}{\partial z_i(f)} = \psi \omega_{in}(f) \left[\phi + (1-\phi)\, \mathbb{I}_{i=n}\right] \tag{28}$$

where $\omega_{in}(f)$ is the share of firm f headquartered in i in total sales of all firms in country n. Expressed relative to the aggregate output in the parent's country, it becomes:

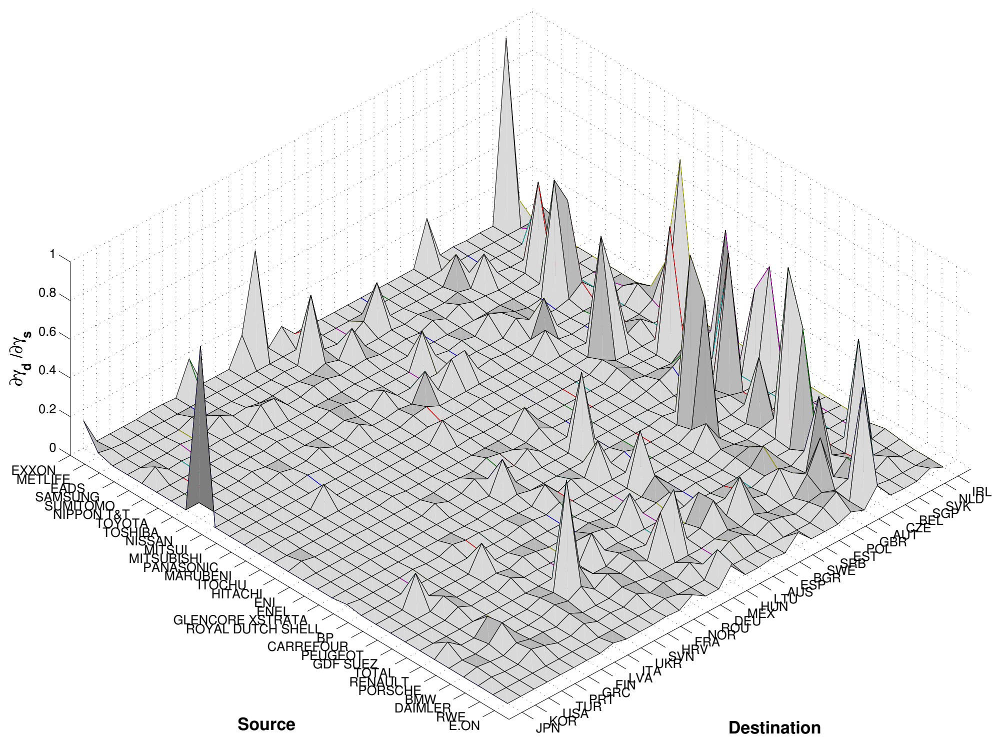
$$\frac{\partial \gamma_n}{\partial z_i(f)} / \frac{\partial \gamma_i}{\partial z_i(f)} = \frac{\omega_{in}(f)\phi}{\omega_{ii}(f)\left[\phi + (1-\phi)\right]} \quad n \neq i. \tag{29}$$

This equation states how much foreign aggregate output moves relative to the domestic aggregate output when a (large) firm experiences a productivity shock.

Figure 5 presents the results for the top 30 largest multinationals in our data by their combined foreign sales. Since we are focusing on firm-level shocks, in this exercise we use $\phi = 0.2$, which is consitent with our firm level estimates. Among these top firms, the average share of sales in the domestic market is 0.02, implying that a 1% shock to those firms moved domestic sales by 0.02% on average. These firms have a broad presence in our sample, with affiliates on average in 17 foreign destinations (out of possible 33). Conditional on having an affiliate, the value of the relative transmission (as in eq. 29) is 0.04. However, this average hides a substantial upper tail: the 95th percentile is 0.22. One particularly globally diversified firm is Porsche (which also owns Volkswagen). Relative to its impact on German aggregate output, its impact is 0.28 on the Czech Republic, 0.19 on the Slovak Republic, 0.15 on Hungary and 0.11 on Mexico, with 3 additional countries with impact above 0.05.

We conclude that while an average top multinational's impact on a randomly selected foreign market is negligible, individual multinationals often have an impact on particular foreign markets that is comparable in order of magnitude to their impact on their home market.

Figure 5: Response of foreign aggregate output relative to domestic aggregate output



Notes: This figure displays the change in foreign aggregate output in each destination relative to the change in the domestic aggregate output of the country in which the firm is headquartered.

5.2 Country pair growth correlations and multinational shares

This section derives how much covariance/correlation in aggregate output would be generated by the presence of multinationals in a world where the only shocks are shocks to country-level productivities z_i that are uncorrelated across countries. Under these conditions, (18) implies that the covariance of aggregate growth rates between any pair of countries n, n' is given by

$$cov\left(\gamma_{n,t}, \gamma_{n',t}\right) = \left[\frac{\psi}{\rho-1}\right]^2 cov\left(\sum_i \omega_{in,t} s_{i,t} + \frac{1-\phi}{\phi} s_{nt}, \sum_{i'} \omega_{i'n',t} s_{i',t} + \frac{1-\phi}{\phi} s_{n't}\right) \quad (30)$$

Noting that $s_{i,t} = \phi\left(\rho-1\right) z_{i,t}$, we can write this as:

$$\begin{aligned} cov\left(\gamma_{n,t}, \gamma_{n',t}\right) &= \left[\phi\left(1-\phi\right)\sum_i \omega_{in,t} cov\left(z_{i,t}, z_{n't}\right) + \phi\left(1-\phi\right)\sum_i \omega_{in',t} cov\left(z_{nt}, z_{i,t}\right)\right. \\ &+ \left.\phi^2 \sum_i \sum_{i'} \omega_{in,t}\omega_{i'n',t} cov\left(z_{i,t}, z_{i',t}\right) + cov\left(z_n, z_{n'}\right)\right]\left[\frac{\psi}{\rho-1}\right]^2. \end{aligned}$$

