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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 comovement: 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 companies are a first-order feature of the world economy, accounting for about one-third of gross output in many developed countries (see, e.g., Alviarez, 2013). Since multinationals encompass production facilities that are spread across different parts of the globe, a natural conjecture is that their rapid growth in recent decades has had an impact on how economic shocks are transmitted across countries. However, the relationship between multinational firms and transmission of shocks is not well-understood at either the micro or the macro levels. At the micro level, there is limited empirical evidence on how the activities of the different parts of a multinational are interrelated at business cycle frequencies. At the macro level, it is yet to be established whether multinationals matter quantitatively for aggregate comovement.

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 and in a broad cross-section of countries. This information allows us to study micro-level cross-country comovement between the different parties of the multinational corporations. At the same time, the data cover the bulk of economic activity in our sample of countries, making it possible to aggregate the firm-level results and derive their implications for business cycle comovement.

Our analysis goes from micro patterns to macro implications in three stages. First, at the firm level, we document strong comovement between multinational affiliates and their parents; 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, so that it captures the role of linkages within the multinational firm. The correlation is pervasive across firms in different sectors, including services, which suggests that it is not driven solely by vertical production linkages. The strong correlation between the parent's and affiliate's growth is also present when we use value added or employment to measure firms' growth, and is highly significant and robust to different samples, time periods, fixed effects, and aggregation methods.

The firm-level estimates show that units of the same firm comove together at the business cycle frequency. However, precisely because they are obtained controlling for very detailed aggregate trends, they may not capture transmission of shocks that are common across parent firms in the source country. With this in mind, in our second step we 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. Source-specific shocks account for about 10% of the variation in bilateral 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. The third step of our analysis assesses the quantitative importance of this phenomenon for aggregate business cycle transmission using a multi-country model that can be taken to 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 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 data.

In the model, 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 foreign affiliates' 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 these parameters using micro estimates of these elasticities, and check the

[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). See Antràs and Yeaple (2014) for a recent overview of modeling approaches.

sensitivity of the results to alternative values.

We use the calibrated model to conduct three quantitative exercises to measure the importance of multinational firms for the transmission of shocks across countries. First, we compute impulse responses to country- and firm-level productivity shocks in each source country, and track the propagation of these shocks across countries. A 1% productivity shock in the rest of the world as a whole raises productivity by 0.12% in the average country, and by as much as 0.2-0.35% in the most integrated countries such as Ireland, the Netherlands, and Slovakia.[2] Not surprisingly, the external impact of individual source country shocks is considerably smaller. A shock that increases GDP by 1% in one of the 4 most important source countries – US, Germany, UK, and France – raises output in the rest of the sample by between 0.01 and 0.02%. Shocks to other source countries have a negligible impact, since multinational affiliates from other source countries tend to have small output shares in a typical destination.

Second, we use the model to compute the business cycle correlation between each pair of countries assuming that the primitive productivity shocks are uncorrelated. This is an assessment of how much correlation can be generated purely by propagation of shocks through multinationals under the observed levels of multinational activity. The variation in model-implied correlations is driven entirely by the pattern of multinational output shares. On the one hand, in most country pairs bilateral multinational shares are small, and thus the model generates little business cycle comovement: the mean model-implied correlation is 0.01 in the full sample of country pairs. On the other hand, for country pairs involving either a major source or a major recipient of multinational firms, the model generates between one quarter and one-tenth of the correlation observed in the data. In addition, in the cross-section of country pairs the model-implied correlations have a positive and highly significant relationship to the GDP correlations in the data.

Third, we conduct two counterfactual exercises that evaluate how the cross-country dispersion of growth rates changes as we change the shares of multinational firms in the world economy. In the first counterfactual, we consider a world in which there are 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).

[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.

Under full integration 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 is small but significant, accounting for about 10% of the productivity shocks in a typical country and leading to a somewhat more synchronized international business cycle. The impact is highly heterogeneous across countries. The transmission of shocks and positive business cycle correlations induced by multinational presence are clearly detectable for the country pairs involving the most important source and destination countries. On the other hand, aggregate interdependence between most individual country pairs is minimal, since most bilateral shares are small.

We highlight three key advantages of our dataset relative to existing empirical analyses of multinationals and business cycle comovement. First, ORBIS provides information on the activities of both the multinational parents and affiliates at a yearly frequency, which allows us to estimate parent-affiliate sales correlations. Second, it includes the local firms in each country along with the domestic and foreign multinationals. This allows us to compute the importance of multinationals in each economy relative to the domestic firms, and also to better estimate the country components of business cycle shocks. Finally, ORBIS covers a broad cross-section of countries. This permits a decomposition of growth rates into source and destination components, an exercise requiring data from multiple sources and destinations. In addition, we can document the large heterogeneity in the impact of multinationals across country pairs.

While the driving mechanism in our model is that productivity shocks are directly transferred across countries within multinational firms, our model is isomorphic to a setup in which comovement arises from the transmission of demand shocks for the firms' product or from certain types of intermediate input linkages (see Appendix B.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 links are not primarily motivated by input trade within the firm. In our own results, the correlation between affiliate and parent sales occurs even among service sector firms, for which input trade is likely to be much less relevant. While our model can accommodate the input linkage 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; Menno, 2014).[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 multinational firms and comovement. A number of papers (e.g., Budd et al., 2005; Desai and Foley, 2006; Desai et al., 2009; Boehm et al., 2014) explore whether parents and affiliates are correlated.[4] 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 comovement with multi-country data in which parents and affiliates are observed within the same dataset. In addition, these papers by and large do not attempt to go from micro estimates to business cycle comovement between countries. We develop a quantitative framework to interpret the empirical findings and evaluate their implications for aggregate comovement.

Finally, a large theoretical literature studies multinationals and technology transfers (see, among many others, McGrattan and Prescott, 2009; Keller and Yeaple, 2013; Ramondo and Rodríguez-Clare, 2013). In addition, an extensive empirical literature investigates the effects of FDI on productivity.[5] Our empirical contribution is to use firm-level data to quantify the extent to which parents 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 firm-level and source-destination-level comovement 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 comovement and for the trans-

[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, 2014), though this line of research is not explicit on whether the production linkages take place within firms.

[4] Alfaro and Chen (2012) investigate whether the affiliates of multinational firms responded to the recent financial crisis differently than local establishments. Their focus is not, however, on parent and affiliate comovement. A number of recent studies examine how liquidity shocks are transmitted through international banks, see for example Acharya and Schnabl (2010), Cetorelli and Goldberg (2011), and Schnabl (2012).

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

mission 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 the affiliates and the parent are in different countries.[6] We specify that a parent should own at least 50% of an affiliate to identify an ownership link between the two firms. The time period is 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, but 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 may include operating revenue of the foreign affiliates. After extensive checking of the data, we retain a sample of 34 countries with sufficiently good coverage and data quality. In particular, the country sample satisfies the following criteria. First, we keep countries with data on more than 750 firms in the average year (as noted below, most countries in our sample are well above this threshold, the median country has data on 100,000 firms in the average year). Second, we keep countries for which the aggregate revenues in ORBIS are at least 40% of aggregate output as reported in standard sources. Third, we keep countries for which the correlation between the growth rate of aggregate revenues in ORBIS and of GDP as reported in the World Bank's World Development Indicators exceeds 0.50.[7] Appendix A describes the data as-

[6] The data do not contain the full ownership structure, implying that intermediate ownership links are not fully observable. Thus, we do not know whether a firm's "global ultimate owner" owns the firm directly or through owning another company (in perhaps another country) that in turn owns the firm.

[7] Bosnia-Herzegovina and the Philippines were dropped from the sample in spite of satisfying the three criteria due to poor data quality. Mexico was kept in the sample despite having a correlation with GDP that is slightly below our threshold (0.49). Finally, ORBIS data for the US contains predominantly consolidated accounts, which implies that the aggregate unconsolidated revenues in ORBIS represent a low share of total revenues as reported in standard sources. We kept 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 on the foreign operations of US-based multinationals even when data on their US operations are missing. The introduction of the US as a destination country

sembly and cleaning steps in greater detail.

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 coverage even in our restricted sample of countries: the country with the smallest number of firms, Australia, has only 766 in an average year. Column 2 reports the number of foreign multinational affiliates in each country. In the median country there are about 2300 foreign multinational firms.

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. 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 cycle 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.

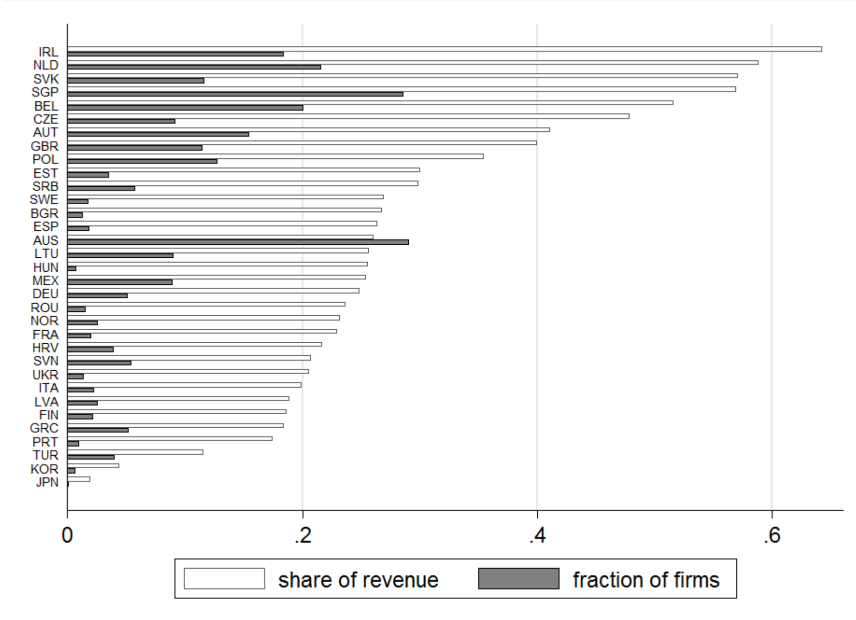
does not affect our quantitative results in Section 5 for the remaining countries.

