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Abstract

The emergence of global supply chains, that is the organization of production processes in factories that are part of a network of suppliers located in different countries and specialized in specific production phases, brings about a number of major changes in the way the global economy works and interacts. To explore more in detail this phenomenon from a microeconomic perspective, in this paper we provide evidence on Business Groups, that is network-like forms of hierarchical organization between legally autonomous firms spanning both within and across national borders.

Exploiting a unique dataset of 270,474 headquarters controlling more than 1,500,000 (domestic and foreign) affiliates in all countries worldwide, we find that business groups account for a significant part of value-added generation in both developed and developing countries, with a prevalence in the latter. In order to characterize their boundaries, we introduce an entropy-like metric able to summarize the hierarchical complexity of a group and its trade-off between exploitation of knowledge as an input across the hierarchy and the associated communication costs.

When relating these metrics to the performance of affiliates across business groups, we find a robust (albeit non-linear) positive relationship between a group's hierarchical complexity and productivity which dominates the already known correlation between vertical integration and productivity. Results are in line with the theoretical framework of knowledge-based hierarchies developed by the literature, in which intangible assets are a complementary input in the production processes.

Keywords

Supply chains; hierarchies; business groups; property rights; organization of production; productivity

1. Global Value Chains (GVCs) and Multinational Enterprises (MNEs)

The past decades have witnessed a rapid globalisation of economic activity which has significantly changed the outlook of the world economy. The fragmentation of production processes and the international dispersion of tasks and activities within them have led to the emergence of borderless production systems, which are commonly referred to as global value chains (GVCs). The current process of globalisation is characterized by an extensive flows of intermediate goods and services. According to the OECD, intermediate inputs represent 56 per cent of goods' and 73 per cent of services' trade among developed economies, with even higher shares for emerging markets (Miroudot et al., 2009).

Much of input trade involves multinational firms locating input processing in their foreign affiliates (Hanson et al., 2003). According to UNCTAD (2013), in 2010 multinational enterprises (MNEs) and their networks of foreign affiliates account for around 80 per cent of global trade. This means that the increasing importance of GVCs and flows of foreign direct investment (FDI) go hand in hand. This second novelty was made possible by the increasing liberalisation of investments which lead to the proliferation of MNEs, able to extend their activities even beyond industrialised countries.

In particular, the creation of GVCs takes place through a mix of outsourcing and off-shoring strategies driven by MNEs, aiming to find access to cheaper, more differentiated, and better quality inputs. According to US BEA data, one third of US exports and 45 % of US imports are due to bilateral shipments between subsidiaries and parent companies (called "related parties' trade").

Several trade models have been introduced with the aim to explain how GVCs shape comparative advantages between countries, among them we consider Baldwin & Venables (2013) and Costinot et al. (2013). The starting point of these models is to show the determinants of the geographic location of different parts of a value chain. Baldwin & Venables (2013) focus on trade costs as an important driver of production fragmentation. However, their model is sensitive to the particular configuration of the production process; they introduced the concepts of "snakes" and "spiders" as two arch-type configurations of production systems. The snake refers to a production chain organised as a sequence of production stages, whereas the spider refers to an assembly process on the basis of delivered components and parts.

However, actual production systems are comprised of a combination of various types. Costinot et al. (2013) developed a trade model which aims to explain how vertical specialization shapes the inter-dependence of nations. They propose a model with sequential production, where absolute productivity differences are a source of comparative advantage among countries. This elementary theory of global supply chains predicts that differences in country technological characteristics shape the trade relationships and competitiveness among nations. The key feature of the theory is that the technological characteristics are exogenous and are approximated by the higher or lower probability of making mistakes along a sequential production chain. The model aims to capture the idea that because of inefficient economic environment, which leads to less skilled worker, worse infrastructure, or inferior contractual enforcement, countries would have different comparative advantage in the global value chains.

These trade models are useful to analyze the current process of fragmentation of production but it is of limited use when studying decisions taken by MNEs. The new trade theories embedding firm heterogeneity provide useful insights in studying the location of MNEs and their affiliates. Starting from the assumption that contracts are incomplete, firms face the problem to understand the best organizational structure of production in the global economy. A growing body of literature has emphasized that companies' organizational decisions depend heavily on countries contractual frictions. Firm boundaries and allocations of control over production decisions within and across those boundaries are central elements of organizational design. For instance, a firm might decide to do business in a country with weak contracting institutions within firm boundaries in order to have more "control" on the production process. However, the lack of contract enforceability might also turn firms to independent suppliers in case they offer a better performance because it might dilute the integrated party's incentives to produce efficiently.

Although the literature has identified a considerable number of trade-offs involving firm boundaries, it has largely left open the question of how such trade-offs are resolved in the market. A body of literature has examined the question of whether goods are sold within or across firm boundaries in the global economy (see, for example, Antras (2003), Antras & Helpman (2006) and Helpman (2008) for an overview). In other words, firms in order to minimize production costs have to answer a two-dimensional decision problem: whether to source intermediate inputs from within the firm or not, i.e. the vertical integration decision; and whether to locate an economic activity in the country of origin or abroad, i.e. the offshoring decision.

In a first attempt to broaden the scope of the property rights approach, Hart and Holstrom (2010) develop a theoretical model in which assets ownership implies non-contractible management decisions, thus shifting the focus of the previous literature from the analysis of incentives for relationship-specific investments to the organization of management decisions. In a complementary approach, Garicano (2000), Garicano and Hubbard (2007) and Garicano and Rossi-Hansberg (2004, 2006, 2012) directly model firms as knowledge-based hierarchies, where coordinated management decisions are taken on the basis of the available knowledge, considered as an intangible and costly input which is complementary to physical inputs in production processes. In their theoretical framework an organizational structure is hence endogenous and dependent on the costs of acquiring and communicating knowledge among agents involved with different tasks within the firm hierarchy. Related to this literature, Marin & Verdier (2010) suggest how firms' organizational decisions are affecting firm performance and the nature of competition in international markets. Caliendo & Rossi-Hansberg (2012) empirically find that exporting firms increase the number of layers of management as a result of trade liberalization, with a more complex organizational design implying a higher firm productivity. A relationship between organization and productivity is also present in Bloom et al. (2010), who suggest that organization of decision making affects productivity with inverted U-shaped pattern, with excessive levels of centralization or decentralization sub-optimal.

