

Business Groups as Knowledge-Based Hierarchies of Firms*

Carlo Altomonte
(Bocconi University)

Gianmarco I.P. Ottaviano
(Bocconi University and LSE)

Armando Rungi
(IMT Lucca)

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Abstract

We propose a new theory of business groups as knowledge-based hierarchies that arise when contractual incompleteness may lead to dissipation of firms' specific knowledge. The theory predicts that a parent firm choosing to organize its activities as a business group rather than as a single integrated entity is more likely to emerge in good institutional environments. When this happens, a 'hierarchical' business group with several layers of subsidiaries controlled by the parent is more likely to appear than a 'flat' one with fewer layers if the firm has better production possibilities (which require more challenging problem solving), faces lower communication costs between hierarchical layers, and incurs a lower skill premium in hiring good managers. We provide empirical support for these theoretical predictions exploiting the unique features of a dataset in which we observe the ownership structures (number of subsidiaries, countries and industries in which subsidiaries operate, and the subsidiaries' positions at different hierarchical layers) of 178,190 business groups incorporated in OECD countries and controlling more than 1,150,000 (domestic and foreign) subsidiaries worldwide in the year 2010.

JEL classification: D23; L23; F23; L25; G34

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1 Introduction

A business groups (BG) is a non-standard organizational form consisting of a collection of at least two legally autonomous firms that function as a single economic entity through a common source of hierarchical control via equity stakes. BGs are crucial components of the global economy. The world's largest businesses by consolidated revenue (as classified in the Fortune 500 list) as well as the top 100 multinational enterprises (as listed by UNCTAD) are all organized as BGs. These multinational groups have on average around 300 affiliates/subsidiaries each, and up to 10 hierarchical layers of control (UNCTAD, 2016). According to BEA data, at least 75% of total US trade can be linked to firms operating in the US as parts of BGs (either as US headquarters or US subsidiaries of foreign groups).¹ Yet, despite the practical relevance of BGs, it is still broadly true what Baker, Gibbons and Murphy (2002) wrote several years ago: "The economics literature has not had much to say about non-standard organizational forms [...] now much discussed in the business and organizational literatures, including [...] business groups".²

The aim of the present paper is to contribute to filling this gap in the economics literature by developing and testing a knowledge-based theory of BGs, in which this organizational form emerges as the optimal solution to a problem of knowledge creation, transmission and potential dissipation in multiteam production when contracts are incomplete.

In principle, a BG can emerge as the result of four types of decisions by a common source of hierarchical control (henceforth called 'headquarter' or simply HQ). First, there is the 'portfolio decision' on *which* activities the HQ would like to be performed. Second, there is the 'integration decision' on *who* should be put in charge of performing any given activity, that is whether the activity should be performed within the boundaries of the HQ (through divisions or branches) or outside the boundaries of the HQ's organization (through controlled subsidiaries or outsourcing).³ Third, there is the 'hierarchy decision' on *how* the activities have to be structured, in particular which type of hierarchical structure should serve the purpose of carrying out them in a systematic way. Fourth and last, there is the 'location decision' on *where* the various activities should be performed within and beyond national borders. While all four decisions together constitute the overall organizational decision of the HQ, it is the integration and hierarchy decisions that define the peculiar traits of BGs. These defining decisions are the focus of the present paper.

Both the integration and hierarchy decisions have received extensive attention in the literature, but never before jointly or even separately in the specific case of BGs. For instance, Belenzon

¹In the case of France around 65% of aggregate imports or exports can be attributed to firms that belong to BGs (Altomonte et al., 2013).

²BGs have been studied by the business literature, although often confined to emerging countries (Colpan and Hikino, 2010; Khanna and Yafeh). Williamson (1975) hints at the view of BGs as organizational forms located between markets and hierarchies. A number of studies point out the difficulty of classifying these network-like organizational forms (Powell, 1990; Granovetter, 1995; Hennart, 1993).

³Divisions are organizational units defined within the premises of the HQ. Branches are production units physically separated by the HQ but not legally independent from it. Subsidiaries are legally independent companies controlled by the HQ. Outsourcing takes place through independent suppliers, thus outside the boundaries of the Business Group.

et al. (2013) highlight the presence of internal capital markets as a crucial advantage of BGs. Bertrand et al. (2002) relate the creation of BGs to the ‘tunneling’ of profits from subsidiaries to HQs. Lewellen and Robinson (2013) stress the tax arbitrage motive behind the emergence of BGs. Almeida and Wolfenzon (2006) study the pyramidal structures of BGs through the lenses of separation between cash flow and voting rights. Differently from but complementarily to all these approaches, we conjecture instead that an additional reason behind the creation of BGs is the efficient management of HQ-specific knowledge, created and transmitted within the boundaries of the group in order to protect it from possible dissipation when contractual incompleteness undermines intellectual property rights (IPR).

Within the conceptual framework we propose, specific knowledge is communicated to, enriched by and embedded in the human resources the HQ relies on for its activities. Specific knowledge can be used repeatedly as an input in production. However, in doing so, the HQ has to deal with two crucial issues. The first issue is that human resources face a time constraint that limits how often their embedded knowledge can be used. The time constraint can be relaxed when human resources are organized as a hierarchical collection of teams according to their knowledgeableability. This arrangement allows less knowledgeable teams to perform activities with lower knowledge intensity under the supervision of more knowledgeable teams, which in parallel can specialize in more knowledge intensive activities. In this perspective, the *hierarchy decision* solves the problem of how to use knowledge efficiently and how to communicate it among human resources so as to minimize the cost of using it as a production input (Garicano and Rossi-Hansberg, 2015).

Specifically, we assume that each activity is performed by a team consisting of a manager and an endogenous number of workers. We abstract from the internal hierarchy of individuals within teams, an issue already studied by Garicano (2000) and Garicano and Rossi-Hansberg (2006) among others.⁴ We focus, instead, on the external hierarchy of teams considered as separate production units within the BG. We study a situation in which the HQ already knows the production possibilities (i.e. owns the ‘blueprints’) of a given set of products and acts as a monopolist for each of them in a perfectly integrated economy in partial equilibrium as in Garicano (2000). The fact that the portfolio and the location decisions are both immaterial in this setup allows us to emphasize the integration and hierarchy decisions.

Each team is involved in the supply of one and only one product. All products face identical CES demand functions as well as identical production possibilities. However, before a team can turn the production possibilities of its product into actual production, its manager has to solve a problem. The problem comes in versions of different level of difficulty. If solved, more difficult versions allow for more efficient production. Their solution, however, requires more knowledgeable managers, whose hiring is more expensive. Problem solving also requires the HQ’s supervision, which can be direct or indirect through a managerial hierarchy. Indirect supervision arises because helping a manager absorbs time due to communication costs and the

⁴See also Caliendo and Rossi-Hansberg (2012) for an extension to a international trade context.

HQ has only a limited amount of time available. It is feasible because more knowledgeable managers not only can solve more difficult versions of the problem, but they can also help less knowledgeable managers solve less difficult versions of the problem. Nonetheless, as the HQ, each manager has only a limited amount of time to devote to supervision. Given all these time constraints, the optimal way to deal with problem solving when direct supervision is not viable is through a knowledge-based hierarchy of teams such that more (less) knowledgeable managers solve harder (easier) versions of the problem in teams assigned to higher (lower) hierarchical layers.

The second crucial issue the HQ has to deal with is that its specific knowledge is only imperfectly contractible and thus dissipable were human resources to walk away. This issue of potential knowledge dissipation is what the *integration decision* has to deal with. To model such decision we rely on the property rights approach to the theory of the firm (Antràs and Rossi-Hansberg, 2009), giving the HQ a choice between integrating a team inside its boundaries with no legal autonomy ('division') and having alternatively the team as a legally autonomous entity under its control ('subsidiary'). The latter arrangement defines the distinctive trait of a BG.⁵

Potential knowledge dissipation arises from the fact that, when the HQ assigns a team with supplying a product, it has to reveal the corresponding production possibilities, i.e. the problem that need to be tackled in order to start production. Contractual incompleteness mars the specific relationship between the HQ and both the division and the subsidiary as neither the quality of the product supplied nor the knowledge revealed are contractible in this case. This contractual situation therefore compounds the standard 'quality holdup' with a novel 'knowledge holdup', which are assumed to be more severe for the subsidiary than the division due to the legal autonomy of the former.

We also assume that, whereas a product of sub-par quality is worthless both inside and outside the relationship between the subsidiary and the HQ, this is not the case for the revealed production possibilities as these have positive value for the subsidiary even outside the specific relationship with the HQ. The underlying idea is that, due to different allocation of residual property rights, the value of the outside option and thus the risk of knowledge dissipation are lower when the team is a division with no legal autonomy rather than a legally autonomous subsidiary. Under these circumstances, a trade-off for the HQ arises from the fact that, thanks to its more valuable outside option, a subsidiary has a stronger incentive than a division to invest in the specific relationship with the HQ, but at the same time the more valuable outside option also implies that the HQ can extract less rent from the relationship. In other words, the surplus the HQ can generate through a subsidiary is larger than through a division, but the

⁵ A third canonical option for the HQ would be to keep the team as an independent agent from which to source ('outsourcing'). However, the tradeoff between in-house and arm's length sourcing has been investigated in depth by the existing literature. For parsimony we thus prefer to abstract from the implied 'make or buy' decision by assuming that circumstances are such that the HQ has already ruled out outsourcing as a profit maximizing option. This allows us to shift the focus of our analysis from the familiar 'make or buy' decision to a 'how to make' decision.

share of surplus the HQ can extract is smaller.

To summarize, in our model an *integration decision* determines whether teams are organized as divisions or subsidiaries: the decision strikes the optimal balance between rent extraction with knowledge protection on the one side, and team incentivization with knowledge dissipation on the other. A BG emerges when the integration decision leads to teams being run as subsidiaries, which the model predicts to be more likely to happen in institutional environments that better protect IPR. How subsidiaries are arranged in hierarchical order is then determined by a *hierarchy decision* that optimally solves the problem of how to use, communicate and enrich HQ-specific knowledge efficiently. In this respect, the model predicts that a BG is more likely to arrange its subsidiaries on a larger number of layers when the HQ is endowed with a larger amount of intangibles, problem solving is more challenging, communication costs between layers are lower, and the skill premium for more knowledgeable managers is smaller.

We test these predictions exploiting the unique features of an original dataset we constructed from Orbis ownership data provided by Bureau Van Dijk. The dataset covers 178,190 parent companies (HQ) incorporated in OECD countries and controlling more than 1,150,000 (domestic and foreign) subsidiaries worldwide in year 2010.⁶ It includes information on the ownership structures of BGs in terms of number of subsidiaries, countries and industries in which subsidiaries operate, and the subsidiaries' positions at different hierarchical layers. It also covers around 4.5 million independent firms not part of BGs in 2010 and before, which we use as control group.