Table 1: Sample and summary statistics

Country	Number of Firms	Number of Foreign Multinationals	Correlation between ORBIS growth and GDP growth	Ratio of ORBIS revenue to total revenue	Country	Number of Firms	Number of Foreign Multination-als	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 foreign multinational affiliates 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 foreign multinationals

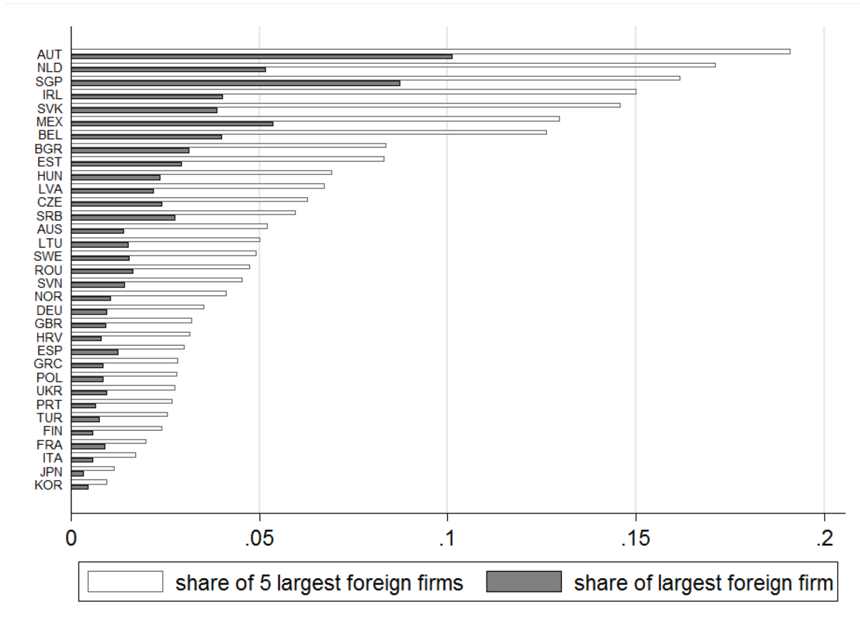


Notes: This figure reports, for each country, the share of foreign multinational affiliates in total revenue (light bars) and the total number of firms (dark bars).

Figure 1 shows the relative importance of foreign multinational affiliates in the countries in our sample for the average year. In the average country, about 7.5% of all firms are affiliates of foreign 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.

Appendix Figure A1 cross-checks the quality of our data on multinational revenue shares. It compares the share foreign multinationals in total output in each destination country in our data and in the aggregate data compiled by Alviarez (2013) from OECD Statistics, Eurostat, and UNCTAD. The foreign multinationals' output shares are remarkably similar in ORBIS and the Alviarez (2013) data, with the exception of some Eastern European countries for which multinationals are underrepresented in ORBIS. In the sample of 28 countries for which multinational shares are available in both datasets, the average ORBIS shares are somewhat lower (mean of 0.28 in ORBIS vs. 0.36 in aggregate data). To the extent that the overall multinational production shares are understated in our data, our results on the aggregate importance of multinationals for business cycles

Figure 2: Top foreign multinational firms



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

will be conservative.

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 source and host economies. Figure 2 reports the shares of the largest one and five affiliates of foreign multinationals 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 correspond 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 used in the empirical analysis below. 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 estimates 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 comovement

We begin by documenting comovement at the firm level between parents and affiliates. In particular, we estimate the following specification:

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

Here $\gamma_{in,t}(f)$ is the sales growth rate of the firms in multinational group f from source country i, operating in destination country n, $\gamma_{ii,t}(f)$ is the growth rate of multinational group f's parent firm in the source country i.[8] The specifications include source $\times$ des-

[8]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

Table 2: Affiliate-parent comovement

	(1)	(2)	(3)	(4)	(5)	(6)
	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 digit level of the NACE classification.

tination × affiliate sector × parent sector × year fixed effects $\bar{a}_{inss',t}$, that control for co-movement 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.

Table 2 presents the results. It reports estimates of a simple bivariate regression with no fixed effects, as well as with the fixed effects. The first panel of the table shows the results for a sample consisting of all 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 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.

3.1.1 Robustness

We now conduct a series of robustness checks. In particular, Appendix Tables A3-A6 evaluate whether our results are driven by vertical input linkages or spurious comovement, whether the observed correlations result from shocks transmitted from the parent to the affiliate or from the affiliate to the parent, and whether our results are robust to alternative aggregation procedures.

the growth rate.

Vertical input linkages Table A3 evaluates, in different ways, whether the results are driven by input linkages. To determine whether the estimated coefficients are 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 and 7-9 repeat the baseline fixed effects regression, but using value added and employment 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, while employment is available for about two thirds of the observations in our sample. There is a strong positive correlation both in the value added growth and in the employment growth of parents and affiliates. This robustness check rules out a mechanical relationship that can occur with sales, when the parent sells some products to the affiliate, and the affiliate resells them in the local market.

Alternative sources of comovement Table A4 investigates alternative mechanisms 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 the Netherlands. The table shows that the result 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. Columns 3 and 4 evaluate if the correlations between affiliate and parent sales growth are driven by aggregate trends that are not accounted for the fixed effects used in the baseline. Column 3 shows that we obtain a similar coefficient if the fixed effects are at the 4-digit (as opposed to 2-digit) level. Column 4 estimates a placebo regression in which we link affiliates to random parents (as opposed to linking them to the affiliates' true parents). In particular, we link affiliates to firms that are parents from the same source country and that operate in the same sector as the true parent of the affiliate. The coefficient falls to zero and becomes insignificant.[9] Finally, it may be that the transmission of shocks is only confined to high-income destination countries. For instance, this could be because multinationals are more reluctant to transfer technology to countries with weaker intellectual property rights (Javorcik, 2004a; Branstetter et al., 2006). Column 5 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.

Direction of shock transmission An important question is whether it is possible to establish that the observed correlation between firms of the same multinational group is driven by shocks that are transmitted from the parent to the affiliates. We address this question by evaluating whether shocks are transmitted from the large to the small firms in the multinational group, irrespective of whether the large firms are the parent or one of the affiliates in the group. With this in mind, we reestimate a version of equation (1) in which, instead having the growth of the parent as the independent variable and the growth of the affiliate as the dependent variable, we use the growth of whichever firm is larger as the independent variable. Appendix Table A5 reports the estimates of ϕ in this model for different samples of firms. The first two columns show that when the affiliate is smaller than the parent there is a positive correlation between parents and affiliates, if anything the estimated ϕ's tend to get larger as the affiliate gets relatively smaller. In contrast, the last two columns show that in cases where the parent is smaller than the affiliate there is no significant correlation between the firms. Our interpretation of these results is that the data reject the notion that the shocks are transmitted from the largest to the smallest firm in the group, since this seems to hold only in cases in which the large party is also the parent.

Alternative aggregation methods 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

[9] We implemented several different placebo specifications in which firms are shuffled randomly within different size bins, from pure random shuffling across the entire sample to a shuffling of firms within the same source-destination-sector pair (reported). In all the placebo experiments the coefficients were close to zero and insignificant.

a particular destination country. To establish that the results are not driven by this approach, Table A6 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.[10] Column 1 shows the estimates based on the entire sample, column 2 for manufacturing, and column 3 for services. The last six columns estimate the relationship using value added and employment data, respectively. Throughout, 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 source 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 source country yields a composite of all the shocks affecting the home operations of a multinational. Second, combining the sales of firms in each country averages out some of the noise in the sales growth data, especially in cases with small constituent firms.

Finally, the finding of strong positive comovement between parent and affiliate growth is robust to a variety of additional checks: estimation year-by-year instead of pooling years, including and excluding domestic affiliates, excluding parent-affiliate pairs in which the parent operates in the financial sector, 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 comovement

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

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

Equation (2) writes the growth rate $\gamma_{in,t}$ of total sales of firms owned by country i operating in country n (e.g., the growth rate of the total sales of all $i =$US multinationals

[10] 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.

operating in n =UK) as a sum of the source effect $s_{i,t}$ common to all firms owned by i worldwide, the destination effect $d_{n,t}$ 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 standard 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.[11]

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 firm-level sales shares in an *in* pair.[12] This approach underscores the usefulness of firm-level data even for the estimation of source- or destination-level outcomes, as firm-level information helps capture 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. The source effects are jointly highly significant in accounting for the variation in the data.

[11]Note that while our sample is comprised by 34 destination countries, every country in the world is a potential source. In this section and in the remainder of the paper, we include all countries (and not just the ones in our sample) as sources. We estimate source country dummies for the 34 countries in our sample and for the following countries that are relatively important as sources for multinational firms: Canada, China, Switzerland, Russia, Brazil, UAE, Bahamas, Luxembourg, the Philippines, Cyprus, South Africa, and Bosnia-Herzegovina. The remaining countries in the world are lumped into a "rest of the world" category.

[12]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. Assuming that $\sigma^2(f)$ does not differ by firm, the variance of the residual of the source-destination level observation is equal to $Var(a_{in,t}) = \sigma^2(f)\sum_{f\in\Omega_{in}}\tilde{\omega}^2_{in,t}(f) \equiv \sigma^2(f)Herf_{in,t}$, where Ω_{in} is the set of firms from i selling in n. The GLS estimator weights the observations by the inverse of the variance of the error term, which in this case is proportional to the Herfindahl index of firm sales shares.

