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MNE and Where to Find Them: an Intertemporal Perspective on the Global Ownership Network

Abstract

This paper introduces a simple procedure to construct ownership maps in Stata, uses a new method to map the development of the global network of multinational business groups over time and investigates the development of core components of the network. Based on Bureau van Dijk's ORBIS database, a full panel of ownership structures from 2000-2018 is reconstructed. The data is subjected to a descriptive analysis and subsequently used to identify key locations within the network. Ownership structures are used to identify outliers in the network even in the absence of financial data on the firm level. The identified locations largely overlap with results in the literature, but also point towards previously overlooked destinations. The aggregate ownership network at the country level is used to provide an intertemporal perspective on countries' development paths within the global network of multinational companies and sheds new light on MNE's expansion paths.

JEL Classification: H25, F23, G30

Keywords: MNE; ORBIS; ownership; control; business groups; conduit countries; visualization; network analysis; corporate strategy; firm-level data; country index; complexity

Oktober 2019

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1 Introduction

Empirical research on multinational ownership structures has remained an elusive quest for clarity. In fact, no paper on the topic foregoes a declaration of the considerable complexity of the subject, this one being no exception. At the firm level, multinational enterprises (MNE) form a globally connected network that changes constantly. Group boundaries are fluid and by connecting different locations and sectors each group stretches across multiple levels of data. Not only can they become very large, evidence also points towards the conclusion that their obscurity is often intentional. A first step in the research process should be to reveal and examine the corporate structures within the data, yet no simple procedure exists to do so in Stata.[1] The first contribution of this paper is thus the introduction of a new method to visualize the corporate structure of any multinational enterprise (or any relational dataset of geocoded information) by slightly altering the use of established standard tools. The resulting ownership maps can help to better understand an MNE's corporate hierarchy, its geographic focus and the quality and coverage of the underlying data.

However, corporate structures can only be investigated reliably with data of global reach and extensive coverage. With almost 300 million firms at the time of writing, Bureau van Dijk's ORBIS database is currently the best option available to empirical researchers. In a seminal analysis of the network's underlying structure Vitali et al. (2011) and Vitali and Battiston (2014) use ORBIS data from 2007 to map the firms' connections between each other. They find that aside from a strongly connected core, different distinct communities of closely connected firms can be identified based on their proximity within the network. Since then ORBIS expanded tenfold while the data quality improved significantly. At the same time, the application of social network analysis has been further expanded to tackle corporate ownership structures on a large scale.[2] De Lombaerde et al. (2018) review the use of network analysis to study globalization, regionalization, and multi-polarity. They

[1] A review of the literature on MNE visualization is provided in section 3.1. Clean illustration of a business group can help to identify errors and inform new identification strategies.

[2] The idea of treating an MNE as a network itself is naturally much older. Scott (1988) identifies the first application of social network analysis to interorganizational research to be Levine (1972)'s study on the interlocking directorates of industrial companies and banks. Levine highlighted the need to simplify complex data structures and proposed a series of manually constructed insightful visualizations.

provide an overview of the literature and discuss key results. A central insight that can be taken away from their review is that an intertemporal perspective on the global corporate ownership network has not yet been provided.[3] Joyez (2017) reconstructs the network of French multinationals and investigates the development of the network over time and finds that the network has become more decentralized. Joyez (2019) adds information on Global Value Chains (GVCs) and finds that MNEs align their structures to GVCs over time. Corporate hierarchies play a key role and they also add multiple layers to the data. Altomonte and Rungi (2013) measure the hierarchical complexity and vertical integration of business groups and find that, conditional on the host country's institutional quality, vertical integration and hierarchical complexity in defining the groups' boundaries are found to be negatively correlated. Both studies emphasize that it is vital to understand the development of the individual business groups over time to be able to understand the development of the network as a whole.

As mentioned previously, ownership structures can be deliberately obscure and intentionally complex. Conduit structures are an infamous expression of this complexity. They are frequently created with the intention to optimize a business group's structure under the given global regulatory framework. The term was coined by Mintz (2004) and the concept has been investigated extensively since then. Weichenrieder and Mintz (2008) use data from the German Bundesbank to identify the causes for the establishment of holding companies and complex ownership chains. They find withholding taxes, profit and loss consolidation, and the type of tax system of the investing country to be the most relevant factors. Using firm-level data from the Netherlands, Weyzig (2013) find evidence for the creation of specific corporate structures to take advantage of reduced withholding taxes under Dutch tax treaties. Fuest et al. (2013) elaborate on the creativity that is on display when it comes to the creation of corporate structures for the purpose of optimized tax planning. Their illustration of the famous "Double Irish Dutch Sandwich" summarizes how a specific setup of five companies in four countries was used for aggressive tax planning. In the meantime, regulatory process hase been made, most notably with the

[3] The only reference of a network analyzed over time is Fracasso et al. (2018) who investigate the evolution of trade in oil.

BEPS agenda OECD (2013) and the aforementioned model is being phased out, but new structures are taking its place. This paper attempts to identify them.

Network analysis provides the tools to see through the structural complexity. Garcia-Bernardo et al. (2017) outline the potential of this approach. They reconstruct the global corporate ownership network in 2015 and demonstrate that Offshore Financial Centers (OFCs) can be reliably identified by a purely data driven approach. They establish a list of 24 "sink-OFCs"[4] and provide evidence that the vast majority of value is routed into these destinations through five major "conduit-OFCs": the Netherlands, the United Kingdom, Switzerland, Singapore, and Ireland. This paper extends their work by relaxing some assumptions and investigating the corporate network's evolution from 2000-2018. Garcia-Bernardo et al. (2017)'s reconstruction of the network is defined by the simultaneous use of financial information as well as the focused target structures. This paper sets out to identify the most common structures in an unrestricted network of majority ownership connections with the intention to uncover previously overlooked constructions.

Furthermore, this paper reveals the entire network's development over time. The assessment of the network's core metrics follows Joyez (2017)'s reconstruction of the sub-network of French multinationals, which is recreated with ORBIS data as a benchmark. Special ownership structures are first identified using the system of archetypes proposed by Alabrese and Casella (2019) and their emergence over time is presented. Relaxing the predefined criteria for ownership chains completely, frequently used routes are then highlighted for different lengths of ownership chains. While the results are largely in line with Garcia-Bernardo et al. (2017), some plausible differences are uncovered. Several countries with exceptionally poor coverage of financial data are found to be core components of the network. Even though very little is known about the actual magnitude of their influence in economic terms, the firms' ownership structures feature them prominently. Finally, the countries' relative position in the network is found to only change gradually over time.

[4] According to Garcia-Bernardo et al. (2017) these destinations to which a vast surplus of value is flowing include the British Virgin Islands, Taiwan, Jersey, Bermuda, Cayman Islands, Samoa, Liechtenstein, Curaçao, Marshall Islands, Malta, Mauritius, Luxembourg, Nauru, Cyprus, Seychelles, Bahamas, Belize, Gibraltar, Anguilla, Liberia, St. Vincent & Grenadines, Guyana, Hong Kong, and Monaco.

The remainder of this paper is structured as follows. Section 2 provides a discussion of the data as well as the reconstruction process of the ownership structures in each year. Section 3 introduces a new method to create ownership maps in Stata (3.1) and outlines the methodological choices that create the foundation for the subsequent network analysis (3.2). Section 4 provides a detailed descriptive analysis of the data and sheds light on several key features. Section 5 presents the results of the network analysis. Section 6 discusses their relevance in the context of both the previously made sample selection choices and potential future refinements. Section 7 concludes.[5]

2 Data

The questions outlined previously make high demands for data coverage and quality. On a global scale, Bureau van Dijk's ORBIS is currently the only database to include high-quality ownership information from a variety of countries. National levels of coverage are generally high, but vary.[6] Built as a daily updating repository, great care has to be taken in the preparation and cleaning of the data.[7] Figure 1 outlines the data preparation process. The ownership data was extracted in batches from 15.04.2019 to 10.05.2019 (ORBIS as of 27.04.2019 for export and up to 10.05.2018 for correction and cleaning), mechanically corrected for human errors and reassembled against a unified backbone of bvdids. The general methodology here is an extended application of the bottom-up approach to reconstructing ownership data first mentioned in Jaraite et al. (2013) and first implemented on a large scale by aus dem Moore et al. (2019). Another application is outlined in Alabrese

[5] Appendix 8.1 elaborates on the construction of ownership maps and provides Stata code. Appendix 8.2 compares the reconstruction of the ownership network to different benchmark studies. Appendix 8.3 supplies detailed summary tables of the network and its most relevant components while appendix 8.4 illustrates a new balance measure for business group hierarchies.

[6] This issue was previously assessed in detail by Kalemli-Ozcan et al. (2015). Aside from a general stock-taking they also discuss the individual sources of the ownership database and provide recommendations for the reconstruction of ownership structures. Comparing ORBIS to OECD FDI data, they find better coverage for countries such as the UK, Germany, Italy, Ireland and Poland. In most countries their reconstruction of the ownership data covers more than 50 percent of the multinational economic activity reported in the OECD and in many countries ORBIS performs even better.

[7] Data accessed through ORBIS' online interface refreshes daily between 10:00 and 11:00 CEST. Data updates are usually carried out on Friday afternoon. Since these updating processes can influence the selection of firms returned by the database it is advisable not to carry out data exports during updates and not to extract batch exports across different vintages of the data.

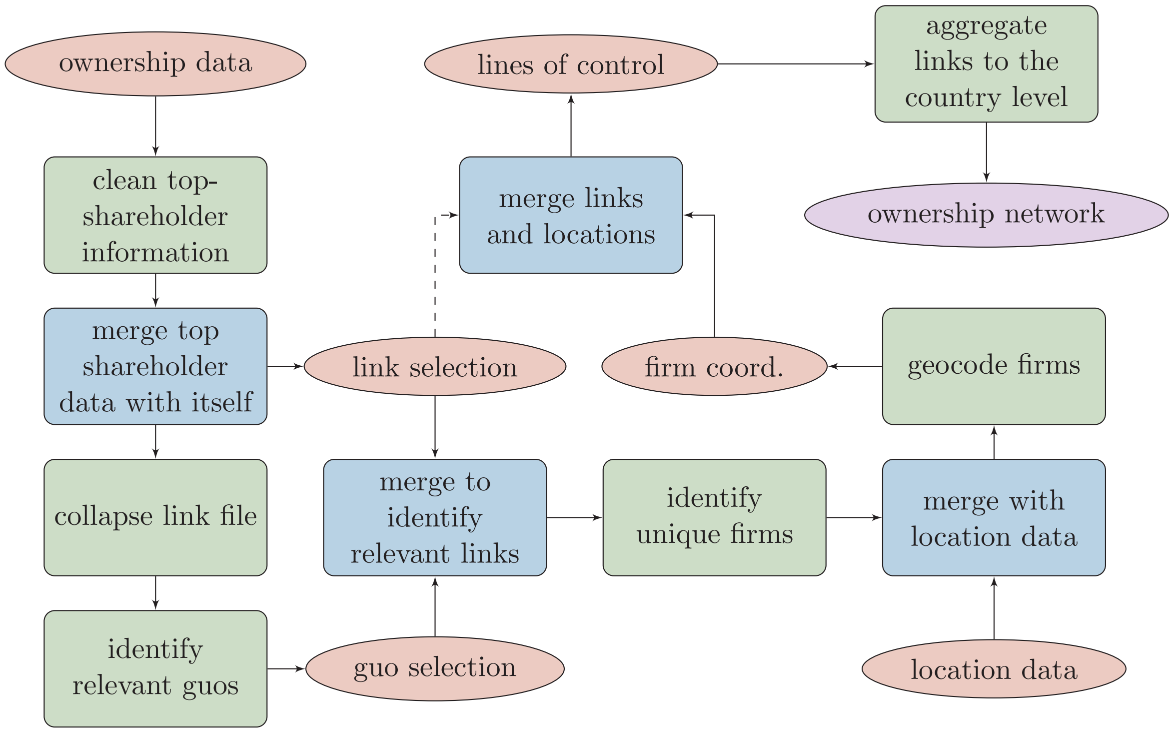

Figure 1: Data preparation flowchart

and Casella (2019), who focus on the identification of corporate investor nationality.[8] The bottom-up approach has several advantages. First, since the reconstruction of ownership structures begins at the level of the individual subsidiary, in the process of identifying the GUO several data points are required for successful identification. Top-down approaches rely entirely on the validity of information at the level of the GUO, which constitutes a potential weakness of the reconstruction method.[9] Identifying ownership structures in this way means that the existence of a single link of majority ownership will lead to the identification of a firm's GUO. Second, the approach is iterative and thus allows for the construction of a variety of business group specific measures. For example, data prepared in this way allows for the investigation of any type of firm-level information at any hierarchy-level and the identification of specific ownership patterns within a business group. Appendix 8.4 takes a closer look at the hierarchies and their development over time. It also allows for the easy transformation of the group structures in a matrix format

[8]An extended discussion of the reconstruction process used in this paper as well as an benchmark comparison with both Jaraite et al. (2013) and ORBIS is provided by Großkurth (2019).

[9]Although data at the level of the subsidiaries can in principle still originate from the same source (annual reports, for example), using many pathways to find one destination has no inherent disadvantages. In the case of an error in the chain to the GUO the impact of this error is limited to the connected firms.

usable for network analysis. Most importantly, the bottom-up approach can be undertaken separately for any given year. While the information on the GUO as provided by ORBIS is only retrievable on a most-recent basis, top shareholder information can be obtained at any cutoff date in the past. This allows for the creation of yearly ownership variables, which can then be merged to build a panel dataset.[10] Figure 2 shows the number of firms which are either part of or controlling[11] the yearly reconstructed business groups. The figure highlights the continuous improvement of ORBIS over time. With each year the body of information on global corporate structures grows larger. This is both an effect of MNE expansion as well as of quality improvements in the data collection. The data is adjusted for gaps in which a year between two identical top shareholders is missing.

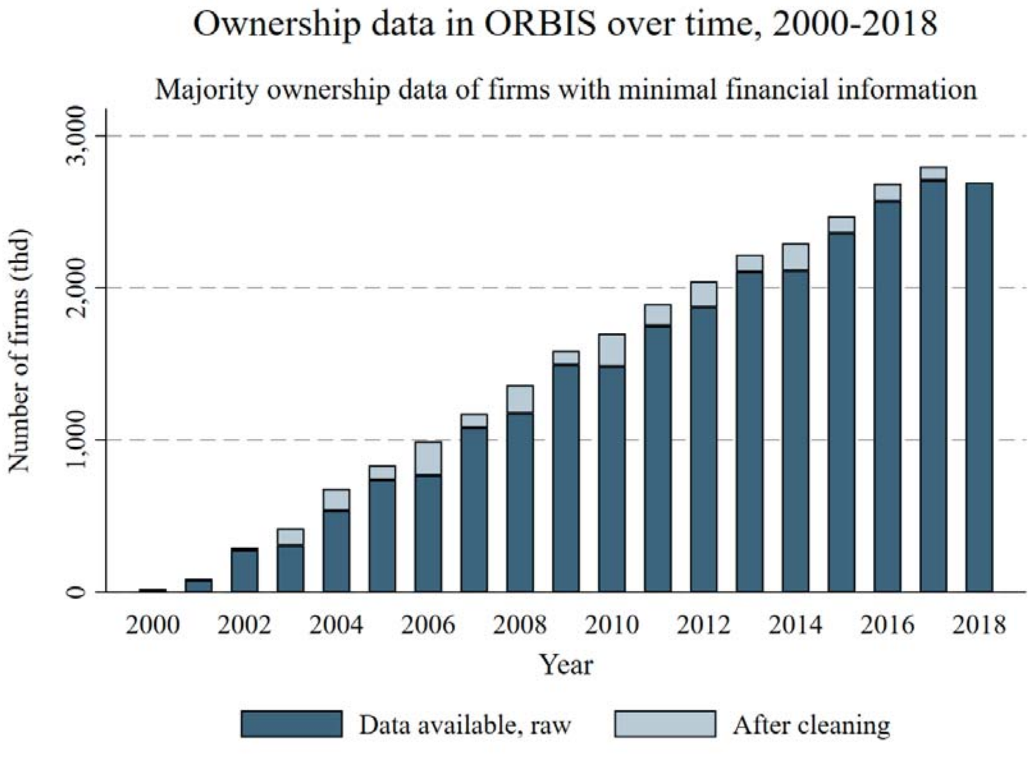

Figure 2: Ownership data over time in ORBIS, 2000-2018

A caveat of the bottom-up approach is that its accuracy and completeness depends on

[10]Großkurth (2019) discusses the implications of time-varying ownership structures. A group structure that changes over time constitutes a considerable challenge for empirical research.

[11]Throughout this paper, the term *controlling* refers to a firm's ownership of another firm through a share of at least 50.01 percent. However, the ability to exert control over this company along the chain of ownership has to be assumed. Furthermore, in the absence of other data ownership structures and management structures can be very different.

the data the process starts with. The iterative merges can only retrieve GUOs of firms which are in the database to begin with. This means that instead of extracting all firms connected to a limited amount of GUOs this approach ideally requires the usage of the entire database.[12] The baseline sample is thus kept as large as possible and included all active firms with at least one value for Total Assets in any year from 2009-2019. For this selection of 24.064m firms, top shareholder data was then extracted for each year from 2000-2018.[13] After the reconstruction of these firms' GUOs, three iterations of firms found missing in the merging process were extracted as well.[14] The final baseline sample enriched in this way included 27.710m firms. Top shareholder information was then reduced to corporate shareholders, ensuring that in cases of non-corporate ultimate ownership the firm in the line of control would be considered as GUO. After cleaning and reconstruction, a refined selection of 4.086m firms was found to either belong to or control a business group.[15]

In addition to that, several subsets of the data were refined for specialized purposes. The initial selection of 24.064m firms with at least one value for Total Assets in any year from 2009-2018 was further narrowed down to a subset of 10.499m firms with nonmissing data for Operating Revenue in 2017. This information was then extracted with a preference for unconsolidated data and is used to assess the data availability situation on different corporate hierarchy levels. A selection of 1.491m identified GUOs was re-uploaded into ORBIS to retrieve information on a wider selection of financial variables. This data was

[12] As Alabrese and Casella (2019) rightfully point out, in the absence of access to the full database this can lead to the identification of subgroups within the full business groups. However, it can be argued that the approach captures all of the most important subgroups and leads to the identification of the same GUO in the vast majority of cases. Although the total number of identified GUOs is lower, identified GUOs match ORBIS in over 99 percent of all cases (see Großkurth, 2019).

[13] For top shareholders, if information on the percentage of ownership was available, at least 50.01 percent ownership was required. It is then assumed that a firm which owns more than half of another firm exerts controlling influence. While this limits the selection of ownership links it also creates business groups with sharp boundaries.

[14] Since the baseline sample was extracted based on economic relevance, firms with missing financial information but nonmissing ownership information are excluded under this definition. This can lead to lines of control being broken if an intermediary firm's financial information is not captured. By iterating three times it is ensured that lines of control can include up to three firms in a row with fully missing financial information, further enhancing the quality of the ownership reconstruction. By the fourth iteration, missing bvdids in all periods combined had declined to 3813, none of which could be found upon reupload.

[15] Another caveat of the procedure is that the amount of data used enforces the identification of correction of mistakes with dedicated algorithms. Manual corrections were applied whenever it was feasible. An extensive discussion of this issue is provided by Aminadav and Papaioannou (2016), who go to great lengths to verify the integrity of their data. They are also among the very few studies that investigate the ownership data over time.

extracted with a preference for consolidated financial information and for a time period from 2010-2018.[16] For the purpose of visualizing the data structures, several business groups with distinctive features were selected. All unique firms connected to these groups were combined with their respective location data[17] and subsequently geocoded using the Stata module *opencagegeo*.[18] ORBIS also includes information on the latitude and longitude of selected companies, which was merged with the results from opencagegeo. In the case of discrepancies or missing information, priority was given to information provided by Bureau van Dijk. A small amount of firms were geocoded manually to ensure accuracy in the case of key locations.

3 Methodology

Two pillars constitute the methodological foundation of this paper. As the first, a simple procedure is introduced to visualize multinational ownership structures in Stata. Geocoded firm-level data combined with refined ownership structures can shed light on both the structural complexity of multinational business groups and the current availability of information about them. As the second, firm-level ownership data is aggregated to the country level to allow for the analysis of the global MNE network's evolution. An alternative method to identify key components of the network is introduced that relies exclusively on ownership data. It builds upon seminal work by Vitali et al. (2011), Joyez (2017), Garcia-Bernardo et al. (2017) and Hussain et al. (2018) and provides a new perspective on business groups' structural adjustment over time.

[16] Although it is possible to extract ownership data in any year, the extraction of financial data is limited to a period covering the last 10 years. Furthermore, the selection of consolidated vs. unconsolidated data in ORBIS is highly influential. If the export preference is set to consolidated data, an existing consolidated account with missing data will take preference over an existing unconsolidated account with nonmissing data (and vice versa).

[17] This data is only retrievable on a most-recent basis and thus constant at the end of 2018. Location data other than a firm's country of incorporation is only used for the visualizations.

[18] opencagegeo is an open source Stata module introduced by Zeigermann (2016) which allows for the free use and storage of the obtained data. Since the purpose of the geocoding is primarily illustrative, preference was given to encoding speed over the accuracy of the coordinates. However, the accuracy of the geocoding process, as evaluated by opencagegeo, surpassed 25km in 95 percent of all cases.

3.1 Ownership Maps

Although there exists an extensive body of literature on MNE, visual representations of the data itself are surprisingly scarce. The first work on this subject dates as far back as Reynaud (1977), referenced in Pumain and Rozenblat (1991), yet there is no simple method available to print the corporate structure of a multinational corporation on demand in a comprehensible way. Visualizations as introduced by Pumain and Rozenblat (1991) and Rozenblat and Pumain (1993) are invaluable to not only illustrate the complexity of the data, but also to identify potential mistakes in it that would remain hidden in other formats. For example, some implausible ownership constructions are impossible to identify by looking at the underlying relational database and too specific to catch with general algorithms. They can also build the foundations for further analysis and inspire new ideas. As Luo et al. (2009) point out, "There is great value in being able to "see" the network in order to tease out important architectural patterns that correlate with the quantitative aggregate metrics."[19] In their network analysis of foreign direct investments of EU28 firms abroad De Masi and Ricchiuti (2018) also underline that "the visualization of a graph is a crucial point in the study of a network". In line with other papers conducting network analysis, they opt for representations based on closeness in the network, but not in terms of the firms' locations.