In line with our theory, the empirical test of the model confirms that firms in a given industry and of a given size/age are more likely to set up subsidiaries when operating in countries with better IPR protection. This finding is robust to the inclusion of other country-specific variables, such as the level of financial development, the past level of income and growth, and the general quality of institutions. We also find evidence consistent with the idea that BGs are more likely to be structured over a larger number of hierarchical layers when communication between parents and subsidiaries is easier, when subsidiaries face less standardized assignments, and when the skill premium for better managers is lower. These results are robust to the inclusion of additional controls at the group level, including locational characteristics of the countries in which the BG operates (such as the tax level, number of patent per inhabitants, financial development, quality of the business environment) that might affect the hierarchical structure of the BG in addition to (or in correlation with) the explanatory variables we target.

The rest of the paper is structured as follows. Section 2 present our dataset and highlighting some stylized facts on their integration and hierarchy patterns. Section 3 presents our knowledge-based theory of BGs. The main empirical implications of the theory are first discussed and then tested in Section 4. Section 5 concludes.

⁶Orbis data have already been used in the literature to study BGs in terms of innovation (Belenzon et al. 2010), the international transmission of shocks (Cravino and Levchenko, 2017), or the effect of managerial culture on firm boundaries (Gorodnichenko et al., 2017). Other studies, related to the global reach of international groups (e.g. Alfaro et al, 2009 and 2017), have relied instead on data sourced from Dun & Bradstreet (D&B), which is one of the different sources integrated in the Orbis Ownership database.

2 Business Groups as Hierarchies of Firms

We define a Business Group (BG) as a collection of at least two legally autonomous firms that function as a single economic entity through a common source of hierarchical control. Control is exerted by a parent company (‘headquarter’, or simply HQ) on one or more affiliates via equity stakes.⁷ Under this definition, multinational enterprises (MNEs) can be considered as a subset of BGs that have at least one legally autonomous affiliate abroad. In the case of economic entities with more than one productive plant (multi-plant firms), or organized internally through multiple divisions, if all plants or divisions are commanded by the same firm under a single legal status, we consider them as branches of that firm, i.e. they are not BGs according to our definition.⁸

2.1 Dataset

As affiliates can be directly or indirectly controlled by the HQ, we identify the boundaries of a BG relying on the notion of ‘corporate control’ established by the international accounting standards (OECD 2005; UNCTAD, 2009; Eurostat, 2007), according to which a parent controls an affiliate when it commands a direct or indirect majority ($> 50\%$) of voting rights.⁹ This notion of control neglects cases in which affiliates are *de facto* controlled through minority ownership ($< 50\%$) as well as cases in which control derives from market advantage (e.g. monopsony) or government regulations (e.g. ‘golden share’). Yet, it has some clear advantages. First, the majority of voting rights applies equally to domestic and multinational BGs. Second, it allows for a straightforward comparison with official statistics, as the majority of voting rights is the criterion commonly used for foreign subsidiaries (Eurostat or OECD FATS) and for international taxation (IAS, IFRS). Last but not least, it prevents multiple accounting of affiliates across different BGs so that each BG is a *closed* set of firms.¹⁰ Henceforth, given that an affiliate majority-owned by a parent company is called ‘subsidiary’ of that company, we will use the terms affiliate and subsidiary interchangeably.

As an illustrative example, Figure 1 represents the structure of a BG as a hierarchical graph, with the parent company located at the top layer 0 and its subsidiaries arranged at different lower layers along the chain of control. Subsidiaries can be directly or indirectly controlled by the parent, and each of them can perform a different activities for the parent.

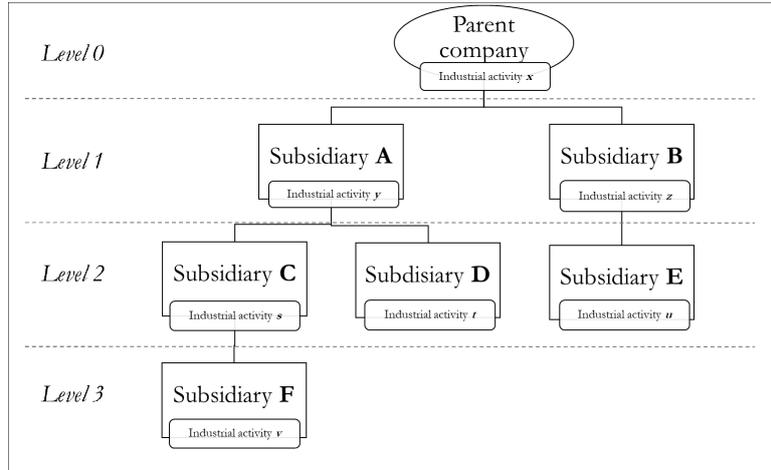
⁷An ‘affiliate’ is defined as a legally independent firm with shares (partially) owned by the parent company.

⁸The notions of branches/divisions and subsidiaries/affiliates tend to overlap in some contexts. In this paper, in accordance with international standards (for example UNCTAD, 2009) we define a branch as a new productive location, division, department or office set up by a corporation and positioned within the original legal boundary of the company. As a result, our definition of BG rules out strategic business alliances, but it includes in principle joint ventures, since in this case corporate assets are owned (and controlled) by more than one proprietary firm.

⁹Corporate control can be derived by a direct, indirect or consolidated concentration of voting rights (Faccio and Lang, 2002; Chapelle and Szafarz, 2007; Del Prete and Rungi, 2017). For example, company H can control 60% of shares of company A, which controls 70% of shares of company B. Although company H does not formally control company B directly, it does indirectly, via company A. The latter is known as the principle of the Ultimate Controlling Institution in the OECD FATS Statistics (or Ultimate Beneficial Owner in UNCTAD data).

¹⁰We are not the first to use this notion of corporate control to identify the boundaries of BG (see, e.g., Belenzon, 2010 and 2013). Appendix A provides further details on the relationship between ownership and corporate control.

Figure 1: A business group as a hierarchy of firms



To build our dataset of BGs, we have sourced worldwide proprietary linkages and firm-level financial accounts from the Orbis ownership database by Bureau van Dijk for the year 2010. Based on these linkages, we have identified the firms for which a parent company has a command of direct or indirect majority of voting rights. Together with the parent company, these majority-owned affiliates form its BG. Firm-level information on affiliates is then stratified according to their hierarchical distance from the parent. For each parent company and each affiliate along the control chain, we also collect industry affiliations following the 6-digit NAICS rev. 2007 classification. We end up with an overall sample of 270,374 parent companies, controlling a total of 1,519,588 (domestic or foreign) affiliates in 207 countries in the year 2010.

Table 1 describes the sample. Two thirds of our BGs' parent companies are headquartered in OECD economies, controlling around 75% of affiliates worldwide. About 20% of the groups incorporated in OECD countries are multinational companies. The proportion of MNEs is only 14% when originating from developing countries. This is in line with previous findings (Khanna and Yafeh, 2007) showing that emerging economies have a relatively larger proportion of domestic firms organized as BGs. The vast majority of parent companies report a primary activity in service industries, especially in OECD countries. The share of primary industries for parents is slightly higher in developing economies. Clearly, a parent can be active in a service industry (e.g. as a holding company classified in the financial industry) and still control affiliates operating in manufacturing, primary or service industries.

To validate our dataset, we rely on UNCTAD (2011), which reports details on the numbers of parents and subsidiaries of MNEs by country for the same year of our sample. The correlations of UNCTAD figures with our corresponding sample of BGs are 0.94 and 0.93 when measured by country at the parent or subsidiary level, respectively.¹¹

At the bottom of Table 1 we also include information on independent firms that are neither

¹¹See Appendix A for additional details.

Table 1: Sample distribution of Business Groups

	Total sample	OECD sample
N. of parents	270,374	178,190
<i>of which:</i>		
- Multinational HQ	49,897	36,314
<i>HQ main activity:</i>		
- Agric. & Mining	6,840	3,467
- Manufacturing	25,718	14,634
- Services	237,816	160,089
<i>HQ controlling:</i>		
Subsidiaries	1,519,588	1,154,138
Independent firms (control group)	-	4,160,047

controlled by any parent nor they control any affiliate in 2010, which we use as a control group. These set of firms, however, may suffer from a potential sample selection bias due to heterogeneity in the quality of data across countries as long as, especially in developing countries, information is typically available only for the largest firms. If this were indeed the case, our control group would under-represent the actual population of firms and, to the extent that parent companies are relatively larger, that could bias some of our results. To deal with this sample selection issue, in this paper we use a restricted sample of all BGs with parents based in OECD countries, for which the representativeness of firm-level data tends to be better, consisting in 178,190 BGs originating from 32 countries and a control group of 4,167,873 independent firms.¹² For the parent firms located in OECD countries we retain all information on their worldwide network of affiliates (around 1.15 million affiliates, as reported in Table 1).¹³

2.2 Stylized Facts

While our dataset is very rich, we want to highlight four main facts coming out of its descriptive analysis. First, while BGs are heterogeneous in terms of numbers of affiliates and hierarchical layers, the majority consists of one parent and one subsidiary. Among the others, only a small fraction have a large number of affiliates. Among these, while many have also a large number of layers, there are BGs that have only very few layers. Second, the most common hierarchical structure of BGs is the ‘inverted pyramid’ with larger density of affiliates in layers that are closer to the parent company along the chain of control. Third, firms headquartered in countries with better institutions are more likely to operate within BGs. However, in the specific case of IPR protection, the probability that a firm operates as part of BG is higher for intermediate levels of IPR protection and lower for low as well as high levels of IPR protection. Fourth and last, BGs specialized in narrower sets of industries have larger numbers of hierarchical layers and subsidiaries at lower hierarchical layers of control are active in industries characterized by a relatively higher degree of task standardization.

¹²We do not have enough information on BGs operating in 2010 out of Estonia, Latvia and Slovenia, three small open economies now members of the OECD.

¹³We will come back to the issue of potential sample selection of the control group later in the paper.