Table 3: Importance of source and destination effects

	(1)	(2)	(3)	(4)	(5)	(6)
	Source			Destination		
	Part. R^2	F-stat.	p-val.	Part. 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 effects. 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. The pooled estimation uses source-year and destination-year effects.

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 comovement. 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 The world economy consists of multiple countries indexed by i and n. Each country is populated by differentiated intermediate good producers potentially owned by firms from different countries. The output of the intermediate producers cannot be traded internationally. In each country, intermediates are aggregated into a final good by competitive final goods producers. We assume that the final good is homogeneous across countries and can be freely traded.[13] The final good is the numeraire of the world economy and its price is set to one. We focus on the model's predictions for productivity and aggregate output. As discussed below, these assumptions coupled with a standard functional form for agent preferences imply that production allocations 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:

$$Q_{n,t} = \left[\sum_i A_{in,t}^{\frac{1}{\rho}} Q_{in,t}^{\frac{\rho-1}{\rho}} \right]^{\frac{\rho}{\rho-1}}, \tag{3}$$

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

[13]The assumption that the final good is homogeneous is not crucial. Appendix B derives the equations under the assumption that country-specific goods are imperfect substitutes, and shows that the results still hold.

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.

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

$$Q_{in,t} = \left[\sum_{f \in \Omega_i} Q_{in,t}(f)^{\frac{\rho-1}{\rho}} \right]^{\frac{\rho}{\rho-1}}, \tag{4}$$

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.

As in Melitz (2003), firms are monopolistically competitive and differ in productivity. Each firm operates a linear technology that uses labor in the destination country as the only input in 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.[14] In particular, the output of the firm is given by:

$$Q_{in,t}(f) = Z_{in,t}(f)\, L_{in,t}(f) = Z_{i,t}^{\phi}(f)\, Z_{n,t}^{1-\phi}(f) L_{in,t}(f), \tag{5}$$

where $L_{in,t}(f)$ is the firm-specific labor input, and $Z_{in,t}(f)$ is a firm-destination specific productivity component.

The second equality in (5) states the key assumption in our framework. Productivity of an affiliate of firm f selling in n and whose parent is from i is a Cobb-Douglas aggregate of the parent's productivity $Z_{i,t}(f)$ and a local productivity component $Z_{n,t}(f)$.[15] The parent thus transfers productivity to the affiliate, with the share ϕ of the affiliate's productivity coming from the parent. This is the only potential endogenous source of aggregate comovement in the model. It is worth noting that, while formally technology transfers are the drivers of comovement between parent and affiliate firms, our model is isomorphic to a setup in which comovement is driven by shocks to demand for the firms' product. In this alternative setup, the term $Z_{in,t}(f)$ would come out of equation (5), and demand shifters for the firm's product would enter as $Z_{in,t}(f)^{\frac{1}{\rho}}$ in equation (4). In addition, our setup can be reinterpreted in a version of the model in which the transmission of

[14] See for example McGrattan and Prescott (2009, 2010), Ramondo and Rappoport (2010), Keller and Yeaple (2013), Ramondo (2014), Antràs and Yeaple (2014).

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

shocks is driven by intermediate input linkages. Appendix B.3 presents this alternative model.

Preferences Consumers in country n experience utility from consumption of the final good and disutility from supplying labor according to the GHH preferences (Greenwood et al., 1988):

$$u\left(C_{n,t},L_{n,t}\right) = \sum_{t}\delta^{t}\nu\left(C_{n,t}-\frac{\psi_{0}}{\bar{\psi}}L_{n,t}^{\bar{\psi}}\right),$$

where $C_{n,t}$ is consumption and $L_{n,t}$ the labor supply.

Equilibrium Let $W_{n,t}$ denote the wage earned by labor in n, and $P_{in,t}(f)$ denote the price charged by firm f from country i operating in n. A *monopolistically competitive equilibrium* at time t is a set of prices $\left\{W_{n,t},\{P_{in,t}(f)\}_{i,f}\right\}_{n}$ and resource allocations $\left\{C_{n,t},L_{n,t},\{L_{in,t}(f)\}_{i,f}\right\}_{n}$ such that (i) consumers maximize utility; (ii) firms maximize profits, and (iii) all goods and factor markets clear.

Profit maximization implies a constant markup over marginal cost:

$$P_{in,t}\left(f\right)=\frac{\rho}{\rho-1}\frac{W_{n,t}}{Z_{in,t}\left(f\right)}. \tag{6}$$

The demand for firm's f product is given by:

$$Q_{in,t}\left(f\right) = \frac{P_{in,t}^{-\rho}\left(f\right)}{P_{in,t}^{-\rho}}Q_{in,t}, \tag{7}$$

where the price index of the country i product aggregate is

$$P_{in,t} = \left[\sum_{f\in\Omega_{i}}P_{in,t}^{1-\rho}\left(f\right)\right]^{\frac{1}{1-\rho}}. \tag{8}$$

Cost minimization by final good producers implies:

$$Q_{in,t} = \frac{A_{in,t}P_{in,t}^{-\rho}}{P_{n,t}^{-\rho}}\,Q_{n,t}, \tag{9}$$

where

$$P_{n,t} = \left[\sum_i A_{in,t} P_{in,t}^{1-\rho}\right]^{\frac{1}{1-\rho}} = 1 \tag{10}$$

is the aggregate price index in country n. The second equality follows from the choice of the numeraire.

Utility maximization implies the following labor supply:

$$L_{n,t} = W_{n,t}^{\frac{1}{\bar{\psi}-1}}. \tag{11}$$

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.[16]

Combining equations (6) and (8) we can write the real wage as:

$$W_{n,t} = \frac{\rho-1}{\rho}\left[\sum_i \sum_{f\in\Omega_i} A_{in,t} Z_{in,t}(f)^{\rho-1}\right]^{\frac{1}{\rho-1}}, \tag{12}$$

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

$$\sum_i P_{in,t} Q_{in,t} = Q_{n,t} = \frac{\rho}{\rho-1} W_{n,t} L_{n,t}, \tag{13}$$

which in combination with (11) and (12) permits expressing the aggregate output as:

$$Q_{n,t} = \left[\sum_i A_{in,t} Z_{in,t}(f)^{\rho-1}\right]^{\frac{\psi}{\rho-1}}, \tag{14}$$

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

Equation (14) implies that aggregate growth in country n is given by:

$$\gamma_{n,t} = \psi \sum_i \sum_{f\in\Omega_i} \omega_{in,t}(f)\left[\frac{a_{in,t}}{\rho-1} + z_{in,t}(f)\right], \tag{15}$$

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

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 (15) becomes:

$$\gamma_{n,t} = \frac{\psi}{\rho - 1} \sum_i \omega_{in,t} \left[a_{in,t} + \phi(\rho - 1) z_{i,t}\right] + \psi(1 - \phi) z_{n,t}, \quad (16)$$

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.

Discussion Equation (16) 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 inherit part of the shock to 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 (16) provides a possible micro foundation for this correlation.

The equation illuminates the key parameters and quantities that determine 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 $\frac{\psi}{\rho-1}$ 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.

Note that output in the model is determined independently of the structure of international asset markets and of how multinational firms' profits are distributed across countries. While these factors will determine how countries split the consumption of the final good, under GHH preferences the labor supply is independent of the level of consumption. As long as firms maximize profits, output growth is solely determined by productivity growth in each country. In this sense, our model is closely related to a standard international business cycle model with one good and no capital. The assumption of a homogeneous final good thus allows us to isolate the comovement arising from the transmission of shocks within multinational firms, while abstracting from the transmission arising from factor supply and relative price movements that are emphasized in the international business cycle literature.

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 comovement

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 (6) and (7), 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:

$$\gamma_{in,t}(f) = \bar{a}_{in,t} + (\rho-1)\,\phi z_{i,t}(f) + (\rho-1)(1-\phi)\, z_{n,t}(f). \tag{17}$$

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

$$\gamma_{ii,t}(f) = \bar{a}_{ii,t} + (\rho-1)\, z_{i,t}(f). \tag{18}$$

Substituting we obtain:

$$\gamma_{in,t}(f) = \tilde{a}_{in,t} + \phi\gamma_{ii,t}(f) + \epsilon_{in,t}(f), \tag{19}$$

where $\tilde{a}_{in,t} \equiv \bar{a}_{in,t} - \phi\bar{a}_{ii,t}$ and $\epsilon_{in,t}(f) \equiv (\rho-1)(1-\phi)\, z_{n,t}(f)$.

Equation (19) states that, after controlling for source-destination-year effects, the coefficient on the parent's growth rate can be interpreted as ϕ. Hence, the empirical results in Table 2 imply that the share of a firm's productivity that is transferred across countries is approximately 20% ($\phi \approx 0.2$).

An identifying assumption required for the structural interpretation of the regression coefficients is that the idiosyncratic component of the destination-specific shock $z_{n,t}(f)$ is orthogonal to the idiosyncratic component of the source shock $z_{i,t}(f)$. A sufficient condition for the assumption to hold is that $z_{n,t}(f)$ is orthogonal to $z_{i,t}(f)$. More generally, if the firm-level shock can be expressed as a combination of a country component and an idiosyncratic firm component: $z_{i,t}(f) = \tilde{z}_{i,t} + \tilde{z}_{i,t}(f)$, then we require that the idiosyncratic components $\tilde{z}_{i,t}(f)$ and $\tilde{z}_{n,t}(f)$ are uncorrelated, while the common components $\tilde{z}_{i,t}$ and $\tilde{z}_{n,t}$ can be correlated as they are absorbed by the fixed effect. Since the actual estimation in Section 3.1 includes source-destination effects by sector, the discussion above applies to the idiosyncratic components relative to a common country-sector shock, rather than a country shock.