2. MNEs as Multinational Groups (MGs)

In an economic environment in which GVCs are becoming increasingly important in shaping trade and production flows internationally, MGs (or Business Groups, BGs) forms are very common across different economic and institutional environments, in both developing and developed economies, accounting for a lion share of world value added. In terms of trade flows, a reading of the US BEA (2012) data along the dimension of MGs reveals that at least 75 per cent of total US trade can be linked to firms organized as multinational groups. A similar exercise for France, where transaction- and firm-level data have been matched to the ownership structure of companies, reveals that some 65 per cent of total French imports or exports can be attributed to firms (domestic or foreign-owned) that are part of a Multinational Group structure (Altomonte & Rungi, 2013).

However, while a large part of economic activity and trade can be attributed to firms organized as MGs, these organizational forms have been relatively neglected in the economic literature, where usually the focus has been on either individual firms choices of vertical integration or, more recently, on the within-firm organizational design for the transmission of management decisions. According to the findings of Altomonte & Rungi (2013), vertical integration choices are not independent from the hierarchical organization of production units along the command chain. The intuition here is that studying vertical integration while considering each affiliate of a MGs as an independent firm, as the literature has done insofar, would miss the structural correlation in vertical integration linking affiliates of the same group, thus generating potentially biased results.

MGs are defined as a set of at least two legally autonomous firms whose economic activity is coordinated through some form of hierarchical control via equity stakes. Legal autonomy and hierarchy are jointly constituent attributes of MGs, distinguishing them from independent firms (as these are legally autonomous but operate without impending hierarchies) and from multidivisional firms (which are organized through internal hierarchies of branches, but without autonomous legal status). Using this general definition, MNEs can also be considered as a special case of MGs, since they have by definition at least one legally autonomous affiliate located abroad, ultimately controlled by a parent located in the origin country.

The main difficulty in identifying MGs is related to the notion of control exerted by a parent. We opt here for a definition of control as established in international standards for multinational corporations (OECD 2005; UNCTAD, 2009; Eurostat, 2007), where control is assumed if (directly or indirectly, e.g. via another controlled affiliate) the parent exceeds the majority (50.01 %) of voting rights of the affiliate and can thus be considered as the Ultimate Beneficial Owner (or Ultimate Owner).

Such a notion of control is not exhaustive, as it leaves outside the boundaries of BGs affiliates de facto controlled through minority ownership, or peculiar forms of control derived by some form of market advantage (e.g. a monopsony), as well as particular forms of government regulations (e.g. .golden shares.). Yet, it has some clear advantages. First, the majority (50.01 %) of voting rights criterion creates a unique standard for both domestic and multinational Business Groups. Second, it allows to rule out cases of double (or triple) accounting of affiliates among different groups, thus generating a definition of the boundaries of a MG which is univocal (technically, each of our MGs is a closed set). Third, such a definition of control allows for a straightforward comparison with official statistics, as the majority of voting rights is the criterion commonly used in international standards on foreign affiliates (Eurostat or OECD FATS) and for international tax purposes (IAS, IFRS).

Figure 1: Multinational Groups as hierarchical graphs

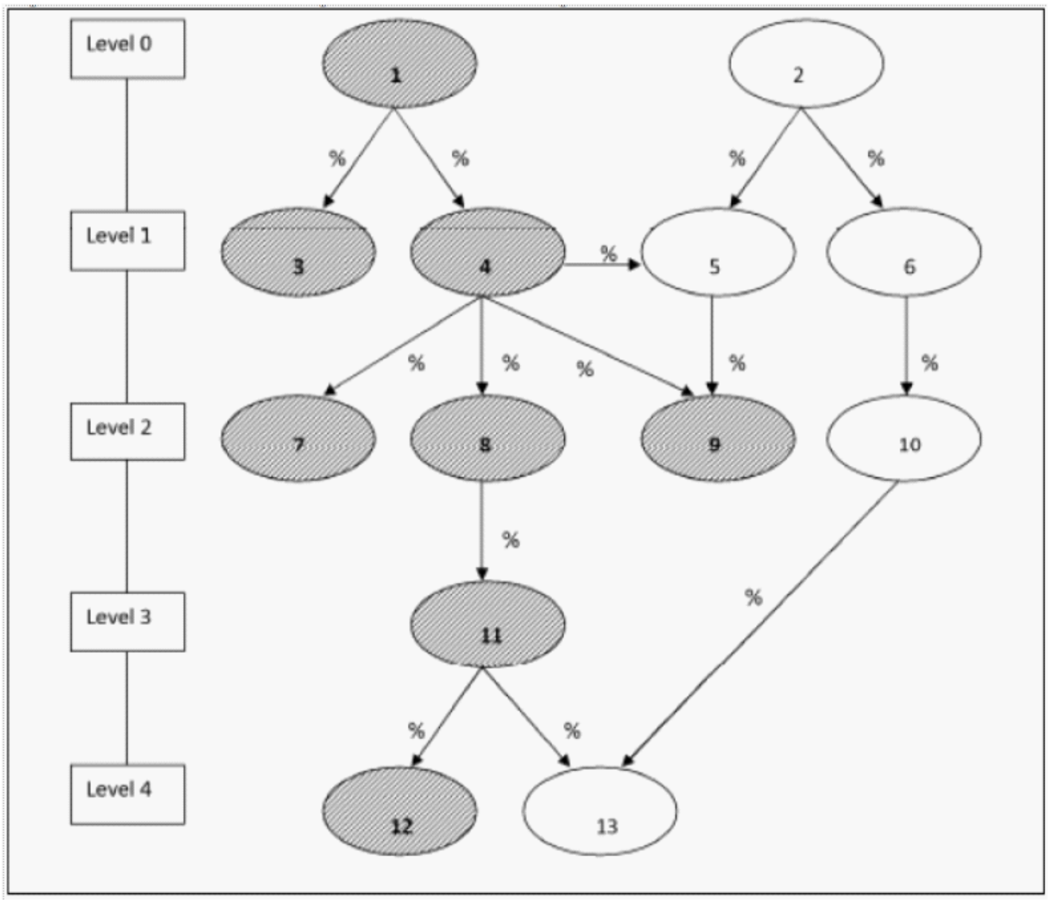


Figure 1 represents the organization of a typical Business Group as it can be derived by the application of the majority ownership notion of control. Such a representation corresponds to a mathematical object known as a hierarchical graph. The upper shaded node (1) represents the headquarters (or parent company), conventionally placed at level 0 of the hierarchy. The lower shaded nodes below level 0 represent the affiliates considered to be inside the boundaries of the same group, on their different hierarchical levels, with the edges connecting the nodes representing participation links. In this graph we interpret edges as control participations, but in a generic hierarchy of firms they could also represent trade flows of intermediate goods and services, or information flows for coordinated management actions. The white nodes are instead firms possibly participated by the considered MG, but excluded from its boundaries on the basis of the majority ownership threshold.