The procedure presented in this paper introduces a fast way to print ownership maps in Stata. First, each firm belonging to the group of a selected GUO is merged with the previously obtained set of coordinates to print them as points on a map, illustrated in figure 3. Second, the ownership structure is overlaid, revealing the actual connections between the firms. Third, the points are scaled by each firm's number of controlled companies (itself included) to represent a firm's individual relevance within a business group (figure 4).[20] The combination of these three dimensions (geographical coverage,

[19]Luo et al. (2009) furthermore discuss the absence of sufficient means to visually represent large and complex networks. Although the literature has advanced considerably since then, visual clarity is still an issue in contemporary representations of network data. An exception is Rozenblat et al. (2017), who provide examples for different ownership structures of relevance before clustering the data at the city level. They shed new light on the interconnections between cities, driven by the cluster-specific ownership structures within and across them.

[20]This is equivalent to the node's *inward degree* + 1. Given that the 50.01 percent ownership criterion enforces unidirectional lines of control, each node's *outward degree* is fixed at 1 while the GUO's

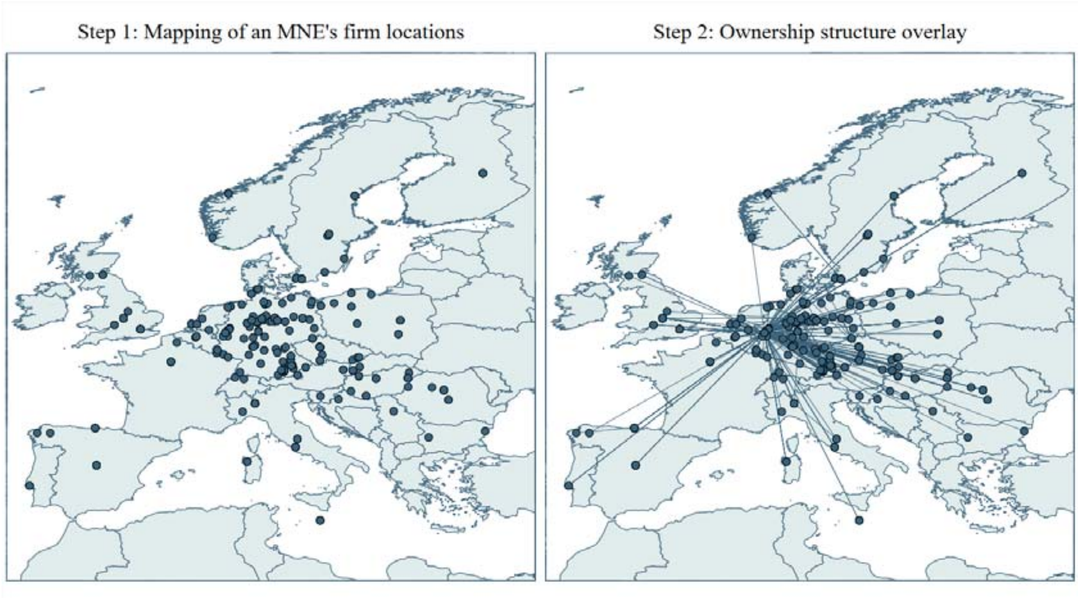

Figure 3: Making the structure visible

ownership structure, and corporate hierarchy) allows for an intuitive assessment of an MNE's corporate structure as well as its geographic focus. The ownership map can also serve as an initial assessment of a group's preferred type of hierarchy. Figure 4 illustrates the corporate structure of a global MNE's European firms, in this case all ultimately controlled from Germany. With 420 firms being directly controlled by the group's GUO, the company's hierarchy is extremely flat and centralized.

Additionally, the points can be scaled by any variable that can be merged to a firm and the encoding of the hierarchy allows for customized assessments. In figure 5, the GUO was excluded from the weighting procedure to allow for an assessment of the group's allocation of employees across different countries.[21] The retrieved image is substantially different and provides deeper insights into the business group.[22] All of these data configurations can be used to construct higher order variables to describe and assess MNE.

outward degree is zero. Consequently, for a controlled subsidiary at the basic level the number of controlled firms is equal to 1 whereas for a GUO it equals the total number of firms in the business group.

[21]When comparing data on different hierarchy levels, consolidation needs to be taken into account. Although the data was extracted with a preference for unconsolidated information, excluding the GUO as a means to assessing lower levels of the corporate hierarchy is a viable strategy on its own.

[22]For a solid understanding of an MNE's profile, several configurations (Ownership, Total Assets, Employment, Taxation, etc.) could be assessed. Furthermore, even though the construction of MNEs based on links of majority ownership shares assumes a chain of control, actual management structures can of course deviate. Ownership maps scaled by different variables of interest can be a powerful tool to investigate MNEs.

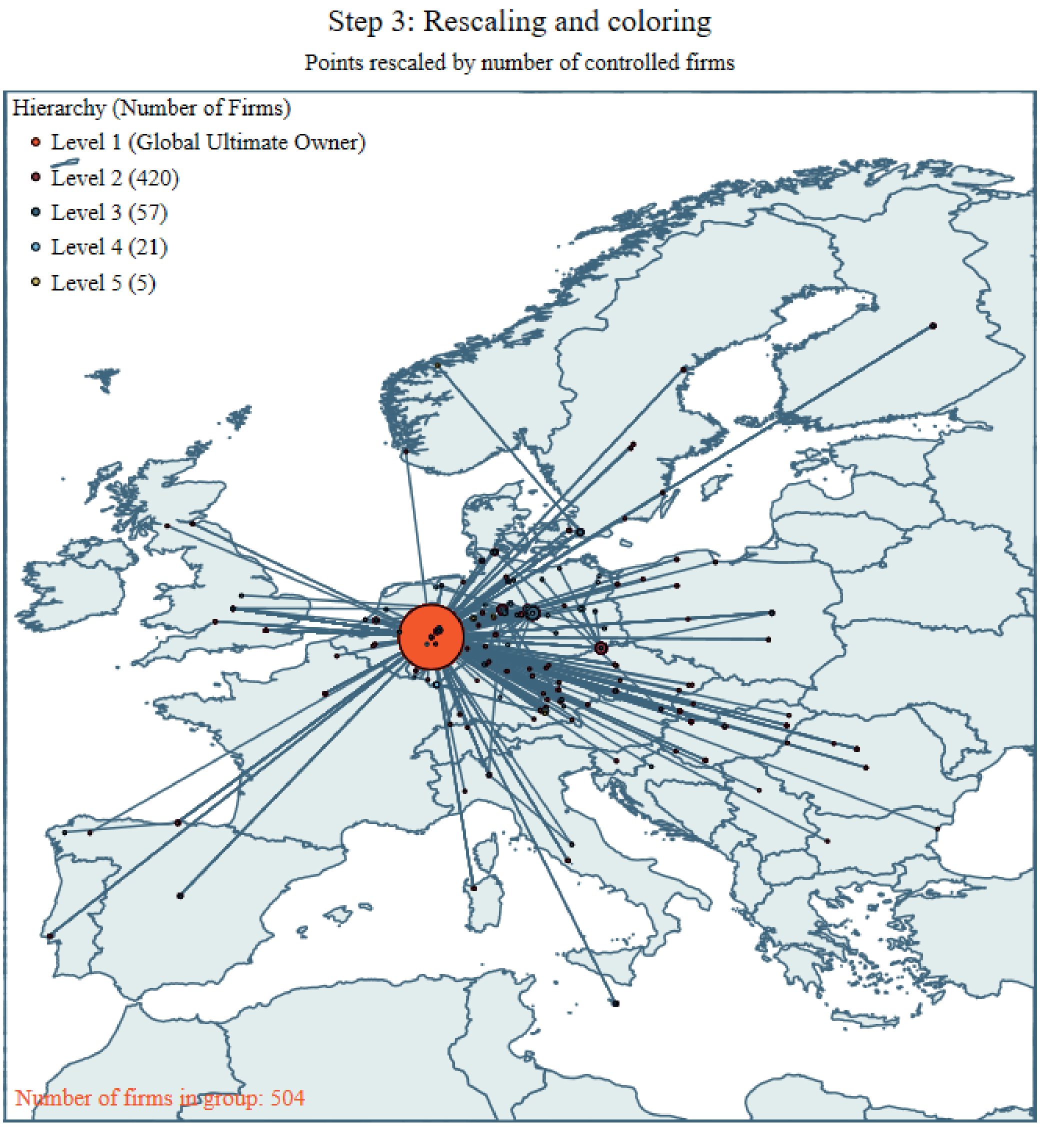

Figure 4: Ownership maps: visualizing the corporate hierarchy

As figure 6 shows, this flexibility can be used to answer very specific questions. For example, the availability of financial data can be unequally distributed within a business group (see section 3.2 for a more detailed discussion). At the same time, some missing values might be a lot more interesting than others. Combining ownership and taxation data reveals that for the case of a different company with its GUO located in Italy, one of the most influential subsidiaries in the context of the group's corporate structure, located in the Netherlands, is missing from the picture.[23]

[23]With a total share of 74.2 percent nonmissing information, the chosen business group's coverage is relatively high. Figure 7 points towards a much lower average.

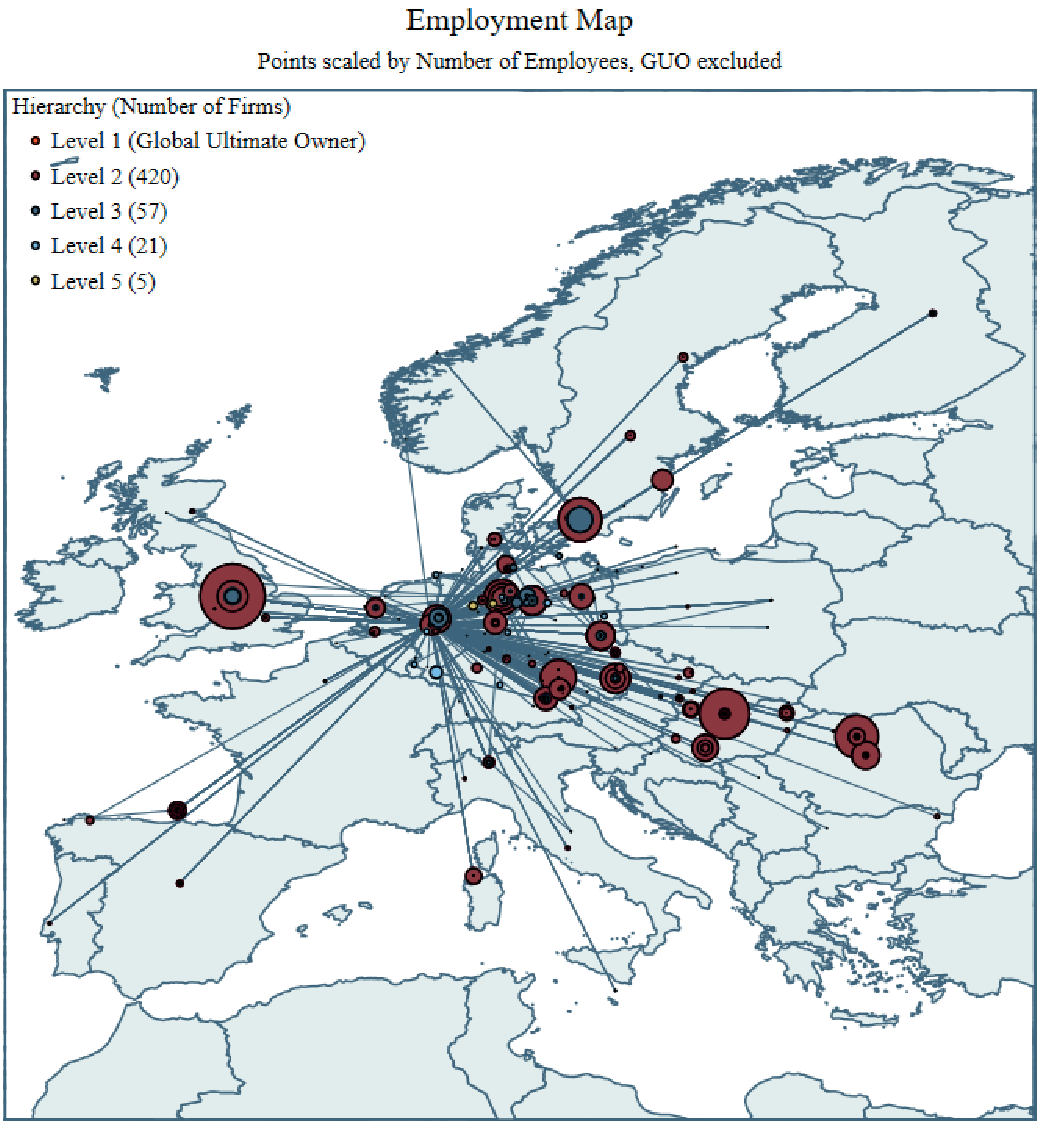

Figure 5: Inspecting other variables

A caveat comes with the large amount of data that is represented simultaneously. The visual impression of an ownership map can become misleading for very large groups if the data is not aggregated to a fitting level. For example, when several firms are located in the same city they would appear as the same dot on the map. In these cases data aggregation is vital for visual accuracy. Ownership connections can also be redundant when both the controlling and the controlled firms stack in the same locations. In this case an accurate representation could apply frequency weights to visualize the network's duplicate edges.[24]

[24]Figures 3 and 4 are to some extent affected by these issues. Preference was given to providing an unaltered representation of the data. Automatic aggregation algorithms, such as the data-driven community detection algorithm employed by Rozenblat et al. (2017), could be an extension of this procedure.

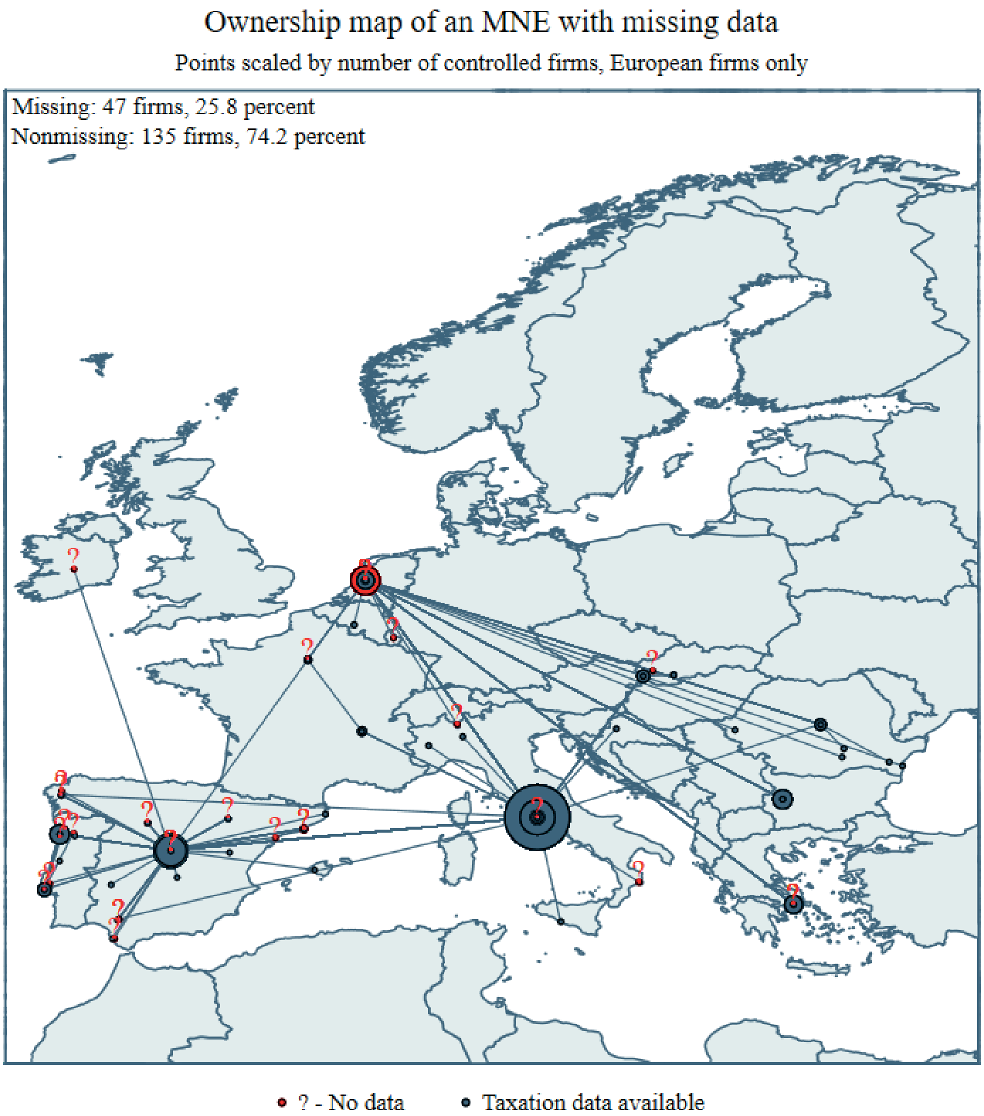

Figure 6: Missing data in a large MNE

The aggregation of ownership structures can both solve the representation problems as well as open a new level of analysis. Rozenblat et al. (2017) aggregate and investigate effects at the city level. They provide visualizations of increased clarity and illustrate how the most relevant cities within the global network are connected. However, data aggregation always comes with the cost of losing detail and its own set of difficult decisions.

3.2 Network reconstruction

Moving beyond the individual business group, network analysis provides the tools to further assess the implications of interconnected multinational ownership structures. This paper adds to the extisting literature by focusing on the evolution of the network over time and connects existing work by Hussain et al. (2018), Joyez (2017), and Garcia-Bernardo et al. (2017).

Hussain et al. (2018) analyse the role of cities in the context of MNE networks. Using ORBIS data from 2010 and 2013 they aggregate firms located in different geographical clusters to a city level. The cities constitute the nodes of the network and the ownership connections between them are aggregated to represent weighted edges. To track changes over time they propose assessing the three dimensions of *diversity*, *strength*, and *centrality*. [25] However, while Hussain et al. (2018) only compare the state of the city network at two points in time this paper tracks the network at the country level in each year from 2000-2018.

The approach follows previous work by Joyez (2017), who maps the network of French multinationals using administrative data from 2005-2011.[26] In both cases the connections of all relevant subsidiaries are aggregated to form a weighted directed network at the country level. An important difference is the assumed connection pattern between the subsidiaries that constitutes the foundation of the network. Joyez (2017) excludes France and connects every subsidiary belonging to one group to every other subsidiary belonging to the same group, simply assuming that all firms within the same group are connected independent of their ownership structures. Compared to tracing ownership structures this leads to a greatly increased amount of edges in the network and fundamentally alters the network's overall shape.[27] Appendix 8.2 extracts the French subnetwork of multinational

[25]In network analysis terms they define diversity as a city's *Unweighted Degree Centrality* (or the number of unique locations a city is connected to), Strength as *Weighted Degree* (the number of total connections a city has in the network) and centrality as *Betweenness Centrality*, referencing the methodological contribution of Freeman (1977).

[26]The LiFi (Liaisons Financières) dataset tracks all French multinationals. Initially the dataset had inclusion thresholds based on employment, turnover, and significant shareholders but it was extended and improved over time. A detailed discussion of the LiFi dataset is provided by Mariotte (2017).

[27]For example, in the case of one company controlling four other companies through direct ownership links

companies as a comparison to the full network constructed in this paper and provides a detailed discussion of both. All remaining network reconstructions in this paper trace ORBIS ownership structures and make no other assumptions regarding the connectedness of the companies.

Although the reconstruction of the network allows for the investigation of important trends at the macro level it is a means to the end of identifying its most important components. Garcia-Bernardo et al. (2017) propose a data-driven method to identify Offshore Financial Centers (OFCs) using ownership network data. Based on ORBIS data for over 98m firms in 2015 they distinguish between "sink-OFCs", countries which attract and retain foreign capital, and "conduit-OFCs", countries which constitute attractive intermediate destinations in the routing of international investments and enable the transfer of capital without taxation. They identify 24 sink-OFCs and five conduit-OFCs. According to Garcia-Bernardo et al. (2017), the Netherlands, the United Kingdom, Ireland, Singapore, and Switzerland canalize the majority of corporate offshore investment. They also identify several territories among the sink-OFCs which belong to or are associated with the United Kingdom. Following their example, firms classified as being located within the United Kingdom are reassigned their country codes to (IM) if they are located on the Isle of Man, (JE) if they are located in Jersey, and (GG) if they are located in Guernsey.

A major difference between Garcia-Bernardo et al. (2017) and this paper is that I do not use the weighting method introduced by Vitali et al. (2011) to calculate to the value of an ownership chain. This method assigns the total value V_p to a chain p according to the formula

$$V_{C_1|C_2|C_3} = RC_1 * MO_{C_1|C_2|C_3} \tag{1}$$

where, as summarized by Garcia-Bernardo et al. (2017), $C_1|C_2|C3$ correspond to a chain of three companies in which C_2 owns C_1 and C_3 owns C_2, R_{C_1} is the operating revenue of company C_1 and MO is the multiplicative ownership (the product of the weights of the links between the subsequent firms in the chain). Although this approach is very

the ownership network would consist of 4 edges (since control only flows in one direction) while the fully connected undirected network would consist of $\frac{(N-1)N}{2} = 10$.

convincing in principle, it becomes problematic once the combined availability of financial and ownership information in ORBIS is taken into account.

Ideally, the aforementioned method is applied to an unbroken chain of data points. If, however, either the financial information at the level of the subsidiary or some of the ownership information along the way to the GUO is missing, generous interpolation and aggregation of the data is required.[28]

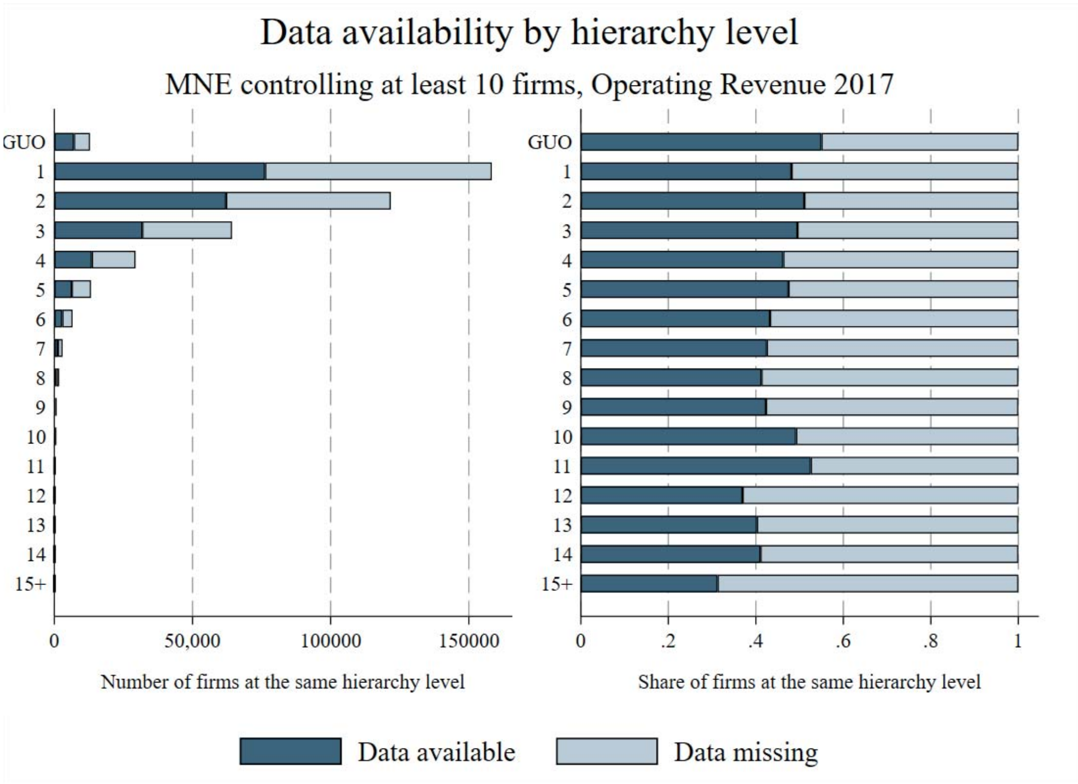

Figure 7: Missing data at different hierarchy levels

Figure 7 illustrates why this constitutes problem. For MNE controlling at least 10 firms, full data for Operating Revenue is generally scarce, but the availability declines even more with the length of the line of control. This means that the further removed a subsidiary is from a GUO the less likely it becomes for the firm to report financial data.[29] There are vir-

[28]For example, Garcia-Bernardo et al. (2017) consider a company A to be a subsidiary of a company B (with consolidated accounts) if they share the same GUO and their values of revenue and number of employees are within 25 percent of each other, even if no ownership link is recorded in the database.