Note that (19) can be thought of as a purely cross-sectional specification, in spite of the variables being indexed by t. Indeed, as mentioned in Section 3.1, the empirical results are unchanged when we estimate the specification separately for each year. Under the assumption that affiliate productivity is a function of only the contemporaneous (and not lagged) parent's productivity, (19) is the correct specification even if there is time dependence in the underlying productivity shocks $z_{n,t}(f)$ and $z_{i,t}(f)$. Indeed, since the idiosyncratic component of the destination-specific productivity $\tilde{z}_{n,t}(f)$ is part of the error term, time dependence in it does not bias coefficient estimates, and clustering at the parent level adjusts for the autocorrelated error structure.

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 the 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 (6), (9), (10), and (14) 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 becomes:

$$\gamma_{in,t} = s_{i,t} + d_{n,t} + a_{in,t}, \qquad (20)$$

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

Equation (20) 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 by 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 the comovement parameter 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 technology transfer parameter ϕ. In particular, the model structure implies the destination components have the form:

$$d_{n,t} \;=\; \left[\frac{\psi}{\rho-1}-1\right]\sum_i \omega_{in,t}\left[a_{in,t}+s_{i,t}\right]+\frac{\psi}{\rho-1}\frac{1-\phi}{\phi}s_{n,t}. \tag{21}$$

Foreign productivity shocks $z_{i,t}$ 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 $Z_{i,t}$, 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 $Z_{i,t}$, 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.

Rearranging (21), taking variances of both sides, and solving for ϕ yields an estimate of ϕ based on observed variabilities of the source and destination effects:

$$\phi \;=\; \frac{\sigma_{s,t}}{\sigma_{s,t}+\sigma_{\Phi,t}}, \tag{22}$$

where $\sigma^2_{s,t}\equiv\frac{1}{N-1}\sum_n\left(s_{n,t}-\frac{1}{N}\sum_m s_{m,t}\right)^2$ is the cross-sectional variance of $s_{n,t}$ at time t, and $\sigma^2_{\Phi,t}\equiv\frac{1}{N-1}\sum_n\left[\frac{\rho-1}{\psi}\left(d_{,t}-\frac{\psi+1-\rho}{\rho-1}\sum_i\omega_{in,t}\left[a_{in,t}+s_{i,t}\right]\right)-\frac{\rho-1}{\psi}\frac{1}{N}\sum_m\left(d_{m,t}-\frac{\psi+1-\rho}{\rho-1}\sum_i\omega_{im,t}\left[a_{im,t}+s_{i,t}\right]\right)\right]^2$ is the variance of the destination effect adjusted for the general equilibrium impact of foreign shocks. Note that in the special case of $\rho-1=\psi$, $\sigma^2_{\Phi,t}=\sigma^2_{d,t}=\frac{1}{N-1}\sum_n\left(d_{n,t}-\frac{1}{N}\sum_m d_{m,t}\right)^2$ is simply the cross-sectional variance of the destination effects at time t.

Equations (21) and (22) use the model structure to connect observables – $s_{i,t}$, $d_{n,t}$, and $a_{in,t}$ 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 (21) and (22) and the estimated $s_{i,t}$, $d_{n,t}$, and $a_{in,t}$ to pin down ϕ.

The basic intuition for this approach can be gleaned from (22) and the fact that the

Table 4: 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 (22). Each column represents the estimate under an alternative value of the GE parameter $\frac{\psi}{\rho-1}$.

source effect is a scaled productivity shock: $s_{n,t} = \phi(\rho-1)z_{n,t}$. Ignoring the general equilibrium effects, (22) says that ϕ determines 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 itself 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 4 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 dominates the effects on increased competition) and $\frac{\psi}{\rho-1} = 2/3$ (the increase in competition dominates the effect of increased income).[17] 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

[17] The special case of $\psi = \rho - 1$ is consistent 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 consistent with $\frac{\psi}{\rho-1} = 1$. Under an aggregate labor supply elasticity of about 0.5, $\frac{\psi}{\rho-1} = 2$ (resp., $\frac{2}{3}$) implies an elasticity of substitution of $\rho = \frac{7}{4}$ (resp., 3.25).

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. The firm-level estimate will shed light on this channel to the extent that common shocks are transmitted with the same intensity as purely idiosyncratic shocks. Alternatively, one can focus on the source-destination level estimates, since 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.

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 affect 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? The exercises in the next two subsections do not require time subscripts, and thus we suppress them to streamline notation.

5.1 Transmission of shocks across countries

We start by assessing 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 change

Table 5: Impulse responses for top source countries and the world

	Destination				
Source	All Countries	High-Income Europe	Emerging Europe	High-Income ROW	Emerging ROW
World	0.121	0.140	0.073	0.126	0.078
United States	0.022	0.036	0.009	0.018	0.019
Germany	0.013	0.013	0.019	0.003	0.005
United Kingdom	0.013	0.019	0.006	0.017	0.004
France	0.009	0.013	0.009	0.002	0.003

Notes: This table reports averages of the impulse responses (24) in the entire sample of countries and 4 regions for the top 4 most important source countries, and the average impulse responses to a world shock.

in destination n's productivity in this experiment is given by

$$\phi(1 - \omega_{nn}).$$

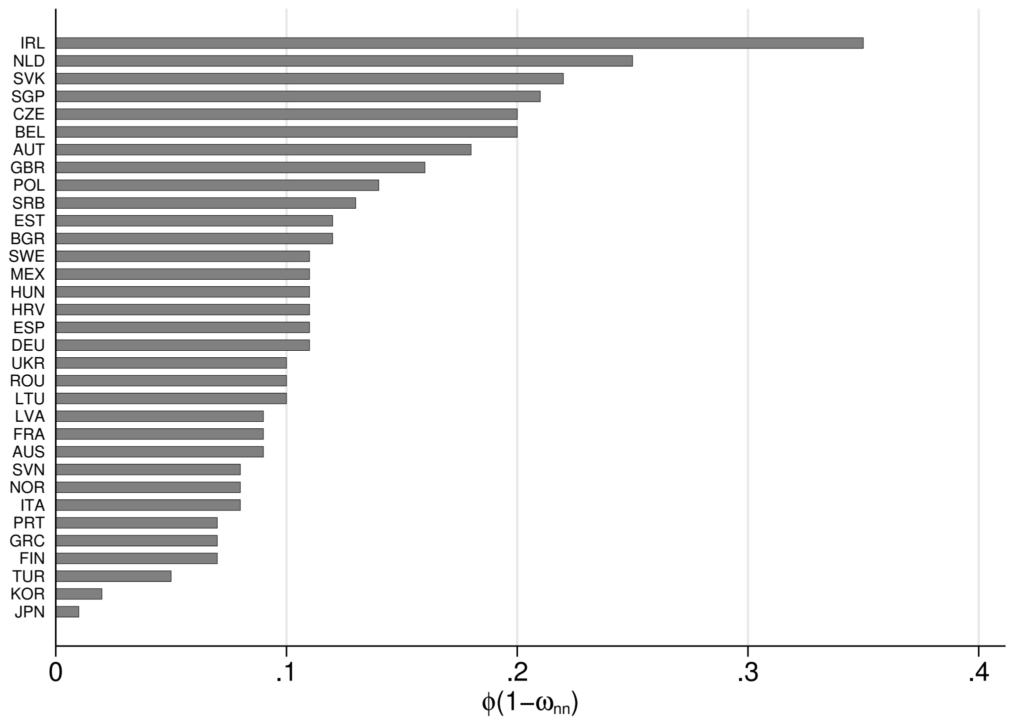
This expression has a clear and intuitive interpretation. The combined importance of foreign shocks in country n is the product of the total presence of multinationals, $1 - \omega_{nn}$, and the strength of the productivity transmission from foreign parents to the local affiliates, ϕ.

The top row of Table 5 and Figure 3 report the results, under the assumption that $\phi = 0.4$. 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 12% of productivity shocks in the average country, or alternatively, foreign shocks are about one-ninth as important as domestic productivity shocks. Foreign shocks are most important on average in the high-income countries in Europe (14%) and outside (12.6%), and less important in emerging markets.[18] In some countries 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.

We next evaluate how productivity shocks to any individual source country spread internationally. From (16), the response of output in n to a productivity shock in any

[18]Country groups are defined as follows. High-Income Europe: Austria, Belgium, Germany, Spain, Finland, France, UK, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Sweden; Emerging Europe: Bulgaria, Czech Republic, Estonia, Croatia, Hungary, Lithuania, Latvia, Poland, Romania, Serbia, Slovenia, Slovakia, Ukraine; High-Income Rest of the World (ROW): Australia, Japan, South Korea, Singapore, USA; Emerging ROW: Mexico, Turkey.

Figure 3: 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.

source country i is given by:

$$\frac{\partial \gamma_n}{\partial z_i} = \psi \left[\omega_{in}\phi + (1-\phi)\,\mathbb{I}_{i=n}\right], \tag{23}$$

where $\mathbb{I}_{i=n}$ is an indicator function that equals 1 if $i = n$ 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:

$$\frac{\partial \gamma_n}{\partial z_i} / \frac{\partial \gamma_i}{\partial z_i} = \frac{\omega_{in}\phi}{\omega_{ii}\phi + (1-\phi)} \quad n \neq i. \tag{24}$$

Equation (24) 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, the 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 4 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 productivity shock in source country i, z_i, relative to the response in the source country, as in (24). We can interpret each square of the figure as the percent change in country n GDP in response to a shock that increases GDP in country i by one percent. We rank countries on 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 (24) 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 is in part a consequence of the fact that most countries are not quantitatively important sources of multinationals. Table 5 reports the average impulse responses to shocks in the top 4 most important source countries: the US, Germany, the UK, and

France. In the entire sample, the average outward impact of these 4 countries ranges from just under 1 to over 2 percent. The next four columns report averages by destination country regions. There is some heterogeneity in the regional impact: the shock to the US affects most strongly high-income Europe, a 3.6% average impulse response. By contrast, a shock to Germany has the largest effect in emerging Europe, 1.9%. In total, 16 country pairs have impulse response coefficients of above 0.03, with the maximum coefficient of 0.17 between US and Ireland.