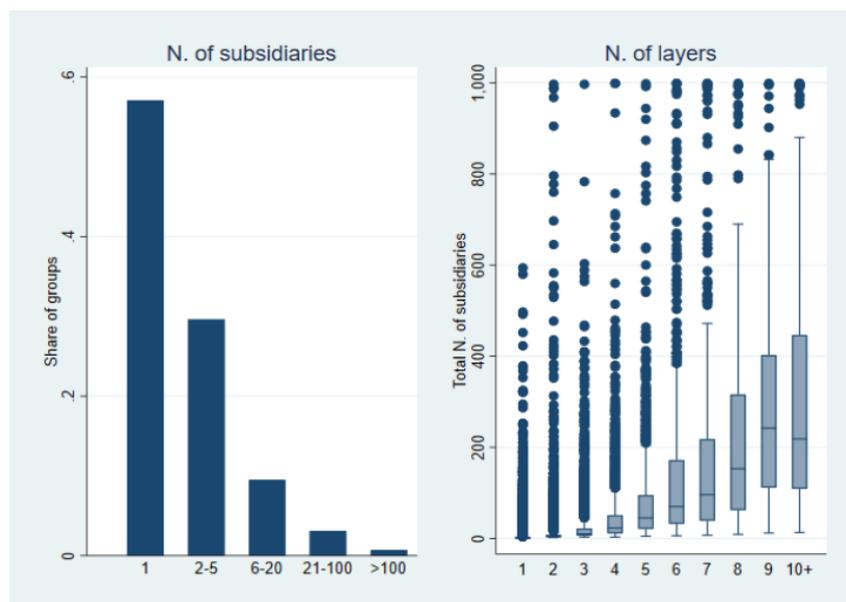
Explaining these facts is the aim of the model of BGs as knowledge-based hierarchies of firms that we will put forth in Section 3 and then test in the following sections.

2.2.1 Heterogeneity in Affiliates and Layers

In the overall sample a BG is composed on average of a parent controlling 5.6 subsidiaries, with a highly skewed distribution. This is shown in Figure 2 where the left panel highlights that 57% of BGs consist of one parent and one subsidiary, about 13% have more than 5 subsidiaries and only 0.7% control more than 100 affiliates.¹⁴

As for the hierarchy of control, the right panel of Figure 2 shows that on average BGs are organized on 1.3 layers, with larger groups being in general more complex. In particular, groups characterized by a higher number of hierarchical layers tend to have a larger number of subsidiaries.¹⁵ There is, however, substantial heterogeneity also in the hierarchy of BGs. While some groups have no more than one or two layers of control and a large number of subsidiaries, others have several layers but only few subsidiaries.

Figure 2: N. of affiliates and N. of layers across Business Groups



Note: Distribution of groups with given number of subsidiaries in sample (left panel). Boxplot (.1; .25; .50; .75;.99 percentiles) of number of subsidiaries for groups characterized by given number of hierarchical layers (right panel)

Restricting the analysis to BGs headquartered in OECD countries reveals a similar pattern: 55% of business groups (vs. 57% in the overall sample) have only one affiliate, while 80% of parents (vs. 82% in the overall sample) organize affiliates on one layer of control.¹⁶

¹⁴Looking at the 208,181 parents for which we could retrieve a complete set of balance sheet information, we have that 0.7% of BGs with more than 100 affiliates account for more than 70% of value added recorded in our dataset.

¹⁵In each boxplot, the horizontal bar refers to the median of the distribution of subsidiaries for BGs with that given number of hierarchical layers. The boundaries of the boxplot refer to the first and third quartiles of the distribution. The lower and upper bars visualize the 1st and 99th percentiles respectively.

¹⁶In the overall sample 165 BGs have 10 or more layers of hierarchical control, while in the OECD sample this

2.2.2 Hierarchies as Inverted Pyramids

It would be tempting to think that the hierarchies of firms within BGs follow the same pyramidal structure as the hierarchies of employees within firms. Table 1 shows that this is not the case as the average number of affiliates per layer decreases with distance from the parent along the control chain. In other words, BGs tend to be organized as ‘inverted’ pyramids, with larger density of affiliates in layers that are closer to the parent company.

Table 2: Number of affiliates per layer across Business Groups

	BG with:				
	10 layers	7 layers	4 layers	3 layers	2 layers
1	62.6	64.8	19.5	11.1	5.8
2	51.8	41.6	14.0	7.4	2.5
3	42.7	34.0	8.5	2.8	
4	40.9	24.2	3.2		
5	30.8	15.0			
6	29.5	7.8			
7	23.9	3.0			
8	21.6				
9	15.7				
10	12.6				
N. of BGs	165	347	3,068	8,697	32,823

Note: Average number of affiliates per layer, for different sized BGs

2.2.3 Institutional Quality and IPR

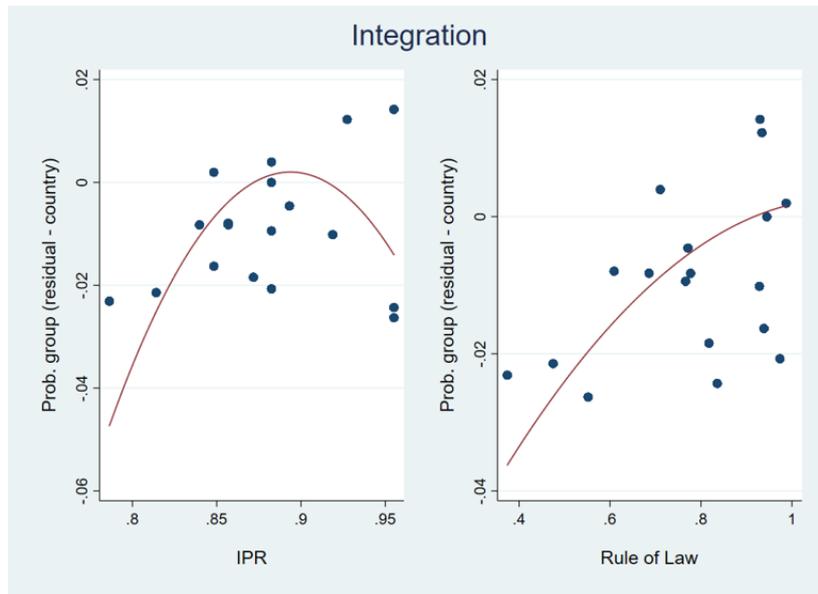
Firms from countries with generally better institutions are more likely to be organized as BGs. This is shown by the right panel of Figure 3, which reports the partial scatterplot relationship between the likelihood of observing a BG headquartered in a country and the normalized average quality of the country’s institutions as measured by the ‘rule of law’ index from the Worldwide Governance Indicators (Kaufmann et al., 2010). In particular, the vertical axis is the average residual at the country-level of a firm-level linear probability regression. The dependent variable in the regression is a dummy equal to one if a firm has incorporated an affiliate before 2010, and zero if the firm has remained independent (neither parent nor affiliate). The dummy is regressed on the country’s market size (GDP) and industry fixed effects. Residuals are averaged at the country level. This specification uses the sample of 178,190 business groups operating in OECD countries versus the control group of 4,167,873 independent firms described above. The panel reveals a positive relation between the probability that firms are organized as BGs and institutional quality.

Differently, the relation between the emergence of BGs and the quality of institutions specifically protecting intellectual property rights (IPR) is not monotonic. The probability that a firm

holds for 146. Hence, the BGs with the largest number of layers tend to belong to OECD parents.

is organized as BGs is higher for intermediate levels of IPR protection and lower for low as well as high levels of IPR protection. This is highlighted by the left panel of Figure 3, which reports the partial scatterplot relationship between the same average residual as before with the IPR protection index calculated by Park (2008) in periods of 5 years for 122 countries until 2005.¹⁷

Figure 3: Stylized facts - Integration decision



Note: Vertical axis in both panels is the average (country) residual of a firm-level linear probability regression. Depvar is a dummy equal to one if a firm has incorporated an affiliate before 2010, and zero if the firm has remained independent (nor parent nor affiliate). Horizontal axis in the left panel is the (normalized) IPR index (Park, 2008) of the same home country; the right panel reports the (normalized) Rule of Law index (Kaufmann et al., 2010).

2.2.4 Specialization and Standardization

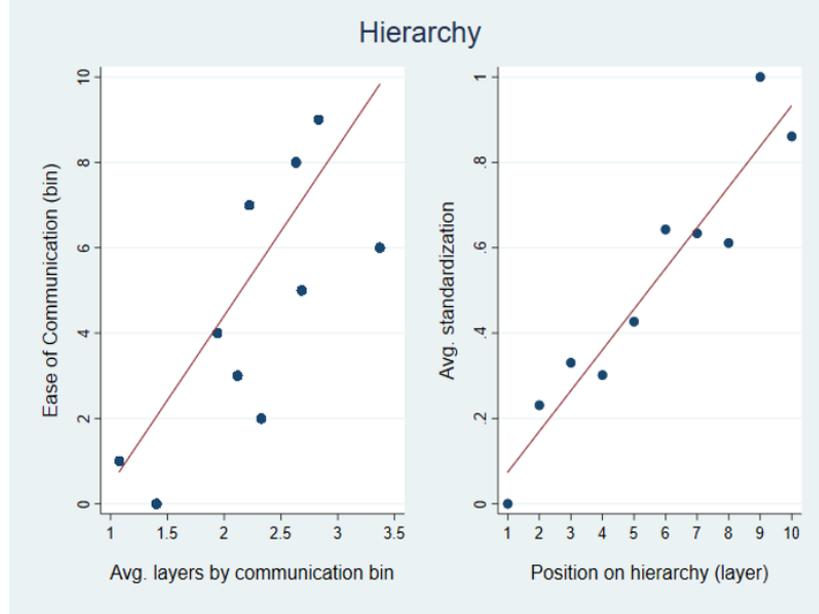
BGs specialized in narrower sets of industries have larger numbers of hierarchical layers. This is revealed by left panel of Figure 4, which reports the partial scatterplot relationship between the share of equal NAICS-2 digit industries in which a BG operates and the number of its layers. In particular, equally spaced class intervals (bins) of that share are measured along the vertical axis, while the horizontal axis measures the average number of layers of the BGs in each bin. Later in the paper, we will use the share of equal NAICS-2 digit industries in which a BG operates as a proxy of the costs of communication among the HQ and the affiliates.

Within BGs subsidiaries placed on lower hierarchical layers of control are active in industries characterized by a relatively higher degree of task standardization. The right panel of Figure 4 plots the average level of standardization of subsidiaries operating at a given layer against the

¹⁷Using the U.S. Related-Party Trade database, Biancini and Bombarda (2017) find empirical evidence in support of a positive link between IPR protection and the relative share of imports from the foreign affiliates of US multinational groups. Eppinger and Kukharskyy (2017) look at the ownership share of some half a million HQ-affiliate pairs from more than one hundred countries, retrieved again from the Orbis ownership database by Bureau van Dijk. They find that the share of equity control of the affiliate by the parent is higher in countries with better contracting institutions.

hierarchical position of the layer. Standardization is measured through a (normalized) industry-level index capturing the relative standardization of tasks of the industries in which the HQ is active (see Blinder and Krueger, 2013).