A particularly convenient property of representing Business Groups as hierarchical graphs is that it is possible to provide a synthetic measure of their organization through some hierarchical form of entropy. We can thus proxy the process of coordinated management that occurs within the hierarchy of firms in a BG by exploiting the information on the command chain that links single affiliates to the ultimate headquarter.

3. Data and GVCs-related metrics of MGs

Empirically, we lack systematic metrics of GVCs at the firm level. Information on MNE ownership structures and financial figures is fragmented, and transactions between co-affiliates within the same group are typically not reported. In order to overcome the data constraints the literature have studied the GVCs implications for national economies focusing along three dimensions: product, sector and country. Dedrick et al. (2008) adopted a product-level approach in order to understand who benefits from the fragmentation of the production processes. Cattaneo et al. (2010)'s volume assess industry-specific dynamics in diverse global industries, focusing on the opportunities and challenges faced by developing countries seeking to enter and upgrade their positions within GVCs. Finally, Hiratsuka (2011) studied the production networks in the Asia-Pacific region using a survey based on Japanese companies operating in Southeast Asia.

The Bureau Van Dijk data provider allows us to retrieve Multinational Groups for companies worldwide. Two different sorts of data have been combined: worldwide proprietary linkages provided by the Ownership Database and firm-level financial accounts, from Orbis. Both proprietary linkages and financial data refer to the information available in year 2010.

To identify the UO we developed an algorithm which starts from the bottom of the control chain, by classifying all the companies recorded in the according EU27 countries according to their degree of independence, as derived from the 50.01 per cent threshold of control. Once the algorithm distinguished companies as independent or controlled by other entities, companies are then partitioned in three categories: headquarters which are independent companies having subsidiaries, i.e. resulting as UO; control group which are independent companies not part of any group; affiliates, companies controlled by other entities matched to their respective UO. Affiliates are then partitioned in either domestic or foreign (according to their and the UO country of incorporation).

We result in a unique firm-level dataset able to map 270'374 headquarters controlling 1'519'588 affiliates in 2010, across more than 207 countries and all industries. Given the hierarchical graph structure described before, firm-level data of affiliates are stratified according to their position in each MG, taking into account the level of proprietary distance from the headquarter. For each headquarter and each affiliate along the control chain we have industry affiliations at the 6-digit NAICS rev. 2002 classification, including both primary and secondary activities from which we can infer measures of vertical integration, as well as balance sheet data from which we retrieve proxies of performance and productivity.

However, not all firms in our dataset report a complete set of financial data. Moreover, country-level data for some institutional variables we use as controls are not available forevery country. Hence, while we discuss here the complete dataset to introduce stylized facts on Business Groups, in our empirical strategies we rely on a restricted sample of data in which both firm-level and country-level information are available. The restricted dataset still encompasses 208,181 headquarters (groups) controlling a total of 1,005,381 affiliates in some 129 countries. The general properties of the data described here also hold for the restricted sample of Business Groups.

In Table 1 we provide a geographical coverage of the whole sample by some main countries/areas. The headquarters of Business Groups (parents) are classified by their home country in the second column, while in the third column we report the total number of affiliates they control worldwide, either domestically or abroad, a distinction provided respectively in column 4 (domestic affiliates) and 5 (affiliates abroad, i.e. outward FDI by parents). In the last column we report the foreign affiliates located in the area, resulting from inward FDI. Two thirds of Business Groups are originated in OECD economies, with those headquarters controlling around 75% of affiliates recorded in our data (66% of which are domestic).

Table 1: Geographic coverage of Business Groups (main countries/areas) by headquarters and affiliates

Economy	N. of parents (Business Groups)	N. of affiliates (A + B)	Domestic affiliates (A)	Affiliates abroad (B)	Foreign affiliates located in economy
OECD	177,306	1,148,011	757,778	390,233	324,255
non-OECD	93,068	371,577	295,882	75,695	141,673
European Union	144,562	735,487	496,209	239,278	258,060
US	9,935	211,265	114,364	96,901	40,404
Rest of the world	115,877	572,836	421,441	151,395	167,464
of which:					
Japan	14,236	119,374	102,306	17,068	4,351
Latin America	3,972	11,480	7,106	4,374	18,656
Middle East	3,130	18,008	7,675	10,333	9,147
China	1,922	24,868	18,146	6,722	17,494
Africa	1,095	10,733	5,961	4,772	12,298
ASEAN	1,870	26,333	15,272	11,061	15,578
Total	***270,374***	***1,519,588***	***1,053,660***	***465,928***	***465,928***

Only selected countries/areas are reported. Totals refer to all countries present in the complete sample.

Headquarters located in countries of the European Union, in particular, control 48% of total affiliates, of which roughly one third (259,278) are located abroad. The situation is different in the US, where around 46% of the affiliates controlled by American headquarters are located abroad. Developing countries, not surprisingly, have a larger share of domestic groups, with about 80% of the 371,577 affiliates controlled by non-OECD headquarters located domestically. Confronting the last two columns of Table 1, we can see how the OECD countries attract the vast majority (70%) of the 465,928foreign affiliates recorded in our data. We also observe a positive difference between outward and inward FDI stock (as proxied by number of affiliates) in developed economies, in particular in the case of US and Japan, where the number of affiliates located abroad outnumbers respectively more than twofold and fourfold the number of foreign affiliates located in the economy. European Union members seem an exception, but in that case it is intra-EU FDI activities that makes the net position almost in balance. In developing countries the inward FDI stock of firms is almost twice as large as the outward one.

To validate our dataset we can rely on few references since, to the best of our knowledge, there is no similar dataset covering control chains of corporate activities both domestically and abroad for all countries of the world. One partial exception is the World Investment Report of UNCTAD, which compiles yearly a list of the biggest corporations currently operating in the world, all present in our dataset with their affiliates. UNCTAD (2011) also reports the number of parents and affiliates involved in FDI activities hosted by each country. Based on these data, in Figure 2 we report the correlation between the number of headquarters controlling foreign affiliates abroad (left panel) and the number of foreign affiliates (right panel) located in each country, as retrieved from our sample and matched against the corresponding figures provided by UNCTAD (2011): correlations are .94 and .93, respectively. Finally, an indirect validation of the data is reported in Altomonte et al. (2012b). In that paper, the authors have matched transaction- and firm-level data for France to the ownership structure of companies as derived from our dataset, in order to estimate the amount of intra-firm (intra-group) and arms' length (non intra-group) exports of French firms to the US in 2009. Looking at the counter-factual of official data on US intra-firm and arms' length imports from France, as retrieved from the US Census Bureau, the two trade flows turned out to match very closely.