5.2 Country-pair growth correlations and multinational shares

This section derives how much comovement 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. Consider a setting in which country productivity shocks have variance σ_z^2 and covariance $\sigma_{z,z'}$, common across z and z'. Under these conditions, the covariance between countries n and n' is:

$$\begin{aligned} cov\left(\gamma_n, \gamma_{n'}\right) &= \left[\frac{\psi}{\rho-1}\right]^2 \sigma_z^2 \left[\left[\phi\left(1-\phi\right)\left[\omega_{n'n}+\omega_{nn'}\right]+\phi^2\sum_i \omega_{in}\omega_{in'}\right]\right. \\ &+ \left.\rho_{z,z'}\left[\phi\left(1-\phi\right)\left(2-\omega_{n'n}-\omega_{nn'}\right)+\phi^2\left(1-\sum_i \omega_{in}\omega_{in'}\right)+\left(1-\phi\right)^2\right]\right], \end{aligned} \tag{25}$$

where $\rho_{z,z'} \equiv \frac{\sigma_{z,z'}}{\sigma_z^2}$ is the correlation of productivity shocks. Under the same assumptions, we can write the variance of γ_n as:

$$var\left(\gamma_n\right) = \left[\frac{\psi}{\rho-1}\right]^2 \sigma_z^2 \bar{\Theta}_n^2,$$

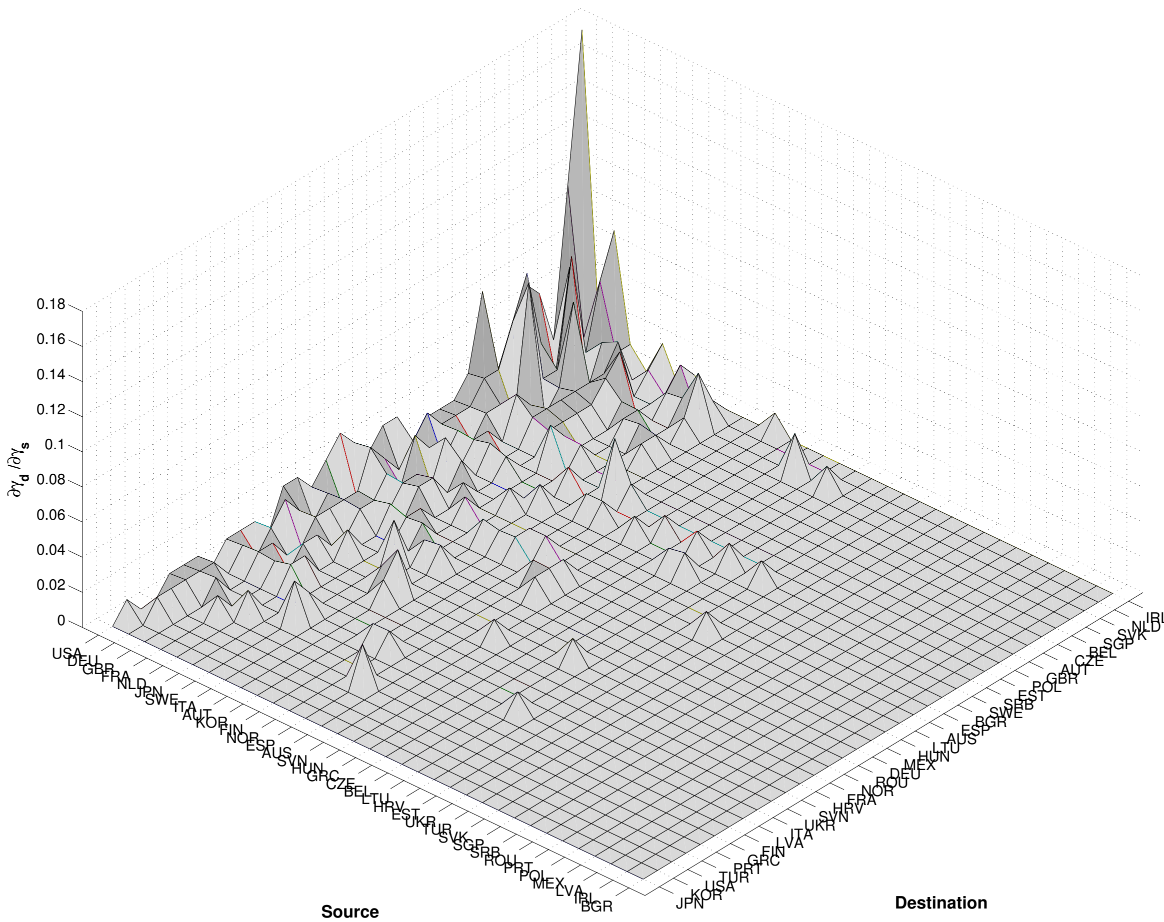
where $\bar{\Theta}_n^2 \equiv \left[2\phi\left(1-\phi\right)\omega_{nn}+\phi^2\sum_i \omega_{in}^2+\left(1-\phi\right)^2\right]\left[1-\rho_{z,z'}\right]+\rho_{z,z'}$.

The correlation between any pair of countries is then:

$$\rho_{n,n'} = \frac{\left[\phi\left(1-\phi\right)\left[\omega_{n'n}+\omega_{nn'}\right]+\phi^2\sum_i \omega_{in}\omega_{in'}\right]\left[1-\rho_{z,z'}\right]}{\bar{\Theta}_n\bar{\Theta}_{n'}} + \frac{\rho_{z,z'}}{\bar{\Theta}_n\bar{\Theta}_{n'}}. \tag{26}$$

Note that while the covariance in equation (25) depends on the size of the general equilibrium effects (captured by $(\psi/(\rho-1))^2$), the correlation $\rho_{n,n'}$ is a function only of the correlation in firm-level growth ϕ, the multinational shares ω_{in}, and the correlation of the shocks $\rho_{z,z'}$. Given a value of ϕ, the size of the general equilibrium effects does not affect the results in this section.

Figure 4: 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.

Equation (26) illustrates how the parameters affect the correlation of growth rates across countries. First, if the primitive shocks are uncorrelated ($\rho_{z,z'} = 0$), and there are no multinational firms ($\omega_{in} = 0$ for $i \neq n$), then countries growth rates are uncorrelated, $\rho_{n,n'} = 0$. Other things equal, the correlation increases for country pairs that share more multinational links, as captured by the terms $\omega_{n'n} + \omega_{nn'}$ and $\sum_i \omega_{in}\omega_{in'}$. Second, the scope for multinational firms to induce cross-country correlations falls as the correlation of the primitive shocks increases. In the limit, if $\rho_{z,z'} = 1$, output is perfectly correlated across countries, $\rho_{n,n'} = 1$, irrespective of the multinational shares ω_{in}.

With this in mind, Table 6 evaluates the model's ability to generate positive cross-country growth correlations. The row labeled "Data" presents the summary statistics for the correlations of GDP growth over the period 1994-2007. The row labeled "Model" presents the correlations implied by the model when $\rho_{z,z'} = 0$. Consistent with our results from the previous section, on average in the whole sample the predicted correlations tend so be small. The mean is only 0.01, and 95% of all the bilateral correlations are below 0.03. However, this is partly a consequence of small multinational shares for most pairs of countries. The bottom two panels of the Table report the correlations for country pairs in which one country is a large source of multinational firms (such as the US, the UK, or Germany), and for country pairs in which one country is an important destination for multinationals (such as Ireland, Netherlands, or Slovakia). Not surprisingly, the predictions of the model come much closer to the data for these country pairs. At the extreme, the model generates about a quarter of the observed correlation for country pairs in which one of the countries is either the US or Ireland.

Second, in the spirit of the literature on international trade and comovement (see, e.g., Johnson, 2014), we compare the correlations predicted by the model to those observed in the data.[19] Figure 5 plots the partial correlation between the GDP correlation in the data (y-axis) against the correlation implied by the model under uncorrelated shocks (x-axis), after controlling for source and destination country effects. There is a positive and highly significant conditional correlation between the model-implied correlations and the correlations in the data.[20] This is remarkable given that the model correlations are computed under the assumption of uncorrelated shocks, and the only source of variation across country pairs in the model is due to differences in multinational shares. The model also

[19] A challenge in empirically demonstrating a causal link between multinational presence and business cycle comovement is that multinational firms may locate in countries that for other reasons have more synchronized shocks. By imposing that the primitive shocks are uncorrelated and the same across country pairs, we can isolate the role of multinationals as a source of transmission from other factors that may induce comovement.

[20] The relationship is equally pronounced and significant unconditionally, without controlling for any fixed effects.

Table 6: Predicted and actual correlations

		Mean	St.Dev.	Min	Max
Across all country pairs					
	Data	0.133	0.352	-0.680	0.870
	Model	0.009	0.017	0.000	0.254
Pairs involving large sources					
US	Data	0.131	0.404	-0.620	0.750
	Model	0.027	0.048	0.001	0.254
UK	Data	0.127	0.304	-0.550	0.590
	Model	0.024	0.029	0.002	0.119
Germany	Data	0.255	0.304	-0.240	0.750
	Model	0.021	0.017	0.005	0.077
Pairs involving large destinations					
Ireland	Data	0.098	0.412	-0.680	0.870
	Model	0.024	0.047	0.002	0.254
Netherlands	Data	0.232	0.430	-0.480	0.850
	Model	0.020	0.023	0.004	0.119
Slovakia	Data	0.050	0.327	-0.510	0.620
	Model	0.011	0.014	0.001	0.065

Notes: This table reports summary statistics for aggregate correlations. The row labeled “Data” reports the actual correlations of aggregate GDP growth sourced from World Development Indicators over the period 1994-2007. The row labeled “Model” reports the results for correlations computed using equation (26) under the assumption that $\sigma_{z,z'} = 0$ for all country pairs.

cannot yield negative correlation coefficients, which are observed in the data. As a result, relative to the data, the model generates substantially less variation in the cross-country correlations than observed in the data.