Figure 4: Stylized facts - Hierarchy decision



Note: On the vertical axis of the left panel we report equally spaced class intervals (bins) of the communication variable, measured as the share of equal NAICS-2 digit industries within each group vs the average number of hierarchical layers of the business groups operating within each communication bin. In the right panel we plot the average level of standardization of subsidiaries operating in a given hierarchical layer (vertical axis) vs. the position of the same affiliates in the hierarchical layer in which they are placed. Standardization is measured through a (normalized) industry-level index (Blinder and Krueger, 2013).

3 A Knowledge-Based Theory of Business Groups

The aim of this section is to present a model of knowledge creation and transmission within organizations that explains how the emergence of BGs is affected by the quality of institutions, and in particular those protecting IPR, and how their hierarchical structure is designed to best serve the internal flow of knowledge. The model will also shed light on the reasons why: the hierarchical structures of BGs look like inverted pyramids; BGs specializing in narrower sets of industries have larger numbers of hierarchical layers of control; and subsidiaries at lower hierarchical layers are active in industries characterized by a relatively higher degree of standardization.

3.1 Headquarter

A ‘headquarter’ (HQ) owns the ‘blueprints’ of a large portfolio of off-the-shelf final products and a distribution network to market them. It has to decide how many of these products to produce and how to organize their production. Its organizational choice consists of two decisions: an *integration decision* on whether products should be supplied by units with legal independence

from the HQ ('affiliates') or without such independence ('divisions');¹⁸ a *hierarchy decision* on how the different production units should be arranged in terms of direct or indirect links to the HQ. A 'business group' (BG) emerges when affiliation is preferred to divisionalization.

3.2 Blueprints and Products

The HQ has exclusive knowledge of the production possibilities of each blueprint but, in order to turn them into actual production, a product-specific problem has to be solved. The problem comes in different versions, indexed $\varphi = 1, \dots, P$ in *decreasing* order of difficulty, and the HQ decides which version to tackle.

Each product faces isoelastic demand $y = Ap^{-\sigma}$, where $\sigma > 1$ is demand elasticity and $A > 0$ is a demand shifter. Its production unit consists of a problem solver ('manager') and a team of producers ('workers') whose number depends on the amount of output. Accordingly, problem solving and production entail a fixed and a variable costs respectively. The manager receives the problem from the HQ in the version the HQ wants. If the manager solves the problem, the productivity of workers in her unit is determined by the difficulty of the chosen version. If she solves version φ , workers' productivity is $\theta_\varphi = e^{-\theta\varphi}$ with $\theta > 0$ so that solving more difficult versions (smaller φ) leads to higher productivity (larger θ_φ). If the manager does not solve the problem, workers in her unit cannot produce and their productivity is zero.¹⁹

All workers have all the same skills. Their wage is equal to one and at this wage their supply is infinitely elastic. There are, instead, different ability types of managers. Solving more difficult versions requires higher ability that not all managers have. Manager types are indexed $\varphi = 1, \dots, P$ in *decreasing* order of ability, so that φ refers indifferently to the difficulty of a problem's version and to the ability type of the managers who can solve it. Managers have only a limited amount of time they can devote to problem solving. In this amount of time a manager of ability φ can solve at most one problem of corresponding or lower difficulty (i.e. indexed φ or above). The ability differential between managers is reflected in different hiring costs, with $w\theta_\varphi$ denoting the fixed cost of hiring a manager of type φ whose problem-solving ability allows workers in her unit to achieve productivity θ_φ ; $w > 0$ can thus be interpreted as the manager's remuneration per worker efficiency unit. At $w\theta_\varphi$ the supply of managers of ability φ is also infinitely elastic.

On top of adequate ability, to solve her unit's problem the manager also needs supervision by the HQ, which can be direct or indirect through other managers. In the latter case, however, the manager cannot be supervised by managers of equal or lower ability so that indirect supervision by the HQ of a manager of ability φ must go through managers of higher ability (i.e. indexed $\varphi - 1$ or below). Supervision is time consuming for the supervisor and the amount of time needed

¹⁸ As the choice between in-house and arm's length production ('outsourcing') has been investigated at length in the existing literature, we abstract from this choice by assuming that the HQ has already decided in favor of in-house production, hence shifting the focus from the 'make or buy' decision to the 'how to make' decision.

¹⁹ One could think of the different versions of the problem as characteristics of the production process. More complex production processes are harder to design, but allow for production at lower marginal cost.

depends on the difficulty of the problem version to be solved as well as the supervisee's ability. Specifically, in order to solve a problem's version of difficulty φ , a manager of ability φ requires $\varphi_\varphi\theta_\varphi$ units of supervision time where $\varphi_\varphi = e^{\varphi\varphi}$, with $\varphi > 0$, captures a 'communication cost' such that the higher the supervisee's ability (smaller φ), the lower is the communication cost for the supervisor (smaller φ_φ). The multiplicative form $\varphi_\varphi\theta_\varphi$ implies that, for given communication cost φ_φ , supervising the solution of more difficult versions absorbs more time.

The amount of available supervision time is the same for the HQ and the managers and is equal to $\tau_\varphi = e^\tau$ with $\tau > 0$ for every φ . Each supervisor, therefore, faces a trade-off between supervising several lower ability managers (with higher φ_φ) in the solution of easier problem versions (with lower θ_φ) and few higher ability managers (with lower φ_φ) in the solution of more difficult problem versions (with higher θ_φ). Supervision is the only activity of the HQ, hence $\tau_\varphi = e^\tau$ is its total amount of time available. Differently, for a manager $\tau_\varphi = e^\tau$ is extra time in addition to the amount she has for problem solving. For simplicity, the manager's supervision and problem-solving amounts of time are not substitutable.

3.3 Contracts and Boundaries

Before a product is ready for distribution, the HQ and the unit's manager sign a contract. After signing the contract, both parties have to make relation-specific investments. The HQ has to reveal the problem to be solved and has to supervise its solution. The unit has to solve the problem and produce the product. The contract parties sign is, however, incomplete as the quality of the product supplied is not verifiable by third parties and a sub-par quality product has no value because it cannot be distributed. Sub-par quality can derive from faulty problem definition or supervision by the HQ; it can also derive from faulty problem solution or faulty production by the unit. Unverifiability leads to ex post Nash bargaining between the HQ and the unit over the product's revenues after all relation-specific investments have been made.

Contractual incompleteness affects the HQ's decision on whether to mandate the product's supply to a 'division' or an 'affiliate'. The difference between the two is in terms of legal independence. While a division has limited legal independence and thus limited residual property rights on the product's output, an affiliate has broader legal independence and broader residual property rights. This gives the affiliate stronger ex post bargaining power for two reasons. The first is familiar in models with quality holdup in *production*: when the two parties have no outside options at the bargaining stage, the party with ownership of the output is stronger. The traditional way to capture this aspect is by assuming larger Nash bargaining weight. If we use ω_d and ω_f to denote the weights of the division and the affiliate respectively, the assumption is $0 < \omega_d < \omega_f < 1$.

The second reason is distinctive and relates to the fact that it is easier for the affiliate to distribute the product independently, which gives the affiliate a stronger outside option at the bargaining stage. This second reason is associated with the fact that production requires relation-specific investments in supervision (as well as problem definition) by the HQ and problem solving

by the unit. Hence, contractual incompleteness gives rise a quality holdup in *knowledge creation*. Independent distributions absorbs additional resources because the manager cannot rely on the HQ's existing distribution network, and also because it might be associated with costly litigation. Specifically, we assume that independent distribution 'melts' a fraction of output so that the quantity delivered to the end consumer is smaller than the quantity produced. The 'melted' fraction per unit produced is $1 - 1/\rho_d$ for a division and $1 - 1/\rho_f$ for an affiliate with $\rho_d > \rho_f > 1$. Equivalently, ρ_d and ρ_f are the units of output to be produced per unit delivered. The assumption that ρ_d is larger than ρ_f reflects the higher obstacles faced by independent distribution in the case of a division.²⁰

For each product the timing of events is as follows. First: the HQ decides whether to supply the product, which version of the corresponding problem to solve, and whether its production takes place through a division or an affiliate. Second: the HQ posts the supply contract specifying the required managerial ability; managerial ability is verifiable. Third: managers apply; the HQ selects and contracts one of them. Fourth: the HQ reveals the problem and the version to be solve to the selected manager. Fifth, the manager solves the problem's version under the (direct or indirect) supervision of the HQ. Sixth, the manager hires her unit's workers and production take place. Last, the HQ and the manager bargain over the division of revenues. At this point the HQ has no outside option. Differently, the manager has the outside option of independent distribution.

3.4 Integration Decision

Consider the generic alternative $o \in \{d, f\}$ for supplying a product. Use ω_o and O_o to denote the production unit's bargaining weight and outside option respectively. Let p_o be the price of the product, y_o the quantity produced, π_o and μ_o the surplus shares accruing to the HQ and the unit respectively. The Nash bargaining solution maximizes

$$(\pi_o)^{1-\omega_o} (\mu_o - O_o)^{\omega_o} \tag{1}$$

with respect to π_o and μ_o subject to $\pi_o + \mu_o = p_o y_o$. The FOC for the maximization of (1) entails $\mu_o = \omega_o (p_o y_o - O_o) + O_o$ with outside option equal to revenues from independent distribution: $O_o = A^{\frac{1}{\sigma}} (y_o/\rho_o)^{\frac{\sigma-1}{\sigma}}$ where y_o and y_o/ρ_o are the quantities produced and delivered. Then, if the unit's workers have productivity θ_φ , its manager chooses y_o so as to maximize

$$v_o = \mu_o - y_o = \omega (p_o y_o - O_o) + O_o - y_o/\theta_\varphi \tag{2}$$

²⁰The risk of technology expropriation can occur also when technology transfers happen within firm's boundaries, for instance due to former licensees and employees infringing the related trademarks and patents (Biancini and Bombarda, 2017).