Under the assumption that $cov\left(z_{n,t}, z_{n',t}\right) = 0$ for $n \neq n'$ we can write:

$$cov\left(\gamma_{n,t}, \gamma_{n',t}\right) = \left[\phi\left(1-\phi\right)\left[\omega_{n'n,t} + \omega_{nn',t}\right] + \phi^2 \sum_i \omega_{in,t}\omega_{in',t}\right]\left[\frac{\psi}{\rho-1}\right]^2 \sigma_z^2, \quad (31)$$

where σ_z^2 is the variance of z. Under the same assumptions, we can write the variance of $q_{n,t}$ as:

$$var\left(q_{n,t}\right) = \Theta_n^2 \left[\frac{\psi}{\rho-1}\right]^2 \sigma_z^2,$$

where $\Theta_n^2 \equiv \left[\phi^2 \sum_i \omega_{in,t}^2 + 2\phi\left(1-\phi\right)\omega_{nn,t} + \left(1-\phi\right)^2\right]$. The correlation between any pair of countries is then:

$$\rho_{n,n'} = \frac{\phi\left(1-\phi\right)\left[\omega_{n'n,t} + \omega_{nn',t}\right] + \phi^2 \sum_i \omega_{in,t}\omega_{in',t}}{\Theta_n \Theta_{n'}}. \quad (32)$$

Note that while the covariance in equation (31) depends on the size of the general equilibrium effects (captured by $\left[\psi/\left(\rho-1\right)\right]^2$) and the variance of the shocks σ_z^2, the correlation $\rho_{n,n'}$ is a function only of the correlation in firm-level growth ϕ, and the multinational shares, ω_{in}. Given a value of ϕ, the size of the general equilibrium effects do not affect the

Table 6: Predicted and actual correlations

$\rho_{n,n'}$	Mean	St.Dev.	Min	Max
Counterfactual	0.01	0.02	0.00	0.25
Data	0.80	0.13	0.44	0.99

Notes: This table reports summary statistics for aggregate correlations. The row labeled "Counterfactual" reports the results for correlations computed using equation (32). The row labeled "Data" reports the actual correlations of aggregate output in ORBIS, 2004-2012.

results in this section.

Table 6 presents the correlations predicted by the model. Consistent with our results from the previous section, the predicted correlations tend so be small. The mean is only 0.01, and 95% of all the bilateral correlations are below 0.03. There are some outliers, however. Ireland has a predicted correlation of 0.25 with the US and 0.12 with the UK. Netherlands has a predicted correlation with the US of 0.12. For the sake of comparison, the bottom row presents the actual aggregate output correlations in ORBIS. As is well-known, correlations are much higher in the data. We conclude that in a large majority of country pairs, transmission of shocks through multinationals in and of itself cannot generate anything close to observed output correlations.

5.3 Predicted and counterfactual comovements

In this section we further investigate the effect of multinationals on output comovements by studying the predicted comovements in our model. We first use our estimates of ϕ, $a_{in,t}$, and $s_{i,t}$ to compute aggregate growth rates in the model using equations (4), (24) and the definitions of $\mathcal{S}_{n,t}$ and $\mathcal{A}_{n,t}$. We thenconduct two sets of counterfactual exercises to investigate how multinationals contribute to cross-country comovement. Our metric of comovement is the cross-sectional dispersion in country-level growth rates (see Section 3.2.1).

Changing multinational shares In the first set of counterfactuals, we ask what the cross-country dispersion in growth rates would look like if multinational shares where different. We focus on two polar opposite counterfactuals: (i) "No multinationals" and (ii) "Full Integration." Under "No Multinationals," we change the values of the ω_{in}'s so that $\omega_{in,t}^{NM} = 1$ if $i = n$, $\omega_{in,t}^{NM} = 0$ if $i \neq n$. That is, the only firms producing in country i are country i firms. Under "Full Integration" we change the ω_{in}'s so that $\omega_{in,t}^{FI} = \bar{\omega}_{i,t}^{FI} = \frac{1}{N}\sum_n^N \omega_{in,t}$.[16] That is, the production shares of firms of all source coun-

[16]Note that $\sum_i \bar{\omega}_{i,t} = \frac{1}{N}\sum_n \sum_i \omega_{in,t} = 1$.

tries is the same in every country, and equal to the average share of each country i across destinations observed in the data.

In each of the counterfactual exercises indexed by $c = \{NM, FI\}$, we compute the counterfactual components $\mathcal{S}^c_{n,t}$, $\mathcal{A}^c_{n,t}$, $\mathcal{D}^c_{n,t}$ using estimated $s_{i,t}$ and $a_{in,t}$ as:

$$\begin{aligned} \mathcal{S}^c_{n,t} &= \sum_i \omega^c_{in,t} s_{i,t} - \frac{1}{N}\sum_n \sum_i \omega^c_{in,t} s_{i,t} \\ \mathcal{A}^c_{n,t} &= \sum_i \omega^c_{in,t} a_{in,t} - \frac{1}{N}\sum_n \sum_i \omega^c_{in,t} a_{in,t} \\ \mathcal{D}^c_{n,t} &= \frac{\psi + 1 - \rho}{\rho - 1}\left[\mathcal{A}^c_{n,t} + \mathcal{S}^c_{n,t}\right] + \frac{\psi}{\rho - 1}\frac{1-\phi}{\phi}\mathcal{S}^{own}_{n,t}. \end{aligned} \tag{33}$$

and use them to compute the counterfactual growth rates $\gamma^c_{n,t}$ and variances $\sigma^c_{\gamma_{n,t}}$ from equations (4) and (5). Our baseline results adopt the assumption that $\frac{\psi}{\rho-1} = 1$ (the destination shocks are independent of the general equilibrium effects).