To underscore the way the model generates correlations, the figure labels the "integrated" and "non-integrated" country pairs differently (though the regression is run on all the data). We label a country pair integrated if its combined bilateral multinational shares $\omega_{n'n} + \omega_{nn'}$ are above the median, and non-integrated if they are below the median. The model generates little to no dispersion in predicted correlation among the non-integrated pairs (hollow dots), and as a result in this subsample the model has no predictive power over the data correlations, which range (in deviations from the country means) from large positive to large negative. On the other hand, for integrated pairs (solid dots) there is a clear positive relationship between the model-implied correlations and those in the data. Indeed, in the subsample of integrated pairs, the model correlations have a greater explanatory power than in the full sample.

Our main takeaway from these exercises is that in most country pairs, transmission of shocks through multinationals in and of itself cannot generate anything close to observed output correlations. This is unsurprising since in most country pairs bilateral multinational shares are small. However, among the more closely integrated country pairs, the model generates both non-negligible correlations, and a significantly positive relationship between model-implied and observed correlations.

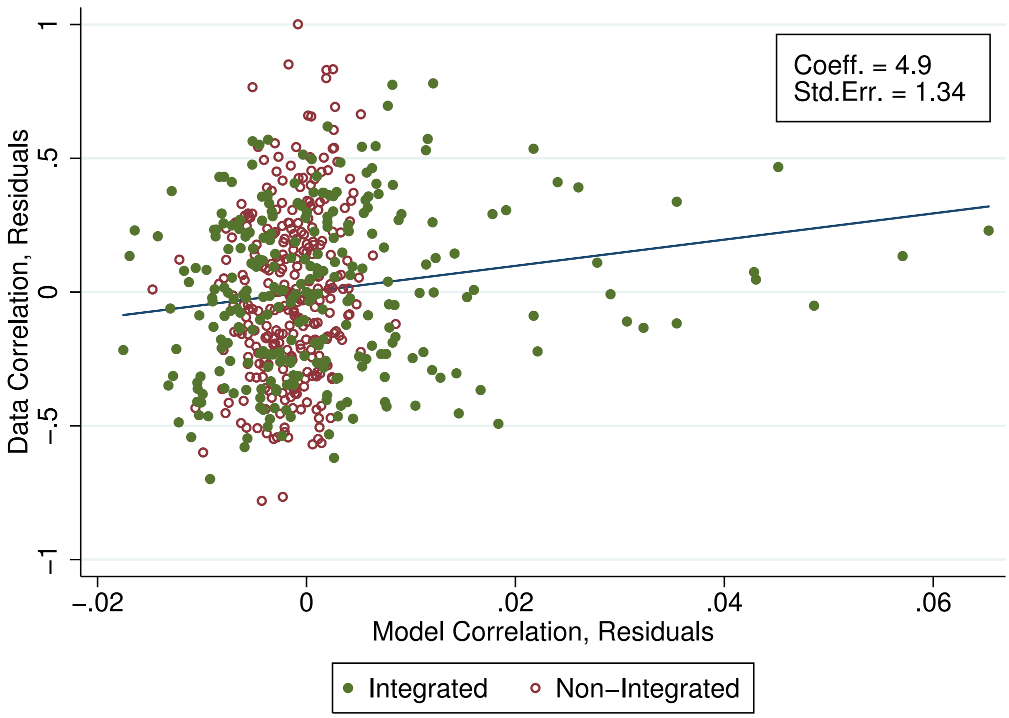
5.3 Predicted and counterfactual comovement

This section studies how business cycle synchronization would change under different scenarios for multinational presence. Rather than assuming an exogenous parsimonious shock correlation structure as in the previous section, here we use the estimated $a_{in,t}$ and $s_{i,t}$ from Section 3.2 to compute aggregate growth rates using model-implied relationships (16) and (21). We then conduct two sets of counterfactual exercises to investigate how multinationals contribute to business cycle synchronization. Our metric of synchronization is the cross-sectional dispersion in country-level growth rates (see Kalemli-Ozcan et al., 2013, for a closely related metric of comovement). We exploit the cross-sectional dimension as the available time series is quite short.

Notation The aggregate growth rate in country n is:

$$\gamma_{n,t} = \sum_i \omega_{in,t}\gamma_{in,t} = \sum_i \omega_{in,t}\left[a_{in,t} + s_{i,t}\right] + d_{n,t}, \qquad (27)$$

Figure 5: Actual and predicted correlations



Notes: This figure plots the partial correlation between the GDP correlation in the data and the aggregate correlation implied by the model, after controlling for source and destination country effects. Dots labeled "Integrated" depict the country pairs with higher than the median combined bilateral multinational shares ($\omega_{n'n} + \omega_{nn'}$). Dots labeled "Non-Integrated" depict country pairs with the combined bilateral multinational shares below the median.

We can express country n's growth rate relative to the cross-sectional average growth rate at time t as:

$$\gamma_{n,t} - \bar{\gamma}_t = \mathcal{A}_{n,t} + \mathcal{S}_{n,t} + \mathcal{D}_{n,t} \tag{28}$$

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

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 were 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 $\omega_{in,t}^{FI} = \bar{\omega}_{i,t}^{FI} = \frac{1}{N} \sum_n^N \omega_{in,t}$.[21] That is, the production shares of firms of all source countries 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 $\mathcal{S}_{n,t}^c$, $\mathcal{A}_{n,t}^c$, $\mathcal{D}_{n,t}^c$ using estimated $s_{i,t}$ and $a_{in,t}$ as:

$$\mathcal{S}_{n,t}^c = \sum_i \omega_{in,t}^c s_{i,t} - \frac{1}{N} \sum_n \sum_i \omega_{in,t}^c s_{i,t} \tag{29}$$

$$\mathcal{A}_{n,t}^c = \sum_i \omega_{in,t}^c a_{in,t} - \frac{1}{N} \sum_n \sum_i \omega_{in,t}^c a_{in,t} \tag{30}$$

$$\mathcal{D}_{n,t}^c = \frac{\psi + 1 - \rho}{\rho - 1} \left[\mathcal{A}_{n,t}^c + \mathcal{S}_{n,t}^c\right] + \frac{\psi}{\rho - 1} \frac{1 - \phi}{\phi} \mathcal{S}_{n,t}^{own}, \tag{31}$$

where $\mathcal{S}_{n,t}^{own} \equiv \left[s_{n,t} - \frac{1}{N} \sum_n s_{n,t}\right]$ captures the deviation of country n's productivity shock from the world average. We use (29)-(31) to compute the counterfactual growth rates $\gamma_{n,t}^c$ as in equation (28) and then report the standard deviations $\sigma_{\gamma_{n,t}}^c = \sqrt{\frac{1}{N-1} \sum_n \left(\gamma_{n,t}^c - \bar{\gamma}_t^c\right)^2}$. Our baseline results adopt the assumption that $\frac{\psi}{\rho - 1} = 1$ (the destination shocks are independent of the general equilibrium effects).

The top panel of Table 7 reports the average baseline and counterfactual dispersions

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

of growth rates across the years in our sample. To facilitate comparison, the second panel of the table reports the average ratios of the counterfactual $\sigma^c_{\gamma_{n,t}}$'s relative to the baseline. The standard deviation of growth rates under the "No multinationals" counterfactual is nearly 10% higher compared to the baseline. Note from equation (29) 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.

The table also reports the average standard deviations of growth rates under the "Full Integration" counterfactual. Note from equation (29) that in this case $\mathcal{S}^c_{n,t} = 0$ (since $\omega_{in,t}$ 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.

The bottom two panels of Table 7 report a sensitivity analysis to alternative values of the general equilibrium 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 (22). 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 $\frac{\psi}{\rho-1} = 2/3$. However, the alternative parameterizations do not change the order of magnitude of the results.

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:

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

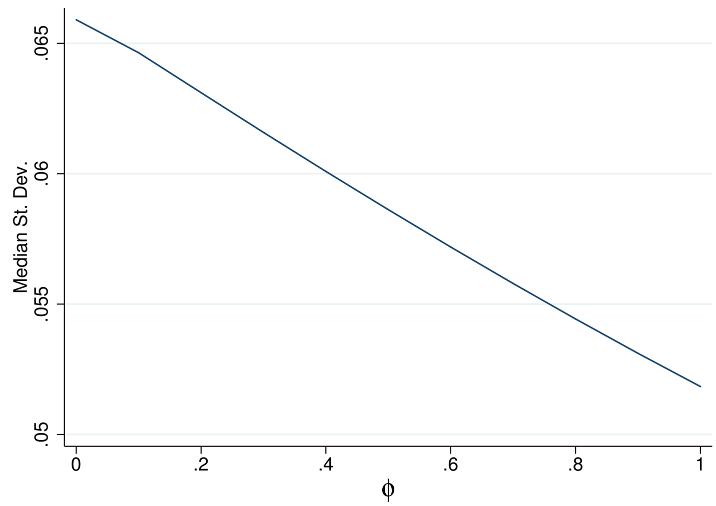
Figure 6 shows the resulting standard deviation in growth rates for alternative values for counterfactual ϕ. As ϕ get closer to zero, there is no transmission of shocks between multinational firms and their foreign affiliates, and the standard deviation in growth rates increases and gets closer to that in the counterfactual of "No Multinationals." As ϕ gets closer to one, the correlation between multinationals and their foreign affiliates becomes

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

	Mean	Median
$\sigma_{\gamma_{n,t}}$:		
Baseline	0.058	0.060
NM: No Multinationals	0.064	0.066
FI: Full Integration	0.039	0.039
Ratio of $\sigma^c_{\gamma_{n,t}}$ to baseline:		
NM: No Multinationals	1.094	1.087
FI: Full Integration	0.673	0.654
$\frac{\psi}{\rho-1} = 2; \phi = 0.5$		
Ratio of $\sigma^c_{\gamma_{n,t}}$ to baseline:		
NM: No Multinationals	1.116	1.105
FI: Full Integration	0.620	0.583
$\frac{\psi}{\rho-1} = 2/3; \phi = 0.3$		
Ratio of $\sigma^c_{\gamma_{n,t}}$ to baseline:		
NM: No Multinationals	1.070	1.066
FI: Full Integration	0.745	0.739

Notes: This table reports the mean and median cross-sectional standard deviations in aggregate growth rates over all years, and the mean and median ratios of the standard deviations in the two counterfactuals relative to the baseline. The bottom two panels summarize the ratios of standard deviations under alternative parameterizations of $\psi/(\rho-1)$.