Figure 2: Sample validation: (Logs of) numbers of multinational parents and foreign affiliates by host country in the sample and in UNCTAD (2011)

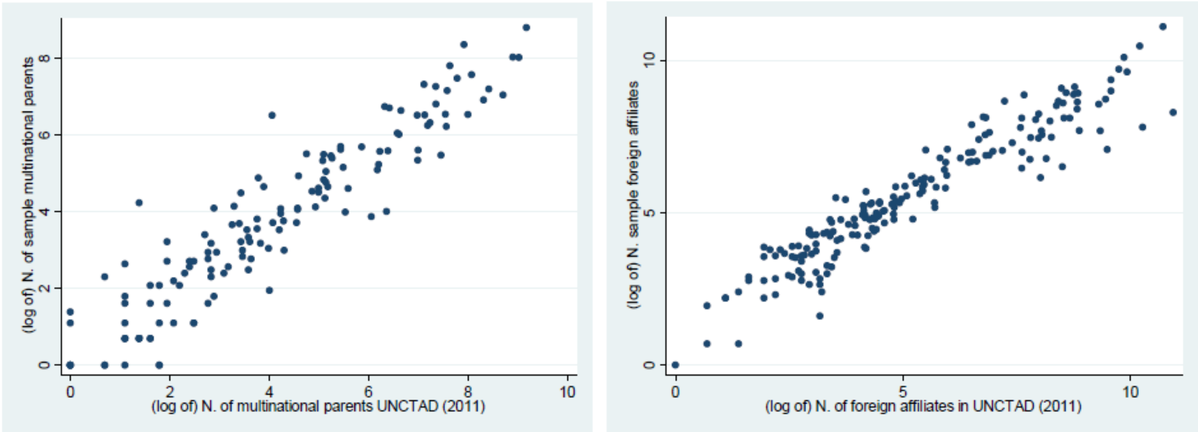


Table 2 shows how firms that are affiliated to MGs are on average bigger than non-affiliated firms along different dimensions: they employ on average 88% more workers, their sales are larger, they are usually more capital-intensive and almost twice more protable. They are also 4% more productive, even after controlling for size and capital-intensity. Moreover, affiliation premia do not display dramatic differences between OECD and non-OECD economies.

In addition to the superior performance of MGs affiliates, another typical characteristic found in the literature on heterogeneous firms is the remarkable skewness of the underlying distributions. In terms of hierarchies, the left panel of Figure 3 shows that 57% of firms in our dataset represent very simple organizations consisting of one headquarter and one affiliate, while about 13% of groups have more than five affiliates and only 0.7% of headquarters control more than 100 affiliates. However, the right panel of Figure 3 also shows that those 0.7% of groups with more than 100 affiliates are responsible for more than 70% of value added recorded in our data.

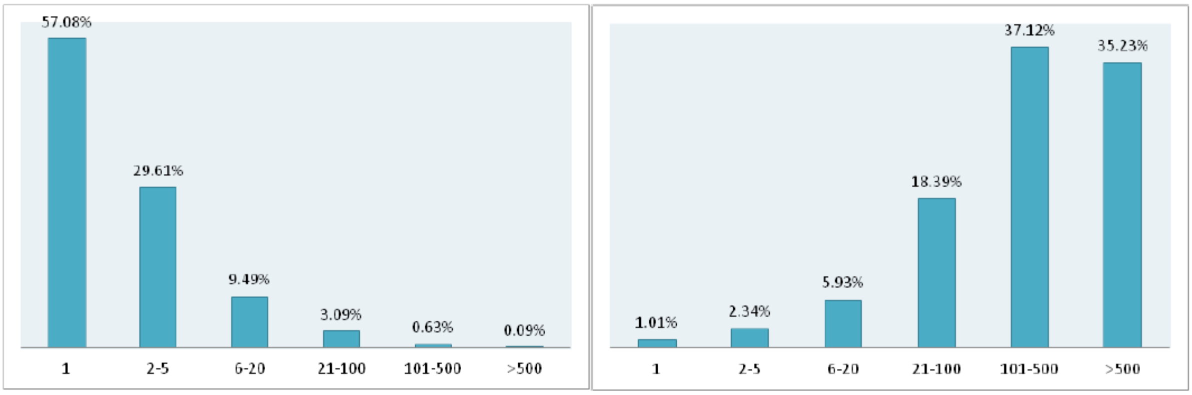
Once the boundaries of Multinational Groups have been identified via a suitable definition of control, and the group thus shaped up as a hierarchical graph, the calculation of a group's entropy (its organizational complexity) requires in principle to take into account the different dimensions in which the group can be organised: the number of nodes (i.e. affiliates); the edges, i.e. the strength of the control links; the number of hierarchical levels, represented by the vertical distance of affiliates from the ultimate owner.

Table 2: Premia for affiliates of Multinational Groups vs non-affiliated firms

Dependent variable	All countries	OECD economies	non-OECD economies
Log of employment	.88***	.90***	.80***
Log of turnover	1.32***	1.34***	1.15***
Log of capital	1.26***	1.25***	1.37***
Log of capital intensity	.30***	.29***	.35***
Log of profit	1.99***	2.01***	1.64***
Log of labor productivity (1)	.04***	.02***	.05***
	(.008)	(.008)	(.008)

Binary regressions with country-per-industry fixed effects; **, *** stand for significance respectively at 5% and 1%; (1) Capital-intensity and size added as a further control for a one-factor measure of productivity. See Appendix A for details on the control group of non-affiliated firms.

Figure 3: Size distribution of Multinational Groups, number of affiliates vs value added



a) Overall distribution of affiliates of Business Groups (size classes)

b) Overall distribution of value added of Business Groups (size classes)

Consider for example the case of two ex-ante similar Business Groups present in our dataset: General Motors and Mitsubishi. Both groups have a century-old tradition in the production of motor vehicles in their own country of origin (the US and Japan). Moreover, in 2010 our data report that these two groups have a similar size, as they control 659 and 652 affiliates in 54 and 32 countries, respectively. Still, when looking at industrial activities beyond motor vehicles, Mitsubishi is involved in some ten lines of business (e.g. electronic products, aircraft, shipbuilding, petroleum products, chemical products, primary metals, food and beverages, bank and insurance, real estate), while GM beyond motor vehicles provides only financial services for its customers. Accordingly, the affiliates of Mitsubishi are able to provide a wider range of intermediate inputs to the group, with firms typically operating in 3 or 4 main different industries, whereas the affiliates of General Motors seem relatively more focused on one or two main intermediate activities. As a result, the degree of vertical integration is higher for Mitsubishi than GM. Crucially, however, Mitsubishi is significantly less complex in terms of organization, with a much flatter hierarchical structure (with no more than 3 levels of hierarchy within the group), while GM is characterized by a deeper (up to 8 levels) and more complex hierarchy of cross-participations in its affiliates. Moreover, we also find that the labor productivity of affiliates belonging to the hierarchically more complex GM group is on average significantly larger than the one of Mitsubishi's affiliates.