[29]Note that the measured data availability is an upper bound estimate. Firms with completely missing financial data did not enter the sample in the first place.

tually no cases of larger MNE with complete financial information at the subsidiary level.[30]

Instead, this paper provides evidence that ownership data reconstructed with a bottom-up approach is sufficient to identify they key actors in the network and can complement existing value-based approaches. Three main arguments support this hypothesis. First, since MNEs can effectively split both their structures and their transactions into parts of optimal size, the route with the largest amount of total transferred value should also be the most frequented one. If MNE optimize their structures, aggregate ownership structures are sufficient to identify outliers in terms of their frequent appearance among all possible pathways in the network. Second, secrecy plays a fundamental role and makes it more likely in this case than in others that a missing value would in fact have been a very interesting one. Relying on ownership data instead of building upon financial information ensures that at least the structural component of the information is not wasted. Third, the availability of financial data quickly declines from GUO to subsidiary along the corporate hierarchy. For large business groups only a small fraction of the connected firms report financial information.[31]

The network itself is created from binational ownership links only. All individual chains of control were first compressed to make sure that no chains would be broken by the exclusion of purely domestic links. Afterwards, ownership chains were chopped up into weighted edges (chunks of size 2) to build the network and into chunks of larger sizes to identify particular conduit structures. Figure 8 illustrates the applied compression method. Each remaining edge was weighted by the amount of controlled companies, making sure that the most relevant actors within the network would not disappear in the process of clean-

[30] At the same time, the situation for smaller MNEs is largely similar. Availability of information at the upper hierarchy levels increases with firm size.

[31] The magnitude of this effect can be gauged by a simple comparison between the initial samples used for analysis. If no quality criterion is applied, data selection as conducted in Garcia-Bernardo et al. (2017) returns over 98m firms. Vitali et al. (2011) identify their initial selection of firms based on an initial list of 43060 transnational companies, a top-down approach. Since the data was extracted in 2007, the total number of firms in the database had not exceeded 30 million yet. If one requires a firm to report at least one nonmissing value of Total Assets in any one of the years from 2009 to 2018, as is done in this paper, the number of relevant firms drops to 24.064m firms, or about a quarter. Total Assets is one of the best-covered variables in ORBIS, which forces the conclusion that the difference between the samples has to be made up entirely of connected firms which do not report any financial information. Section 6 elaborates on this topic.

ing out purely national business groups. This method allows for the identification of the most frequented pathways of arbitrary length and is used to reveal structures that did not appear previously.[32]

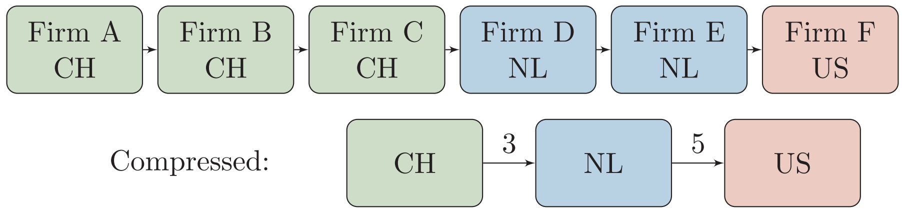

Figure 8: Ownership chain compression

4 Descriptive Analysis

Several special features of ownership panel data need to be taken into account before building the network. Most importantly, a decision should be taken to split the ownership structures into national and multinational groups. Figure 9 illustrates the size distribution of business groups in 2017. The vast majority of ownership connections is accounted for by fully national groups. In this case, all firms connected to a GUO as well as the GUO itself are located in the same country. If MNE are to be the subject of analysis, including a substantial amount of national business groups in the sample might blur the results.[33] However, this status criterion can also change over time. Although there are some exceptions of firms which are "born global", most MNE emerge from previously fully national business groups. Reducing a panel dataset to "multinationals only" thus implies a reduction of a business group's time series to those periods in which the group was already active in several countries. This can break up a time series and make it considerably more difficult to investigate the factors which led to the group's decision to become an MNE in the first place. The chosen classification is thus strongly dependent upon the research

[32]Without weighting the links with financial data the precise amount of shifted value cannot be assessed. However, future studies could be targeted to investigate the very specific structural outliers identified in this paper.

[33]Selecting a sample of firms controlled by a GUO in the ORBIS interface does not lead to this separation, because a GUO of a fully national business group is technically still a "global" ultimate owner. Similarly, the selection of firms owned by a domestic ultimate owner would not exclude national groups either. The domestic ultimate owner is the last firm in a line of control that is still located within the same country, but this has no implication on a group's multinational composition.

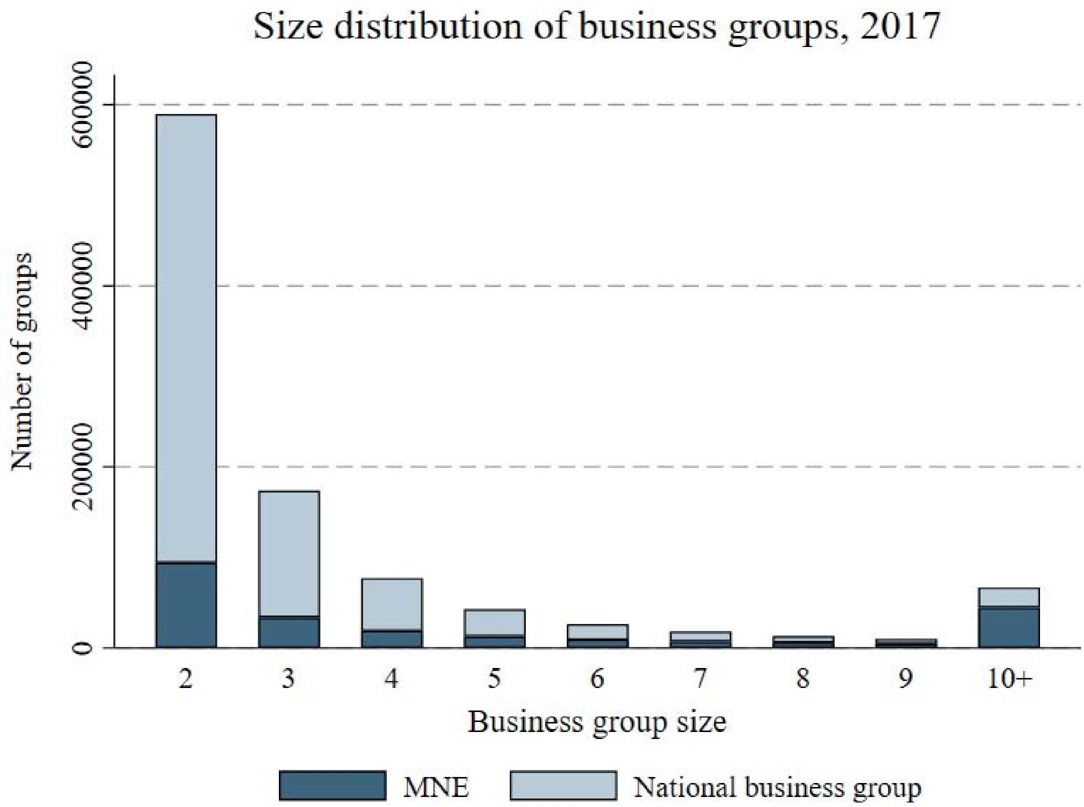

Figure 9: Size of business groups, 2017

question. This paper uses MNE if data is pooled across years and groups which are MNE in any period if the time dimension is taken into account. For the reconstruction of the network later on, all business groups are initially considered, but after excluding purely national links only international substructures remain.[34]

The reconstructed ownership panel allows for an empirical assessment of MNEs' expansion pathways over time. Here the unit of analysis is the full business group, which allows for the investigation of aggregate measures at the group level. Figure 10 illustrates the growth pattern of all business groups which were classified as multinational at any given point in time.[35] Each line represents a business group's development over time while the cumulative opacity of the lines approximates the panel's density. There is a substantial amount of movement within the panel and groups can fluctuate in size between periods.

[34]The method used does not break any of the groups, it merely compresses the structures.

[35]For the sake of visual clarity, 147 observations of groups larger 1000 are excluded. This does not affect the overall result. The remaining sample includes a total of 329376 unique business groups.

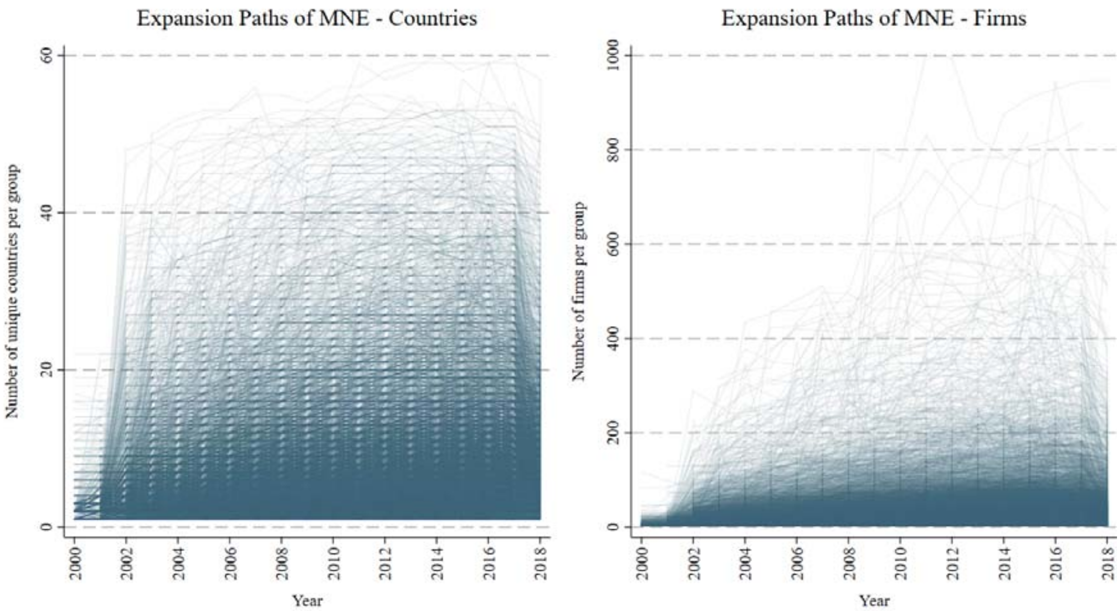

Figure 10: MNE expansion paths

As result of the hierarchical construction of the business groups, M&A events instantly change a business group's size and other metrics. The general drop in 2018 is likely a result of the data extraction and reconstruction process and visible in all representations of the panel.[36] It suggests a lag of almost two years until ownership data is updated comprehensively. Consequently, ownership data extracted in the latest available year should be cleaned for outdated links and great care should be taken when data extracted on a "most recent" basis is analyzed and interpreted.[37]

There is also considerable heterogeneity across MNE in terms of their size and growth patterns. The majority of MNE is rather small and does not grow much over time. Figure 11 plots the size of MNE with fewer than 200 subsidiaries in 2010 against their size in 2017. While there is a lot of movement within the ownership data and a minor tendency

[36]ORBIS refreshes the date of information of an ownership link in case of either the discovery of new data or the confirmation of an existing ownership link. However, the database does not include information on the termination date of links, which means that links are retired once they fall too far behind a chosen deadline. This panel was reconstructed by using only information newer than 18 months behind the yearly rolling deadline, which means that in 2018 all links are deleted which are older than June 2017. Since it takes some time until new ownership data is included in ORBIS, these are likely links which will be refreshed in the near future, but have not been updated yet.

[37]This effect also contributes to the explanation of the discrepancy between the total sample size used in this paper and in others. Indiscriminate aggregation of ownership links from different time periods inflates the number of found connections and vastly increases the sample sizes at the expense of internal consistency.

towards simplifying structures over time, the vast majority of groups does not exceed a size of 10 connected firms at any point in time.[38] There are several reasons for this. First,

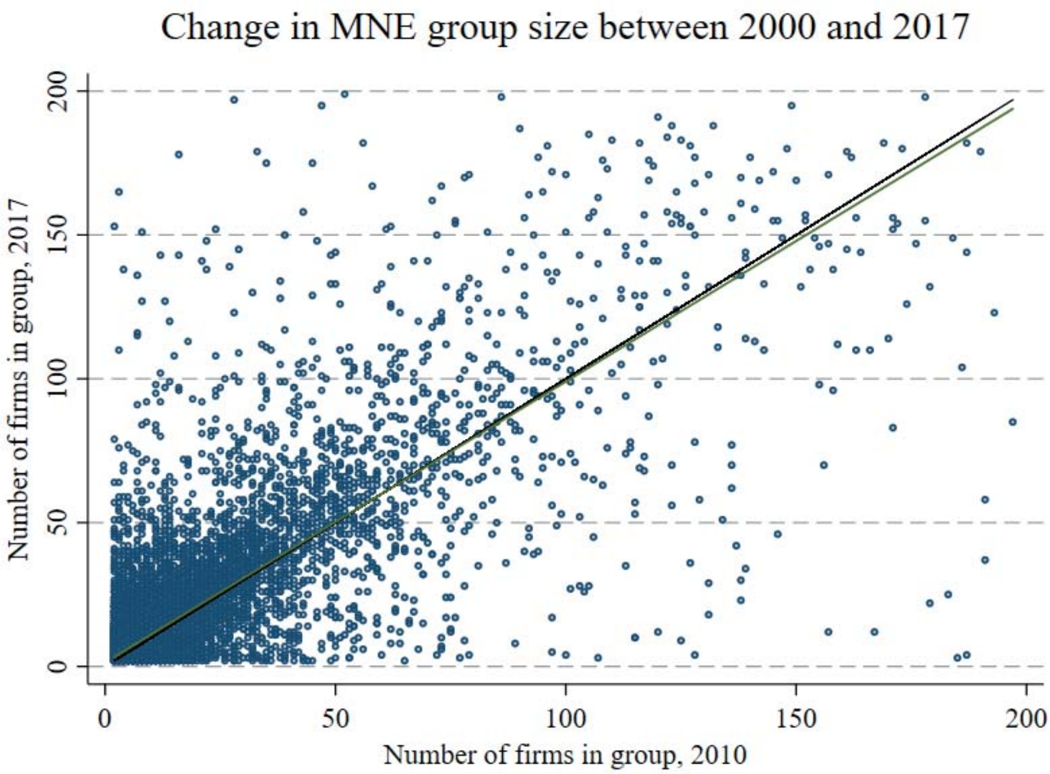

Figure 11: Change in size of MNE between 2010 and 2017

not all subsidiaries report financial data and any who never did would not be captured by the initial firm selection. The identified group sizes are thus likely to be smaller than the real group sizes overall. Some connections within business groups might be severed for the same reason if an intermediary has fully missing data, both increasing the number of small groups and reducing the number of large ones. Second, growing at the extensive margin is likely more difficult for a firm than simply getting acquired by another firm. Small MNE might thus simply disappear from the dataset at some point and become part of a larger MNE in later periods. There is some evidence for this in the form of group size numbers jumping to higher levels between years. Third, some firms might simply not have enough time to grow within the window captured by the dataset.

[38] The inclusion of larger groups in the figure would not prevent this observation. It is also worth emphasizing that this figure can only include MNEs which exist both in 2010 and 2017. When merging the total number of identified MNE in both years, only about 21 percent (42901) of the groups present in any of the two periods are present in both. While the same assessment could be undertaken for earlier periods the sample of successful merges would be considerably smaller.

As previously illustrated in figure 2, the entire dataset is growing over time. This means that in each year more groups enter the dataset than leave it, making it difficult to differentiate between the growth pattern of the average business group and the growth pattern of business groups on average. Furthermore, many groups are only present for a small number of periods, as can be seen in figure 12. For this representation of the data, all individual spells of business groups were normalized to start at the same period in time. This recombination of the database allows for an investigation of the average business group's growth path over successive periods.[39]

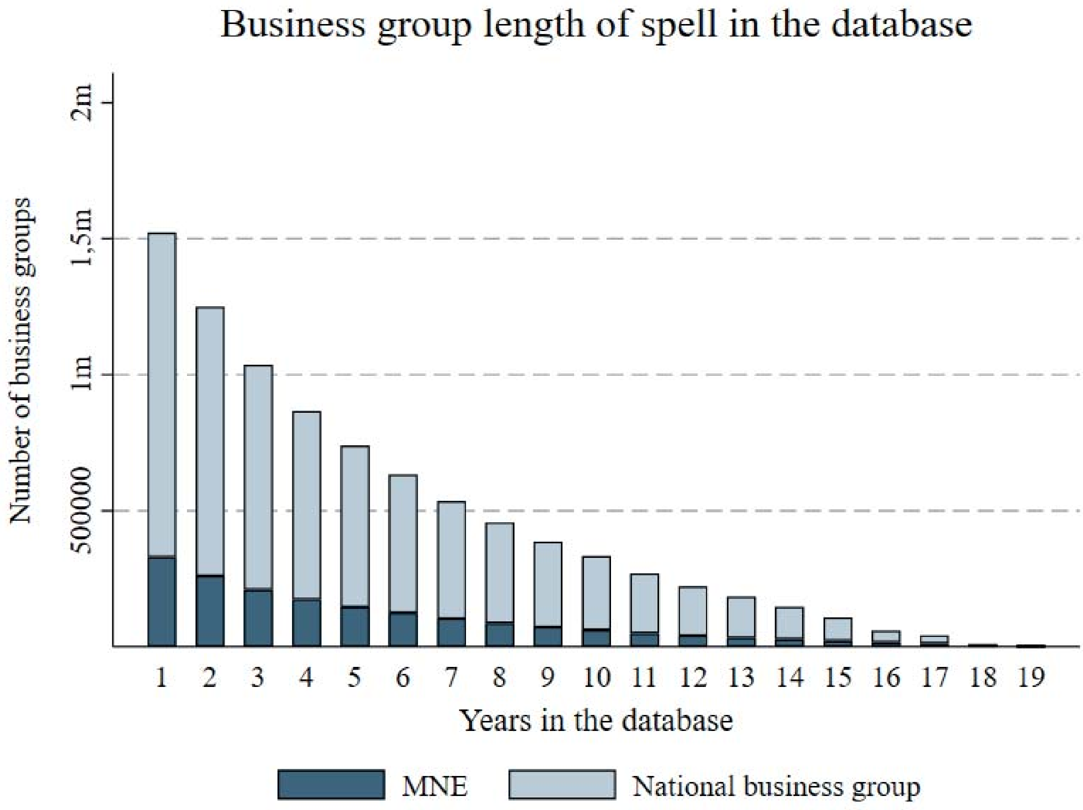

Figure 12: Length of spell of business groups in the database

On the following page, figure 13 illustrates the impact of the transformation from standard years to years in the database. The results are reported for all groups which can be

[39] Although this effectively overlays different periods, the alignment with the original time periods increases with length of spell. This means that any potential bias induced by this method only affects the early periods (the realigned years closest to the beginning of the expansion path), not the later ones. At the same time, the early periods overlay much more diverse data, reducing potential bias through the larger variety within the stacked group-year combinations. To put simply, the problem is either averaged out or not a problem anymore.

classified as MNE in at least one year, a total of 329392.[40] While the average group size in each year (left) is essentially flat, the average group grows considerably over each year of its existence (right), given that it survives and is not taken over by another group.[41] This means that even though the total number of multinational business groups has increased considerably, the average multinational today is about as large and multinational as it was over a decade ago. Given that the average hovers above five companies in a bit more than two countries, this image is considerably different from the vast corporate empires at the very right side of the size distribution.

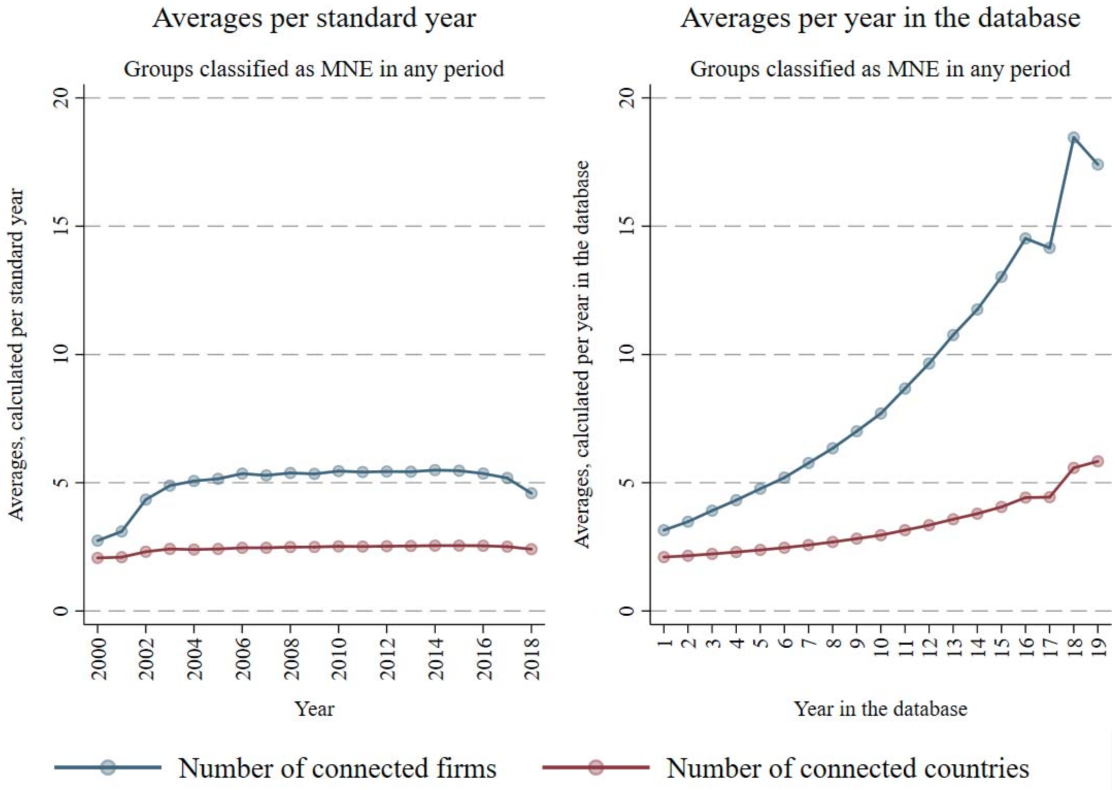

Figure 13: Average MNE size and country coverage for different data structures

Increasing size of an MNE naturally goes along with a much wider country coverage (figure 14 left), yet the vast majority of groups try to keep their hierarchies as simple

[40]About 11 percent of these groups' observations are from years in which they were not active in more than one country. Excluding these observations from the analysis reinforces the results, but does not change the overall visual impression.