Table 7 reports the actual and counterfactual dispersion of growth rates for every year in our sample. The second column shows that the standard deviations of growth rates produced by the model are somewhat higher but strongly related to those in the data. Column 3 reports the standard deviation of growth rates under the "No multinationals" counterfactual. Note from equation (33) that the dispersion of $\mathcal{S}^c_{n,t}$ is higher under this scenario, since multinationals are not there to spread the source shocks across countries. We see that for the median year, the standard deviation of growth rates would increase by 10% in the absence of multinationals.

Column 4 reports the standard deviation of growth rates under the "Full Integration" counterfactual. Note from equation (33) that in this case $\mathcal{S}^c_{n,t} = 0$ (since ω_{in} is constant across destinations). Source shocks are completely shared across destinations under full integration, hence, differences do not contribute to the dispersion in growth rates. As a consequence, the dispersion in growth rates is significantly smaller under this scenario. For the median year, the standard deviation of growth rates would increase by 35% if all barriers to multinationals are eliminated.

Table 8 conducts sensitivity analysis to alternative values of the GE parameter $\frac{\psi}{\rho-1}$. We focus on the cases of $\frac{\psi}{\rho-1} = 2$ and $\frac{\psi}{\rho-1} = 2/3$ discussed in Section 4.4. Under each alternative parameterization, we re-calibrate the parameter ϕ according to equation (25). The table shows that the case $\frac{\psi}{\rho-1} = 2$ is associated with slightly larger counterfactual changes in the cross-sectional variance of growth rates, while the opposite is true for the case of $\frac{\psi}{\rho-1} = 2/3$. Note, however, that the alternative parameterizations do not change the order of magnitude of the results.

Table 7: Cross-sectional standard deviation in $\gamma_{n,t}$

Year	Data	Model	NM: No Multinationals	FI: Full Integration	NM/Model	FI/Model
2005	0.039	0.066	0.072	0.042	1.093	0.642
2006	0.026	0.051	0.058	0.036	1.126	0.697
2007	0.023	0.039	0.041	0.028	1.047	0.698
2008	0.052	0.066	0.071	0.044	1.065	0.663
2009	0.056	0.069	0.081	0.045	1.175	0.646
2010	0.047	0.065	0.070	0.052	1.081	0.803
2011	0.041	0.056	0.063	0.033	1.134	0.603
2012	0.032	0.051	0.053	0.032	1.029	0.633
Mean	**0.039**	**0.058**	**0.064**	**0.039**	**1.094**	**0.673**
Median	**0.040**	**0.060**	**0.066**	**0.039**	**1.087**	**0.654**

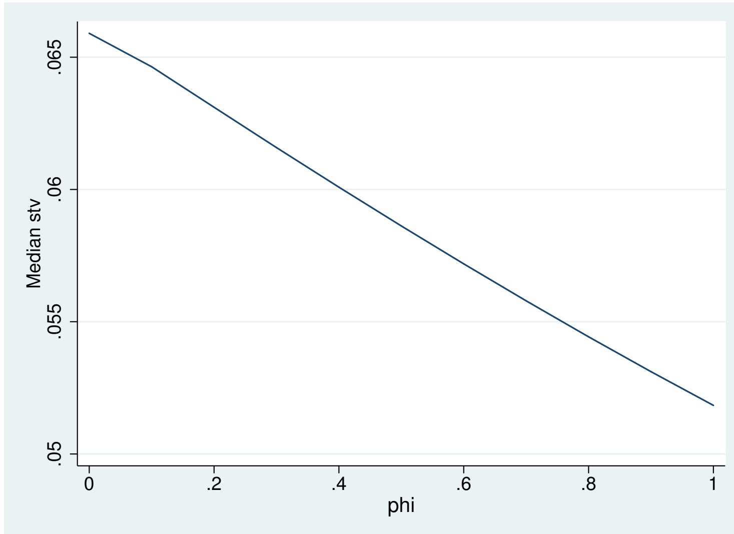
Notes: This table reports the cross-sectional standard deviation in aggregate growth rates. Column "Data" reports this standard deviation from the data. "Model" reports the same standard deviation from the simulated model. Columns "NM" and "FI" report the results of the two counterfactuals, and the last two columns report the ratios of counterfactuals and model.

Table 8: Sensitivity to GE parameter

Year	NM/Model	FI/Model	NM/Model	FI/Model
	$\frac{\psi}{\rho-1}=2;\phi=0.5$		$\frac{\psi}{\rho-1}=2/3;\phi=0.3$	
2005	1.111	0.582	1.071	0.724
2006	1.157	0.648	1.094	0.766
2007	1.058	0.673	1.035	0.751
2008	1.089	0.585	1.044	0.748
2009	1.213	0.577	1.134	0.729
2010	1.099	0.775	1.061	0.842
2011	1.165	0.544	1.101	0.685
2012	1.036	0.576	1.022	0.712
Mean	**1.116**	**0.620**	**1.070**	**0.745**
Median	**1.105**	**0.583**	**1.066**	**0.739**

Notes: This table reports the ratios the cross-sectional standard deviation of growth rates between the counterfactuals and model under the parameterization specified in the colum headers.

Figure 6: Correlation between multinationals and their foreign affiliates (ϕ) and the cross-sectional dispersion of aggregate growth rates



Notes: This table reports the standard deviation of aggregate growth rates on the y-axis against the share of source shocks in the affiliates' technology shocks (ϕ) on the x-axis.