The corresponding profit-maximizing output is

$$y_o(\theta_\varphi) = A \left\{ \frac{\sigma - 1}{\sigma} \theta_\varphi \left[\omega_o + (1 - \omega_o) \rho_o^{\frac{1-\sigma}{\sigma}} \right] \right\}^\sigma \quad (3)$$

This expression reveals the implications of the quality holdups in production and knowledge creation. With respect to complete contracts, the holdup problem in production materializes in lower output for given workers' productivity (due to $\omega_o < 1$). The knowledge holdup works, instead, in the opposite direction. Stronger bargaining power, associated with a positive outside option, increases the unit's surplus share μ_o , leading to stronger incentives to invest in the relation with the HQ. In this respect, the knowledge holdup mitigates the underprovision of output caused by the quality holdup in production. However, as ρ_o grows, independent distribution becomes increasingly expensive and in the limit prohibitive for infinite ρ_o . This explains why $y_o(\theta_\varphi)$ is a decreasing function of ρ_o . The unit's operating profit associated with output (2) evaluates to

$$v_o(\theta_\varphi) = a \left[\omega + (1 - \omega) \rho_o^{\frac{1-\sigma}{\sigma}} \right]^\sigma \theta_\varphi^{\sigma-1} \quad (4)$$

with $a \equiv (A/\sigma) [\sigma / (\sigma - 1)]^{1-\sigma}$.

Turning to the problem of the HQ, the FOC for the maximization of (1) entails that the HQ receives operating profits $\pi_o = (1 - \omega_o) (p_o y_o - O_o)$, which evaluates to

$$\pi_o(\theta_\varphi) = a \Omega(\rho_o, \omega_o) \theta_\varphi^{\sigma-1} \text{ with } \Omega(\rho_o, \omega_o) \equiv \sigma (1 - \omega_o) \left(1 - \rho_o^{\frac{1-\sigma}{\sigma}} \right) \left[\omega_o + (1 - \omega_o) \rho_o^{\frac{1-\sigma}{\sigma}} \right]^{\sigma-1} \quad (5)$$

The HQ's operating profit (5) is a hump-shaped function of ρ_o . As ρ_o goes to one, $\pi_o(\theta_\varphi)$ tends to zero: independent distribution by the unit becomes costless and the HQ's contribution to knowledge creation is completely dissipated. As ρ goes to infinity, the unit's outside option vanishes and $\pi_o(\theta_\varphi)$ converges to the familiar case of quality holdup in production. Between these two extremes the humped shape is explained by two opposite effects. On the one hand, larger ρ_o makes the unit supply more output as its outside option gains strength. This is good for total surplus and thus also for the HQ's profit. On the other hand, by strengthening the manager's outside option, larger ρ_o reduces the HQ's bargaining power over total surplus, which is bad for the HQ's profit.

Equipped with (5), we are now ready to determine when the HQ prefers to run a production unit as an affiliate rather than a division, thereby giving rise to a BG. This happens when $\pi_f(\theta_\varphi) \geq \pi_d(\theta_\varphi)$, or equivalently when (ω_f, ρ_f) solves

$$\max_{(\omega_o, \rho_o)} \Omega(\rho_o, \omega_o) \text{ s.t. } (\omega_o, \rho_o) \in \{(\omega_d, \rho_d), (\omega_f, \rho_f)\} \quad (6)$$

To determine the conditions under which a division or an affiliate is optimal for the HQ, it is useful to follow the approach in Antràs and Helpman (2004, 2008) and, more recently, by Antràs and Chor (2013). This approach considers first the 'relaxed' problem in which the HQ can freely

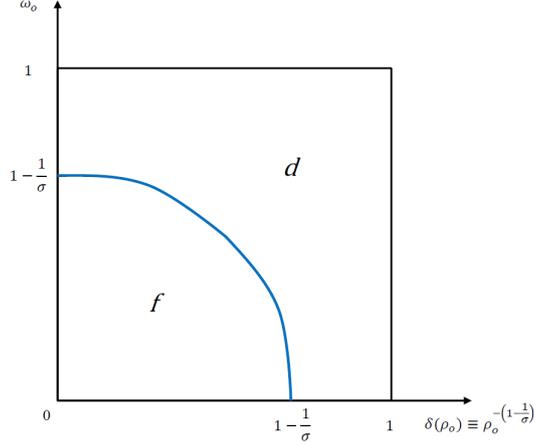


Figure 5: Integration decision

choose (ω_o, ρ_o) from the whole set of all pairs (ω_o, ρ_o) simultaneously satisfying $0 < \omega_o < 1$ and $\rho_o > 1$ rather than from those that only take on values in the set $\{(\omega_d, \rho_d), (\omega_f, \rho_f)\}$. The solution of this relaxed problem identifies a unique profit-maximizing locus consisting of the values (ω_o, ρ_o) satisfying

$$\omega_o = 1 - \frac{1}{\sigma} [1 - \delta(\rho_o)]^{-1} \quad \text{with } \delta(\rho_o) \equiv \rho_o^{-(1-\frac{1}{\sigma})} \quad (7)$$

with $\delta'(\rho_o) < 0$ so that $\delta(\rho_o)$ measures the strength of the unit's outside option.

Figure 5 shows the optimal locus of the relaxed problem as a curve that cuts the set of all pairs (ω_o, ρ_o) simultaneously satisfying $0 < \omega_o < 1$ and $\rho_o > 1$ in two sub-sets.

Going back to the original problem (6), given that the value of $\Omega(\rho_o, \omega_o)$ decreases moving away from the locus, $\omega_f > \omega_d$ and $\rho_f < \rho_d$ – i.e. $\delta(\rho_f) > \delta(\rho_d)$ – imply $\Omega(\rho_f, \omega_f) > (<) \Omega(\rho_d, \omega_d)$ when both $(\delta(\rho_f), \omega_f)$ and $(\delta(\rho_d), \omega_d)$ belong to the sub-set 'd' ('f') north-east (south-west) of the locus. Accordingly, an affiliate (a division) is optimal for $(\delta(\rho_f), \omega_f)$ and $(\delta(\rho_d), \omega_d)$ in the south-west (north-east) sub-set: a BG emerges when, under both affiliation and divisionalization, the unit's bargaining weights (ω_f and ω_d) are small and its outside options are weak (small ρ_f and ρ_d). This is more likely to be the case when the product's profit margin is smaller (i.e. for larger σ). When $(\delta(\rho_f), \omega_f)$ and $(\delta(\rho_d), \omega_d)$ belong, instead, to different sub-sets, the ranking of $\Omega(\rho_f, \omega_f)$ and $\Omega(\rho_d, \omega_d)$ is ambiguous. This ambiguity may explain the non-monotonicity highlighted in Section 2.2, according to which the probability that a firm is organized as BGs is higher for intermediate levels of IPR protection and lower for low as well as high levels of IPR protection, as long as IPR protection can be expected to affect $\delta(\rho_f)$ and $\delta(\rho_d)$ differentially.

3.5 Hierarchy Decision

Having established when a BG emerges from the optimal integration decision, we can now characterize its endogenous hierarchical structure.²¹ Through the optimal integration decision the HQ solves, for each production unit, the trade-off between rent extraction (better achieved through a division) and incentive provision (better achieved through an affiliate) when holdups affect both production and knowledge creation. Differently, through the optimal hierarchy decision the HQ solves, for each production unit, the trade-off between supervising several lower ability managers in the solution of easier problem versions and few higher ability managers in the solution of more difficult problem versions. It is quantity versus quality of knowledge created.

The latter trade-off is captured by the following recursive time constraint requiring that, for each problem-solving ability type φ , the amount of available supervision time matches its required amount:

$$\tau_{\varphi-1}n_{\varphi-1} = \varphi_{\varphi}\theta_{\varphi}n_{\varphi} \quad (8)$$

where n_{φ} is the number of managers of ability φ hired by the HQ, with $\varphi = 0$ referring to the HQ, in which case $n_0 = 1$ holds. Solving the recursion under the assumed functional forms for τ_{φ} , φ_{φ} and θ_{φ} yields

$$n_{\varphi} = \prod_{s=1}^{\varphi} \frac{\tau_{s-1}}{\varphi_s \theta_s} = e^{\tau + \sum_{s=1}^{\varphi} (\theta - \varphi)s} = e^{\tau + \frac{1}{2}\varphi(\varphi+1)(\theta - \varphi)}. \quad (9)$$

According to (9), n_{φ} is increasing (decreasing) in φ for $\theta > (<)\varphi$. This constraint on supervision time will crucially affect the HQ's decision on how to use knowledge efficiently and how to communicate it between teams so as to optimize its use as an input for the solution of problems.

The aim of the hierarchy decision is to determine the HQ's profit maximizing number of blueprints to turn into products, and how to structure supervision and problem solving in layers across the corresponding production units, given the supervision time constraint (9), a fixed cost $F > 0$ of activating a hierarchical layer and a fixed cost $w\theta_{\varphi}$ of hiring managers of ability φ .

The outcome of this decision can be characterized recursively going layer by layer from the top, focusing on a 'contiguous' hierarchy, such that managers of ability φ supervise managers of ability $\varphi + 1$ and are supervised by managers of ability $\varphi - 1$. We assume that such contiguity is an equilibrium outcome and then characterize the conditions under which this is indeed the case.

First, at layer $\ell = 0$ there is only the HQ and no operating profit is generated at that layer as the HQ's time can be used for supervision but not for problem solving. Second, as the HQ cannot produce without opening at least one unit, the minimum number of layers of an active hierarchy is two ($\ell = 0$ and $\ell = 1$). Third, given (5), the HQ profits generated by units placed at layer $\ell = 1$ are an increasing function of the ability of managers (i.e. a decreasing function of φ), which implies that the HQ has an incentive to appoint the managers with the highest ability

²¹In our setup the integration and hierarchy decisions are separable. A simple way to break separability would be to assume that communication costs are different for divisions and affiliates.