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



Notes: This figure plots the median 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.

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 business cycle transmission 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 comovement.

All foreign multinationals together account for a large share of total output, and thus the rest of the world is responsible for about 10% of the productivity shocks in an average country. On the other hand, bilateral multinational production shares tend to be small, limiting the contribution of multinationals for observed comovement between individual country pairs. In the benchmark parameterization, eliminating barriers to multinational production decreases the cross-country standard deviation in growth rates by 35 percent, indicating that international comovement may become significantly stronger as the share of multinationals in the world economy increases.

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Appendix A Data Assembly

This Appendix describes the downloading and cleaning steps that we followed in constructing the final dataset, as well as some additional statistics.

A.1 Downloading

The data were downloaded using the web-based utility available by subscription from Bureau Van Dijk. We downloaded the following variables from ORBIS: Company Name, Company ID, Global Ultimate Owner name (GUO name), Global Ultimate Owner ID (GUO ID), Consolidation Code, Independence Indicator, the firm's NACE Sector Code, and "Turnover" and Value Added denominated US$ in for each year available between 2004-2012.

In downloading the data we made a number of choices. First, in cases where several types of firm accounts were available, we prioritized *local registry filings* over *annual reports*. Second, we built the dataset based on "unconsolidated" accounts, since accounts that are consolidated across the many firms that comprise the corporation are not useful for our analysis. In particular, we downloaded companies with unconsolidated accounts only (consolidation code U1) and companies that present both consolidated and unconsolidated accounts (consolidation code C2/U2). By doing this we exclude firms with no recent financial information (NRF), with limited financial information (LF), no recent limited financial information (NRLF) and no financial variables at all (NF), since it is not clear which is the level of consolidation for these firms. Third, we only downloaded firms for which data on turnover was available in at least one of the years, since this is the main variable that we use in our analysis. This results in an initial download of 8,271,838 firms, 99% of which have a consolidation code U1, while the remaining have an consolidation code U2.

A.2 Defining ownership

The firm ownership matrix is constructed from an independence indicator provided by ORBIS, and variables reporting the Global Ultimate Owner (GUO) ID and name. The independence indicator characterizes the degree of independence of a company with regard to its shareholders. In defining the ownership structure, we took the following steps. First, we only assigned "owners" to those firms that have an independence indicator of "D", which is allocated to any company with a recorded shareholder with a direct ownership of over 50 percent.

Second, about 25% of the firms in ORBIS contain information on their GUO name but not the GUO ID. This issue arises mainly because some firms are owned by individuals or families,[22] and ORBIS only defines ID numbers for firms. In cases in which the ultimate owner is a person or a family, we need to establish which of the firms in the group will be assigned the role of the 'parent' of the group. In such cases, the parent firm is assumed to be the firm with the largest revenue owned by that GUO name (to be used in firm-level

[22] For instance, family Porsche is the GUO owning Volkswagen and all its affiliates.

exercises), and source country is assumed to be the country in which the GUO name has the largest revenues (to be used in guo-destination level exercises). The results in the paper remain unchanged if instead we exclude the firms for which the GUO IDs are not available. Firms with neither GUO ID or GUO name data are by default assumed to have no owner (that is, they are their own global ultimate owner).

A.3 Cleaning

This section describes all the steps to get the data ready for use. First, for those firms for which both consolidated and unconsolidated accounts are available, we keep the unconsolidated accounts. Second, we convert the revenue and value added to local currency and adjust for inflation using GDP deflator from the World Bank. Finally, for a subset of firms, we manually checked the data on the independence status and ownership, which resulted in corrections to independence indicators, GUO, and/or source country. The manual checks were performed by closer examination of the Bureau van Dijk web interface and internet searches. The manual coding supersedes any automatic algorithm discussed above. The following subsets were checked:

- The largest 15 domestic firms in each country (we include firms that are in the top 15 in any year), resulting in 42 manual recodes.
- The largest 15 GUOs in each country (we include GUOs that are top 15 in any year), resulting in 134 manual recodes.
- The largest 15 firms with a GUO name but not GUO ID in each country, resulting in 37 manual recodes.
- The largest 100 GUOs that are listed as being in offshore locations (i.e. Bermuda, Virgin Islands, Curaçao, Cayman Islands, Gibraltar, Bahamas, Marshall Islands, Mauritius, and unidentified "YY" and "WW" firms), resulting in 66 manual recodes.
- Some firms in Croatia have GUO IDs that do not identify the country of ownership, and are coded as "YY". We classify these firms as owned by an "unknown" country, while at the same time we manually checked the largest 100 of these firms, which resulted in 30 manual recodes.

In addition to this manual cleaning, we remove outliers by excluding observations in which DHS sales growth rates are below -2/3 and above 2/3 (where growth rates are defined as $\gamma_t \equiv \frac{1}{2}\frac{x_t - x_{t-1}}{x_t + x_{t-1}}$). Finally, in calculating growth rates at any level of aggregation (whether it is country-level, GUO-destination level, etc.), we include only firms that are present in two consecutive years (e.g. the 2005 growth rate is computed using firms that are present in both 2004 and 2005; the 2006 growth rate is computed using firms present in both 2005 and 2006, etc.).

Appendix B Extensions

B.1 Armington final goods aggregation

This subsection extends the 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:

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

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

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

where $P_{c,t}$ is the price index associated with the aggregator (B.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 (19) 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.

B.2 Low elasticity of substitution between Z_i and Z_n

This subsection presents an extension of 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 individual firm production function is given by:

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

where

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

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

Aggregate output is given by equation (14), and output growth is given by (19). Differences from out baseline framework are driven by the effect of η on the growth rate of $Z_{in,t}(f)$ (B.3). We show that the difference is zero to a first order approximation. In particular, log-linearizing (B.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.

B.3 Intermediate input linkages

In this section we present a version of the model 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:

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

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 inputs 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,

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

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 (B.4).

The production function in equation (B.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 (B.5) and (7). Profit maximization implies a constant markup over marginal cost:

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

Combining equations (8) and (B.6) we can write the real wage as:

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

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

$$\sum_{i} P_{in,t}Q_{in,t} = P_{n,t}Q_{n,t} = \frac{\rho}{\rho-1}\frac{1}{1-\phi}W_{n,t}L_{n,t}, \tag{B.8}$$

which in combination with (12) and (11) permits expressing the aggregate production function as:

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

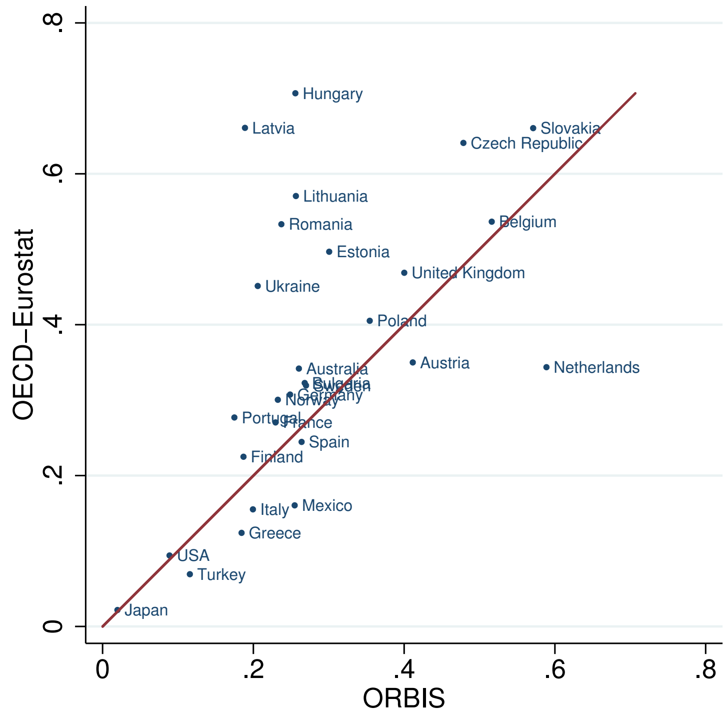
Equation (B.9) implies that the growth rate of output and value added (which is a fraction $1-\phi$ of output) in the model is given by equations (15) and (16), where the parameter ψ is now substituted with $\bar{\bar{\psi}} \equiv \frac{\psi}{1-\phi}$.

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 (19) represents value added growth at the firm level.[23] 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

[23] In this version of the model, equation (17) 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 (18) 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 featuring intermediate input linkages.

Figure A1: MP shares: ORBIS vs. OECD-Eurostat data



Notes: This figure displays a scatterplot of the multinational production shares (defined as the share of gross output in a country produced by affiliates of foreign multinationals), in the ORBIS data against the those from OECD and Eurostat, as compiled by Alviarez (2013). The line through the data is the 45-degree line.