3.1 The Global Index of Complexity

A particularly convenient property of representing Business Groups as hierarchical graphs, as in Figure 1, is that it is possible to provide a synthetic measure of their organization through some hierarchical form of entropy. We can thus proxy the process of coordinated management that occurs within the hierarchy of firms in a MG by exploiting the information on the command chain that links single affiliates to the ultimate headquarter. Borrowing from graph theory, the entropy of a hierarchical graph G characterized by a total of L levels of hierarchies can be constructed by assigning a discrete probability distribution $p : L \rightarrow [0, 1]$ to every level l in the hierarchy, where the probability $p_l = n_l / N$ is a function of the n_l number of nodes on each level l and the total number of nodes N, yielding a measure of node entropy which is specific for hierarchical graphs (Emmert-Streib and Dehmer, 2007).

$$H(G) = -\sum_{l} p_l \log(p_l) \qquad (1)$$

The H (G) measure of entropy is characterized by some useful properties: a) it is continuous; b) it is additive in L, so that each level l (order) of nodes can be considered a subsystem of the whole graph G; c) the measure is maximal when all the outcomes are equally likely, i.e. there is an equal number of nodes on each level l. Finally, the logarithmic entropy is also symmetric, meaning that the measure is unchanged if levels L are re-ordered. The symmetry of the measure is however an unpleasant property when applied to the case of Multinational Groups, since it implies that adding one node (affiliate) to the network increases its complexity independently from the hierarchical level at which the node is added. The latter is counter-intuitive in the case of a hierarchical organization characterized by a headquarter, because one might expect that the degree of coordination of the whole control chain (its complexity) should increase relatively more when affiliates are incorporated at proprietary levels more distant from the vertex.

For this reason we have refined the original H (G) formula introducing an additional weight to the probability distribution of levels more distant from the parent. After some straightforward manipulations we can rewrite our node entropy measure for Multinational Groups, which we refer to as Group Index of Complexity (GIC), as:

$$GIC = \sum_{l}^{L} l \frac{n_l}{N} \log\left(\frac{N}{n_l}\right), \qquad (2)$$

where as before the measure is a function of the n_l number of affiliates on a given hierarchical level l, of the total number N of affiliates belonging to the group and of the total number of levels (L). The index can theoretically range within the $[0; +\infty)$ interval, with zero now indicating a very simple organization in which a headquarter controls one or more affiliates located just one level of control below ($l = 1$). Moreover, the index retains some desirable properties of the original node entropy, as it is (logarithmically) increasing in the number of hierarchical levels. Importantly for our purposes, and contrary to the original hierarchical entropy measure $H(G)$, the GIC now allows to take into account the marginal increase in complexity brought about by affiliates added to lower hierarchical levels.

The economic rationale for a decreasing marginal complexity when affiliates are added at the same hierarchical level is associated to the idea that some economies of scale intervene when firms expand their network of affiliates horizontally, while coordination (and communication) costs can become more and more important once the network enlarges and deepens by locating affiliates to further levels from the headquarter. This is in line with the literature on knowledge-based hierarchies (see for example Garicano, 2000, or more recently Caliendo & Rossi-Hansberg (2012), according to which the optimal design of a management hierarchy is the result of a trade-off between knowledge and communication. A further layer of management increases the utilization of knowledge, for which some economies of scale are assumed, but at the same time it also increases the cost of communication along the hierarchy.

Accordingly, in our case the hierarchical distance from the headquarter implies a higher fixed cost of communication (hence our correction for node entropy), while further affiliates on the same level imply a decreasing marginal cost of knowledge. As a result, the hierarchical complexity of an object such as a Multinational Group cannot simply be proxied by its total number of affiliates N or by its number of hierarchical levels, with the index of complexity being not strictly monotonous in N. Another way to measure the complexity of the hierarchy developed by a Multinational Group could be the explicit introduction of an edge entropy, i.e. considering the strength of the cross participations as a further dimension to be included in the entropy index. In this case, the index would differ if an affiliate can be finally owned through direct participation (held by the headquarter) or indirect cross participations (held by any other affiliates in the control chain). However, given the scope of our analysis, the latter would not yield qualitatively different results, as we only use data on Multinational Groups characterized by a majority threshold for control that includes direct and indirect equity ties, in line with international business statistics. In terms of interpretation, that is equivalent to assume that, once the group boundaries are identified through control, any share above such a threshold would not significantly affect the complexity of the organization, as the headquarter would retain in any case the decision power.

In Table 3 we report some descriptive statistics that already show how both the node entropy in the second column and the GIC in the third column reproduce long right-tail distributions similar to the more simple number of affiliates but with some differences.

Skewness is much higher in the case of N, while H(G) and GIC start increasing rapidly only after the 83rd percentile of our sample, differently from the distribution of N which already has a right tail from the 75th percentile. Since until the 57th percentile our sample is represented by Business Groups having only one affiliate, both the node entropy and the GIC end up with null figures until that point of the distribution. However, given the logarithmic weight, also groups that have few affiliates but all positioned on a same control level ($N = n_l$;whatever l) end up with a H(G) and a GIC that both have null figures until the 83rd percentile. The top 1% of complex BGs has more than 900 affiliates and 10 levels of control, with a GIC higher than 4.7 reaching the maximum value of 19.

Table 3: Comparison of distributions: number of affiliates (N), node entropy (H(G)) and GIC

Statistics	N	H(G)	GIC
Mean	5.62	0.18	0.35
standard deviation	32.62	0.43	1.02
Skewness	28.59	2.43	5.34
50th percentile	1	0	0
75th percentile	3	0	0
90th percentile	8	0.92	1.45
95th percentile	16	1.00	1.88
99th percentile	74	1.83	4.70
Maximum	1000	3.27	19.07

In Table 4 we report sample averages of the Group Index of Complexity (GIC), for some selected industries and geographical areas. The industry is identified as the core sector where the majority of value added is created within the Business Group, even though many larger BGs can be involved in more than one line of business. The country is instead the home country where the headquarter is located, even though the group can have some affiliates abroad. The third and fourth columns of Table 4 show that the hierarchical complexity index is constantly higher for OECD economies with respect to non-OECD economies for each reported industry.