(i.e. the lowest $\varphi = 1$) at that layer. We thus have $\ell = \varphi = 1$, with the HQ receiving profits from each unit equal to

$$\Pi_o(\theta_1) = \left[\Omega(\rho_o, \omega_o) e^{-\theta(\sigma-2)} \bar{\pi} - w \right] e^{-\theta}$$

Fourth, due to the time constraint (9), the number of units that can be opened at layer $\ell = 1$ equals

$$n_1 = \frac{\tau_0 n_0}{\varphi_1 \theta_1} = e^{\tau+(\theta-\varphi)}.$$

Hence, the total profits received by the HQ from layer $\ell = 1$ evaluate to

$$\Pi_o(\theta_1)n_1 - F = \left[\Omega(\rho_o, \omega_o) e^{-\theta(\sigma-2)} \bar{\pi} - w \right] e^{\tau-\varphi} - F$$

where $F > 0$ is the fixed costs of activating a layer. It then follows that layer $\ell = 1$ will be activated at all if and only if

$$\Pi_o(\theta_1)n_1 - F \geq 0$$

Consider now layer $\ell = 2$. Given (5), also profits generated by affiliates at layer $\ell = 2$ are an increasing function of managers' ability, which implies that the HQ appoints the managers with the highest feasible ability. This is $\varphi = 2$ as managers of ability $\varphi = 1$ potentially assigned to level $\ell = 2$ cannot be supervised by the managers of the same ability assigned to level $\ell = 1$. We thus have $\ell = \varphi = 2$ with the profit of each unit equal to

$$\Pi_o(\theta_2) = \left[\Omega(\rho_o, \omega_o) e^{-2\theta(\sigma-2)} \bar{\pi} - w \right] e^{-2\theta}$$

Due to the time constraint (9), the number of units that will be opened at layer $\ell = 2$ equals

$$n_2 = e^{\tau+3(\theta-\varphi)}$$

with total profit of the layer

$$\Pi_o(\theta_2)n_2 - F = \left[\Omega(\rho_o, \omega_o) e^{-2\theta(\sigma-2)} \bar{\pi} - w \right] e^{\tau+\theta-3\varphi} - F$$

Layer $\ell = 2$ will thus be activated at all if and only if

$$\Pi_o(\theta_2)n_2 - F \geq 0$$

This constraint is more stringent than $\Pi_o(\theta_1)n_1 - F \geq 0$ as long as $\Pi_o(\theta_1)n_1 > \Pi_o(\theta_2)n_2$ holds. The latter condition is always verified if $\theta < \varphi$, as in this case $n_2 < n_1$ ('inverted pyramid') while $\Pi_f(\theta_\varphi)$ is always decreasing in φ . If instead $\theta > \varphi$, and thus $n_2 > n_1$ ('pyramid'), the condition holds for φ large enough.²² As long as this restriction holds, a necessary condition for $\ell = 2$ to

²²Specifically, in the case of pyramidal hierarchies (i.e. when $\theta > \varphi$) the condition always holds if $\varphi >$

be worth activating is that $\ell = 1$ is itself worth activating. Vice versa, a sufficient condition for $\ell = 1$ to be worth activating is that $\ell = 2$ is itself worth activating. In other words, when the restriction holds, the hierarchy is contiguous as initially assumed.

These results obtained for $\ell = 1$ and $\ell = 2$ can be generalized by induction to the generic layer. For this generic layer we will have $\ell = \wp$, with unit profit

$$\Pi_o(\theta_\wp) = \left[\Omega(\rho_o, \omega_o) e^{-\wp\theta(\sigma-2)} \bar{\pi} - w \right] e^{-\wp\theta}$$

as long as the hierarchy is contiguous, which is the case if and only if

$$\varphi > \varphi_c \equiv \frac{\wp}{\wp+1} \theta + \ln \frac{\Omega(\rho_o, \omega_o) e^{-(\wp+1)\theta(\sigma-2)} \bar{\pi} - w}{\Omega(\rho_o, \omega_o) e^{-\wp\theta(\sigma-2)} \bar{\pi} - w} \quad (10)$$

Given (9), the corresponding number of units will be

$$n_\wp = e^{\tau + \frac{1}{2}\wp(\wp+1)(\theta-\varphi)}$$

with total profit

$$\Pi_o(\theta_\wp) n_\wp - F = \left[\Omega(\rho_o, \omega_o) e^{-\wp\theta(\sigma-2)} \bar{\pi} - w \right] e^{\tau + \frac{1}{2}\wp(\wp+1)(\theta-\varphi) - \wp\theta} - F \quad (11)$$

The activation of the layer will happen at all if and only if

$$\Pi_o(\theta_\wp) n_\wp - F \geq 0$$

Hence, the hierarchy stops at layer $\ell = \wp^*$ where \wp^* is the largest integer \wp compatible with

$$\left[\Omega(\rho_o, \omega_o) e^{-\wp\theta(\sigma-2)} \bar{\pi} - w \right] e^{\tau + \frac{1}{2}\wp(\wp+1)(\theta-\varphi) - \wp\theta} - F \geq 0$$

At that layer there are

$$n_{\wp^*} = e^{\tau + \frac{1}{2}\wp^*(\wp^*+1)(\theta-\varphi)}$$

production units. Note that we have a pyramid (inverted pyramid) hierarchical structure for $\theta > (<) \varphi$, as n_\wp is increasing (decreasing) in \wp . Moreover an inverted pyramidal structure is always contiguous: $\theta < \varphi$ implies $\varphi > \varphi_c$ as in (10) we have $0 < \varphi_c < \theta\wp/(\wp+1) < \theta$.

3.6 Organization Choice

We can now combine the findings on the integration and hierarchy decisions to obtain the following:

$$\frac{\theta}{2} + \frac{1}{2} \ln \frac{\Omega_o e^{-2\theta(\sigma-2)} \bar{\pi} - w}{\Omega_o e^{-\theta(\sigma-2)} \bar{\pi} - w}.$$

Proposition 1 *A BG arises in equilibrium iff*

$$\Omega(\rho_f, \omega_f) \geq \Omega(\rho_d, \omega_d)$$

with $\Omega(\rho_o, \omega_o) \equiv \sigma(1 - \omega_o) \left(1 - \rho_o^{\frac{1-\sigma}{\sigma}}\right) \left[\omega_o + (1 - \omega_o) \rho_o^{\frac{1-\sigma}{\sigma}}\right]^{\sigma-1}$ for $o \in \{d, f\}$. When this condition holds together with (10): (i) the BG is organized as a hierarchy of φ^* layers of affiliates, where φ^* is the largest integer φ such that the profit of the BG at layer φ is larger than the fixed costs of activating the layer, i.e.

$$\left[\Omega(\rho_f, \omega_f) e^{-\varphi\theta(\sigma-2)} \bar{\pi} - w\right] e^{\tau + \frac{1}{2}\varphi(\varphi+1)(\theta-\varphi) - \varphi\theta} - F \geq 0$$

(ii) the total number of affiliates of the BG is

$$M^* = \sum_{\varphi=1}^{\varphi^*} n_{\varphi} = \sum_{\varphi=1}^{\varphi^*} e^{\tau + \frac{1}{2}\varphi(\varphi+1)(\theta-\varphi)}$$

(iii) the number of affiliates assigned to layer φ of the BG is

$$n_{\varphi} = e^{\tau + \frac{1}{2}\varphi(\varphi+1)(\theta-\varphi)}$$

(iv) the total profit of the BG is

$$\sum_{\varphi=1}^{\varphi^*} \left[\Omega(\rho_f, \omega_f) e^{-\varphi\theta(\sigma-2)} \bar{\pi} - w\right] e^{\tau + \frac{1}{2}\varphi(\varphi+1)(\theta-\varphi) - \varphi\theta} - F \varphi^*$$

In terms of comparative statics, we thus have that, controlling for the parameters that drive the integration condition $(\rho_f, \omega_f, \rho_d, \omega_d, \sigma)$, across BGs higher communication costs (larger φ) are associated with fewer affiliates and lower profits per layer, and thus fewer layers (as larger φ 's are associated with relatively lower profits). BGs characterized by simpler production processes (smaller θ_{φ}) in turn display a smaller number of affiliates, and fewer layers. Also higher managers' remuneration per worker efficiency unit (larger w), higher fixed costs per layer (larger F) and less time available for supervision (smaller τ) are associated with fewer layers. We now turn to empirically test some of these predictions.

4 Empirical Analysis

We test two main implications of Proposition 1 for the hierarchy decision, controlling for the covariates that affect the integration decision.

4.1 Empirical Strategy

The first implication links the number of subsidiaries in a BG to the communication cost between affiliates and to the difficulty of the problem versions. Proposition 1 implies that lower commu-

nication costs (smaller φ) and more difficult problem versions (larger θ_φ) should be associated with a larger number of subsidiaries.

The second implication refers to the number of hierarchical layers. According to (11), higher communication costs (larger φ) are associated with lower profits per layer, and thus fewer hierarchical layers. Fewer layers are also associated with higher remuneration for managers (larger w). Moreover, more standardized tasks should be performed by subsidiaries placed at lower hierarchical levels, as units located there are predicted to solve easier problem versions.

As anticipated in Section 2.2, communication costs are proxied through the similarity (the share of equal NAICS-2 digit industries) of the activities performed by subsidiaries and parent within each BG. The underlying idea is that, if the subsidiaries and the parent operate in exactly the same industries (share equal to one), communication costs should be at a minimum. The ability to solve more difficult problems is measured through the standardization index of Blinder and Krueger (2013) computed for the main industry of the affiliate. Managers' skill premia are proxied through the average share of population with tertiary education in the countries in which the BG operates, the idea being here that higher share of tertiary education in a country leads to higher the managerial salaries. Standardization will be captured by a binary variable, equal to one if the group has an average level of standardization higher than the sample mean, and zero otherwise. The idea here is that BGs characterized by a relatively higher level of standardization are more likely to be organized into relatively flatter hierarchies.

In Proposition 1 the hierarchical organization of the BG is conditional on HQ-related characteristics that drive the integration decision, leading to possibly inconsistent estimates were these characteristics unaccounted for. In addition to our main covariates, we thus include a second set of controls related to the integration decision as derived from our model: the level of IPR protection in the country in which the parent is incorporated (including its squared term), a full set of fixed effects for the industries in which the parent is active, as well as the parent's age and size (small, medium, large, very large). To better account for possible technological factors driving the integration decision, we also include a variable measuring the vertical integration of activities within the group. Short of actual data on internal shipments of intermediate goods and services among affiliates, we follow Acemoglu et al. (2009) and proxy the vertical integration of group's activities exploiting information on the set of industries in which activities take place, combined with the input coefficient requirements that link those industries as retrieved from input-output tables.²³ We thus employ in our estimates a refined measure of their index, adapted to the input/output structure of BGs (see Appendix B for details). We also include a dummy capturing the multinational status of our BGs.

Another critical element for the correct identification of the drivers of the hierarchy decision is the fact that, especially for multinational groups, the organizational choice can be partly driven by specific local characteristics (such as financial opportunities or tax savings). For example, an European affiliate of a US group that, according to the model, should be placed relatively close to

²³ Alfaro et al. (2016) also use this index at the individual firm level on a global dataset.

the US parent in the hierarchy (e.g. due to low standardization of its activities), may be placed under the European headquarter of the group for regulatory reasons. It would thus end up in a lower layer than the model would predict. To the extent that these local characteristics are correlated with our theory-based explanatory variables, their omission could induce a spurious correlation between the model’s drivers and the hierarchical organization of the BG, invalidating our identification. For this reason, we also include a set of controls related to the characteristics of the countries across which the group operates. In particular, we include: the average tax level faced by the BG, the average number of patent per inhabitants, the average level of financial development, and the average quality of the business environment (captured by the average number of days required to enforce a contract), a piece of information retrieved from the World Bank Development Indicators.²⁴

Finally, when we use the number of layers as dependent variable, we also control for the total number of subsidiaries of the BG, as the latter number might mechanically influence the former. In other words, we condition our equation to explain variation in the hierarchy choice within groups constituted by the same number of subsidiaries.