[41]In the figure on the left, both the upward trend in the first years and the drop in 2018 are results of the database's construction. The wiggle of the curve in database years 17-19 is a side effect of the relatively small number of firms which report data in all years and should thus be taken with a grain of salt as well.

and flat as possible. Deep hierarchies are not excluded by the initial choice of the 50.01 percent majority ownership criterion, but extremely rare. Instead, business groups prefer to control their subsidiaries directly. Figure 14 (right) shows the average hierarchical depth depending on a business group's size. Although large groups tend to include long ownership chains much more frequently (not shown), the vast majority of firm connections in groups of any size is situated on the first three hierarchy levels. [42]

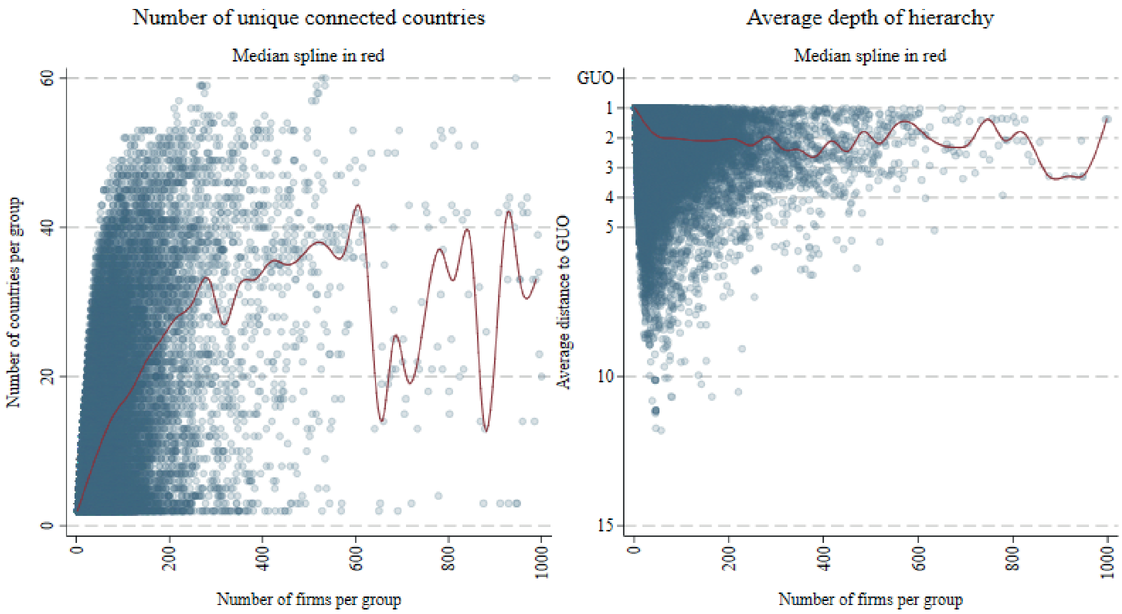

Figure 14: MNE pooled over all years, hierarchy and country coverage

This means that a reconstruction of an ownership network following Garcia-Bernardo et al. (2017) will capture the vast majority of links between firms and countries even if the data were to be limited to five degrees of separation only. A reduction to chunks of size three would still include a substantial portion of the dataset. The previously reported descriptive results also illustrate that any change in the network over time is more likely to be the result of the changing sample composition than a result of the change within individual groups over time.

[42]This result also motivated the decision to conduct the chain merges of shareholder information to rebuild the chains of control recursively up to twenty times. There were virtually no firms left in the database with longer paths of control.

5 Results

The reconstructed country-level network is described in detail in table 2 in appendix 8.3. In 2017, a total of 2.8m firms are controlled by 868463 GUOs through 1.931m ownership chains. These chains are then split into 2.708m chunks of size 2. After compression and cleaning for purely domestic connections, a selection of 551756 cleaned chunks remains. In 2017 the network is composed of 204 countries connected to each other over 5116 edges weighted by the number of firms connected across borders. At the same time, the network connects a total of 845654 firms through 161366 MNEs.

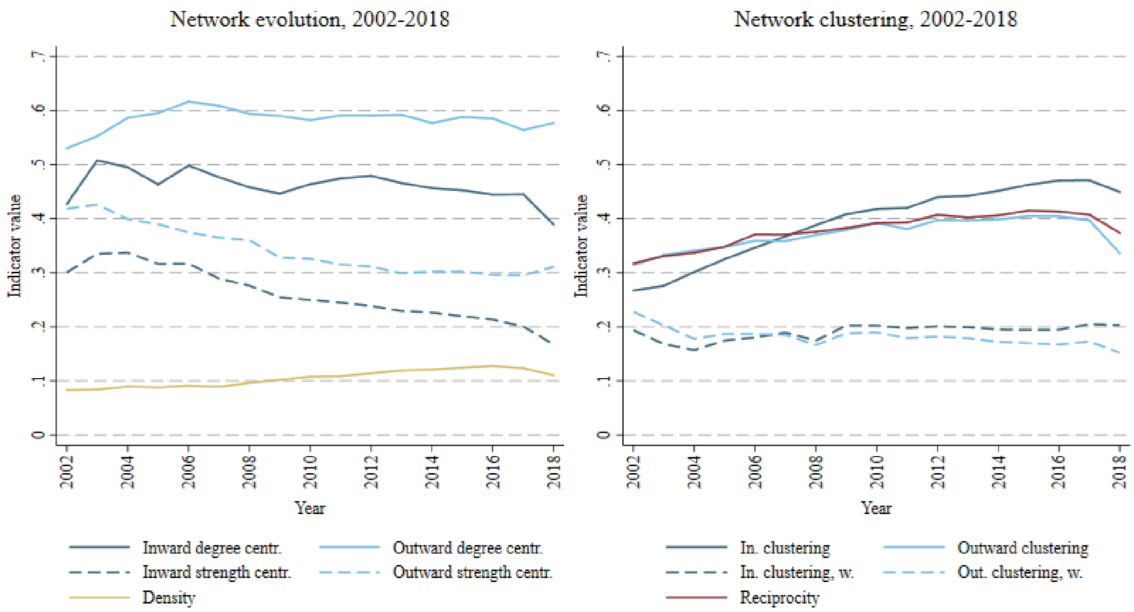

Figure 15: Network features over time

Since the business groups constituting the network change over time the network's structure also changes. Figure 15 (left) illustrates the network's density as well as degree and strength centralization over time.[43] Given the large number of ownership connections that constitute the foundation of this network, it is extremely sparse. This means that out of all the available connections the firms could have established, only a relatively small amount of routes across countries are actually used. Basically, the network is more akin to an electricity grid than a fisher's net. The density is slowly increasing over time, suggesting

[43]For further reference, Bonchev and Buck (2005) provide a compendium of quantitative measures of network complexity.

that new connections are added to the network.

The other four measures depicted in 15 (left) illustrate *where* these connections are added. Inward and outward degree centralization provide a measure for a network's internal inequality in terms of the nodes' connectedness. In this case a high value for inward degree centralization means that a small amount of countries have a lot of (unweighted) connections to other countries while a large amount of countries only have a few. Since inward strength centralization corresponds to the previous measure weighted by the number of firm connections between the countries it can be interpreted as the corporate network's tendency to accumulate lots of connections on the firm level in a small amount of countries.[44] Taken together this paints the picture of a network where the countries with the largest amounts of connections have remained relatively unchallenged while the firm connections between them are becoming more evenly distributed.

Figure 15 (right) illustrates how this changes the internal structure of the network. The clustering coefficients measure the countries' tendency to appear close to each other in the network, either inward (countries with a lot of controlling connections to other countries group together) or outward (countries which are controlled by many other countries group together).[45] Similar to their centralization counterparts, the weighted forms take the number of firm connections between countries into account. The result illustrates that countries of both previously outlined types are moving closer to each other over time, but the countries with a controlling influence do so at a faster rate. The more balanced addition of firm connections between them keeps the weighted clustering coefficients relatively stable over time. Finally, the network's reciprocity measure closely follows the outward clustering coefficient. This highlights that new connections are also added in the opposite direction of existing connections, making the network more reciprocal over time.

Aside from investigating these trends at the macro level, the network can also be dis-

[44]The respective outward measures flip this concept on its head. Outward degree centralization would be interpreted as the inequality in the distribution of the most foreign-controlled locations.

[45]Technically, countries are not controlling other countries but firms located within countries control other firms located within other countries. These connections are then aggregated at the country level. Only a weighted directed network allows for the investigation of all of these aspects.

sected into its most relevant components. At the very basic level, each country has incoming and outgoing connections in the form of domestic firms owning foreign firms and foreign firms owning domestic firms, respectively.

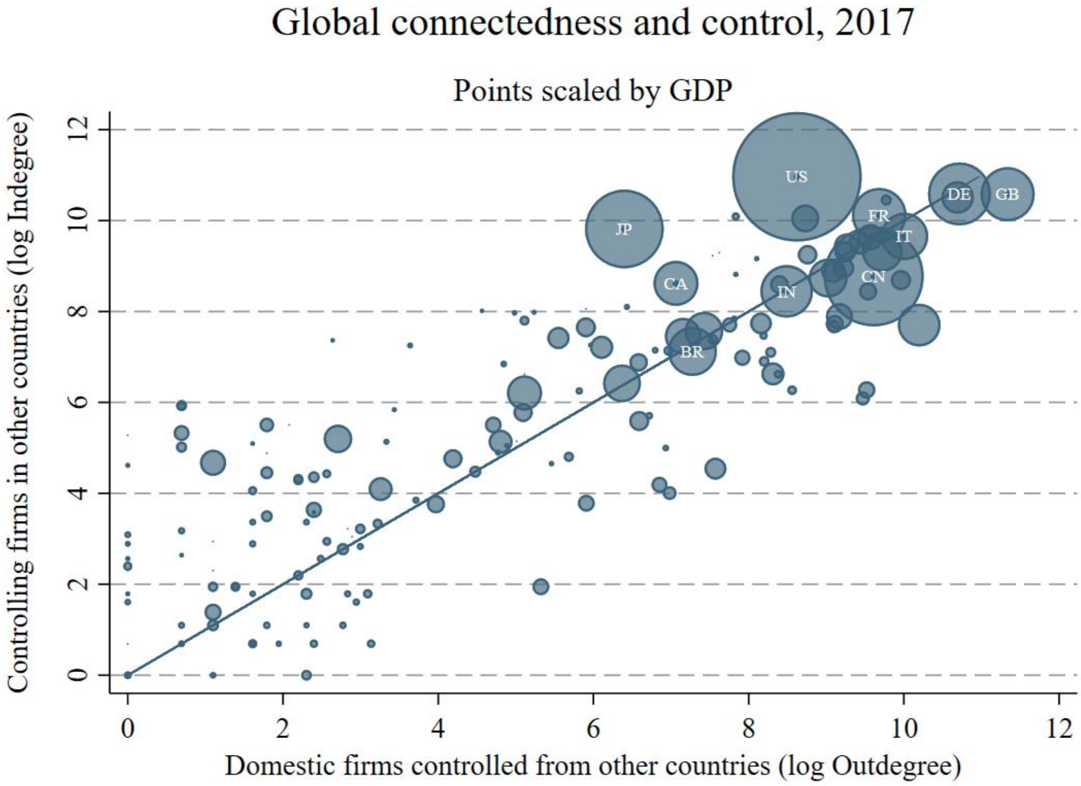

Figure 16: Outflow vs. Inflow of Control

Figure 16 illustrates the inflow and outflow of control in the global network in 2017. The points are scaled by each country's GDP, highlighting that the world's largest economies score high on both accounts. A noteworthy outlier is Japan, the only country that is large, externally dominant and internally closed at the same time. Although data for this representation is a cross section of 2017, the countries' development over time can be investigated. Over time the countries tend to move towards the upper right corner.[46] In line with the previously established MNE characteristics, more connected countries are also home to larger and older MNEs. However, each country's MNE profile can be investigated in more depth. With a slight twist of the data, figure 17 ranks the countries most relevant in the context of the global corporate network by their own MNEs' ownership profiles. To

[46]This trend can be nicely illustrated in the form of video where the countries' swarm movement is revealed, but unfortunately not printed in a static form without changing the dimensions of the representation.

do this, all firms globally owned by MNE with a GUO located within a specific country are counted. Next, the firms are split into domestic and foreign and their respective share is calculated. Finally, the difference between the foreign and the domestic share is reported. This means that, for example, Japanese MNE own almost 20 percentage points more foreign than domestic firms. Interestingly, some very small economies make it to the top of this list, which only includes the top 20 countries with the highest number of ownership connections.

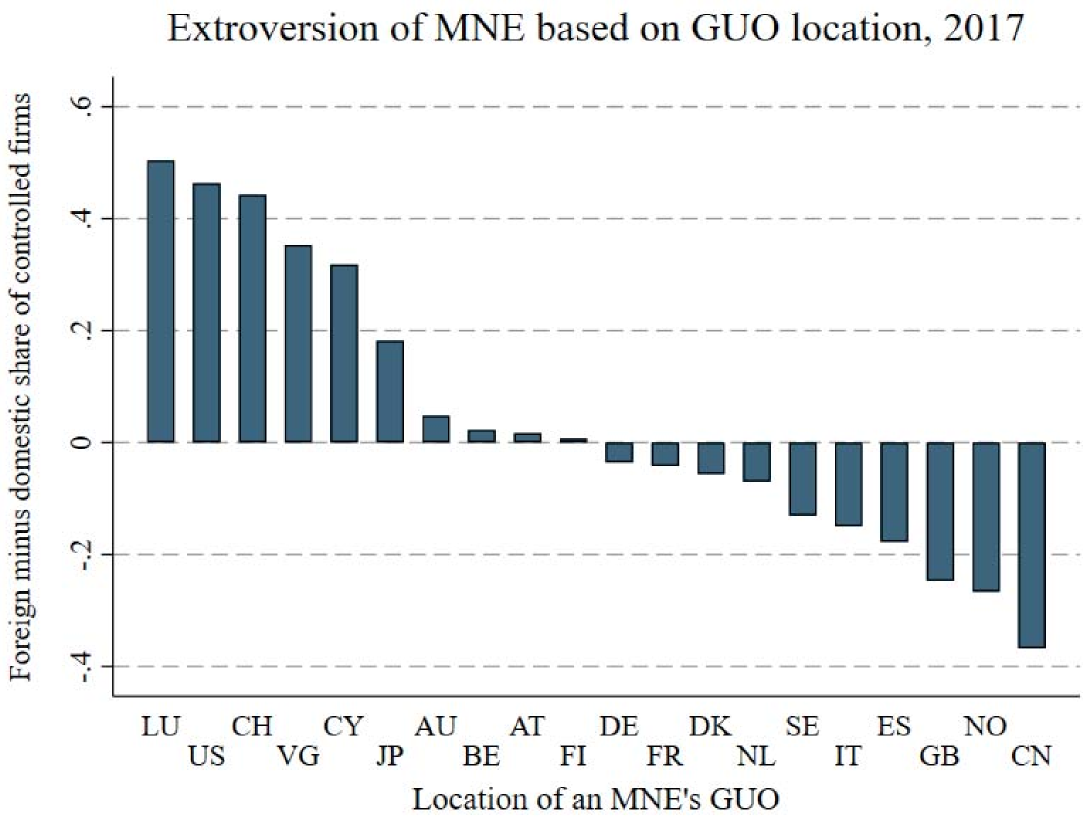

Figure 17: Extroversion of multinational business groups

The sensible next step in the analysis would be to investigate the firms' financial data to be able to attach a weight to the connections between the countries. As outlined in section 3.2, this is challenging. Even though Total Assets is one of the variables with the highest general availability, coverage varies greatly from country to country. In fact, a considerable number of GUOs do not report financial data. Figure 18 contrasts the number of firms controlled in other countries (essentially a measure of "how much we would really like to know what these countries are doing") with the availability of data for its GUOs.[47] This time the points are rescaled by the sum of a country's GUOs' Total Assets divided by the GDP of the country. The result emphasizes that a few tiny islands host a disproportionate amount of Assets even though the vast majority of the GUOs located there do not report any data. Any attempt to aggregate this financial data or use it to weigh ownership links is thus bound to underestimate the true relevance of these and other locations considerably. Given the nature of the issue it is not plausible to argue that missing data is missing at random.

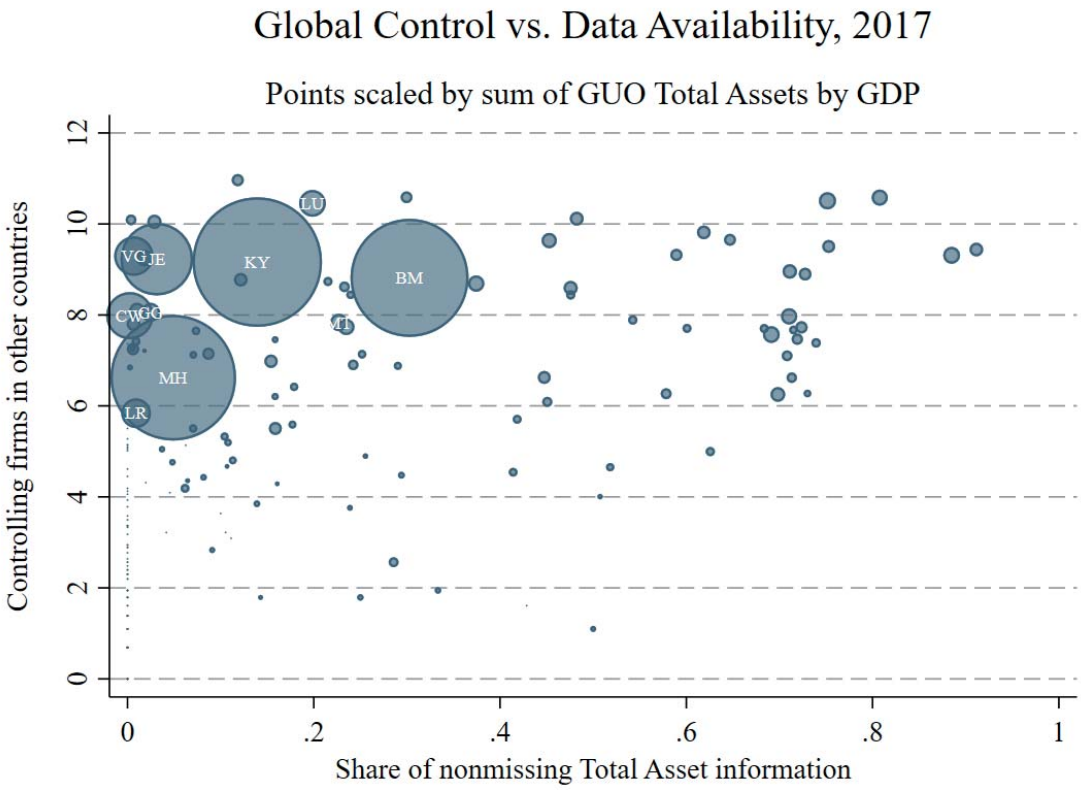

Figure 18: Data is missing where it counts the most

Following this logic, discarding the use of financial information at the firm level entirely can point towards locations which have been previously overlooked. Following Garcia-Bernardo et al. (2017) I apply a data driven method to identify the most frequent connections of different lengths within the ownership network. The resulting structures can have many purposes, but their suspiciously frequent appearance in the network could merit a closer look in the future. Table 4 and 5 in appendix 8.3 list the top 30 most frequently used

[47] All 1.491m GUOs were retrievable from ORBIS based on an uploaded list of identification numbers.

direct connections in the network from 2000-2018. The list allows for the identification and tracking of specific structures over time, which makes the approach useful for future work on the effectiveness of related regulation. Figure 19 illustrates the rise of the top five destinations. While the top spot is confidently taken by the combination of a US-American GUO controlling a British subsidiary, the combination of a Russian subsidiary owned by a GUO in Cyprus seems to have gained significant prominence since the global financial crisis of 2007-2008. Likewise, British subsidiaries controlled from Jersey have been on an upward trajectory. The last two spots in the top five are taken by connections involving the Netherlands, featuring either Germany as the location of the subsidiary of the US as the location of the GUO.