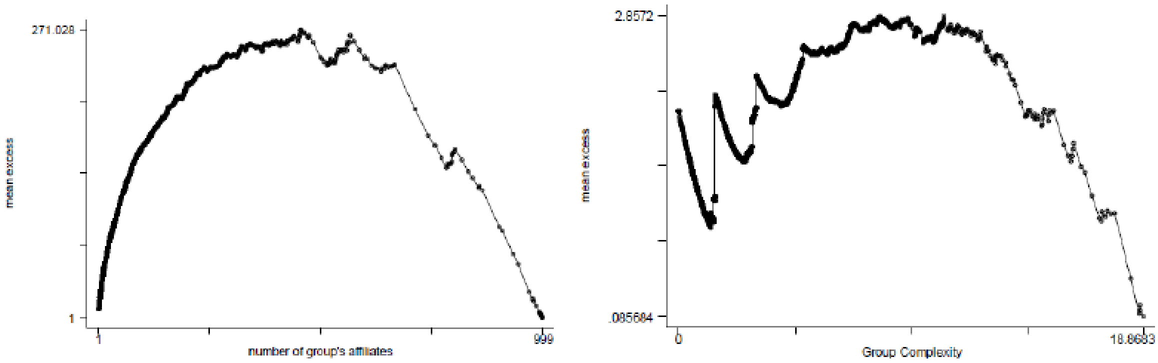
Table 4: Group vertical propensity and organizational complexity (averages) by selected industries and countries

Industry	OECD	non-OECD	European Union	USA	Japan	China	Africa	South America	ASEAN	All countries
Mining	0.626	0.356	0.124	0.764	0.339	0.370	0.597	0.924	0.922	0.530
Food	0.650	0.216	0.561	1.537	0.299	0.272	0.760	0.210	0.818	0.425
Textiles and clothing	0.503	0.170	0.426	1.639	0.257	0.134	1.160	0.366	0.836	0.349
Chemical products	0.789	0.278	0.538	1.579	0.455	0.096	0.301	0.293	0.736	0.588
Automotive	0.944	0.424	0.775	2.169	0.501	0.243	2.340	0.113	1.484	0.746
Electronic products	0.736	0.276	0.655	1.032	0.651	0.182	0.950	0.103	0.733	0.537
Business services	0.531	0.205	0.530	0.833	0.261	0.482	0.348	0.073	0.854	0.426
All industries	0.418	0.233	0.410	0.989	0.114	0.311	0.601	0.308	0.808	0.354

Groups originated in the US are the ones showing higher figures for hierarchical complexity in most industries, while Japanese groups display instead lower delegation of control (they are hierarchically less complex). The figures for developing economies show instead a higher variation across industries. Looking at the automotive industry in US and Japan, the preliminary evidence of the case studies is confirmed on industry aggregates, since the hierarchical complexity of the US car industry is higher than Japan. Overall, cross-country variation seems to dominate cross-industry variation.

The evidence that the GIC is characterized by a Pareto distribution, shown in Figure 4, can be interpreted in terms of graph theory as a minimum complexity of the hierarchical graph when nodes are all adjacent on a same level. From an economic point of viewit makes sense that Business Groups having affiliates all located at the same proprietary distance from the headquarter are more easily coordinated in the management of their activities. Moreover, if we assume that control runs univocally from the headquarter to each single affiliate, the cost of maintaining a control chain with only one affiliates and the cost of it where more affiliates are however located at the same level are virtually the same. The previous is the reason why GIC (and node entropy) is not monotonic in the number of affiliates, since the GIC (and the node entropy) is additive in proprietary levels but not in number of affiliates. Groups with the same number of affiliates can arrange them in one or more levels and the cost of exerting control through the network is higher in the latter case.

Figure 4: A visual comparison of number of affiliates (N) and GIC distributions: mean excess functions



4. Group Boundaries and Performance

Consistent with a large body of literature (for an overview see Helpman et al. (2004), Bernard et al. (2011) and Altomonte et al. (2012a)), UNCTAD (2013) find that participation in global supply chains is linked to firm productivity using firm-level data.[1] Compared with non-exporters (or non-importers), firms that engage in international activities show significantly higher productivity levels. Similarly, firms that engage in GVCs with NEMs have productivity levels that are lower than those of MNEs, which have activities in more than one country. Internationalization is therefore closely linked to productivity levels of firms. Firm-level productivity and country competitiveness go hand in hand. It is firms with high productivity levels that are behind countries participation in GVCs, and it is the further improvement of these firms productivity that is, to a great extent, behind countries success in upgrading.

Consistently with these findings, in Table 2 we have shown that also in our dataset firms that are affiliated to Business Groups (and thus to some extent might participate to global supply chains) are on average bigger and more productive than non-affiliated firms. What remains to be seen, however, is the extent to which different boundaries / organizational shapes of Business Groups map

[1] The EFIGE survey data merged with Amadeus, by Bureau Van Dijk, allow to implement Levinsohn and Petrin (2003) estimation algorithm to retrieve a measure of total factor productivity at firm level. Then each firm is categorized in a specific group of internationalization.

into a different productivity of affiliates. To explore these issues, we test whether the productivity levels of BGs' affiliates are systematically correlated to the degree of vertical integration and/or hierarchical complexity of the group, controlling for a number of additional groups' characteristics.