4.2 Empirical Results and Robustness

Table 3 presents the baseline estimates for the total number of subsidiaries. Column 1 shows that, in line with Proposition 1, BGs characterized by lower communication costs and more complex (less standardized) activities tend to have a larger number of subsidiaries. Column 2 confirms that this result holds controlling for the HQ-specific variables affecting the parent integration choice: size and age of the parent, the level of IPR protection in the home country where the HQ is incorporated (together with its squared term), the size of the home country, and a full set of NAICS 3-digit fixed effects. The result also holds adding the proxy of the degree of vertical integration of the BG as well as the multinational status of the group. Both variables are positive and significant.

Column 3 replicates the analysis of the number of subsidiaries including the characteristics of the countries in which the BG operates. Our main result does not change. In Column 4 we also add additional controls at the home country level: the level of GDP per capita and the level of financial development in the home country (lifted from the World Bank Development Indicators), a variable identified in the literature as influencing both the rate of birth of business groups (Belenzon, 2013) and the vertical integration choices of firms (Acemoglu et al., 2009). Our result does not change.

In Table 4 we replicate the analysis using the number of layers as dependent variable through an ordered probit estimation. Consistently with our model, we find that BGs tend to be characterized by a significantly larger number of hierarchical layers when communication costs between parents and affiliates are lower, the skill premia of managers are not too high, and problems to

²⁴For domestic groups, these averages obviously coincide with the values of the home country in which the HQ is incorporated.

Table 3: Hierarchy regression - Number of subsidiaries

VARIABLES	(1)	(2)	(3)	(4)
Estimation method	OLS	OLS	OLS	OLS
Ease of communication	0.029*** [0.008]	0.048*** [0.008]	0.049*** [0.008]	0.051*** [0.008]
Standardization	-0.149*** [0.008]	-0.150*** [0.008]	-0.152*** [0.008]	-0.152*** [0.008]
Vertical integration	0.655*** [0.066]	0.520*** [0.065]	0.466*** [0.066]	0.457*** [0.066]
Multinational Group	0.991*** [0.014]	0.993*** [0.014]	0.973*** [0.015]	0.959*** [0.014]
Age (HQ)	0.036*** [0.004]	0.034*** [0.004]	0.034*** [0.004]	0.038*** [0.004]
IPR index (HQ)		17.720*** [1.251]	20.003*** [1.342]	18.566*** [1.401]
IPR index'sq. (HQ)		-30.222*** [2.199]	-33.882*** [2.339]	-32.411*** [2.435]
Population (HQ)		0.060*** [0.004]	0.061*** [0.005]	0.128*** [0.007]
Tax rate (group)			0.005*** [0.001]	0.002** [0.001]
Patent (group)			-0.046*** [0.009]	-0.069*** [0.009]
Contract enforcement (group)			-0.251*** [0.029]	0.075** [0.032]
GDP per capita (HQ)				0.365*** [0.019]
Fin. Development (HQ)				-0.008 [0.010]
Constant	0.215*** [0.048]	11.965*** [0.937]	14.993*** [1.043]	8.103*** [1.108]
Size HQ (dummy)	YES	YES	YES	YES
Industry FE (3-digit)	YES	YES	YES	YES
Observations	52,962	52,962	52,962	52,962
R-squared	0.514	0.522	0.524	0.528

Note: Columns report OLS regressions on the total number of subsidiaries in each BG. Robust standard errors in brackets. *** p<0.01, ** p<0.05, * p<0.1

be solved are more difficult (i.e. the industries across which the group operates exhibit relatively lower standardization). As before, results are robust to adding HQ-specific variables (Column 1), the drivers of the integration choice (Column 2) and locational characteristics at the group level (Column 3). We also control for the total number of subsidiaries of the BG to avoid picking up a mechanical correlation, as larger groups in terms of subsidiaries are more likely to be organized over a larger number of hierarchical layers. Hence, in Table 4 we explain the variation in the hierarchy choice of layers across groups constituted by the same number of subsidiaries. Column 4 includes the level of GDP per capita and the level of financial development in the home country as additional controls, while Column 5 replicates the analysis only for groups with more than two subsidiaries. Results remain virtually unchanged.

Table 4: Hierarchy regression - Number of layers

VARIABLES	(1)	(2)	(3)	(4)	(5)
	Layers	Layers	Layers	Layers	Layers
Estimation method	O. Probit				
Ease of communication	0.120*** [0.019]	0.123*** [0.019]	0.126*** [0.019]	0.126*** [0.019]	0.146*** [0.022]
Standardization	-0.027* [0.014]	-0.028* [0.014]	-0.028** [0.014]	-0.028** [0.014]	-0.023 [0.015]
Skill Premium	-0.139*** [0.017]	-0.107*** [0.019]	-0.104*** [0.020]	-0.091*** [0.022]	-0.110*** [0.021]
Vertical integration	-0.160* [0.093]	-0.174* [0.094]	-0.109 [0.096]	-0.102 [0.096]	-0.039 [0.092]
Multinational Group	0.192*** [0.019]	0.199*** [0.019]	0.228*** [0.020]	0.229*** [0.020]	0.267*** [0.020]
Age (HQ)	-0.122*** [0.007]	-0.123*** [0.007]	-0.120*** [0.007]	-0.120*** [0.007]	-0.120*** [0.007]
IPR index (HQ)		11.998** [4.798]	15.100*** [4.620]	16.330*** [4.598]	11.069** [4.612]
IPR index'sq. (HQ)		-6.405** [2.650]	-8.454*** [2.562]	-9.187*** [2.560]	-6.110** [2.552]
Population (HQ)		0.011* [0.007]	0.023*** [0.007]	0.017* [0.009]	0.033*** [0.008]
Tax rate (group)			-0.008*** [0.001]	-0.006*** [0.001]	-0.007*** [0.001]
Patent (group)			0.029** [0.013]	0.034** [0.013]	0.024* [0.013]
Contract enforcem.t (group)			0.116*** [0.039]	0.104** [0.045]	0.117*** [0.039]
GDP per capita (HQ)				-0.009 [0.031]	
Fin. Development (HQ)				0.036** [0.017]	
N. of subsidiaries	1.122*** [0.011]	1.120*** [0.011]	1.124*** [0.011]	1.124*** [0.011]	0.959*** [0.012]
Size HQ (dummy)	YES	YES	YES	YES	YES
Industry FE (3-digit)	YES	YES	YES	YES	YES
Observations	52,962	52,962	52,962	52,962	30,148
R-squared	0.514	0.522	0.524	0.528	0.603

Note: Columns report ordered probit regressions on the number of layers in each group. Column 5 is calculated only for groups with >2 subsidiaries. Robust standard errors in brackets.
*** p<0.01, ** p<0.05, * p<0.1

5 Conclusions

We have proposed and confronted with data a theory of business groups (BGs) as ‘knowledge-based hierarchies’ of firms (Garicano and Rossi-Hansberg, 2015) in a business environment characterized by ‘incomplete contracts’ (Antràs and Rossi-Hansberg, 2009). In our model the emergence of a BG and its hierarchical structure are the outcomes of two parallel decisions. The *integration decision* solves the tradeoff a headquarter (HQ) faces between better knowledge protection and easier rent extraction from integrated divisions on the one hand, and stronger team incentivization through legally independent subsidiaries on the other hand. The *hierarchy decision* solves the problem of how to use, communicate and enrich scarce HQ-specific knowledge efficiently.

The model predicts that a HQ is more likely to select the BG as the organizational form of its activities in the presence of better contractual institutions, and it is more likely to arrange

its subsidiaries along a larger number of hierarchical layers when its intangibles are better, the problems it has to solve are more challenging, communication costs between layers are lower, and the skill premium for more knowledgeable managers is smaller.

We have tested these predictions exploiting the unique features of a dataset we have constructed from ORBIS. The dataset covers 178,190 business groups operating in 32 OECD countries and controlling more than 1,150,000 (domestic and foreign) affiliates in all countries worldwide in the year 2010. The dataset allows us to observe the worldwide organization of BGs, with special emphasis on their ownership structure in terms of both the number of equity-controlled affiliates and their positions along the parent company's hierarchy of control.

In line with our theory, we have found significant and robust evidence that firms (in a given industry and of a given size) are more likely to set up subsidiaries when operating in countries characterized by better institutions. Conditional on this result, we have also found that BGs are more likely to be structured across several layers of hierarchy when communication costs between parents and affiliates are easier, the skill premia for good managers are smaller, and problem solving is more challenging (as proxied by lower standardization of the industries in which the BG operates). These results are robust to the inclusion of additional controls, as well as to different partitions of our sample in terms of industries or number of layers.

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Appendix A: Business Groups and ORBIS Ownership Database

Our two main sources of data are both compiled by Bureau Van Dijk (BvD), a Belgian consulting firm, and comprise the Ownership Database, from which we derive information on intra-group control linkages, and the Orbis database, from which we retrieve companies' balance sheet information. We exploit the 2010 version of both databases in this paper. The Ownership Database, in particular, includes information on over 30 million shareholder/subsidiary links for companies worldwide. Information on proprietary linkages is collected directly from single companies, from official bodies when in charge, or from some national and international providers. In Table A.1 we include a list of the information providers, with the indication of the countries/areas they cover, as reported by the Ownership Database. In case of conflicting information among providers covering the same country/area, the Ownership Database is updated according to the latest available report. Among the international providers, Bureau van Dijk enlists also Dun & Bradstreet, a data source that has already been exploited in other academic works mentioned in this paper (Acemoglu, Johnson and Mitton, 2009; Alfaro et al., 2009 and 2016).