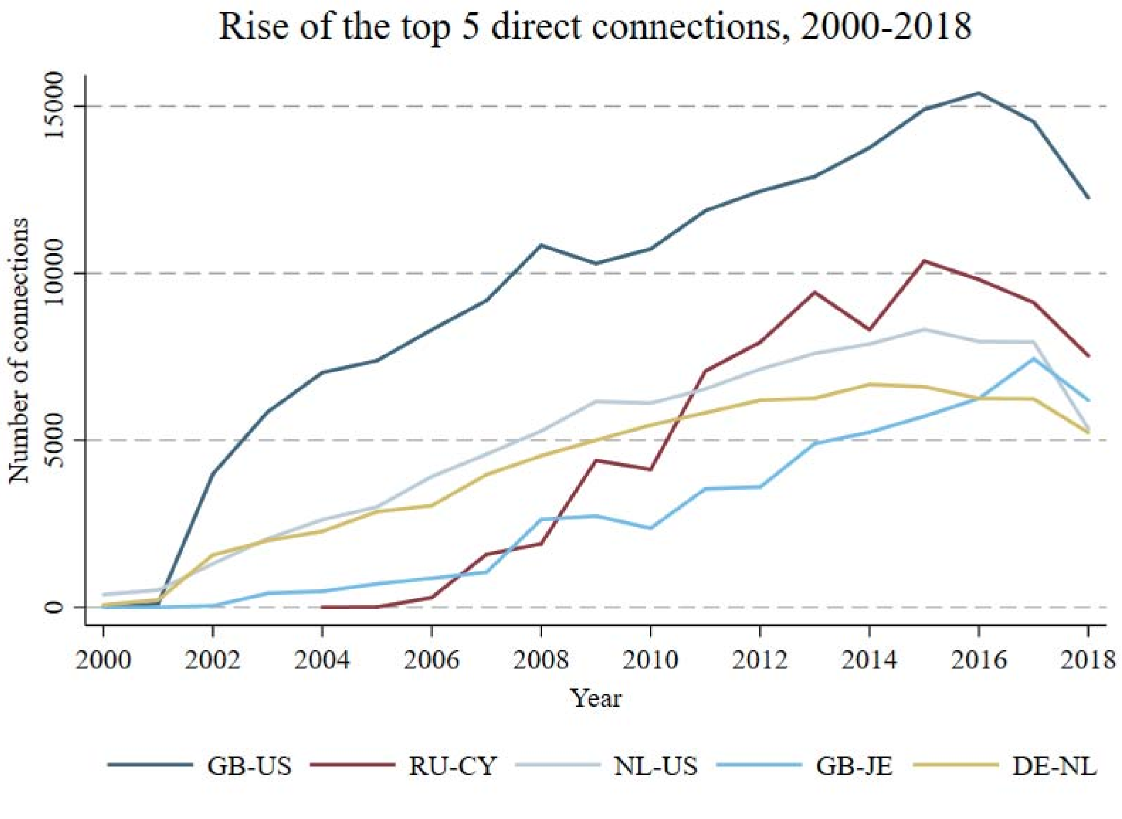

Figure 19: Development of the top 5 direct connections, 2000-2018

The results naturally get more complex when indirect connections are investigated. Table 6 and 7 in appendix 8.3 list the top 30 most frequently used indirect connections from 2000-2018. Once again the different types can be tracked over time and the comprehensive selection provides a foundation for further research. Figure 20 shows the rise of the top five indirect connections from 2000-2018. In addition to Garcia-Bernardo et al. (2017), Luxembourg appears prominently as a potential conduit location. Both the connections GB-LU-US as well as GB-NL-US seem to have been substantially impacted by the global financial crisis of 2007-2008. An interesting point is the appearance of a round-tripping structure in the form of GB-JE-GB among the top five most frequently used routes in the global network. The results indicate that the majority of ownership chains including a conduit country connect large economies.

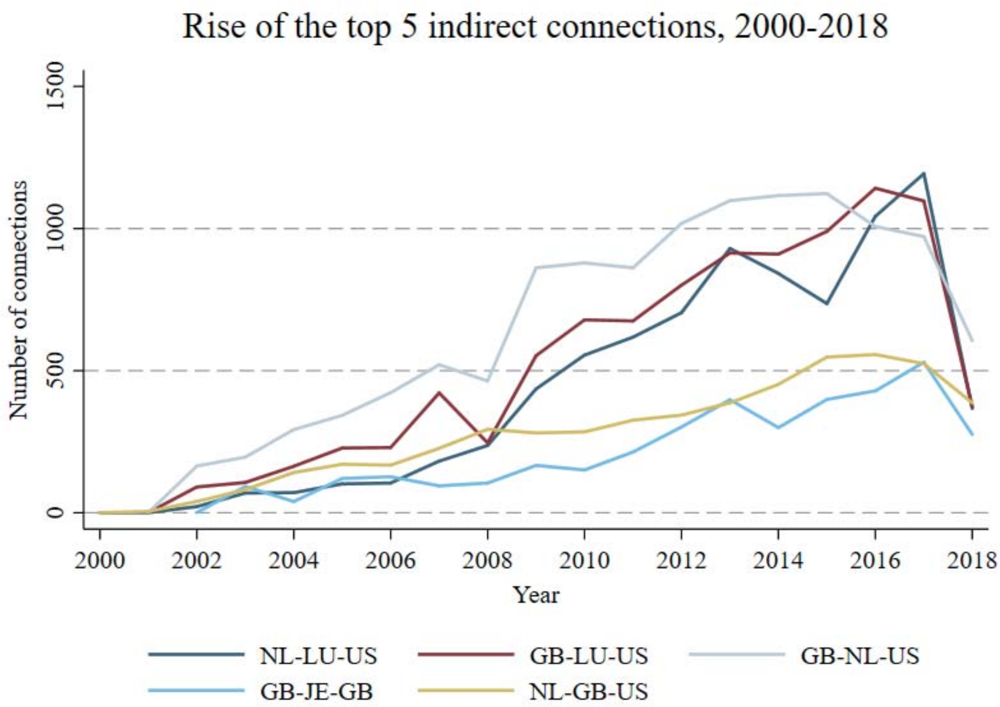

Figure 20: Development of the top 5 indirect connections, 2000-2018

Revisiting the insights from figure 18, potential sink OFCs can be identified even without weighting the individual ownership links. In fact, simply weighting the number of inward connections by the countries' GDP returns a selection of "control hubs", destinations which control a large amount of foreign firms given the size of their economy. Table 9 reports the top 30 destinations from 2010-2018. Out of the 24 sink OFCs identified by Garcia-Bernardo et al. (2017), 18 are identified within the top 24, including the top 15. Finally, instead of weighting the number of controlled firms by GDP to receive an identification of control hobs, weighting the aggregate Total Assets of a country's GUOs by GDP reveals an image of asset hubs. Figure 21 places the results for the top five side by side. While the British Virgin islands are unrivalled in terms of externally controlled firms, the asset

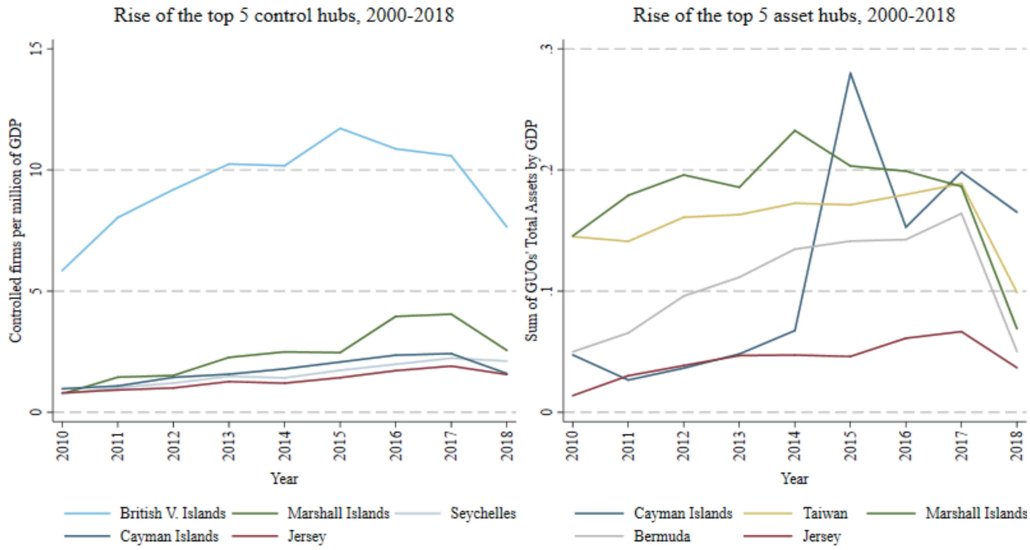

Figure 21: Development of control and asset hubs, 2010-2018

hub situation is more diverse.[48] Rising trends are visible for Bermuda and Taiwan only. The full ranking is once again fiven by table 9 and 8 in appendix 8.3.

6 Discussion

The results presented in the previous section illustrate the degree to which the global corporate ownership network is concentrated around a few main routes. The approach could be extended to cover chains of length four and more to study more specific patterns, but the backbone of the network is already identified. The change reflected in the network's metrics illustrates a macro-level trend towards more connectedness to the benefit of very few locations.

The results have to be discussed in the context of the chosen data preparation method. First of all, the criterion of 50.01 percent ownership reduces the full network to its most essential veins. This has both positive and negative side effects. On the plus side, reconstructing an ownership network in this way is relatively fast and leads to a clear separation of the business groups. At the same time a superior approach would be to use all available ownership connections and test if a weighting by ownership percentages along the

[48]The jump in the figure for the Cayman islands is not a data error. In one year firms simply report more information on Total Assets.

network's edges would not discard too much information. Likewise, the sample selected in this paper is fundamentally based upon a financial data quality criterion, which means that the unweighted results are still a subset of the true network. In the future this criterion could be left out entirely to recreate a full network panel of ORBIS, but this approach would require a substantial team effort. Yet in spite of these caveats, the structure of the network could be verified against the two benchmark studies of Alabrese and Casella (2019) and Joyez (2017) and performed generally well. The results provide deep insights into the network's structure and more importantly, its change over time.

7 Conclusion

This paper reconstructed the global corporate ownership network from 2000-2018 using Bureau van Dijk's ORBIS database. A new method to visualize business groups was introduced that recombines existing tools in Stata. National and multinational business groups were investigated in terms of their main characteristics and several core insights were obtained from the data. MNE are generally very small and not very international. In any given year the average MNE consists of around five companies covering a little more than two countries, much in contrast to the general image of the large conglomerate. Generally, MNE keep their hierarchies flat and simple. Over time, the global network has become more dense and even though the most central countries have not changed their position their firm-level connections are becoming more diversified over time. The clustering of the network has increased as well. Based on a purely data driven approach, the most frequently used direct and indirect connections were identified. Finally, an alternative selection of control and asset hubs was constructed from the network. With the introduction of the ownership map, researchers and policy makers have a new tool at hand to visualize complex corporate structures in an easily understandable way. In a time where stories call for images to get attention, intuitively understandable representations can help to inform the discussion on all sides. The results also open up new avenues for targeted research. In particular, the network's most frequently utilized structures call for individual attention. Tracing the groups' structural adjustments could furthermore help to identify previously shrouded behavior in response to regulation and help to prevent evasive movements.

References

Alabrese, E. and B. Casella (2019). The Blurring of Corporate Investor Nationality and Complex Ownership Structures. *Available at SSRN 3372329*.

Altomonte, C. and A. Rungi (2013). Business Groups as Hierarchies of Firms: Determinants of Vertical Integration and Performance. *ECB Working Paper No. 1554*.

Aminadav, G. and E. Papaioannou (2016). *Corporate Control Around the World*. SSRN Scholarly Paper ID 2892434. Rochester, NY: Social Science Research Network.

aus dem Moore, N., P. Großkurth, and M. Themann (2019). Multinational Corporations and the EU Emissions Trading System: The Specter of Asset Erosion and Creeping Deindustrialization. *Journal of Environmental Economics and Management* 94, 1–26.

Bonchev, D. and G. A. Buck (2005). Quantitative Measures of Network Complexity. In: *Complexity in Chemistry, Biology, and Ecology*. Springer, 191–235.

De Lombaerde, P., L. Iapadre, A. Mccranie, and L. Tajoli (2018). Using Network Analysis to Study Globalization, Regionalization, and Multi-Polarity—Introduction to Special Section. *Network Science* 6 (4), 494–516.

De Masi, G. and G. Ricchiuti (2018). The Network of European Outward Foreign Direct Investments. *Networks of International Trade and Investment: Understanding globalisation through the lens of network analysis*, 205.

Fracasso, A., H. T. Nguyen, and S. Schiavo (2018). The evolution of oil trade: A complex network approach. *Network Science* 6 (4). bibtex*[publisher=Cambridge University Press], 545–570.

Freeman, L. C. (1977). A Set of Measures of Centrality Based on Betweenness. *Sociometry*, 35–41.

Fuest, C. et al. (2013). Profit Shifting and'aggressive'tax Planning by Multinational Firms: Issues and Options for Reform. *ZEW-Centre for European Economic Research Discussion Paper* (13-078).

Garcia-Bernardo, J., J. Fichtner, F. W. Takes, and E. M. Heemskerk (2017). Uncovering Offshore Financial Centers: Conduits and Sinks in the Global Corporate Ownership Network. *Scientific Reports* 7 (1).

Großkurth, P. (2019). Dynamic Structure - Dynamic Results? Re-Estimating Profit Shifting with Historical Ownership Data. Ruhr Economic Papers.

Grund, T. (2019). *Tutorials and Slides — Network Analysis Using Stata.* https://nwcommands.wordpress.com/tutorials-and-slides/.

Grund, T. et al. (2015). Social Network Analysis Using Stata. In: *United Kingdom Stata Users' Group Meetings 2015.* 21. Stata Users Group.

Hussain, O. A., F. Zaidi, and C. Rozenblat (2018). Analyzing Diversity, Strength and Centrality of Cities Using Networks of Multinational Firms. *Networks and Spatial Economics*, 1–27.

Jaraite, J. et al. (2013). *Matching EU ETS Accounts to Historical Parent Companies. A Technical Note.* SSRN Scholarly Paper ID 2384537. Rochester, NY: Social Science Research Network.

Joyez, C. (2017). On the Topological Structure of Multinationals Network. *Physica A: Statistical Mechanics and its Applications* 473, 578–588.

– (2019). *Alignment of Multinational Firms along Global Value Chains: A Network-based Perspective.* Tech. rep. Groupe de REcherche en Droit, Economie, Gestion (GREDEG CNRS), Université Nice Sophia Antipolis.

Kalemli-Ozcan, S. et al. (2015). *How to Construct Nationally Representative Firm Level Data from the ORBIS Global Database.* SSRN Scholarly Paper ID 2663407. Rochester, NY: Social Science Research Network.

Levine, J. H. (1972). The Sphere of Influence. *American Sociological Review* 37 (1), 14–27.

Luo, J., D. E. Whitney, C. Y. Baldwin, and C. L. Magee (2009). *Measuring and Understanding Hierarchy as an Architectural Element in Industry Sectors.* Harvard Business School.

Mariotte, H. (2017). *LIFI: The French Groups Register.* Insee (French national statistical institute).

Mintz, J. (2004). Conduit Entities: Implications of Indirect Tax-Efficient Financing Structures for Real Investment. *International Tax and Public Finance* 11 (4), 419–434.

OECD (2013). *Action Plan on Base Erosion and Profit Shifting.* OECD.

Pisati, M. (2018). SPMAP: Stata Module to Visualize Spatial Data.

Pumain, D. and C. Rozenblat (1991). Multinational Firms and the Restructuring of the European Urban System. In: *38th North American Meeting of the Regional Science Association*.

Reynaud, A (1977). La Localisation Des Sièges Sociaux En Europe Occidentale. In: *Annales de Géographie*.

Rozenblat, C. and D. Pumain (1993). The Location of Multinational Firms in the European Urban System. *Urban Studies* 30 (10), 1691–1709.

Rozenblat, C., F. Zaidi, and A. Bellwald (2017). The Multipolar Regionalization of Cities in Multinational Firms' Networks. *Global Networks* 17 (2), 171–194.

Scott, J. (1988). Social Network Analysis. *Sociology* 22 (1), 109–127.

Vitali, S. and S. Battiston (2014). The Community Structure of the Global Corporate Network. *PLoS ONE* 9 (8). Ed. by R. Lambiotte, e104655.

Vitali, S., J. B. Glattfelder, and S. Battiston (2011). The Network of Global Corporate Control. *PLoS ONE* 6 (10). Ed. by A. R. H. Montoya, e25995.

Weichenrieder, A. J., J. Mintz, et al. (2008). What Determines the Use of Holding Companies and Ownership Chains. *Centre for Business Taxation Working Paper WP08/03. Oxford University, Oxford, UK.*

Weyzig, F. (2013). Tax Treaty Shopping: Structural Determinants of Foreign Direct Investment Routed through the Netherlands. *International Tax and Public Finance* 20 (6), 910–937.

Zeigermann, L. (2016). Opencagegeo: Stata Module for Forward and Reverse Geocoding.

8 Appendix

8.1 Visualization in Stata

All visualizations of MNE in this paper are constructed with Maurizio Pisati's seminal Stata module *spmap*. Originally launched in 2007, the module has since been refined and updated constantly (Pisati, 2018). The module is able to draw polygons of essentially infinite complexity by connecting a sorted list of dots with straight lines (to draw maps, for example) as well as a variety of simpler shapes. The key to using the module for an accurate representation of the complex shapes of MNE is to rearrange the original data into a structure that *spmap* can interpret and print.

The next subsection 8.1.1 illustrates the data structure before and after the reshaping process. Figure 22 contains the lines of control after they have been assembled as a combination of ownership and location data. Each row represents one line of control and each firm's bvdid (variables ID-0, ID-1, etc.)is accompanied by the respective latitude (Y-0, Y-1, etc.) and longitude (X-0, X-1, etc.). By manually inserting empty columns to the right and to the left, the data can then be directly reshaped into a long format for printing. The Stata code of this process is detailed in section 8.1.2. Figure 23 illustrates the final result. Each block is separated from the next by a row of missing values in all three variables. This row of missings indicates to spmap that the next row is the first point of a new object to be drawn. Consequently, the first block can be interpreted as a line object from point B (subsidiary) through point C (intermediary) to point D (GUO). The superimposition of these lines then creates the correct network structures on the map. The same file can then be enriched with additional data for each firm, in this case the hierarchy level and a point's custom weight (the number of controlled firms). The points are then printed on top of the lines and rescaled proportionally with the custom weight. The same procedure is applied to financial data and can be used to represent anything that can be merged at the firm level. The duplication of the points and lines is unproblematic, because their superimposition does not alter the final shape.[49]

[49]In some cases it can be an advantage to change the blockwise sorting of the data to make sure larger points do not hide smaller points. For larger groups it becomes sensible to aggregate the data to a regional level, but printing could then be done in the same way.

8.1.1 Reshaping for smpap: Illustration

link	ID-0	Y-0	X-0	ID-1	Y-1	X-1	ID-2	Y-2	X-2	ID-3	Y-3	X-3
1	B	13.23	35.1	C	14.7	30.7	D	8.1	21.6	·	·	·
2	C	14.7	30.7	D	8.1	21.6	·	·	·	·	·	·
3	A	10.4	15.4	B	13.23	35.1	C	14.7	30.7	D	8.1	21.6

Figure 22: Lines of control, before reshaping

link	ID	Y	X
1	·	·	·
1	B	12.23	35.1
1	C	14.7	30.7
1	D	8.1	21.6
2	·	·	·
2	C	14.7	30.7
2	D	8.1	21.6
3	·	·	·
3	A	10.4	15.4
3	B	13.23	35.1
3	C	14.7	30.7
3	D	8.1	21.6

Inserting blank rows between each link block allows spmap to interpret the data as lines.

Figure 23: Lines of control, after reshaping

8.1.2 Reshaping for spmap: Stata code

```
*** Loading and cleaning
use "firm coordinates", clear
keep ID

* Merging with links of firms to guos
fmerge 1:1 ID using "link selection", keep(3) nogenerate
* Note: firms which could not be geocoded are lost on the first level

* Dropping fully empty variables
dropmiss, force trim piasm
* Reason: the full link file might include remnants of longer links

*** Adding geodata to each linked firm
local counter = 1
gen byte flag = 0

* Finding the highest number of ID after pruning
qui des
local varnum = r(k)-1
local plusone = r(k)

foreach var of varlist ID-ID`varnum' {
        rename `var' ID

        * Add coordinates to links
        fmerge m:1 ID using "firm coordinates", keep(1 3)

        * Identify interrupted links
        replace flag = 1 if bvdid != "" & _merge == 1
        drop _merge
        rename Y Y`counter'
        rename X X`counter'
        rename ID ID`counter'

        local counter = `counter'+1
}
```

```
* Deleting links where a firm couldn't be geocoded
drop if flag == 1
drop flag

* Deleting guos (singular points)
drop if ID2 == ""

*** Adding blank rows before and after each link block
gen str ID0 = ""
gen double Y0 = .
gen double X0 = .

gen str ID`plusone' = ""
gen double Y`plusone' = .
gen double X`plusone' = .

*** Reshaping into long format
gen link = _n
sreshape long ID X Y, i(link) j(level)

*** Cleaning out unused blank rows
xtset id number

gen double oneforward = f.Y
gen double marker = Y
replace marker = oneforward if oneforward != .
keep if marker != .
drop oneforward marker

*** Saving
compress
save "lines of control", replace
```

8.2 Network integrity verification

The evolution of the aggregated network is a result of changes in its components and its composition. If the data reconstruction is accurate, any subsection of the network should compare favorably to previous research on corporate ownership structures. To verify the integrity of the network, two subsets of it are compared to previous results in the literature. First, a cross section of the network in 2015 is used to identify special ownership structures as classified by Alabrese and Casella (2019). Second, the subnetwork of French multinationals is investigated using Joyez (2017)'s reconstruction of the ownership network based on French microdata as a benchmark.

Alabrese and Casella (2019) use ORBIS data from November 2015 to identify four special ownership structures based on the location of the controlled firm, the location of its first top shareholder, and the location of its GUO. Cases where both the top shareholder and the GUO are located in the same foreign country are classified as *plain foreign*. If both the top shareholder and the GUO are each located in different countries than the firm itself, the construction is identified as a *conduit structure*. If both the GUO and the firm are in the same country but the top shareholder is in a different one this is labelled as *round tripping*. If both the top shareholder and the firm are in the same country, but the GUO is in another one, the structure is identified as a *domestic hub*. Alabrese and Casella (2019) provide an in-depth discussion of each structure's special characteristics.

Table 1 undertakes both an absolute and a relative comparison of the results. Since Alabrese and Casella (2019) apply no financial data quality criterion before extracting

Comparison to Alabrese and Casella (2019)

	Total			Share		
Type	A. & C.	Network '15	Diff.	A. & C.	Network '15	Diff.
Plain Foreign	426427	286238	140189	59.0	66.2	-7.2
Conduit Structure	78722	47362	31360	10.9	11.0	-0.1
Round-Tripping	7903	3674	4229	1.1	0.9	0.2
Domestic Hub	209229	95117	114112	29.0	22.0	7.0

Table 1: Verifying the composition of the network, 2015 ownership data

the ownership data as a cross section in 2015, their sample for this time period is much larger.[50] However, the composition itself is relatively close across all categories. The remaining differences are plausible if direct foreign subsidiaries are more likely to report financial data than direct national subsidiaries, but could also point towards changes in the composition of the database since 2015. Most importantly, however, the share of identified conduit structures is nearly identical.