Changing the correlation in firm level growth In the second set of counterfactuals, we maintain the observed multinational shares and change the correlation between parents and affiliates ϕ^c. In this case we can compute the counterfactual components as:

$$\begin{aligned}
\mathcal{S}^{c\phi}_{n,t} &= \frac{\phi^c}{\phi}\mathcal{S}_{n,t}, \\
\mathcal{A}^{c\phi}_{n,t} &= \mathcal{A}_{n,t} \\
\mathcal{D}^{c\phi}_{n,t} &= \left[\frac{\psi}{\rho-1}-1\right]\left[\mathcal{A}_{n,t}+\mathcal{S}^{c\phi}_{n,t}\right]+\frac{\psi}{\rho-1}\frac{1-\phi^c}{\phi}\mathcal{S}^{own}_{n,t}.
\end{aligned}$$

Figure 6 shows the resulting standard deviation in growth rates for alternative values for counterfactual ϕ. As ϕ get closer to zero, there is no transmission of shocks between multinational firms and their foreign affiliates, and the standard deviation in growth rates increases and gets closer to that in the counterfactual of "No Multinationals." As ϕ gets closer to one, the correlation between multinationals and their foreign affiliates becomes stronger, and the dispersion in growth rates decreases. Yet, this effect is limited by the fact that the share of multinationals in the economy is small.

6 Conclusion

Understanding how economic shocks are transmitted across countries is one of the central questions in international macroeconomics. In this paper, we used new data and a quantitative model to assess how shocks are transmitted internationally through firms that operate in multiple countries. Our empirical results demonstrate important interdependence between source countries and their foreign affiliates. This interdependence is detectable both at the firm and the source-destination level. We use a quantitative model to interpret these findings and to evaluate the role of multinationals for international business cycle comovements. Even though foreign multinationals account for a large share of total output, bilateral shares tend to be small, limiting the contribution of multinationals for observed comovements. Yet, for for some country pairs with strong multinational activity, the effects of multinationals on the observed transmission of shocks is significant. In the benchmark parameterization, eliminating barriers to multinational production decreases the cross-country standard deviation in growth rates by 35 percent, indicating that international comovements may become significantly stronger as the share of multinationals in the world economy increases.

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Appendix A Extensions

A.1 Armington final goods model

We now show how to extend our model to a case in which the final goods produced in each country are differentiated by origin. In particular, we assume that the consumption composite is given by:

$$C_t = \left[\sum_n Q_{n,t}^{\frac{\epsilon-1}{\epsilon}}\right]^{\frac{\epsilon}{\epsilon-1}}, \tag{A.1}$$

so that $C_t = \sum_i C_{i,t}$. The inverse demand for the final output of each country n is given by:

$$P_{n,t} = \left[Q_{n,t}\right]^{-1/\epsilon}\left[\frac{C_t}{P_{c,t}^{-\epsilon}}\right]^{-1/\epsilon},$$

where $P_{c,t}$ is the price index associated with the aggregator (A.1). Aggregate revenues in country n are given by:

$$P_{n,t}Q_{n,t} = Q_{n,t}^{\frac{\epsilon-1}{\epsilon}}\left[\frac{C_t}{P_{c,t}^{-\epsilon}}\right]^{-1/\epsilon}.$$

The growth rate is

$$\gamma_{n,t} = \frac{\epsilon-1}{\epsilon}\psi\sum_i\sum_{f\in\Omega_i}\omega_{in,t}(f)\left[\frac{a_{in,t}}{\rho-1}+z_{in,t}(f)\right],$$

which coincides with equation (21) up to the constant $\frac{\epsilon-1}{\epsilon}$. Differences in growth rates across countries are given by:

$$\gamma_{n,t}-\bar{\gamma}_t = \frac{\epsilon-1}{\epsilon}\left[\bar{q}_{n,t}-\bar{q}_t\right],$$

while the counterfactual growth rates will be given by

$$\gamma_{n,t}^c-\bar{\gamma}_t^c = \frac{\epsilon-1}{\epsilon}\left[\bar{q}_{n,t}^c-\bar{q}_t^c\right].$$

Thus, for given values of ϕ and shares ω_{in}, the ratio of actual to counterfactual growth rates and variances is independent of ϵ.

A.2 Low elasticity of substitution between Z_i and Z_n

We now show how to extend the model to a setting in which parent and affiliate productivities are combined by a CES aggregator, as opposed to Cobb-Douglas. In particular, we assume that the production function for intermediate goods is given by:

$$Q_{in,t}(f) \;=\; Z_{in,t}(f)\, L_{in,t}(f)\,. \tag{A.2}$$

where

$$Z_{in,t}(f) \;=\; \left[\phi Z_{i,t}(f)^{\frac{\eta-1}{\eta}} + (1-\phi)\, Z_{n,t}(f)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}. \tag{A.3}$$

The formulation in the main text corresponds to the limiting case of $\eta = 1$.

Aggregate output is given by equation (16), and output growth is given by (21). Differences from out baseline framework are driven by the effect of η on the growth rate of $Z_{in,t}(f)$ (A.3). We show that the difference is zero to a first order approximation. In particular, log linearizing (A.3) around a symmetric $Z_n = Z_i$ we obtain:

$$z_{in,t} = \;\; \phi z_{i,t} + (1-\phi)\, z_{n,t}.$$

which coincides with the growth rate used in the text.

A.3 Intermediate input linkages

In this section we present a version of the model in Section 4 in which the transmission of shocks within multinationals is driven by vertical production linkages. In particular, we maintain the structure of the model in Section 4, but assume that each firm operates a Cobb-Douglas technology that uses labor in the destination country and intermediate inputs that are produced in the firm's headquarter. The firm-level production function is given by:

$$Q_{in,t}(f) \;=\; \left(Z_{n,t}(f)\, L_{in,t}(f)\right)^{1-\phi} X_{in,t}(f)^{\phi}\,, \tag{A.4}$$

where $Z_{n,t}(f)$ is a firm specific productivity component, and $X_{in,t}(f)$ is a intermediate input that is specific to the multinational group. In what follows we refer to $Q_{in,t}(f)$ as intermediate goods, and to $X_{in,t}(f)$ as intermediate inputs. Intermediate input are produced by the firm's parent using the homogeneous final good. Crucially, affiliates cannot produce the intermediate input themselves and cannot use the intermediate inputs produced by other firms.