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	Fraction of groups	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	0.017	0.008	0.064
02	Forestry and logging	0.003	0.004	0.002	0.066
03	Fishing and aquaculture	0.001	0.001	0.001	0.106
05	Mining of coal and lignite	0.000	0.000	0.003	0.106
06	Extraction of crude petroleum and natural gas	0.001	0.001	0.017	0.336
07	Mining of metal ores	0.000	0.000	0.004	0.299
08	Other mining and quarrying	0.002	0.003	0.002	0.240
09	Mining support service activities	0.001	0.001	0.002	0.239
10	Manufacture of food products	0.014	0.015	0.031	0.264
11	Manufacture of beverages	0.002	0.002	0.007	0.432
12	Manufacture of tobacco products	0.000	0.000	0.002	0.461
13	Manufacture of textiles	0.005	0.005	0.004	0.210
14	Manufacture of wearing apparel	0.006	0.006	0.004	0.160
15	Manufacture of leather and related products	0.002	0.002	0.002	0.184
16	Manufacture of wood and of products of wood and cork, except furniture	0.007	0.008	0.006	0.196
17	Manufacture of paper and paper products	0.003	0.003	0.007	0.345
18	Printing and reproduction of recorded media	0.006	0.007	0.003	0.123
19	Manufacture of coke and refined petroleum products	0.001	0.001	0.022	0.369
20	Manufacture of chemicals and chemical products	0.006	0.006	0.018	0.423
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	0.001	0.001	0.009	0.513
22	Manufacture of rubber and plastic products	0.007	0.008	0.010	0.370
23	Manufacture of other non-metallic mineral products	0.006	0.007	0.011	0.370
24	Manufacture of basic metals	0.003	0.003	0.021	0.390
25	Manufacture of fabricated metal products, except machinery and equipment	0.019	0.020	0.015	0.222
26	Manufacture of computer, electronic and optical products	0.006	0.007	0.022	0.434
27	Manufacture of electrical equipment	0.005	0.005	0.012	0.462
28	Manufacture of machinery and equipment n.e.c.	0.011	0.012	0.016	0.367
29	Manufacture of motor vehicles, trailers and semi-trailers	0.003	0.003	0.030	0.509
30	Manufacture of other transport equipment	0.001	0.002	0.005	0.296
31	Manufacture of furniture	0.005	0.006	0.004	0.128
32	Other manufacturing	0.005	0.006	0.004	0.305
33	Repair and installation of machinery and equipment	0.007	0.007	0.005	0.200
35	Electricity, gas, steam and air conditioning supply	0.005	0.005	0.045	0.216
36	Water collection, treatment and supply	0.001	0.001	0.003	0.073
37	Sewerage	0.001	0.001	0.000	0.068
38	Waste collection, treatment and disposal activities; materials recovery	0.004	0.004	0.004	0.172
39	Remediation activities and other waste management services	0.001	0.001	0.000	0.066
41	Construction of buildings	0.050	0.053	0.022	0.102
42	Civil engineering	0.012	0.013	0.015	0.151
43	Specialised construction activities	0.059	0.064	0.014	0.146
45	Wholesale and retail trade and repair of motor vehicles and motorcycles	0.027	0.029	0.031	0.330
46	Wholesale trade, except of motor vehicles and motorcycles	0.134	0.145	0.201	0.332
47	Retail trade, except of motor vehicles and motorcycles	0.081	0.086	0.079	0.297
49	Land transport and transport via pipelines	0.026	0.028	0.022	0.118
50	Water transport	0.002	0.002	0.004	0.307
51	Air transport	0.001	0.001	0.004	0.157
52	Warehousing and support activities for transportation	0.013	0.013	0.018	0.252
53	Postal and courier activities	0.001	0.001	0.003	0.195
55	Accommodation	0.010	0.011	0.004	0.180
56	Food and beverage service activities	0.024	0.025	0.004	0.231
58	Publishing activities	0.007	0.007	0.004	0.217
59	Motion picture, video and television programme production, sound recording and music publishing	0.004	0.004	0.002	0.237
60	Programming and broadcasting activities	0.001	0.001	0.002	0.217
61	Telecommunications	0.003	0.003	0.020	0.435
62	Computer programming, consultancy and related activities	0.021	0.022	0.010	0.366
63	Information service activities	0.004	0.004	0.001	0.321
64	Financial service activities, except insurance and pension funding	0.026	0.027	0.046	0.318
65	Insurance, reinsurance and pension funding, except compulsory social security	0.003	0.002	0.033	0.367
66	Activities auxiliary to financial services and insurance activities	0.011	0.011	0.007	0.276
68	Real estate activities	0.068	0.071	0.013	0.142
69	Legal and accounting activities	0.020	0.022	0.003	0.143
70	Activities of head offices; management consultancy activities	0.033	0.036	0.016	0.256
71	Architectural and engineering activities; technical testing and analysis	0.027	0.029	0.008	0.196
72	Scientific research and development	0.003	0.003	0.002	0.264
73	Advertising and market research	0.012	0.013	0.006	0.334
74	Other professional, scientific and technical activities	0.012	0.013	0.002	0.201
75	Veterinary activities	0.001	0.001	0.000	0.057
77	Rental and leasing activities	0.008	0.008	0.004	0.328
78	Employment activities	0.004	0.004	0.002	0.323
79	Travel agency, tour operator reservation service and related activities	0.007	0.007	0.004	0.284
80	Security and investigation activities	0.003	0.003	0.001	0.295
81	Services to buildings and landscape activities	0.009	0.010	0.007	0.197
82	Office administrative, office support and other business support activities	0.013	0.014	0.006	0.256
84	Public administration and defence; compulsory social security	0.002	0.002	0.003	0.084
85	Education	0.014	0.015	0.004	0.050
86	Human health activities	0.019	0.020	0.008	0.065
87	Residential care activities	0.003	0.004	0.001	0.046
88	Social work activities without accommodation	0.011	0.012	0.002	0.008
90	Creative, arts and entertainment activities	0.004	0.005	0.000	0.104
91	Libraries, archives, museums and other cultural activities	0.001	0.002	0.000	0.100
92	Gambling and betting activities	0.001	0.001	0.005	0.110
93	Sports activities and amusement and recreation activities	0.008	0.009	0.001	0.108
94	Activities of membership organisations	0.017	0.019	0.001	0.021
95	Repair of computers and personal and household goods	0.003	0.003	0.001	0.185
96	Other personal service activities	0.012	0.013	0.002	0.174
97	Activities of households as employers of domestic personnel	0.000	0.000	0.000	0.000
98	Undifferentiated goods-and services-producing activities of private households for own use	0.009	0.011	0.000	0.004
99	Activities of extraterritorial organisations and bodies	0.000	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 part 1

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		Sales			Value Added			Employment	
Specification	Services, parent and affiliate in operating in the same sub-sector	Services, excluding wholesale trade	Services, excluding retail trade	All	Manufacturing	Services	All	Manufacturing	Services
ϕ	0.191***	0.179***	0.225***	0.140***	0.128*	0.139***	0.089***	0.070	0.089***
	(0.0201)	(0.0205)	(0.0123)	(0.0163)	(0.0535)	(0.0190)	(0.013)	(0.040)	(0.015)
Obs.	73856	111795	169790	68627	8948	36166	124423	15873	67915
N. mult.	7095	12824	17270	7594	1342	4513	13663	2181	8548
R^2	0.746	0.829	0.727	0.733	0.799	0.669	0.728	0.749	0.691

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 × destination × affiliate sector × parent sector × year fixed effects. Sectors are defined at the 2 digits of the NACE classification.

Table A4: Affiliate-parent comovement: Robustness part 2

	(1) Excluding Netherlands and Ireland as source and destination	(2) Excluding crisis years (2008-2012)	(3) 4 Digit Sectoral Classification	(4) Placebo	(5) High income interaction
ϕ	0.228***	0.179***	0.207***	-0.0134	0.154***
	(0.0118)	(0.0209)	(0.0377)	(0.00891)	(0.0264)
$\phi \times DUM_{HI}$					0.0912**
					(0.0290)
Obs.	170135	55796	181978	181978	181978
N. mult.	18173	10953	18881	18881	18881
R^2	0.717	0.720	0.933	0.711	0.724
FE	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-digit NACE classification, with the exception of column (3), which defines the sectors at the 4-digit NACE classification. DUM_{HI} is a dummy variable for whether the destination is a high-income country.

Table A5: Affiliate-parent comovement by parent and affiliate size

	(1)	(2)	(3)	(4)
	Affiliate sales < parent sales	Affiliate sales < $\frac{1}{4}\times$ parent sales	Affiliate sales > parent sales	Affiliate sales > $4\times$ parent sales
ϕ	0.260***	0.276***	0.0789	0.115
	(0.0131)	(0.0158)	(0.0704)	(0.227)
Obs.	164502	134636	17476	7411
N. mult.	17398	14441	4126	1885
R^2	0.731	0.747	0.906	0.962
FE	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 $\times$ destination $\times$ affiliate sector $\times$ parent sector $\times$ year fixed effects. Sectors are defined at the 2 digits of the NACE classification.

Table A6: Affiliate-parent comovement: Firm-level data

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Sales			Value Added			Employment		
	All	Manufacturing	Services	All	Manufacturing	Services	All	Manufacturing	Services
ϕ	0.0843***	0.0772***	0.117***	0.0718***	0.136***	0.0669***	0.0392***	0.0780***	0.0387***
	(0.00139)	(0.00152)	(0.00363)	(0.00219)	(0.00844)	(0.00251)	0.0020	0.0085	0.0023
Obs.	1638049	1142582	158824	524671	48362	347579	772841	70599	490033
N. mult.	223271	169596	37743	83587	7751	59306	118792	11119	83921
R^2	0.249	0.194	0.109	0.273	0.356	0.216	0.295	0.379	0.242
FE	Yes	Yes	Yes	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.