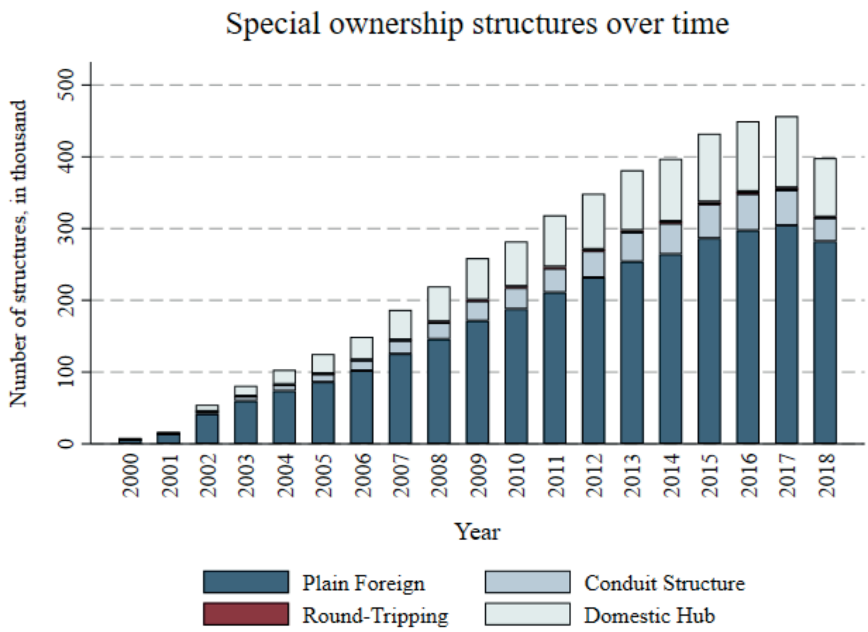

Figure 24: Special ownership structures within MNE

Figure 24 highlights the emergence and prevalence of the different types of special ownership structures within MNE over time. Round tripping under this definition is negligible and conduit structures are found to be relatively rare as well. The vast majority of all structures can be identified as *plain foreign*.[51] Although the total number of identified firms is consistently lower, so are the identified numbers of each type of structure. In fact, the shares have stabilized (see figure 25) since 2008. In each year, the number of newly added structures seems to be split into about 66 percent plain foreign, 22 percent domestic hubs, 10 percent conduit structures, and 2 percent round tripping. Once again

[50] Although the data was said to have been extracted in November 2015 it is no clear whether this refers to all data of 2015 or all data as of 2015. This subtle difference, as discussed previously, can have a significant impact on both sample size and GUO identification results.

[51] As in Alabrese and Casella (2019), about 78 percent of these are cases in which the GUO and the top shareholder are identical.

the results for the early years of the dataset as well as for 2018 should be taken with a grain of salt. The overall impression suggests differences in absolute magnitude to be the result of different sample selection choices and reinforces the conclusions of Alabrese and Casella (2019) as well as the network reconstruction in this paper.

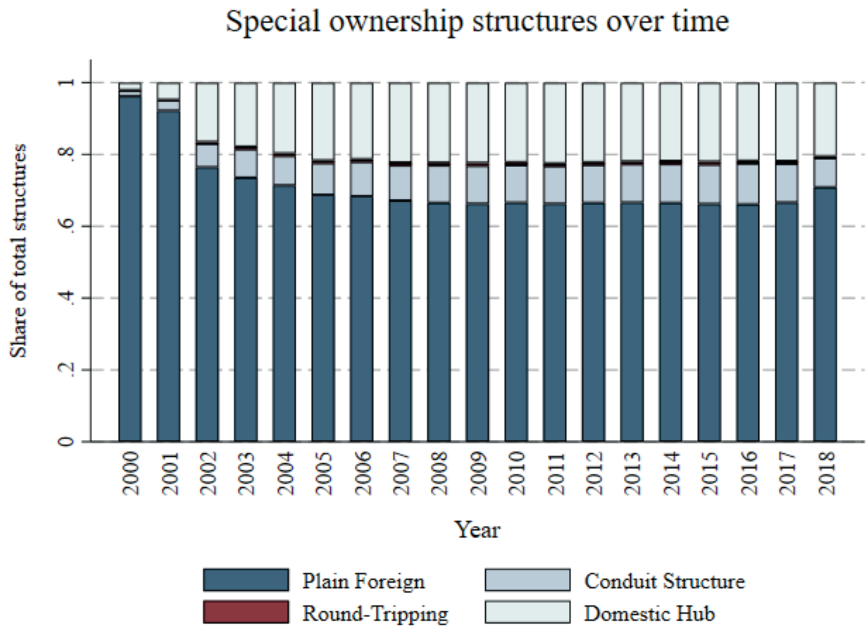

Figure 25: Special ownership structures within MNE, shares

Since the reconstruction of a network involves a series of important choices, having a benchmark to compare the structure to is helpful to both assess the integrity of the data and to support the interpretation of the results. Out of the entire network, the subset of firms owned by GUOs located in France is extracted. Similar to Joyez (2017), the network's development is then assessed over time. Table 3 in appendix 8.3 reports a selection of network metrics overlapping with the selection in Joyez (2017). Several striking differences need to be discussed. First, while the number of MNEs as well as the number of affiliates is larger in this paper, the number of nodes and edges is considerably smaller. Aside from potential differences between the data sources, this is explained by a fundamental difference in the chosen network construction method. The benchmark network in Joyez (2017) was reconstructed by removing France from the data and then connecting all remaining French foreign affiliates within their respective business groups.

In contrast, the network in this paper maps ownership structures as they appear in the data, placing no assumptions on the potential connectivity of firms within the same group. The result is a network in which, unsurprisingly, all roads lead to Paris. The network is sparse and highly inward centralized, which does not change over time. The extreme shape also makes it more difficult to interpret the results. However, in line with Joyez (2017) I find growing numbers of firms, groups, nodes, edges, and disparity. I also find a falling trend in the network's outward strength centralization measure. This means that French multinationals are diversifying the countries in which they control affiliates. However, in my reconstruction there is a clear falling trend for the weighted outward clustering coefficient, indicating that investments are targeted towards previously underappreciated locations. At the same time, unweighted inward clustering increased alongside reciprocity. This means that connectivity between intermediate firms close to the top of the corporate hierarchies is increasing. In sum, even though both approaches use different data sources and network reconstruction methods they confirm the same tendencies within the French multinational network.

Both reproductions provide reference points for the results obtained in this paper. The reconstructed global ownership network can successfully be transformed to investigate individual periods as well as entire subnetworks. Furthermore, reinforcing evidence was provided for the reproduced benchmark studies.

8.3 Network tables

Network characteristics of multinational business groups, 2000-2018

	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
All groups	8307	30307	93916	129982	220235	268974	317730	372419	427905	499330	528563	586693	627792	679861	697690	748084	824869	868463	875145
All chains	13198	53982	199855	289355	460027	565478	675253	803943	937033	1.091m	1.175m	1.311m	1.418m	1.542m	1.599m	1.723m	1.863m	1.931m	1.820m
All firms	21505	84289	293771	419337	680262	834452	992983	1.176m	1.365m	1.591m	1.703m	1.898m	2.046m	2.222m	2.296m	2.471m	2.688m	2.800m	2.696m
Chunks (raw)	13944	61150	262204	393344	613600	772265	926277	1.127m	1.314m	1.540m	1.663m	1.868m	2.027m	2.202m	2.288m	2.459m	2.635m	2.708m	2.409m
MNE	4421	9644	22605	28671	34854	41632	47667	61521	71021	85390	91632	104799	115323	127297	131733	143462	153392	161366	161151
MNE chains	7781	20176	79372	120213	155009	188958	226934	281689	330143	389963	427359	481077	527862	576599	605604	652968	679374	684288	581191
Firms in MNE	12202	29820	101977	148884	189863	230590	274601	343210	401164	475353	518991	585876	643185	703896	737337	796430	832766	845654	742342
Chunks (clean)	6441	15923	60159	92320	117753	144834	174737	220245	261164	311200	338459	383032	420295	461352	481047	525122	547816	551756	451991
Nodes	95	117	147	159	166	176	180	191	193	197	196	199	199	200	201	201	201	204	204
Edges	598	1061	1783	2108	2456	2708	2934	3229	3573	3931	4123	4290	4496	4753	4858	5011	5133	5116	4574
Density	0.067	0.078	0.083	0.084	0.090	0.088	0.091	0.089	0.096	0.102	0.108	0.109	0.114	0.119	0.121	0.125	0.128	0.124	0.110
Reciprocity	0.259	0.283	0.318	0.331	0.337	0.348	0.371	0.371	0.376	0.383	0.392	0.393	0.407	0.402	0.406	0.415	0.413	0.407	0.374
Disparity (in)	0.531	0.420	0.398	0.415	0.412	0.405	0.409	0.446	0.432	0.419	0.411	0.389	0.371	0.360	0.347	0.363	0.362	0.352	0.372
Disparity (out)	4551	121.4	22.61	16.88	13.08	14.68	16.38	105.4	39.58	66.28	112.5	460.7	367.2	300.1	130.6	244.4	106.5	299.4	1012
Deg. cent. (in)	0.427	0.373	0.427	0.508	0.495	0.463	0.498	0.477	0.458	0.446	0.464	0.474	0.479	0.466	0.456	0.453	0.445	0.445	0.389
Deg. cent. (out)	0.631	0.504	0.530	0.552	0.587	0.595	0.616	0.609	0.594	0.590	0.582	0.591	0.591	0.592	0.577	0.588	0.585	0.564	0.577
Str. cent. (in)	0.204	0.237	0.301	0.335	0.337	0.316	0.317	0.289	0.276	0.255	0.250	0.245	0.239	0.229	0.226	0.220	0.213	0.201	0.167
Str. cent. (out)	1.042	0.537	0.419	0.426	0.399	0.390	0.375	0.365	0.360	0.328	0.326	0.315	0.312	0.299	0.302	0.302	0.296	0.295	0.311
Cluster. (in)	0.203	0.252	0.267	0.276	0.301	0.325	0.346	0.367	0.388	0.408	0.418	0.420	0.440	0.442	0.451	0.463	0.471	0.471	0.449
Cluster. (out)	0.264	0.283	0.314	0.333	0.341	0.347	0.359	0.359	0.370	0.379	0.392	0.381	0.397	0.397	0.399	0.405	0.405	0.397	0.336
W. Clust. (in)*	0.299	0.431	0.194	0.168	0.157	0.175	0.180	0.190	0.174	0.202	0.202	0.198	0.201	0.199	0.195	0.194	0.195	0.205	0.203
W. Clust. (out)*	0.389	0.483	0.228	0.203	0.178	0.187	0.187	0.185	0.166	0.188	0.190	0.179	0.182	0.179	0.172	0.170	0.167	0.173	0.152

Ownership chains were split in chunks of size 2, then cleaned for purely national chunks. All network analysis undertaken in this paper made use of Thomas Grund's fundamental *nwcommands* package for Stata. Definitions of the network measures are given by Grund (2015) and the supporting documentation of the package provided by Grund (2019). Nodes refer to individual countries, to which level the data was subsequently aggregated. Edges refer to individual unweighted direct connections between countries. Density is defined as the proportion of actually observed ties among the potentially observable ones. Reciprocity is defined as the proportion of actually reciprocated ties among the potentially reciprocable ones. Nodes, arcs, density, and reciprocity were calculated by Thomas Grund's *nwsummarize*. Inward and outward disparity measure the distribution of a node's strength over its various edges (a high value meaning that a few edges a responsible for the majority of a node's strength) and were calculated by using Charlie Joyez's *nwdisparity*. Inward and outward degree centralization were calculated using Thomas Grund's *nwdegree*. Inward and outward strength centralization were calculated with Charlie Joyez's *nwStrengthcent*. In all four cases a higher value indicates a more centralized network. Weighted and unweighted clustering coefficients were calculated by using Charlie Joyez's *nwcluster*. The coefficients for weighted inward and outward clustering (*) were multiplied by 100 for visual purposes only. A higher value indicates that nodes are more likely to arrange themselves in connected structures within the network.

Table 2: The corporate network (majority-owned ties) over time

French business groups only, 2000-2018

	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
All groups	304	864	2120	5063	6242	8034	11586	19571	21360	23428	25617	27741	29279	28125	22833	18435	18436	16984	14556
All chains	686	2224	9126	16683	20492	24986	34133	52618	57758	64184	70044	76940	82268	82367	75737	70434	70841	65666	50331
All firms	990	3088	11246	21746	26734	33020	45719	72189	79118	87612	95661	104681	111547	110492	98570	88869	89277	82650	64887
Chunks (raw)	723	2467	12667	24135	30337	37318	50227	78417	86709	96121	105886	118431	127749	131606	124663	121209	120797	111310	81860
MNE	190	561	1206	1429	1640	1889	2088	2434	2686	3080	3278	3584	3951	4164	4359	4577	4938	5158	5235
MNE chains	501	1543	7615	11001	13550	15376	18805	23665	26113	29220	31189	34319	36813	39131	40427	41176	41759	40754	31885
Firms in MNE	691	2104	8821	12430	15190	17265	20893	26099	28799	32300	34467	37903	40764	43295	44786	45753	46697	45912	37120
Chunks (clean)	368	1073	5177	7194	9167	10393	12192	14746	16126	18277	19332	21359	22588	24622	25031	25341	25738	25497	21106
Nodes	37	49	75	80	81	86	89	92	95	95	98	97	98	97	99	93	94	94	83
Edges	41	61	203	247	278	354	380	432	448	499	488	535	548	574	580	598	626	595	455
Density	0.031	0.026	0.0366	0.040	0.043	0.048	0.049	0.052	0.050	0.056	0.051	0.058	0.058	0.062	0.060	0.070	0.072	0.068	0.070
Reciprocity	0.051	0.034	0.134	0.144	0.154	0.161	0.159	0.180	0.158	0.182	0.173	0.176	0.184	0.179	0.186	0.194	0.195	0.185	0.204
Disparity (in)	0.139	0.088	0.187	0.204	0.177	0.192	0.198	0.247	0.270	0.312	0.324	0.315	0.315	0.366	0.408	0.369	0.353	0.315	0.273
Disparity (out)	54.80	545.5	36.97	5.983	4.834	7.479	6.016	2.795	3.834	3.854	4.131	2.547	2.553	0.775	0.714	1.139	2.997	3.406	5.421
Deg. cent. (in)	0.996	0.994	0.963	0.947	0.956	0.915	0.905	0.925	0.928	0.922	0.927	0.910	0.900	0.938	0.919	0.896	0.906	0.920	0.907
Deg. cent. (out)	0.026	0.037	0.155	0.166	0.134	0.141	0.146	0.181	0.154	0.180	0.177	0.195	0.160	0.180	0.197	0.193	0.221	0.170	0.155
Str. cent. (in)	1.977	1.966	1.849	1.805	1.792	1.773	1.764	1.727	1.751	1.740	1.749	1.726	1.718	1.695	1.704	1.713	1.721	1.730	1.787
Str. cent. (out)	0.596	0.341	0.377	0.430	0.397	0.382	0.374	0.374	0.339	0.321	0.316	0.304	0.303	0.271	0.280	0.273	0.280	0.286	0.282
Cluster (in)	0.002	0.001	0.039	0.039	0.046	0.049	0.054	0.068	0.062	0.074	0.067	0.067	0.067	0.074	0.081	0.089	0.091	0.094	0.098
Cluster (out)	0.375	0.107	0.304	0.272	0.308	0.291	0.287	0.312	0.279	0.300	0.277	0.239	0.248	0.264	0.274	0.285	0.275	0.287	0.370
W. Clust. (in)*	0.013	0.009	0.030	0.036	0.036	0.036	0.038	0.046	0.040	0.044	0.042	0.043	0.042	0.041	0.046	0.047	0.043	0.045	0.047
W. Clust. (out)*	1.998	0.684	0.235	0.250	0.240	0.218	0.202	0.209	0.180	0.180	0.173	0.152	0.156	0.148	0.155	0.151	0.131	0.139	0.178

All metrics are calculated identically to table 2. Feedback and guidance in the process reproducing the the French network from ORBIS data was provided by Charlie Joyez and is gratefully acknowledged. The values for several measures describe a network that is both extremely sparse and extremely inward centralized. Basically, all roads lead to Paris. Future research could investigate whether national networks of other countries follow the same pattern.

Table 3: The French corporate network (majority-owned ties) over time

Most frequent direct connections, 2000-2009

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1	NL-CW (656)	NL-CW (751)	GB-US (3992)	GB-US (5849)	GB-US (7027)	GB-US (7385)	GB-US (8312)	GB-US (9183)	GB-US (10836)	GB-US (10294)
2	NL-DE (419)	NL-DE (532)	DE-NL (1568)	GB-NL (2069)	NL-US (2623)	NL-US (3003)	NL-US (3917)	NL-US (4580)	NL-US (5279)	NL-US (6163)
3	NL-US (383)	NL-US (515)	GB-DE (1496)	NL-US (2055)	GB-NL (2381)	DE-NL (2864)	DE-NL (3044)	DE-NL (3975)	DE-NL (4535)	DE-NL (5001)
4	NL-GB (335)	NL-GB (460)	DE-US (1340)	DE-NL (1999)	DE-NL (2275)	GB-NL (2701)	GB-DE (2931)	GB-DE (3698)	GB-DE (4019)	GB-DE (4415)
5	NL-BE (299)	MY-SG (450)	GB-NL (1312)	DE-US (1866)	DE-US (2202)	GB-DE (2493)	GB-NL (2854)	GB-NL (3298)	GB-NL (3516)	RU-CY (4399)
6	NL-LU (150)	NL-BE (421)	NL-US (1303)	GB-DE (1857)	GB-FR (1892)	DE-US (2340)	DE-US (2728)	NL-CW (3217)	NL-CW (3507)	GB-NL (4267)
7	NL-CH (131)	MY-JP (293)	DE-CH (1285)	DE-CH (1575)	DE-CH (1779)	NL-GB (2304)	NL-GB (2440)	NL-GB (3159)	NL-GB (3361)	DE-CH (3636)
8	GR-CY (126)	ES-DE (268)	AT-DE (1077)	GB-FR (1535)	NL-GB (1759)	DE-CH (2135)	GB-FR (2403)	DE-CH (2905)	DE-CH (3256)	NL-CW (3527)
9	NL-JP (124)	ES-NL (238)	GB-FR (1030)	AT-DE (1350)	AT-DE (1715)	GB-FR (2128)	DE-CH (2313)	DE-US (2856)	DE-US (3049)	NL-GB (3488)
10	NL-SE (121)	DE-NL (224)	NL-CW (924)	NL-GB (1226)	NL-CW (1400)	AT-DE (1856)	AT-DE (2279)	GB-FR (2795)	AT-DE (3030)	DE-US (3405)
11	NL-FR (115)	ES-FR (204)	DE-GB (884)	DE-GB (1112)	GB-DE (1356)	NL-CW (1788)	NL-CW (2255)	AT-DE (2613)	GB-FR (2951)	NL-LU (3297)
12	NL-IT (109)	AT-DE (195)	DE-FR (821)	NL-CW (1073)	DE-GB (1340)	NL-BE (1628)	NL-BE (1853)	NL-LU (2243)	NL-LU (2797)	AT-DE (3195)
13	DE-NL (74)	NL-LU (192)	NL-GB (798)	DE-FR (1051)	NL-BE (1334)	NL-DE (1495)	DE-GB (1677)	DE-GB (2198)	DE-GB (2656)	GB-FR (3052)
14	DE-CH (69)	NL-CH (176)	NL-DE (796)	NL-DE (966)	NL-DE (1265)	DE-GB (1459)	NL-DE (1644)	DE-AT (2160)	GB-JE (2629)	DE-GB (2996)
15	NL-IL (63)	DE-CH (173)	NL-BE (639)	NL-BE (959)	DE-FR (1186)	FR-US (1402)	FR-US (1561)	FR-DE (2133)	DE-AT (2344)	DE-LU (2753)
16	NL-DK (61)	NL-FR (168)	DE-AT (628)	FR-DE (958)	FR-US (1180)	DE-FR (1343)	DE-FR (1554)	NL-BE (2027)	DE-LU (2273)	GB-JE (2733)
17	BE-NL (57)	RO-DE (153)	FR-DE (583)	FR-US (935)	FR-DE (1081)	FR-DE (1264)	FR-DE (1541)	NL-DE (1996)	FR-DE (2242)	DE-AT (2558)
18	AT-DE (53)	FR-DE (152)	GB-CH (558)	FR-BE (801)	FR-BE (925)	ES-FR (1124)	NL-LU (1414)	FR-US (1927)	NL-BE (2201)	GB-LU (2457)
19	FR-NL (52)	NL-IT (151)	ES-DE (536)	DE-AT (797)	ES-FR (916)	FR-BE (1091)	FR-BE (1287)	DE-FR (1792)	FR-US (2103)	FR-DE (2393)
20	GB-NL (52)	FR-BE (147)	ES-FR (523)	GB-CH (704)	DE-AT (913)	GB-CH (1088)	DE-AT (1260)	DE-LU (1717)	NL-DE (2092)	NL-DE (2387)
21	FR-IT (51)	BE-NL (146)	FR-BE (518)	DK-SE (681)	BE-FR (840)	DE-AT (1064)	ES-FR (1244)	GB-IE (1686)	DE-FR (2008)	NL-BE (2311)
22	NL-ES (50)	ES-GB (145)	GB-JP (504)	FR-NL (666)	FR-NL (774)	ES-NL (978)	GB-CH (1199)	RU-CY (1585)	RU-CY (1902)	FR-US (2244)
23	ES-IT (45)	NL-JP (142)	ES-NL (479)	BE-FR (662)	NO-SE (770)	NL-LU (977)	BE-FR (1155)	FR-NL (1583)	GB-IE (1823)	DE-FR (2218)
24	DE-GB (42)	DE-US (142)	MY-SG (468)	NO-SE (660)	ES-DE (770)	FR-NL (952)	ES-NL (1155)	FR-BE (1517)	ES-NL (1803)	IT-LU (2202)
25	GB-SE (41)	NL-SE (141)	FR-US (432)	ES-FR (659)	GB-LU (766)	BE-FR (949)	FR-NL (1134)	ES-FR (1460)	FR-BE (1721)	LU-US (2050)
26	FR-DE (40)	TH-JP (138)	NL-IT (432)	GB-JP (612)	ES-NL (715)	ES-DE (946)	ES-DE (1098)	GB-CH (1449)	ES-FR (1716)	ES-NL (2037)
27	NL-IE (39)	ES-IT (132)	DE-IT (401)	NL-IT (603)	DK-SE (707)	NL-FR (896)	IE-GB (1092)	GB-LU (1399)	ES-DE (1647)	PL-DE (1866)
28	DE-FR (35)	GB-NL (131)	DK-SE (398)	ES-DE (586)	NL-FR (696)	NO-SE (844)	NO-SE (1004)	PL-DE (1371)	FR-NL (1628)	FR-BE (1864)
29	GB-FR (33)	GR-CY (126)	BE-FR (389)	FR-GB (582)	GB-BE (695)	BE-NL (825)	GB-IE (993)	BE-FR (1338)	GB-LU (1619)	ES-FR (1805)
30	IT-NL (33)	DE-GB (125)	BE-NL (348)	BE-NL (535)	GB-JP (695)	GB-LU (791)	FR-IT (976)	BE-NL (1334)	GB-CH (1582)	ES-DE (1791)