Parent firms operate a technology that turns one unit of the final good into $Z_{i,t}(f)$ units in of the firm-specific intermediate input,

$$X_{i,t}(f) \;=\; Z_{i,t}(f)\, M_{i,t}(f)\,, \tag{A.5}$$

where $M_{i,t}(f)$ is the amount of the final good used by firm f in country i to produce intermediate inputs. Note that market clearing in intermediate inputs implies: $X_{i,t}(f) = \sum_n X_{in,t}(f)$, that is, production of intermediate inputs by the headquarter is equal to the combined the demand of intermediate inputs by the parents affiliates in all destinations (including the domestic destination). The firm's parent can also produce intermediate inputs $Q_{ii,t}(f)$ with the production function given in (A.4).

The production function in equation (A.5) implies that the cost of producing a unit of the intermediate input is given by $C^x_{i,t}(f) = P^W_t / Z_{i,t}(f) = 1/Z_{i,t}(f)$. The marginal cost of producing a unit of the intermediate good in destination country n is given by: $C_{in,t}(f) = \bar{\phi}^{-1}(W_{n,t}/Z_{n,t}(f))^{1-\phi}(1/Z_{i,t}(f))^{\phi}$, where $\bar{\phi} \equiv \phi^{\phi}(1-\phi)^{1-\phi}$ is a constant. The multinational firm chooses $X_{in,t}(f)$ and $L_{in,t}(f)$ to maximize world-wide profits subject to equations (A.5) and (11). Profit maximization implies a constant markup over marginal cost:

$$P_{in,t}(f) \;=\; \frac{\rho}{\rho-1}\bar{\phi}^{-1}\left(\frac{W_{n,t}}{Z_{n,t}(f)}\right)^{1-\phi}\left(\frac{P^w_t}{Z_{i,t}(f)}\right)^{\phi}. \tag{A.6}$$

Combining equations (9) and (A.6) we can write the real wage as:

$$\frac{W_{n,t}}{P_{n,t}} \;=\; \bar{\phi}^{-1}\frac{\rho-1}{\rho}\left[\sum_i\sum_{f\in\Omega_i} A_{in,t}Z_{in,t}(f)^{(\rho-1)}\right]^{\frac{1}{(1-\phi)(\rho-1)}}. \tag{A.7}$$

Profit maximization by intermediate good producers implies that aggregate revenues are a constant share ϕ of total labor payments:

$$\sum_i P_{in,t}Q_{in,t} = P_{n,t}Q_{n,t} \;=\; \frac{\rho}{\rho-1}\frac{1}{1-\phi}W_{n,t}L_{n,t}, \tag{A.8}$$

which in combination with (14) and (13) permits expressing the aggregate production function as:

$$Q_{n,t} \;= \tfrac{1}{1-\phi}\;\left[\sum_i\sum_{f\in\Omega_i} A_{in,t}Z_{in,t}(f)^{\rho-1}\right]^{\frac{\bar{\bar{\psi}}}{1-\rho}}. \tag{A.9}$$

Equation (A.9) implies that the growth rate of output and value added (which is a fraction $1-\phi$ of output) in the model is given by equations (17) and (18), where the parameter ψ is now substituted with $\bar{\bar{\psi}} \equiv \frac{\psi}{1-\phi}$.

We can parameterize ϕ in this version of the model using either firm-level or source-destination level data, as in Section 4. In particular, since value added at the firm level is proportional to firm-level revenues, equation (21) represents value added growth at the firm level.[17] Hence, we can interpret the coefficients of our value added regression in Section 3 as ϕ in this model, which gives us $\phi = 0.14$. Alternatively, equation (2) represents value added growth rate at the source-destination level, which for a given combination of the GE parameters $\frac{\bar{\bar{\psi}}}{1-\rho}$ can be used to calibrate ϕ. Given values for ϕ and, revenue shares

[17] In this version of the model, equation (19) represents both value added and revenue growth for the affiliates. Note, however, that the parent's revenue now includes exports of the intermediate input, so that equation (20) does not represent the parents' revenue growth, though it does represent parents' value added growth.

$\omega_{in,t}$ and a the composite parameter $\frac{\bar{\bar{\psi}}}{1-\rho}$, we can reinterpret our quantitative results in Section 5 through the lens of this model of intermediate input linkages.