In our specification we take as dependent variable (the log of) labor productivity calculated as value added per employee of each affiliate a belonging to the g group, operating in core industry k and located in country c_a

$$\ln prod_{a(g)kc_a} = \beta_0 + \beta_1 v_{a(g)kc_a} + \beta_2 v_g + \beta_3 GIC_g^{\theta} + \beta_4 hdist_{a(g)kc_a} + \beta_5 for_{a(g)kc_a} + \\ + \beta_5 \ln emp_{a(g)kc_a} + \beta_6 \ln emp_g + \beta_7 \ln kl_{a(g)kc_a} + \lambda_{kc_a} + \varepsilon_{a(g)kc_a}$$

We also control for the affiliate-level and group-level of vertical integration ($v_{a(g)kc_a}$, v_g), as well as hierarchical complexity (GIC^{θ}) with $\theta = 1,2$ to control for possible non-linear effects. We also control for the hierarchical distance ($hdist_{a(g)kc_a}$) of each affiliate a within group g. The latter is the level at which the single firm is located within the network of affiliates that form a Business Group, as depicted in Figure 1, and can be interpreted as a control for the communication ability of the affiliate with the center of decision represented by the headquarter. Controls for capital intensity and size at the affiliate level ($emp_{a(j)kc_a}$, $kl_{a(j)kc_a}$) correct for the possible bias deriving from the use of a one-factor productivity indicator, at the same time controlling for relation-specific investments that a firm with a higher capital-intensive production can undertake. Total employment is included as a control at the level of the group (emp_g), together with a full set of (country-per-industry) fixed effects (λ_{kc}), in order to neutralize at this stage of the analysis all possible differences in institutional environments combined with industrial composition (here considered at the 3 digit level of disaggregation), and thus isolate as much as possible the effects of organizational design on affiliates' performance. Errors are clustered at the headquarter level, to account for within-group correlation. Results are presented in Table 5.

Looking at results, when we do not control for country fixed effects, as in the first column of Table 5, we obtain a negative correlation between vertical integration and productivity, both at the group- and at the affiliate-level. This is because Business Groups and their constituent firms are more vertically integrated in developing economies, where institutional frictions are more present and firm performance is on average lower than in developed economies. On the other hand, including country fixed effects but excluding industry fixed effects (column 2 of Table 5), we find a positive correlation between both indexes of vertical integration and productivity, although in this case several omitted variables can bias the correlation, among which the degree of market competition and the specific contractual completeness of the industry in which the firms operate. This is why starting from column 3 we include country-per-industry fixed effects.

Controlling for country-level heterogeneity combined with industrial composition (column 3), we find that only affiliate vertical integration is associated to average affiliates productivity, while group integration is not significant. The latter result is confirmed also controlling for foreign affiliates (which in turn, consistently with other findings in the literature, are found to be some 25% more productive than the average firm).

When also controlling for the hierarchic organization of the group (column 4), we find that all the measures of vertical integration lose both significance and magnitude, while hierarchical complexity appears to be positively and significantly related to productivity. This result is partially in line with the evidence provided by Atalay et al. (2012) in the case of US data, according to which much of the positive correlation between plant performance and vertical ownership structures fades away when controlling for firm size as proxied by total revenues, employment or number of establishments. However, differently from Atalay et al. (2012), in our strategy we distinguish between actual (affiliate or group) size, measured by (affiliate or group) employment in the above specifications, and hierarchical complexity, being able to show that also this latter dimension matters for affiliates' productivity.

The finding that the positive correlation between hierarchical complexity and productivity dominates the one between vertical integration and productivity can be related to the theoretical framework developed by Garicano and Rossi-Hansberg (2006) and Garicano and Hubbard (2007), who model firms as knowledge-based hierarchies. According to this strand of literature, knowledge is a typical intangible asset which is complementary to physical inputs involved in vertically linked products. Knowledge can be accumulated for example by hiring better managers and adopting better managerial procedures, but it has a fixed cost.

Table 5: Productivity levels and Business Groups' dimensions

Dependent variable :	OLS fe	OLS fe	OLS fe	OLS fe	OLS fe	OLS fe
log of (labor productivity)	(I)	(II)	(III)	(IV)	(V)	(VI)
affiliate integration	-2.092***	.377***	.133**	.106*	.104*	.104*
	(.085)	(.055)	(.059)	(.063)	(.063)	(.063)
group integration	-.587***	.239***	.055	.041	.035	.034
	(.097)	(.050)	(.037)	(.039)	(.040)	(.041)
group complexity	.062***	.020***		.009***	.038***	.041***
	(.004)	(.003)		(.002)	(.005)	(.005)
group complexity^2					-.002***	-.002***
					(.000)	(.000)
foreign			.283***	.256***	.246***	.250***
			(.012)	(.012)	(.012)	(.012)
hierarchical distance						-.012***
						(.004)
(log of) group employment	.073***	.027***	.019***	.015***	.013***	.013***
	(.002)	(.002)	(.002)	(.002)	(.002)	(.002)
(log of) affiliate employment	.264***	-.037***	-.030***	-.020***	-.022***	-.022***
	(.003)	(.003)	(.003)	(.003)	(.003)	(.003)
(log of) capital intensity	.264***	.171***	.181***	.181***	.180***	.180***
	(.003)	(.003)	(.003)	(.003)	(.003)	(.003)
Constant	3.956***	4.337***	4.294***	4.295***	4.280***	4.295***
	(.020)	(.016)	(.017)	(.015)	(.015)	(.015)
3-digit industry fixed effects	Yes	No	No	No	No	No
Country fixed effects	No	Yes	No	No	No	No
Country*industry fixed effects	No	No	Yes	Yes	Yes	Yes
Errors clustered by headquarter	Yes	Yes	Yes	Yes	Yes	Yes
Observations (N. of affiliates)	219,368	219,368	219,368	219,368	219,368	219,368
N. of Business Groups	64,026	64,026	64,026	64,026	64,026	64,026
Industries	105	105	105	105	105	105
Countries	129	129	129	129	129	129
adjusted R_squared	.288	.164	.479	.487	.488	.488

*, **, *** significance at 10%, 5% and 1%. Errors clustered by headquarters.

Therefore, given a firm size (in our case group size), best intangible assets can be shared in the presence of a larger number of units of production and hence their costs can be smoothed on a larger scale. Our results add to these findings, by showing that, within a Business Group structure, besides the positive relationship between group size and performance, also the complexity of the command chain is positively correlated with productivity. A well designed mechanism for the transmission of knowledge seems here crucial since it allows for an efficient exploitation of intangible assets throughout appropriately designed hierarchies able to decentralize decisions at the level where they are needed.

Unfortunately we have no direct information on the actual delegation of authority occurring within Business Groups. Still, we can presume that a higher number of layers of management (both in levels and nodes) could imply a more complex /delegated decision process. Under this assumption, our results can then be considered also in line with the findings of Bloom, Sadun and Van Reenen (2012), according to which more delegation of authority implies a higher firm-level performance thanks to a better reallocation of resources.