Table 4: Most frequent direct connections, 2000-2009

Most frequent direct connections, 2010-2018

	2010	2011	2012	2013	2014	2015	2016	2017	2018
1	GB-US (10727)	GB-US (11874)	GB-US (12458)	GB-US (12898)	GB-US (13761)	GB-US (14903)	GB-US (15395)	GB-US (14539)	GB-US (12259)
2	NL-US (6113)	RU-CY (7071)	RU-CY (7934)	RU-CY (9427)	RU-CY (8312)	RU-CY (10366)	RU-CY (9813)	RU-CY (9123)	RU-CY (7530)
3	DE-NL (5455)	NL-US (6537)	NL-US (7128)	NL-US (7603)	NL-US (7884)	NL-US (8319)	NL-US (7959)	NL-US (7943)	GB-JE (6199)
4	GB-NL (4724)	DE-NL (5826)	DE-NL (6200)	DE-NL (6260)	DE-NL (6671)	DE-NL (6602)	DE-NL (6254)	GB-JE (7441)	NL-US (5348)
5	GB-DE (4503)	GB-NL (4864)	GB-NL (5154)	GB-NL (5415)	GB-NL (5817)	GB-NL (5975)	GB-JE (6253)	DE-NL (6240)	DE-NL (5231)
6	RU-CY (4128)	GB-DE (4770)	GB-DE (5102)	DE-CH (5086)	DE-CH (5470)	GB-DE (5868)	GB-NL (5831)	GB-LU (5844)	GB-LU (4816)
7	DE-CH (4023)	DE-CH (4456)	DE-CH (4768)	GB-DE (5055)	GB-JE (5242)	GB-JE (5720)	GB-LU (5605)	GB-NL (5426)	GB-NL (4740)
8	DE-US (3605)	NL-LU (3884)	DE-LU (4309)	GB-JE (4901)	DE-LU (5198)	DE-CH (5565)	NL-LU (5577)	LU-US (5374)	AT-DE (4717)
9	NL-GB (3580)	DE-US (3822)	NL-LU (4231)	DE-LU (4770)	GB-DE (5053)	GB-LU (5268)	DE-CH (5368)	NL-LU (5259)	DE-CH (4492)
10	NL-LU (3435)	DE-LU (3815)	AT-DE (3904)	NL-LU (4451)	GB-LU (4533)	DE-LU (5130)	LU-US (5316)	DE-CH (5207)	GB-DE (4339)
11	AT-DE (3432)	NL-GB (3786)	NL-GB (3898)	LU-US (4267)	AT-DE (4419)	DE-GB (4683)	GB-DE (5047)	DE-LU (4967)	NL-GB (3939)
12	NL-CW (3308)	AT-DE (3664)	DE-US (3861)	AT-DE (4202)	DE-GB (4340)	AT-DE (4647)	DE-LU (4703)	GB-DE (4948)	NL-LU (3895)
13	DE-LU (3292)	GB-JE (3547)	GB-LU (3671)	GB-LU (4106)	NL-LU (4304)	NL-LU (4641)	NL-GB (4628)	AT-DE (4908)	DE-LU (3670)
14	GB-FR (3284)	DE-GB (3469)	LU-US (3639)	NL-GB (4102)	NL-GB (4287)	NL-GB (4585)	AT-DE (4588)	NL-GB (4611)	UA-CY (3518)
15	DE-GB (3242)	GB-FR (3326)	GB-JE (3599)	DE-GB (3842)	LU-US (4287)	LU-US (4453)	DE-GB (4464)	DE-GB (4421)	DE-GB (3435)
16	DE-AT (2888)	LU-US (3221)	DE-GB (3527)	DE-US (3769)	DE-US (3845)	DE-US (4018)	GB-FR (4070)	UA-CY (4122)	GB-FR (3330)
17	GB-LU (2865)	GB-LU (3180)	GB-FR (3431)	GB-FR (3490)	GB-FR (3667)	GB-FR (3996)	DE-US (3798)	GB-FR (3778)	DE-AT (3328)
18	GB-IE (2748)	NL-CW (3132)	NL-CW (3264)	DE-AT (3298)	DE-AT (3511)	DE-AT (3478)	IT-LU (3345)	DE-US (3691)	IT-LU (3141)
19	FR-DE (2578)	DE-AT (2977)	GB-IE (3072)	NL-CW (3102)	IT-LU (3181)	IT-LU (3401)	DE-AT (3318)	IT-LU (3539)	CN-JP (2997)
20	NL-DE (2561)	IT-LU (2831)	DE-AT (3053)	IT-LU (2981)	NL-CW (3013)	GB-IE (3135)	GB-IE (3285)	CN-HK (3392)	NL-BE (2872)
21	LU-US (2519)	FR-DE (2810)	FR-DE (2959)	RU-VG (2888)	GB-IE (2909)	NL-BE (3034)	NL-BE (3174)	DE-AT (3361)	DE-US (2853)
22	NL-BE (2437)	NL-DE (2651)	IT-LU (2956)	FR-DE (2880)	NL-BE (2867)	CN-JP (2893)	CN-HK (3117)	NL-BE (3188)	SK-CZ (2626)
23	FR-US (2422)	DE-FR (2514)	NL-DE (2774)	NL-DE (2866)	DE-FR (2821)	RU-VG (2864)	NL-DE (3021)	CN-JP (3172)	IT-GB (2557)
24	GB-JE (2367)	NL-BE (2440)	RU-VG (2679)	GB-IE (2829)	NL-DE (2765)	DE-FR (2839)	GB-VG (2893)	GB-IE (3105)	NL-DE (2511)
25	DE-FR (2354)	GB-IE (2434)	DE-FR (2674)	NL-BE (2785)	FR-DE (2502)	GB-VG (2824)	CN-JP (2837)	NL-DE (2910)	GB-IE (2497)
26	IT-LU (2342)	RU-VG (2432)	NL-BE (2573)	DE-FR (2732)	BE-FR (2482)	NL-DE (2763)	DE-FR (2775)	SK-CZ (2745)	PT-ES (2468)
27	PL-DE (2127)	FR-US (2332)	FR-US (2490)	BE-FR (2682)	GB-VG (2409)	CN-HK (2676)	SK-CZ (2764)	GB-VG (2729)	ES-DE (2402)
28	GB-CH (1992)	PL-DE (2301)	BE-FR (2477)	FR-US (2531)	ES-NL (2386)	NL-CW (2673)	FR-LU (2705)	IT-GB (2701)	NO-SE (2397)
29	FR-BE (1987)	FR-BE (2198)	PL-DE (2339)	FR-BE (2494)	FR-BE (2379)	FR-US (2591)	SE-NO (2556)	NO-SE (2664)	IT-DE (2377)
30	ES-DE (1979)	BE-FR (2186)	FR-BE (2332)	CZ-DE (2296)	FR-US (2374)	FR-LU (2473)	IT-GB (2537)	DE-FR (2661)	CN-HK (2321)

Table 5: Most frequent direct connections, 2010-2018

Most frequent indirect connections, 2000-2009

	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
1	GB-NL-GB (6)	ES-NL-US (15)	GB-NL-US (165)	GB-NL-US (196)	GB-NL-US (293)	GB-NL-US (343)	GB-NL-US (423)	GB-NL-US (521)	GB-NL-US (464)	GB-NL-US (862)
2	SE-NL-SE (6)	VG-MY-ID (11)	GB-LU-US (91)	DE-NL-US (116)	GB-LU-US (164)	GB-LU-US (228)	GB-LU-US (230)	GB-LU-US (422)	DE-NL-US (333)	GB-LU-US (553)
3	DE-NL-SE (4)	DE-NL-IT (10)	DE-NL-US (78)	GB-LU-US (107)	NL-GB-US (142)	DE-NL-US (225)	DE-NL-US (218)	DE-NL-US (301)	NL-GB-US (294)	DE-LT-DK (471)
4	BE-NL-DK (4)	FR-NL-US (9)	DE-GB-US (67)	GB-JE-GB (93)	DE-NL-US (127)	NL-GB-US (171)	GB-NL-CW (189)	NL-GB-US (227)	DE-GB-US (248)	NL-LU-US (436)
5	FR-NL-LU (3)	SE-NL-SE (8)	GB-US-GB (64)	IT-NL-IT (93)	GB-DE-GB (117)	GB-NL-GB (149)	NL-GB-US (168)	GB-NL-GB (204)	GB-LU-US (246)	DE-NL-US (373)
6	BE-NL-DE (3)	SG-AT-GB (8)	DE-NL-GB (63)	DE-GB-US (92)	DE-GB-US (113)	DE-NL-GB (141)	GB-DE-GB (160)	GB-NL-CW (199)	NL-LU-US (237)	ES-NL-CH (294)
7	DE-NL-US (3)	ES-NL-GB (8)	GB-PA-LU (57)	DE-NL-GB (90)	SE-LU-SE (101)	DE-GB-US (137)	DE-GB-US (147)	GB-DE-GB (196)	DE-GB-DE (235)	DE-GB-DE (292)
8	BE-NL-CW (3)	IT-LU-IT (7)	GB-DE-GB (50)	SE-LU-SE (89)	DE-NL-GB (96)	GB-CH-US (126)	DE-NL-GB (145)	DE-GB-US (188)	GB-NL-CW (221)	NL-GB-US (281)
9	IT-NL-CW (3)	DE-NL-US (7)	GB-GG-KW (42)	GB-BE-FR (89)	GB-NL-GB (94)	GB-DE-GB (122)	GB-NL-GB (141)	NL-LU-US (182)	ES-NL-CH (202)	NL-CH-ES (261)
10	DK-US-SE (2)	GB-NL-GB (7)	NL-GB-US (40)	GB-NL-GB (86)	GB-BE-FR (94)	GB-JE-GB (121)	GB-US-GB (132)	DE-NL-GB (180)	NL-CH-ES (195)	DE-GB-US (235)
11	HU-NL-US (2)	DE-NL-FR (6)	GB-NL-CW (40)	NL-GB-US (82)	DK-NL-US (93)	GB-CA-US (120)	ES-NL-US (127)	GB-IN-FR (163)	FR-DE-GB (194)	FR-DE-GB (230)
12	AT-NL-DK (2)	SG-VG-MY (6)	IT-NL-IT (37)	GB-NL-BM (78)	GB-CA-US (82)	SE-LU-SE (102)	GB-JE-GB (127)	GB-US-GB (157)	GB-DE-GB (186)	GB-NL-GB (226)
13	FR-NL-IT (2)	ES-NL-CW (6)	SE-LU-SE (35)	NL-LU-US (70)	BE-FR-CW (80)	NL-LU-US (102)	GB-CH-US (117)	FR-NL-US (148)	GB-NL-GB (185)	GB-DE-LT (223)
14	FR-DE-FR (2)	LU-NL-IT (5)	ES-NL-US (35)	GB-KY-HK (69)	GB-NL-CW (79)	GB-BE-FR (98)	GB-CA-US (111)	DE-NL-LU (142)	ES-NL-US (185)	FR-NL-US (213)
15	IT-NL-SE (2)	DE-NL-SE (5)	GB-US-JP (32)	FR-NL-US (66)	NL-GB-LU (77)	GB-US-GB (98)	NL-LU-BM (110)	GB-CH-US (130)	DE-NL-GB (168)	GB-DE-GB (197)
16	DE-NL-IT (2)	NL-GB-DE (5)	GB-CH-US (31)	SE-NL-SE (66)	FR-NL-US (75)	BE-FR-CW (83)	NL-LU-US (105)	FR-LU-IT (129)	DE-LU-US (157)	ES-NL-US (196)
17	CZ-NL-US (2)	BE-NL-DK (5)	GB-NL-IT (30)	GB-PA-LU (61)	GB-NL-BM (73)	NL-LU-BM (81)	GB-BE-FR (102)	NL-LU-NL (123)	FR-NL-US (148)	GB-CH-US (193)
18	NL-GB-FR (1)	CZ-NL-BE (5)	DE-LU-DE (29)	FR-IT-NL (59)	NL-LU-US (71)	ES-NL-US (79)	SE-LU-SE (99)	NL-LU-BM (116)	NL-LU-BM (143)	GB-NL-CW (187)
19	NL-DK-SE (1)	NL-GB-US (5)	NL-BM-DE (29)	GB-US-FR (59)	DK-LU-US (68)	GB-NL-BM (78)	FR-NL-US (95)	GB-CA-US (114)	GB-US-FR (138)	DE-LU-US (186)
20	DE-NL-CW (1)	FR-IT-BE (5)	GB-FR-DE (29)	GB-DE-GB (58)	ES-NL-US (64)	GB-NL-CW (77)	FR-LU-NL (91)	NL-CH-US (111)	NL-GB-JE (126)	IT-NL-US (183)
21	AT-NL-GB (1)	BE-NL-GB (4)	ES-GB-US (28)	ES-NL-US (58)	GB-NL-JP (62)	GB-DK-US (71)	DK-NL-US (85)	ES-NL-US (107)	DE-NL-LU (121)	DE-NL-LU (181)
22	ES-NL-CW (1)	AT-NL-CH (4)	DE-IL-US (27)	FR-GB-US (53)	GB-PA-LU (62)	GB-DE-US (68)	US-SE-US (84)	GB-DK-GB (104)	GB-CH-US (121)	GB-NL-FR (181)
23	HU-NL-DK (1)	MY-NL-GB (4)	SE-NL-SE (26)	DK-NL-US (52)	GB-US-FR (58)	GB-NL-FR (67)	BE-FR-CW (82)	FR-GB-US (98)	ES-NL-LU (116)	GB-CA-US (179)
24	LV-NL-DE (1)	ES-NL-LU (4)	ES-NL-IT (24)	GB-NL-IT (48)	FR-GB-US (54)	ES-NL-GB (67)	NL-CH-US (80)	GB-BE-FR (98)	NL-CH-US (115)	GB-SG-IN (172)
25	HU-AT-DE (1)	AT-NL-DE (4)	DE-NL-IL (24)	GB-NL-JP (47)	NL-BE-FR (53)	GB-NL-JP (66)	IE-NL-US (79)	GB-JE-GB (95)	FR-GB-US (113)	DE-NL-GB (168)
26	FI-NL-CW (1)	PA-VG-MY (4)	GB-FR-US (23)	GB-NL-CW (47)	DE-LU-US (53)	DK-NL-US (65)	FR-GB-US (79)	GB-NL-JP (93)	GB-NL-LU (111)	GB-JE-GB (167)
27	LU-IT-DK (1)	RO-AT-DE (4)	FR-NL-US (23)	GB-FR-US (46)	GB-US-GB (50)	GB-PA-LU (63)	IT-NL-SE (78)	IT-NL-US (87)	US-GB-JE (107)	GB-LU-GB (153)
28	BM-PA-VG (1)	BE-NL-DE (4)	DE-NL-IT (23)	DE-NL-IT (45)	DE-LU-DE (50)	NL-BE-FR (59)	GB-NL-CA (76)	DE-LU-US (86)	ES-NL-CW (106)	NL-CH-US (153)
29	NL-PL-NL (1)	FR-NL-JP (4)	GB-NL-JP (23)	GB-US-GB (44)	GB-GG-IE (48)	GB-GG-IE (59)	ES-NL-CW (74)	GB-NL-LU (86)	CH-NL-US (106)	GB-US-GB (144)
30	FR-NL-JP (1)	FR-BE-LU (4)	DE-GB-JP (22)	GB-GG-IE (42)	GB-FR-US (48)	DE-LU-DE (59)	ES-GB-US (73)	GB-DK-US (85)	GB-JE-GB (105)	ES-NL-LU (142)

Table 6: Most frequent indirect connections, 2000-2009

Most frequent indirect connections, 2010-2018

	2010	2011	2012	2013	2014	2015	2016	2017	2018
1	GB-NL-US (879)	GB-NL-US (862)	GB-NL-US (1018)	GB-NL-US (1098)	GB-NL-US (1116)	GB-NL-US (1123)	GB-LU-US (1142)	NL-LU-US (1193)	GB-NL-US (606)
2	GB-IE-JE (724)	GB-LU-US (675)	GB-LU-US (801)	NL-LU-US (930)	GB-LU-US (910)	GB-LU-US (990)	NL-LU-US (1043)	GB-LU-US (1097)	GB-LU-JE (402)
3	GB-LU-US (679)	NL-LU-US (618)	NL-LU-US (704)	GB-LU-US (914)	NL-LU-US (842)	NL-LU-US (736)	GB-NL-US (1007)	GB-NL-US (972)	NL-GB-US (387)
4	DE-LT-DK (568)	DE-NL-US (400)	GB-IE-JE (608)	GB-GG-JE (526)	DE-NL-US (535)	DE-GB-US (564)	NL-GB-US (557)	GB-JE-GB (530)	GB-LU-US (373)
5	NL-LU-US (555)	NL-GB-US (326)	DE-NL-US (410)	DE-NL-US (484)	NL-GB-US (452)	NL-GB-US (548)	DE-NL-US (464)	NL-GB-US (525)	NL-LU-US (367)
6	DE-NL-US (431)	DE-GB-US (296)	NL-GB-US (344)	GB-JE-GB (398)	DE-GB-US (428)	DE-NL-US (476)	GB-JE-GB (429)	GB-NL-LU (524)	DE-GB-US (316)
7	NL-GB-US (285)	DE-LU-US (295)	DE-GB-US (319)	NL-GB-US (387)	GB-NL-GB (385)	GB-NL-GB (415)	GB-NL-LU (424)	CN-HK-KY (516)	DE-NL-US (303)
8	GB-NL-GB (245)	FR-DE-GB (253)	DE-LU-US (308)	DE-GB-US (370)	DE-LU-US (364)	GB-JE-GB (399)	CN-HK-KY (414)	DE-NL-US (484)	GB-JE-GB (276)
9	FR-DE-GB (236)	FR-LU-US (250)	GB-JE-GB (302)	GB-NL-LU (356)	GB-NL-LU (349)	DE-LU-US (394)	DE-GB-US (407)	GB-LU-JE (414)	GB-NL-GB (222)
10	GB-DE-LT (225)	GB-NL-GB (246)	GB-BE-FR (284)	DE-LU-US (328)	NL-GB-JE (301)	GB-NL-LU (360)	DE-LU-US (391)	DE-GB-US (386)	NL-AT-BR (220)
11	DE-NL-LU (223)	IT-NL-US (240)	GB-NL-LU (273)	FR-BE-FR (309)	GB-JE-GB (300)	FR-DE-GB (335)	FR-DE-GB (331)	DE-LU-US (380)	GB-NL-LU (218)
12	GB-CH-US (221)	GB-BE-FR (240)	FR-DE-GB (273)	FR-DE-GB (272)	FR-DE-GB (281)	FR-LU-FR (315)	US-GB-US (314)	DE-GB-JE (295)	FR-GB-AU (216)
13	DE-GB-US (216)	GG-IE-GG (236)	RU-CY-VG (257)	GB-NL-GB (263)	FR-LU-FR (281)	LU-NL-US (296)	GB-DE-US (266)	CH-NL-US (293)	NL-GB-JE (212)
14	DE-LU-US (212)	GB-NL-LU (227)	IT-NL-US (251)	RU-CY-VG (259)	IT-NL-US (277)	NL-LU-NL (279)	NL-GB-JE (253)	NL-GB-JE (289)	GB-NL-IE (194)
15	ES-NL-US (207)	GB-GG-IE (225)	GB-NL-GB (239)	FR-LU-FR (249)	RU-CY-VG (265)	RU-CY-VG (274)	HK-KY-TW (248)	GB-BE-FR (274)	DE-GB-JE (193)
16	GB-DE-GB (199)	GB-JE-GB (214)	GB-CH-US (239)	ES-NL-US (248)	FR-BE-FR (253)	DE-LU-DE (265)	IT-NL-US (235)	CN-HK-CN (262)	SG-NL-US (191)
17	GB-NL-IE (183)	DE-NL-GB (212)	DE-NL-GB (213)	NL-GB-JE (241)	NL-AT-BR (233)	CN-HK-KY (260)	GB-NL-GB (227)	GB-AT-BR (260)	IT-GB-US (180)
18	GB-CA-US (183)	ES-NL-US (208)	GB-GG-IE (208)	IT-NL-US (235)	ES-NL-US (231)	CH-NL-US (254)	GB-NL-IE (227)	DE-NL-LU (251)	IT-NL-US (174)
19	GB-NL-LU (179)	FR-NL-US (199)	GB-DE-NL (203)	NL-AT-BR (233)	GB-US-GB (228)	NL-GB-JE (246)	IT-GB-US (227)	SG-NL-US (243)	GB-DE-US (167)
20	GB-SG-IN (178)	GB-DE-GB (197)	FR-NL-US (197)	GB-US-GB (213)	GB-NL-CW (228)	ES-NL-US (240)	FR-NL-LU (225)	GB-DE-US (240)	DE-NL-LU (166)
21	GB-NL-FR (175)	GB-US-GB (191)	FR-NL-CW (197)	GB-SG-IN (203)	CH-NL-US (218)	IT-NL-US (232)	RU-CY-VG (225)	GB-NL-GB (238)	ES-NL-LU (162)
22	DE-NL-GB (171)	NL-GB-JE (189)	GB-SG-IN (193)	NL-US-GB (201)	DE-NL-GB (212)	CN-HK-VG (223)	FR-LU-US (223)	HK-KY-TW (236)	NL-GB-NL (160)
23	ES-NL-LU (166)	GB-SG-IN (188)	CH-LU-US (189)	GB-NL-CW (196)	FR-LU-US (207)	GB-US-GB (222)	NL-AT-BR (220)	CN-HK-US (231)	DE-LU-US (158)
24	FR-NL-US (164)	IT-NL-LU (187)	GB-CA-US (186)	DE-NL-LU (194)	DE-LU-KY (207)	NL-AT-BR (221)	GB-US-GB (207)	IT-GB-US (227)	SE-LU-CW (157)
25	NL-BM-US (163)	CH-LU-US (185)	FR-BE-FR (186)	DE-NL-GB (194)	DE-LU-DE (203)	DE-LU-KY (217)	IT-LU-US (207)	IT-NL-US (226)	DE-AT-DE (156)
26	GB-NL-CW (155)	GB-CA-US (183)	ES-NL-LU (181)	GB-CH-US (191)	GB-LU-KY (186)	NL-GB-LU (205)	GB-AT-BR (206)	NL-AT-BR (224)	NL-GB-LU (154)
27	IT-NL-US (154)	FR-NL-LU (180)	ES-NL-US (178)	FR-NL-US (190)	NL-GB-NL (184)	DE-NL-GB (199)	GB-US-JP (206)	DE-AT-DE (223)	DE-GB-JP (150)
28	GB-LU-GB (152)	GB-LU-GB (178)	DE-NL-LU (178)	IE-NL-US (187)	ES-NL-LU (182)	GB-DE-GB (196)	CN-HK-US (196)	IT-LU-US (220)	DE-NL-GB (142)
29	GB-LU-KY (152)	ES-NL-LU (177)	DE-LU-DE (177)	ES-NL-LU (184)	CN-HK-KY (181)	DE-GB-JP (192)	DE-NL-LU (196)	GB-BM-US (206)	ES-NL-US (137)
30	GB-JE-GB (151)	FR-BE-FR (166)	IE-NL-US (174)	ES-LU-US (179)	DE-NL-LU (180)	DE-GB-JE (191)	GB-SG-IN (194)	GB-NL-IE (200)	ES-GB-JE (134)