Table A1: Bilateral Multinational Shares

Source → *Dest* ↓	AUT	AUS	BEL	BUL	CZE	DEU	EST	ESP	FIN	FRA	GBR	GRE	HRV	HUN	IRL	ITA	JPN	KOR	LTU	LVA	MEX	NLD	NOR	POL	PRT	ROM	SRB	SWE	SGP	SVN	SVK	TUR	UKR	USA	ROW
AUT	58.9	0.0	0.2	0.0	0.0	13.1	0.0	0.2	0.4	1.4	4.6	0.0	0.0	0.1	0.2	1.4	3.8	0.5	0.0	0.0	0.1	1.4	0.2	0.1	0.1	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	3.5	9.3
AUS	0.0	74.0	0.1	0.0	0.0	0.7	0.0	0.2	0.1	1.1	5.4	0.0	0.0	0.0	0.1	0.0	2.7	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.1	0.7	0.0	0.0	0.0	0.0	5.7	8.6
BEL	0.2	0.1	48.4	0.0	0.0	4.6	0.0	0.2	0.2	14.1	1.8	0.2	0.0	0.0	0.2	1.4	5.8	0.2	0.0	0.0	0.0	3.1	0.2	0.0	0.0	0.0	0.0	1.4	0.1	0.0	0.0	0.0	0.0	10.9	6.9
BUL	2.3	0.0	0.4	73.2	1.4	4.0	0.0	0.1	0.0	0.6	0.9	1.5	0.2	0.1	0.0	0.4	0.1	0.0	0.0	0.0	0.0	0.9	0.5	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.3	0.1	1.6	10.9
CZE	3.4	0.0	0.4	0.0	52.1	14.8	0.0	1.3	0.2	2.9	3.3	0.0	0.0	0.1	0.2	1.9	1.9	0.7	0.0	0.0	0.0	2.3	0.0	0.4	0.0	0.0	0.0	0.8	0.0	0.0	0.6	0.0	0.0	3.8	8.4
DEU	0.7	0.1	0.5	0.0	0.0	75.1	0.0	0.2	0.3	1.9	3.5	0.0	0.0	0.0	0.1	0.8	2.3	0.5	0.0	0.0	0.1	2.0	0.3	0.1	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0	5.9	4.2
EST	0.3	0.0	0.1	0.0	0.0	1.9	69.9	0.0	7.2	1.5	2.2	0.0	0.0	0.0	0.2	0.1	0.5	0.0	0.5	0.4	0.0	0.6	1.0	1.0	0.0	0.0	0.0	6.9	0.2	0.0	0.0	0.0	0.2	1.3	3.9
ESP	0.2	0.0	0.2	0.0	0.0	3.7	0.0	73.6	0.1	5.2	1.9	0.0	0.0	0.0	0.2	2.2	0.9	0.2	0.0	0.0	0.1	1.6	0.1	0.0	0.7	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	3.9	4.8
FIN	0.2	0.0	0.0	0.0	0.0	1.8	0.2	0.0	81.3	0.9	1.0	0.0	0.0	0.0	0.2	0.2	0.9	0.3	0.0	0.0	0.0	0.8	0.4	0.0	0.0	0.0	0.0	4.2	0.0	0.0	0.0	0.0	0.0	2.3	5.3
FRA	0.1	0.1	1.0	0.0	0.0	2.9	0.0	0.4	0.2	77.1	2.6	0.0	0.0	0.0	0.2	1.1	1.1	0.2	0.0	0.0	0.0	2.7	0.1	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	5.7	3.9
GBR	0.1	0.6	0.3	0.0	0.0	4.2	0.0	1.1	0.2	3.8	60.0	0.0	0.0	0.0	1.0	0.6	2.0	0.3	0.0	0.0	0.2	1.5	0.2	0.0	0.0	0.0	0.0	0.5	0.1	0.0	0.0	0.0	0.0	14.2	9.2
GRE	0.1	0.0	0.9	0.0	0.0	2.1	0.0	0.2	0.1	1.1	2.6	81.6	0.0	0.0	0.4	0.7	0.3	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	2.4	6.1
HRV	4.6	0.0	0.1	0.0	0.2	4.4	0.0	0.1	0.0	1.6	0.3	0.0	78.3	0.4	0.1	2.3	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.1	0.0	0.0	0.2	0.2	0.0	1.8	0.0	0.0	0.0	0.9	3.8
HUN	1.4	0.0	0.1	0.0	0.0	6.8	0.0	0.1	1.7	2.6	1.5	0.0	0.0	74.4	0.0	0.9	1.1	0.9	0.0	0.0	0.1	1.2	0.3	0.0	0.0	0.0	0.0	0.6	0.9	0.0	0.0	0.0	0.0	3.5	2.0
IRL	0.0	0.2	0.6	0.0	0.0	4.0	0.0	3.4	0.2	4.9	18.2	0.0	0.0	0.1	16.5	1.8	2.7	0.6	0.0	0.0	0.1	1.3	0.3	0.0	0.0	0.0	0.0	0.6	0.2	0.0	0.0	0.0	0.0	35.7	8.7
ITA	0.2	0.0	0.2	0.0	0.0	2.6	0.0	0.3	0.2	3.7	1.6	0.0	0.0	0.1	0.1	80.0	0.7	0.1	0.0	0.0	0.0	1.5	0.1	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	3.5	4.7
JPN	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	98.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.5