Table A.1: Original sources of ownership linkages collected by Bureau Van Dijk

CIBI Information, Inc. (Philippines), Creditreform (Bulgaria, Ukraine & Rep. of Macedonia) , Chamber of Commerce & Industry of Romania (Romania), CMIE (India), CFI Online (Ireland), Creditreform-Interinfo (Hungary), Infocredit Group Ltd, (Cyprus & Middle East), CreditInform (Norway), Creditreform Latvia (Latvia), Creditreform (Rep. of Macedonia), Informa Colombia SA (Colombia), Contact database, Credinform (Russia & Kazakstan), Creditreform Austria (Austria), Coface Slovenia (Slovenia), Dun & Bradstreet (USA, Canada, Latin America & Africa), DGIL Consult (Nigeria), MarketLine, (previously Datamonitor), PT. Dataindo Inti Swakarsa (Indonesia), DP Information Group (Singapore), Finar Enformasyon derecelendirme ve danismanlik hizmetleri A.S (Turkey), Suomen Asiakastieto (Finland), Factset, Worldbox (Switzerland), Honyvem (Italy), Creditreform Croatia (Croatia), Huaxia (China), Inforcredit Group (Cyprus), Informa del Peru (Peru), ICAP (Greece), Informa (Spain), InfoCredit (Poland), Ibisworld (Australia), Jordans (UK, Ireland), Patikimo Verslo Sistema (Lithuania), Krediidiinfo (Estonia), Købmandstandens Oplysningsbureau (Denmark), KIS (Korea), LexisNexis (Netherlands), Bureau van Dijk (Luxemburg), Creditreform Belgrade (Bosnia-Herzegovina, Serbia & Montenegro), Coface MOPE (Portugal), National Bank of Belgium (Belgium), Novcredit (Italy), Qatar Chamber of Commerce and Industry (Qatar), Annual return (UK), Coface SCRL (France), Creditinfo Schufa GmbH (Czech Republic, Slovakia, Iceland, Malta), SeeNews (Moldova, Albania, Georgia & Uzbekistan), Chinese source, Statistics Canada (Canada), China Credit Information Service Ltd (Taiwan), Taiwan Economic Journal (Taiwan), Teikoku Databank (Japan), Transunion (South Africa), UC (Sweden), Verband der Vereine Creditreform (Germany), Worldbox (New Zealand, Hong Kong, Switzerland, Monaco, Liechtenstein, Pakistan, Sri Lanka & Cuba)

The observation unit collected by the Ownership Database is the single link between a company and each of its shareholders, with additional information on the total (direct and indirect) equity participation when relevant. For the year 2010 there are 7,707,728 companies with information on shareholding structures in the original database. An algorithm provided by Bureau van Dijk allows to identify the ultimate owners (UOs) of a single company. However, since our purpose is to track the whole network of firms developed by each Business Group and model it as a hierarchical graph (see Figure 1), we have to depart from the complete shareholding structure of each company, in order to identify one ultimate parent company, its set of affiliates and their relative distance within the hierarchy. To that purpose, we have slightly modified the original BvD algorithm in two ways: we reconcile conflicting information that can arise from a mismatch between controlling and controlled subjects, and we differentiate between corporate and individual ultimate owners.

Conflicting information deriving from controlling and controlled subjects can arise in the presence of cross-participations. In accordance with international standards we apply a threshold criterion ($>50.01\%$) for the definition of control on the basis of (direct and indirect) participation. The latter is the methodology currently used across international institutions (OECD 2005; UNCTAD, 2009; Eurostat, 2007), although it can lead to an overestimation of control in some bigger networks of affiliates. That is, even after adopting a majority threshold as a criterion of control, it is still possible to end up with one affiliate controlled by more than one ultimate parent company. To solve that problem, we rely on information officially provided by companies' consolidated financial accounts, when available. In particular, if we find that an affiliate is enlisted in more than one Business Group, we give priority to the ultimate parent company that enlists that affiliate in its consolidated accounts. In case no consolidated accounts are available, we include the affiliate in the group where it is located at shorter control distance from the parent.

The other correction that we apply to the standard BvD algorithm relates to the fact that this algorithm reports every property linkage between a company and each of its shareholders, thus including as members of potential business groups (as previously defined) also affiliates that are directly controlled by individual (non-corporate) shareholders, and that are not controlling subjects of any other company. As we want to characterize the drivers of BGs starting from the maximization of a firm problem, we have excluded these non-corporate UOs from our sample, although we include in our analysis these corporate networks that involve at least one intermediate property linkage of a corporate nature.²⁵ Specifically, our modified algorithm partitions all firms for which information on ownership is available in two groups:

- a) a set of independent companies that have as controlling shareholder individuals or a family or no specific corporate entity, and that are not themselves controlling shareholders of any other company;
- b) all other companies for which information on property linkages is available; these companies are either owned by a corporate controlling (immediate) shareholder or are themselves independent, but act as controlling shareholders of other companies.

The set a) of independent firms is used as a control group. The algorithm then screens every firm belonging to group b) for the highest total (direct and indirect) participation in the equity of each company, as provided by the Ownership Database. Once it finds a corporate controlling entity A that sums up to more than 50.01% of control in a given company B, company B is classified as an affiliate, while the same algorithm checks the shareholding structure of company A. If the latter is in turn ultimately owned by another corporate entity C, the process is repeated until a controlling company that has no corporate controlling shareholder is found. The latter is considered as the ultimate parent company of affiliate companies A, B and C. In the case of quoted companies, we consider as ultimate parent the highest company in the path of proprietary linkages we can identify. The procedure run for the year 2010 has recovered a total of 270,374 parents and 1,519,588 majority-owned affiliates (or subsidiaries) according to our definition.

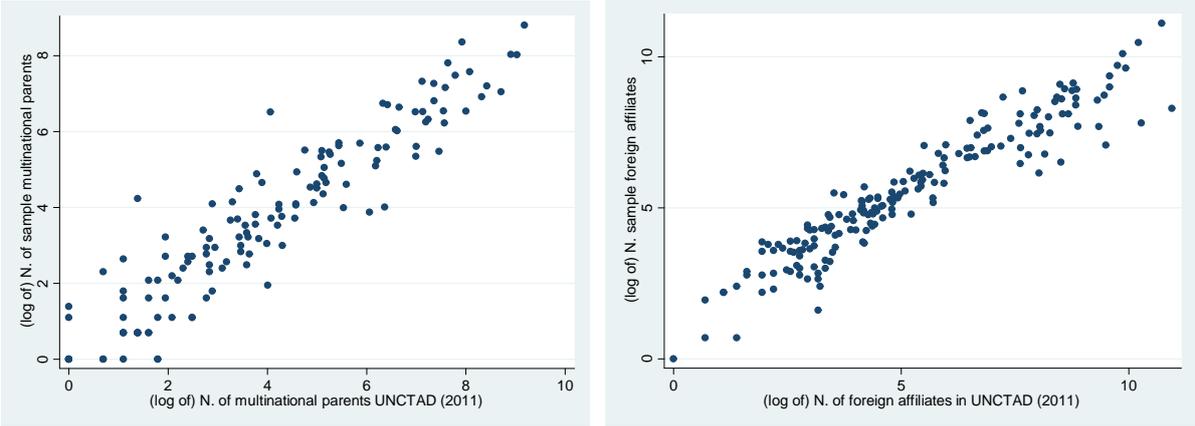
Having identified the set of affiliates and their parent, the algorithm then assigns a hierarchical level within each BG, counting from the parent how many steps of intermediate property are required for ultimate control. In

²⁵If for example an individual X directly controls affiliates A and B, we do not consider the X-A-B network as a business group. Whereas, in the case of an individual X that indirectly controls affiliates C and D through a third company E, we consider the E-C-D network as a Business Group, in which company E is the ultimate (corporate) owner.

case the same affiliate is encountered more than once in the same path (due to cross-participations), we consider it as located on the closest level where we have finally encountered it. A limit of the Ownership Database concerns the maximum number of control levels that can be obtained after considering cross-participations: the algorithm allows to reach a maximum of 10 levels for a maximum of 1,000 affiliates. However, in our data less than 0.1% of BGs exceed such limits.

In the figure below 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). The original source for data on affiliates in UNCTAD (2011) is Dun & Bradstreet, which is one of the sources of ownership data on which the ORBIS database also relies. The survey of UNCTAD (2011) refers to data in 2009, while our data are updated to 2010. We have excluded from the validation reported in the figure the datapoint on China, since the country does not adopt the international standard definition of control (>50.01%) in reporting the number of affiliates, preferring a different criterion of ‘foreign-funded enterprises’, leading to non comparable figures.

Figure A.2: Sample validation



Appendix B: Vertical Integration in Business Groups

In absence of actual data on internal shipments of intermediate goods and services across firms, Acemoglu et al. (2009) proposed to proxy vertical integration exploiting the information on the set of industries in which a firm is engaged, combined with the input coefficient requirements that link those industries as retrieved from input-output tables. A firm-level index was therefore calculated summing up all input-output coefficients that linked each firm’s primary activity to the secondary activities in which it was involved. The assumption is thus that a firm engaged in more industries, where backward and forward linkages in production are important, is supposed to have a higher capacity to source internally more inputs for its final output.

In order to take into account the BG dimension, we have refined the original index. In particular, we assume that within a group two sets of activities can be identified: a set of output activities $j \in N_H$, and a set of intermediate activities $i \in N_A$. The set of output activities coincides with the primary and secondary activities of the headquarter (N_H), whereas the range of intermediate activities at the group-level is represented by the set of primary and secondary activities in which controlled affiliates (N_A) are involved. With these assumptions, we can build a group-specific input-output table, where we report outputs in columns and inputs by row and where each combination VI_{ij} is the i th coefficient requirement to produce the j th output. As in Acemoglu et al. (2009) or Alfaro et al. (2016), we assume that industrial backward and forward linkages for all firms in our sample can be proxied by US input-output tables and adopt the industrial classification provided by the US Bureau of Economic Analysis, with 61 main industries mainly at a 3-digit level of disaggregation of the NAICS rev. 2002 classification. By summing up input coefficient requirements by column, we obtain the vertical integration for each line of business in which the Business Group is involved.²⁶ To retrieve the vertical integration index for the whole group, we average the total of all input coefficient requirements (VI_{ij}) by the number of output activities ($|N_H|$), thus correcting for the potential conglomerate nature of the group. The result is the following group-specific (g) vertical integration index:

$$v_g = \sum_{\substack{i \in N_A \\ j \in N_H}} \frac{1}{|N_H|} VI_{ij} \quad (12)$$

where VI_{ij} are the input coefficient requirements for any output activity $j \in N_H$ sourcing from all input activities $i \in N_A$. The group-specific vertical integration index can range from 0 to 1, where 1 corresponds to complete vertical integration.

In our dataset the average vertical integration across groups (v_g) is 0.062 (i.e., on average 6 cents worth of inputs are sourced within groups for a one dollar unit of output). For comparison, the figure obtained by Acemoglu et al. (2009) on their (unconstrained) sample is of 0.0487. Alfaro et al. (2016) also calculated in a similar way a vertical integration index for manufacturing firms with more than 20 employees, obtaining an average vertical integration of 0.063.

²⁶In absence of actual data on internal shipments of intermediates, we can interpret this number as a mere propensity to be vertically integrated, where the sum of industry-level requirements gives us only the maximum possible integration of production processes.