Table 7: Most frequent indirect connections, 2010-2018

Most popular asset hubs, 2010-2018

	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
1	MH (14.56)	MH (17.91)	MH (19.59)	MH (18.58)	MH (23.26)	KY (27.99)	MH (19.91)	KY (19.83)	KY (16.52)
2	TW (14.5)	TW (14.11)	TW (16.1)	TW (16.31)	TW (17.25)	MH (20.33)	TW (17.98)	TW (18.88)	TW (9.89)
3	BM (4.99)	BM (6.55)	BM (9.6)	BM (11.15)	BM (13.47)	TW (17.13)	KY (15.28)	MH (18.64)	MH (6.9)
4	KY (4.74)	JE (3.02)	JE (3.86)	KY (4.81)	KY (6.75)	BM (14.14)	BM (14.26)	BM (16.41)	BM (5.02)
5	CW (1.83)	KY (2.67)	KY (3.65)	JE (4.69)	JE (4.72)	JE (4.61)	JE (6.12)	JE (6.67)	JE (3.68)
6	VG (1.53)	CW (1.92)	CW (2.05)	CW (2.22)	CW (2.17)	CW (2.23)	CW (2.58)	CW (2.42)	CW (2.36)
7	JE (1.38)	VG (1.66)	VG (1.82)	VG (1.98)	VG (2.09)	VG (1.53)	VG (1.47)	VG (1.62)	LR (1.05)
8	LR (.98)	LR (.92)	LU (.53)	LR (.79)	LR (.81)	LR (.82)	LR (.89)	LR (.87)	VG (.96)
9	LU (.4)	LU (.48)	GG (.37)	LU (.5)	LU (.51)	LU (.66)	LU (.63)	LU (.68)	HK (.27)
10	MT (.35)	MT (.48)	MT (.34)	MT (.45)	GG (.35)	MT (.56)	GG (.43)	GG (.48)	KR (.19)
11	GG (.29)	MY (.29)	CY (.29)	GG (.44)	CY (.29)	GG (.4)	MT (.41)	MT (.25)	DK (.18)
12	MY (.24)	GG (.29)	MY (.29)	CY (.4)	MY (.26)	MY (.28)	HK (.25)	NL (.24)	GG (.14)
13	GB (.22)	GB (.22)	GB (.22)	MY (.29)	GB (.25)	NL (.23)	NL (.24)	DK (.23)	CH (.12)
14	IS (.21)	NL (.2)	NL (.21)	NL (.24)	NL (.23)	IE (.22)	MY (.24)	KR (.22)	PA (.12)
15	NL (.2)	IS (.2)	KR (.2)	GB (.24)	NZ (.23)	GB (.21)	IE (.21)	HK (.22)	LU (.1)
16	KR (.18)	CY (.19)	SE (.19)	SE (.21)	DK (.22)	DK (.2)	DK (.2)	MY (.21)	FR (.1)
17	SE (.17)	SE (.18)	NZ (.18)	KR (.21)	IE (.21)	HK (.2)	SG (.2)	SG (.21)	NL (.1)
18	NZ (.16)	NZ (.18)	PA (.17)	NZ (.21)	KR (.2)	NZ (.2)	KR (.2)	GB (.2)	FI (.09)
19	NO (.15)	KR (.16)	HK (.17)	IS (.19)	HK (.2)	KR (.19)	GB (.18)	IM (.18)	LI (.09)
20	FI (.15)	NO (.16)	NO (.17)	PA (.18)	SE (.18)	SG (.18)	IM (.17)	SE (.18)	US (.09)
21	CH (.14)	HK (.16)	FI (.16)	HK (.18)	PA (.16)	SE (.17)	NZ (.16)	IS (.16)	CN (.09)
22	FR (.13)	FI (.15)	CH (.15)	IE (.17)	MT (.16)	CY (.17)	SE (.16)	IE (.15)	GB (.09)
23	HK (.13)	IE (.14)	IE (.15)	FI (.16)	CH (.15)	PA (.16)	PA (.16)	CH (.15)	TH (.09)
24	IE (.12)	CH (.14)	FR (.14)	NO (.16)	FI (.14)	CH (.15)	CH (.15)	FI (.14)	MU (.07)
25	ES (.12)	FR (.13)	AT (.14)	CH (.16)	NO (.14)	IM (.15)	IS (.15)	FR (.14)	MY (.07)
26	IM (.12)	AT (.12)	SG (.13)	IM (.15)	IS (.14)	BE (.14)	CN (.14)	PA (.14)	IS (.07)
27	JP (.11)	JP (.12)	PT (.13)	FR (.15)	FR (.12)	FI (.13)	FI (.14)	JP (.13)	NZ (.06)
28	PT (.1)	ES (.11)	IS (.12)	SG (.14)	AT (.12)	IS (.13)	JP (.12)	BE (.13)	PG (.05)
29	AT (.1)	GI (.11)	ES (.12)	AT (.14)	IM (.12)	CN (.13)	BE (.11)	NZ (.12)	CA (.05)
30	IT (.1)	IM (.11)	IM (.12)	ES (.13)	PT (.11)	NO (.12)	FR (.11)	CN (.12)	ES (.04)

Table 8: Total Assets controlled from this country divided by GDP, 2010-2018 (rescaled to percentages)

Most popular control hubs, 2010-2018

	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
1	VG (5.85)	VG (8.04)	VG (9.19)	VG (10.25)	VG (10.18)	VG (11.72)	VG (10.87)	VG (10.59)	VG (7.65)
2	CW (1.35)	MH (1.45)	MH (1.52)	MH (2.27)	MH (2.5)	MH (2.46)	MH (3.96)	MH (4.05)	MH (2.56)
3	KY (.97)	CW (1.24)	KY (1.44)	KY (1.57)	KY (1.79)	KY (2.08)	KY (2.36)	KY (2.42)	SC (2.12)
4	JE (.81)	KY (1.09)	CW (1.23)	SC (1.48)	SC (1.42)	SC (1.74)	SC (1.99)	SC (2.23)	KY (1.6)
5	MH (.76)	SC (1.02)	SC (1.21)	JE (1.27)	JE (1.2)	JE (1.43)	JE (1.72)	JE (1.91)	JE (1.56)
6	SC (.76)	JE (.92)	JE (1.01)	CW (1.2)	CW (1.15)	BM (1.33)	BM (1.44)	BM (1.56)	BM (1)
7	BM (.64)	BM (.75)	BM (.92)	BM (1.01)	BM (1.12)	CW (1.14)	CW (1.1)	BZ (.99)	CY (.76)
8	GI (.63)	GI (.63)	CY (.66)	CY (.85)	CY (.84)	CY (.97)	CY (.91)	CW (.94)	GG (.69)
9	GG (.45)	CY (.58)	GI (.6)	BZ (.75)	BZ (.72)	BZ (.88)	BZ (.91)	CY (.93)	CW (.68)
10	KN (.4)	BZ (.53)	BZ (.59)	GG (.66)	GG (.64)	GG (.75)	GG (.83)	GG (.84)	BZ (.63)
11	BZ (.38)	KN (.5)	GG (.57)	GI (.62)	GI (.57)	TW (.62)	GI (.63)	GI (.6)	GI (.52)
12	CY (.37)	GG (.5)	KN (.48)	LU (.48)	TW (.56)	GI (.57)	TW (.62)	TW (.54)	LU (.42)
13	LU (.34)	LU (.39)	LU (.44)	KN (.42)	LU (.48)	LU (.54)	LU (.55)	LU (.54)	DM (.4)
14	NR (.26)	IM (.26)	IM (.31)	TW (.38)	IM (.4)	IM (.47)	IM (.44)	DM (.43)	IM (.31)
15	TW (.24)	TW (.25)	TW (.27)	IM (.37)	KN (.36)	KN (.36)	DM (.31)	IM (.42)	TW (.3)
16	LI (.23)	LI (.24)	LI (.26)	DM (.25)	DM (.23)	DM (.3)	KN (.3)	KN (.27)	KN (.23)
17	IM (.21)	NR (.24)	DM (.21)	LI (.23)	LI (.22)	LI (.23)	LI (.22)	LI (.23)	LI (.19)
18	KI (.17)	DM (.2)	NR (.18)	WS (.17)	VC (.19)	VC (.21)	VC (.21)	WS (.23)	WS (.18)
19	DM (.11)	KI (.13)	VC (.13)	VC (.16)	MT (.17)	MT (.2)	WS (.21)	VC (.21)	VC (.18)
20	LR (.11)	VC (.13)	WS (.13)	MT (.16)	WS (.15)	WS (.16)	MT (.2)	MT (.2)	MT (.16)
21	WS (.11)	LR (.11)	MT (.13)	NR (.14)	LR (.1)	LR (.11)	LR (.11)	LR (.13)	MU (.12)
22	VC (.11)	WS (.11)	LR (.09)	LR (.09)	NR (.1)	NR (.1)	MU (.11)	MU (.1)	LR (.11)
23	MT (.08)	MT (.1)	BS (.09)	BS (.09)	BS (.08)	BS (.09)	BS (.1)	SM (.09)	SM (.09)
24	BS (.08)	BS (.08)	SM (.08)	SM (.07)	SM (.07)	MU (.09)	NR (.08)	BS (.09)	EE (.06)
25	SM (.05)	SM (.08)	KI (.06)	MU (.06)	MU (.07)	SM (.08)	SM (.08)	NR (.08)	NR (.06)
26	MU (.05)	MU (.05)	MU (.06)	PA (.05)	EE (.05)	EE (.06)	EE (.07)	EE (.07)	BS (.06)
27	PA (.04)	PA (.05)	PA (.05)	EE (.05)	PA (.05)	PA (.05)	PA (.05)	PA (.05)	PA (.04)
28	IS (.04)	EE (.04)	EE (.05)	KI (.05)	NL (.04)	NL (.04)	NL (.04)	NL (.04)	ST (.04)
29	EE (.04)	IS (.04)	IS (.04)	NL (.04)	IS (.04)	IS (.04)	AW (.04)	AW (.04)	BB (.04)
30	NL (.03)	NL (.04)	NL (.04)	IS (.04)	CH (.03)	CH (.04)	CH (.04)	ST (.04)	AW (.04)

Table 9: Firms controlled from this country devided by GDP, 2010-2018 (rescaled to Firms per million of GDP)

8.4 Corporate Ownership Hierarchies

The bottom-up method of reconstructing ownership chains allows for a comprehensive assessment of business groups' hierarchies and their development over time. Altomonte and Rungi (2013) introduce a Group Index of Complexity (GIC) to measure a business group's hierarchical complexity an demonstrate its behaviour for different group sizes. This section introduces a simple complementary measure for a group's hierarchical "balance".

Figure 26 illustrates how several lines of control connect firms to a GUO on different hierarchy levels. The structure consists of 9 firms and 4 hierarchy levels arranged across 4 rows (the GUO excluded) and 4 columns. If expressed as a list of firm to firm connections, this structure can be directly transformed into an adjacency matrix for further network analysis. [52] Figure 26 also provides an example for a business group visualized as a directed network.

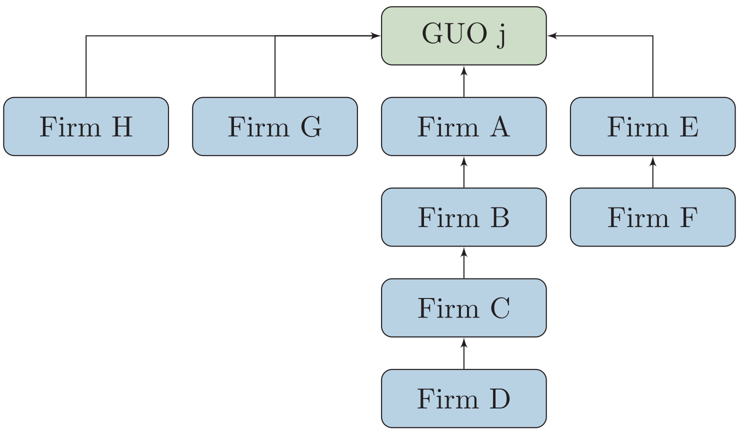

Figure 26: Business group illustration, hierarchy as a directed network

Based on this representation it is difficult to tell whether this group is more "horizontal" or more "vertical" in nature than another one. However, after aligning all firms to the left the resulting shapes become comparable and can be measured in terms of their vertical or horizontal fragmentation.

[52] If the top shareholder selection criterion is relaxed, firms can be a part of several networks at the same time. In fact, as a relational database ORBIS itself can be transformed this way.Vitali et al. (2011) use ORBIS data from 2007, identifying a supercluster of connected firms that control a large share of the global multinational network though ownership shares of varying size.

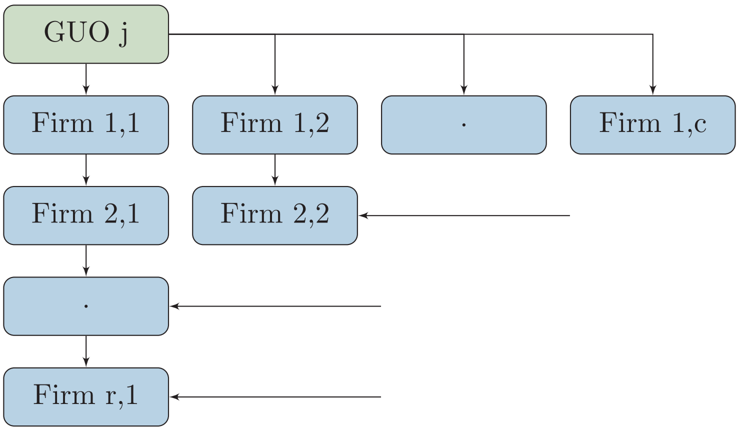

Figure 27: Business group illustration, chains of control aligned left

Figure 27 translates into a general matrix representation

$$\boldsymbol{H_{j,t}} = \begin{bmatrix} Firm_{1,1} & Firm_{1,2} & . & Firm_{1,c} \\ Firm_{2,1} & Firm_{2,2} & . & Firm_{2,c} \\ . & . & . & . \\ Firm_{r,1} & Firm_{r,2} & . & Firm_{r,c} \end{bmatrix} \tag{2}$$

for each business group j in year t where each cell takes a value of either 0 or 1, determined by the group's structure. A measure of a group's structural balance is then given by

$$\Omega\left\{\mathbf{H_{j,t}}\right\} = \mathbf{xx}' - \mathbf{y}'\mathbf{y} \tag{3}$$

where

$$\mathbf{x} = \left(\mathbf{1}'_r\mathbf{H}\right)\frac{1}{s} \;\;,\;\; \mathbf{y} = \left(\mathbf{H}\mathbf{1}_c\right)\frac{1}{s} \;\;,\;\; s = \mathbf{1}'_r\mathbf{H}\mathbf{1}_c \;\;,\;\; \mathbf{1}_c = \begin{bmatrix} 1 \\ 1 \\ . \\ 1 \end{bmatrix} \;\; and \;\; \mathbf{1}'_r = \begin{bmatrix} 1 & 1 & . & 1 \end{bmatrix}. \tag{4}$$

For a business group consisting of one long chain of control, essentially a fully vertical structure, $\Omega\left\{\mathbf{H_{j,t}}\right\}$ converges towards 1. Similarly, for a business group consisting only of direct subsidiaries of the GUO the measure will converge towards -1. A balanced group will have a value of zero. The measure allows for many different shapes to fall within the "balanced" spectrum, but only extreme shapes will return extreme values. This allows for the identification of outliers in terms of their hierarchies among the plethora of possible combinations, but needs to be taken into consideration if the measure is used for further analysis. Figure 28 illustrates the connection between group size and hierarchy shape. Although the data is pooled across all years, points are connected according to each business group's expansion path. The result shows a strong preference to expand horizontally instead of vertically as the groups grow in size.

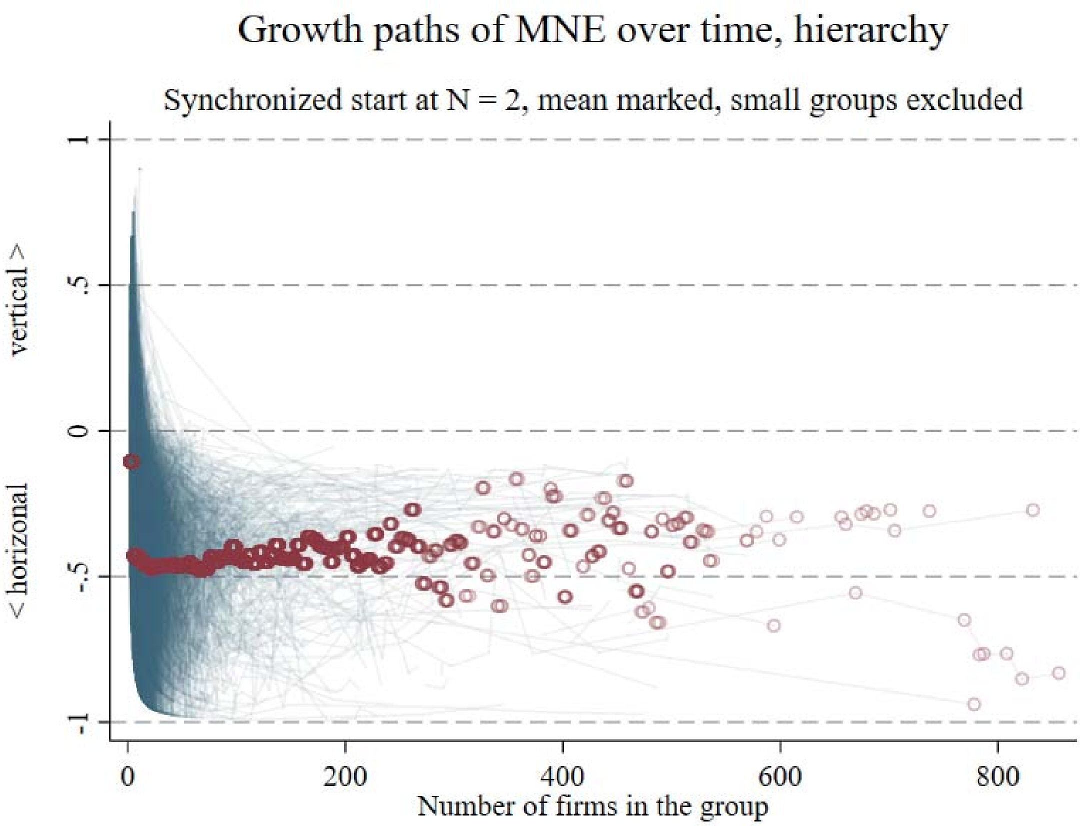

Figure 28: Hierarchy balance and group size

The result is more nuanced when geographical expansion is considered. Figure 29 highlights that some groups stay almost fully horizontal and enter other countries primarily through subsidiaries directly connected to the GUO. The strategy does not seem to be used beyond 20 countries. Others, which focus on either one or two countries, do so in the form of more vertical structures. Although there is great variety in the chosen shapes, groups converge to a value of -0.5.

The balance measure gives a quick indication as to whether a business group is special in shape, but ignores a vast amount of other relevant factors. In particular, it makes no assumption on the underlying value chain or management structure. Nevertheless it can serve as an easy tool to identify expansion strategies an reveal preferences for certain hierarchy types.

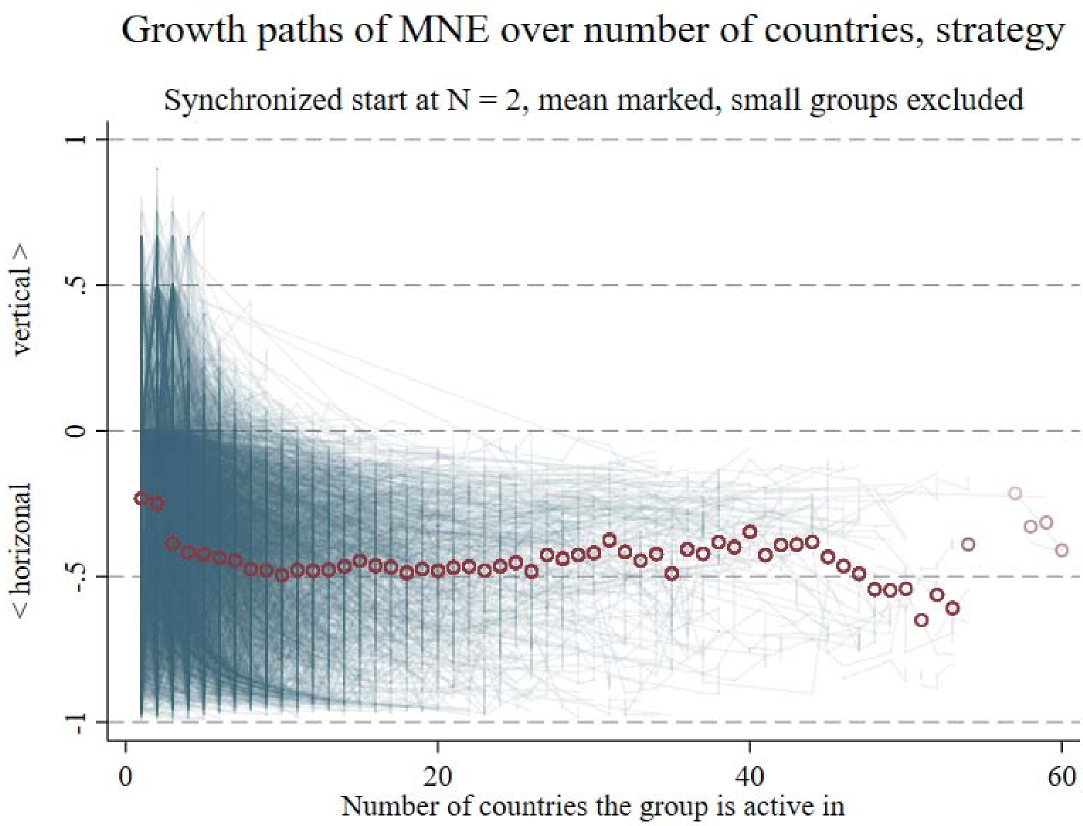

Figure 29: Hierarchy balance and country coverage