KOR	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.2	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.8	95.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.6
LTU	0.2	0.0	0.1	0.0	0.0	1.7	1.6	0.0	1.7	1.3	0.4	0.0	0.0	0.0	0.0	0.2	0.3	0.0	74.4	0.3	0.1	1.1	1.6	0.7	0.0	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0	2.7	9.2
LVA	0.1	0.0	0.1	0.0	0.0	1.0	0.7	0.0	2.3	0.4	0.6	0.0	0.0	0.0	0.0	0.1	0.1	0.2	1.6	81.1	0.1	0.3	1.8	1.0	0.0	0.0	0.0	3.4	0.0	0.0	0.0	0.0	0.0	0.4	4.5
MEX	0.7	0.0	0.0	0.0	0.0	1.3	0.0	2.3	0.0	0.3	1.0	0.0	0.0	0.0	0.1	0.0	0.6	0.7	0.0	0.0	74.5	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	15.2	2.3
NLD	0.2	0.1	0.4	0.0	0.0	2.5	0.0	0.3	0.3	1.9	9.7	0.0	0.0	0.0	0.2	6.6	2.9	2.0	0.0	0.0	0.0	41.1	0.4	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.0	0.0	0.0	20.2	10.7
NOR	0.1	0.0	0.1	0.0	0.0	1.2	0.0	0.1	0.5	2.3	1.6	0.0	0.0	0.0	0.0	0.7	0.6	0.2	0.0	0.0	0.0	0.6	76.8	0.0	0.0	0.0	0.0	5.2	0.0	0.0	0.0	0.0	0.0	6.6	3.5
POL	0.8	0.0	0.4	0.0	0.1	6.9	0.0	0.6	0.5	4.9	2.4	0.0	0.0	0.1	0.2	2.0	1.2	0.7	0.0	0.0	0.1	1.9	0.3	64.6	0.8	0.0	0.0	1.6	0.1	0.0	0.0	0.0	0.1	4.1	5.2
PRT	0.1	0.0	0.4	0.0	0.0	2.6	0.0	3.7	0.0	3.1	1.5	0.0	0.0	0.0	0.1	0.5	0.2	0.1	0.0	0.0	0.0	0.6	0.0	0.0	82.5	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	1.7	2.7
ROM	3.7	0.0	0.2	0.0	0.2	3.1	0.0	0.2	0.2	2.7	1.5	0.4	0.0	0.5	0.1	1.4	0.7	0.0	0.0	0.0	0.0	0.7	0.0	0.2	0.0	76.3	0.0	0.2	0.0	0.0	0.0	0.1	0.0	1.2	6.1
SRB	1.8	0.0	1.5	0.2	0.1	2.3	0.0	0.1	0.0	1.5	0.5	1.6	1.5	0.3	0.1	1.0	0.1	0.0	0.0	0.0	0.0	0.9	0.4	0.1	0.0	0.1	70.1	0.2	0.0	1.9	0.1	0.0	0.0	1.5	12.1
SWE	0.2	0.0	0.1	0.0	0.0	4.2	0.0	0.1	3.2	1.5	2.2	0.0	0.0	0.0	0.1	0.3	1.6	0.1	0.0	0.0	0.0	1.3	1.8	0.0	0.0	0.0	0.0	73.0	0.1	0.0	0.0	0.0	0.0	3.6	6.5
SGP	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	1.1	14.8	0.0	0.0	0.0	0.7	0.1	10.7	3.2	0.0	0.0	0.0	1.8	0.1	0.0	0.0	0.0	0.0	0.2	43.1	0.0	0.0	0.0	0.0	13.6	10.3
SVN	3.8	0.1	0.1	0.0	0.1	3.0	0.0	0.1	0.1	3.1	1.9	0.0	0.8	0.2	0.0	0.9	0.4	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.1	0.0	79.3	0.0	0.0	0.0	2.2	2.6
SVK	4.0	0.0	0.6	0.0	1.7	16.2	0.0	0.2	0.1	4.5	2.0	0.0	0.0	4.0	0.2	3.2	0.7	5.2	0.0	0.0	0.1	3.4	0.5	0.3	0.0	0.0	0.0	0.4	0.0	0.0	42.9	0.0	0.0	4.3	5.5
TUR	1.2	0.0	0.1	0.0	0.0	1.5	0.0	0.1	0.1	1.0	2.2	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	1.1	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	88.4	0.0	0.5	2.5
UKR	0.3	0.0	0.1	0.0	0.0	0.8	0.0	0.0	0.0	0.5	1.2	0.0	0.0	0.1	0.0	0.1	0.2	0.1	0.0	0.0	0.0	1.2	0.0	0.2	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	79.4	1.8	13.7
USA	0.0	0.1	0.0	0.0	0.0	1.3	0.0	0.3	0.0	0.2	1.0	0.0	0.0	0.0	0.0	0.1	0.6	0.2	0.0	0.0	0.1	0.8	0.3	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	91.1	3.9