Our results also show that too complex an organization can also be problematic. As previously discussed, our measure of hierarchical complexity takes into account the higher fixed costs of communication between the single affiliate and the headquarter when more than one layer of management is involved in the decision process. From the point of view of the headquarter, it might be efficient to decentralize decisions at lower levels of hierarchies to better exploit intangible assets, but at the same time, as coordinating a decision with a distant affiliate is relatively more cumbersome, internal coordination costs can become so high that the organization becomes too complex to be managed efficiently. To capture this effect, in column 5 of Table 5 we have introduced a squared term in our hierarchical complexity variable, which turns out to be negative and significant. This latter result is in line with the microfoundation of organization provided by Caliendo & Rossi-Hansberg (2012), in which a minimum efficient scale exists in the acquisition and communication of knowledge throughout the hierarchy, associated to the emergence of endogenous communication costs.

Although we do not have information on a groups minimum efficient scale of production, from our estimates we can calculate the optimal threshold of complexity after which, ceteris paribus, returns from hierarchical complexity start to decrease: this is quite large, as it corresponds to a GIC of around 9.5, associated to groups exceeding the number of 550 affiliates and/or organized in control chains with over 5 levels of hierarchical distance. Such an evidence of marginally decreasing returns from increasing complexity is relevant, as it puts a natural limit to the growth in complexity: indeed, only 1 per cent of groups in our sample (the critical value of GIC is around the 99th percentile of its distribution) exceed this average ”optimal” organizational threshold.

Finally, as a robustness check of the theoretical assumption of increasing marginal costs of communication across hierarchical levels, in the last specification of Table 5 we have introduced a control for the simple hierarchical distance of the affiliate, i.e. the length of the command chain linking each affiliate to the parent company. We find that on average the further the firm is from the decision making center, the lower its level of productivity appears to be. But the latter result only holds when we control at the same time for our measure of hierarchical complexity. When considering only hierarchical distance in the model, i.e. excluding hierarchical complexity, affiliates located at further levels of control would actually display higher levels of productivity. This is consistent with the idea that across BGs affiliates located at lower hierarchical levels discount a higher positive premium for productivity thanks to the organization effects discussed before, while within BGs (that is, when we do control for hierarchical complexity) the higher marginal costs of internal communication affects the single affiliate’s performance.

5. MGs and transmission of shocks

Another channel through which global supply chain can affect the competitiveness of countries is via their ability to affect the speed and depth of crises acting as a channel through which shocks can be propagated.

Indeed, the "Great Trade Collapse" has been one of the most striking features of the recent global financial crisis. Apart from its magnitude, the fall in trade during the crisis has also been quite homogeneous across all countries: more than 90 per cent of OECD countries have exhibited simultaneously a decline in exports and imports exceeding 10 per cent. The fall has also been very fast, with trade virtually grinding to a halt in the last quarter of 2008. Looking at US trade, Alessandria et al. (2011) find an extraordinary high trade elasticity to GDP, above 5. All these findings have led to qualifying the drop in trade during the crisis as severe, sudden and synchronized (Baldwin and Evenett, 2009). A number of transmission mechanisms (Baldwin, 2009) have been proposed which could account for such peculiarities, making the latest generalized trade drop quite unique among the many episodes of trade decline after a financial crisis (Abiad, Misha and Topalova, 2010). Considering the transmission mechanism of global value chains, a first argument is that the magnitude of the trade drop is due to a problem of multiple accounting. In a world increasingly characterized by vertical specialisation, i.e. with goods produced sequentially in stages across different countries, the same component of a final good is exchanged (and thus recorded at gross value as trade) several times before the final product reaches the consumer. As a result, for a given reduction in income, trade should decline not only by the value of the finished product, but also by the value of all the intermediate trade flows that went into creating it (Yi, 2009; but also previously Bergoeing et al., 2004).

A second channel that relates the magnitude and the synchronization of the latest trade drop to the emergence of global value chains is the inherent adjustment in inventories after a demand shock that the existence of inter-firm linkages implies. The wider fluctuations in terms of trade elasticities are in this case an overreaction due to adjustments in the stocks of intermediate inputs by firms involved in complex supply chains (Stadtler, 2008; Escaith et al., 2010; Freund, 2009). According to this argument known as the "bullwhip effect" (Forrester, 1961), each participant to a supply chain had a greater observed variation in demand during the crisis and the initial negative shock propagated up the value chain. The logic is as follows. When final demand is subject to volatility, businesses typically face forecast errors against which they try to shelter by building safety stocks of inventories. Upstream participants to a supply chain face greater demand volatility than downstream ones, so the need for such stocks rises moving up the value chain. The result is that variations in final demand are amplified as one moves away from the final customer. When applied to the current context, the foregoing logic implies that, with falling demand, orders decreased more than proportionally because firms were able to draw on inventories after expectations of lower future demand. Firms involved in value chains reduced their stocks more than proportionally while the shock propagated up the value chain. Alessandria et al. (2011) successfully tested this argument for the US.

A role has also been acknowledged for the credit crunch suffered by internationalized firms. According to (Bricongne et al., 2011), credit constraints emerged as an important aggravating factor for a sample of French firms operating in sectors of high financial dependence. About 20 per cent of the contraction in exports of financially constrained firms was explained by their status of being financially constrained. This effect seems to be entirely driven by developments in sectors of high financial dependence. Nonetheless, as the weight of financially constrained firms is small relative to the universe of French exporters, and since their number did not increase much during the crisis, the impact of credit constraints on overall trade remains limited.

To this extent, Altomonte et al. (2012b) exploit transaction level French trade data matched with ownership data on Business Groups located in France for the period 2007-2009 to find evidence of a role for global value chains in explaining the magnitude of the trade collapse. Consistent with other results, they find that trade in intermediates has been the main driver of the trade collapse. However we also find that different organizational modes of the supply chain entailed different dynamic responses: related party trade in intermediates exhibits a faster drop followed by a faster rebound with respect to arm's length trade in intermediates. In other words, trade originated within multinational groups seems to have reacted faster to the negative demand shock but has also recovered faster in the following months than arm's length trade.

Among the alternative channels of transmission of a demand shock to trade proposed in previous studies, the adjustment in inventories seems the most consistent with these findings. Indeed, through an adjustment of inventories, amplified fluctuations of trade with respect to GDP could be associated to the so called ”bullwhip effect”, i.e. a magnification of the initial (negative) demand shock along the supply chain due to an adjustment of production and stocks to the new expected levels of output. In this case, our finding of a better performance of related party trade could be explained by a better handling of inventories within multinational groups, thanks to a more efficient and synchronized (vs. sequential) circulation of information and the ensuing optimal management of stocks within the boundaries of the group.

Clearly, a role for trade credit constraints cannot be excluded, since hierarchies of firms may have relied on an internal capital market to soften the crunch of external financing, but that would however explain only a faster recovery of related party trade and not the faster drop at the outburst of the crisis.

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