Notes: This table reports the shares of revenue (in percent) of firms owned by the country in the column in total revenues of all firms in the row country, in percent.

Table A2: Sectoral Shares

NACE code	sector description	Fraction of firms	Average share of sector in aggregate sales	Average share of foreign firms in the sector
01	Crop and animal production, hunting and related service activities	0.016	0.008	0.064
02	Forestry and logging	0.003	0.002	0.066
03	Fishing and aquaculture	0.001	0.001	0.106
05	Mining of coal and lignite	0.000	0.003	0.106
06	Extraction of crude petroleum and natural gas	0.001	0.017	0.336
07	Mining of metal ores	0.000	0.004	0.299
08	Other mining and quarrying	0.002	0.002	0.240
09	Mining support service activities	0.001	0.002	0.239
10	Manufacture of food products	0.014	0.031	0.264
11	Manufacture of beverages	0.002	0.007	0.432
12	Manufacture of tobacco products	0.000	0.002	0.461
13	Manufacture of textiles	0.005	0.004	0.210
14	Manufacture of wearing apparel	0.006	0.004	0.160
15	Manufacture of leather and related products	0.002	0.002	0.184
16	Manufacture of wood and of products of wood and cork, except furniture	0.007	0.006	0.196
17	Manufacture of paper and paper products	0.003	0.007	0.345
18	Printing and reproduction of recorded media	0.006	0.003	0.123
19	Manufacture of coke and refined petroleum products	0.001	0.022	0.369
20	Manufacture of chemicals and chemical products	0.006	0.018	0.423
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	0.001	0.009	0.513
22	Manufacture of rubber and plastic products	0.007	0.010	0.370
23	Manufacture of other non-metallic mineral products	0.006	0.011	0.370
24	Manufacture of basic metals	0.003	0.021	0.390
25	Manufacture of fabricated metal products, except machinery and equipment	0.019	0.015	0.222
26	Manufacture of computer, electronic and optical products	0.006	0.022	0.434
27	Manufacture of electrical equipment	0.005	0.012	0.462
28	Manufacture of machinery and equipment n.e.c.	0.011	0.016	0.367
29	Manufacture of motor vehicles, trailers and semi-trailers	0.003	0.030	0.509
30	Manufacture of other transport equipment	0.001	0.005	0.296
31	Manufacture of furniture	0.005	0.004	0.128
32	Other manufacturing	0.005	0.004	0.305
33	Repair and installation of machinery and equipment	0.007	0.005	0.200
35	Electricity, gas, steam and air conditioning supply	0.005	0.045	0.216
36	Water collection, treatment and supply	0.001	0.003	0.073
37	Sewerage	0.001	0.000	0.068
38	Waste collection, treatment and disposal activities; materials recovery	0.004	0.004	0.172
39	Remediation activities and other waste management services	0.001	0.000	0.066
41	Construction of buildings	0.050	0.022	0.102
42	Civil engineering	0.012	0.015	0.151
43	Specialised construction activities	0.059	0.014	0.146
45	Wholesale and retail trade and repair of motor vehicles and motorcycles	0.027	0.031	0.330
46	Wholesale trade, except of motor vehicles and motorcycles	0.134	0.201	0.332
47	Retail trade, except of motor vehicles and motorcycles	0.081	0.079	0.297
49	Land transport and transport via pipelines	0.026	0.022	0.118
50	Water transport	0.002	0.004	0.307
51	Air transport	0.001	0.004	0.157
52	Warehousing and support activities for transportation	0.013	0.018	0.252
53	Postal and courier activities	0.001	0.003	0.195
55	Accommodation	0.010	0.004	0.180
56	Food and beverage service activities	0.024	0.004	0.231
58	Publishing activities	0.007	0.004	0.217
59	Motion picture, video and television programme production, sound recording and music publishing	0.004	0.002	0.237
60	Programming and broadcasting activities	0.001	0.002	0.217
61	Telecommunications	0.003	0.020	0.435
62	Computer programming, consultancy and related activities	0.021	0.010	0.366
63	Information service activities	0.004	0.001	0.321
64	Financial service activities, except insurance and pension funding	0.026	0.046	0.318
65	Insurance, reinsurance and pension funding, except compulsorysocial security	0.003	0.033	0.367
66	Activities auxiliary to financial services and insurance activities	0.011	0.007	0.276
68	Real estate activities	0.068	0.013	0.142
69	Legal and accounting activities	0.020	0.003	0.143
70	Activities of head offices; management consultancy activities	0.033	0.016	0.256
71	Architectural and engineering activities; technical testing and analysis	0.027	0.008	0.196
72	Scientific research and development	0.003	0.002	0.264
73	Advertising and market research	0.012	0.006	0.334
74	Other professional, scientific and technical activities	0.012	0.002	0.201
75	Veterinary activities	0.001	0.000	0.057
77	Rental and leasing activities	0.008	0.004	0.328
78	Employment activities	0.004	0.002	0.323
79	Travel agency, tour operator reservation service and related activities	0.007	0.004	0.284
80	Security and investigation activities	0.003	0.001	0.295
81	Services to buildings and landscape activities	0.009	0.007	0.197
82	Office administrative, office support and other business support activities	0.013	0.006	0.256
84	Public administration and defence; compulsory social security	0.002	0.003	0.084
85	Education	0.014	0.004	0.050
86	Human health activities	0.019	0.008	0.065
87	Residential care activities	0.003	0.001	0.046
88	Social work activities without accommodation	0.011	0.002	0.008
90	Creative, arts and entertainment activities	0.004	0.000	0.104
91	Libraries, archives, museums and other cultural activities	0.001	0.000	0.100
92	Gambling and betting activities	0.001	0.005	0.110
93	Sports activities and amusement and recreation activities	0.008	0.001	0.108
94	Activities of membership organisations	0.017	0.001	0.021
95	Repair of computers and personal and household goods	0.003	0.001	0.185
96	Other personal service activities	0.012	0.002	0.174
97	Activities of households as employers of domestic personnel	0.000	0.000	0.000
98	Undifferentiated goods-and services-producing activities of private households for own use	0.009	0.000	0.004
99	Activities of extraterritorial organisations and bodies	0.000	0.000	0.075

Notes: This table reports the distribution of the number of firms, revenues across sectors. The last column reports the share of sales in each sector by foreign firms. All numbers are simple averages across countries and years.

Table A3: Affiliate-Parent Comovement: Robustness

	(1)	(2)	(3)	(4)	(5)	(6)
		Turnover			Value Added	
Specification	Services, parent and affiliate in operating in the same sub-sector	Services, excluding wholesale trade	Services, excluding retail trade	All	Manufacturing	Services
ϕ	0.191***	0.179***	0.225***	0.140***	0.128*	0.139***
	(0.0201)	(0.0205)	(0.0123)	(0.0163)	(0.0535)	(0.0190)
Obs.	73856	111795	169790	68627	8948	36166
N. mult.	7095	12824	17270	7594	1342	4513
R^2	0.746	0.829	0.727	0.733	0.799	0.669

Notes: Standard errors clustered at the parent level in parentheses. ***: significant at the 1% level. This table presents the results of estimating equation (1) using different specifications of the outcome variable and the sample of firms. All specifications include source $\times$ destination $\times$ affiliate sector $\times$ parent sector $\times$ year fixed effects. Sectors are defined at the 2 digits of the NACE classification.

Table A4: Affiliate-Parent Comovement: Firm level data

	Excluding Netherlands and Ireland as source and destination	Excluding crisis years (2008-2012)	High income interaction
ϕ	0.228***	0.179***	0.154***
	(0.0118)	(0.0209)	(0.0264)
$\phi \times DUM_{HI}$			0.0912**
			(0.0290)
Obs.	170135	55796	181978
N. mult.	18173	10953	18881
R^2	0.717	0.720	0.724
FE	Yes	Yes	Yes

Notes: Standard errors clustered at the parent level in parentheses. ***: significant at the 1% level. This table presents the results of estimating equation (1). "FE" refers to source × destination × affiliate sector × parent sector × year fixed effects. Sectors are defined at the 2 digits of the NACE classification.

Table A5: Affiliate-Parent Comovement: Firm level Data

	Sales			Value Added		
	All	Manufacturing	Services	All	Manufacturing	Services
ϕ	0.0843***	0.0772***	0.117***	0.0718***	0.136***	0.0669***
	(0.00139)	(0.00152)	(0.00363)	(0.00219)	(0.00844)	(0.00251)
Obs.	1638049	1142582	158824	524671	48362	347579
N. mult.	223271	169596	37743	83587	7751	59306
R^2	0.249	0.194	0.109	0.273	0.356	0.216
FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Standard errors clustered at the parent level in parentheses. ***: significant at the 1% level. This table presents the results of estimating equation (1). "FE" refers to source × destination × affiliate sector × parent sector × year fixed effects. Sectors are defined at the 2 digits of the NACE classification.