Essays on the network structure of global production

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Essays on the Network Structure of Global Production

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To my beloved Danai.

Declaration

I hereby declare that the material contained in this thesis has not been used, or published, before and has not been submitted for another degree at another university. I also declare that this Thesis represents the result of my own work, except Chapter 3, which was conducted in collaboration with Ashok Kumar, Giorgos Galanis and Lilit Popoyan. For this chapter, the basic idea was mine and was further developed through joint discussions. The methodological and empirical research parts, as well as, the vast majority of the literature review, were conducted by me, whereas the write-up and final editing was shared equally among the authors.

Date: 19 November 2020

Panagiotis (Takis) Iliopoulos

Abstract

The present PhD thesis consists of three research papers that investigate the theoretical and empirical linkages between, on the one hand, the network structure of global production and. GVCs, and on the other, the a) conceptualization of market power at the global level of production, b) the assessment of functional income distribution within countries that participate in GVCs, and c) the hierarchical distribution of value-added contributions among cross-country sectoral buyers-suppliers in global production. The methodology that I use in this thesis is multidisciplinary. On the one hand, my thesis focuses on analytical frameworks and theoretical approaches that investigate market power, income distribution, globalization, and the structures of GVCs. On the other hand, I introduce analytical tools borrowed from complex and network theory, and input-output analysis, in order to explore the structural properties of the economic relations between economic actors, quantitatively and empirically. The thesis attempts to contribute to a diverse array of literatures, combining elements from complex analysis and network theory, in order to unravel the structural/topological properties of global economic networks and provide new insights into the analysis of market power, functional income and sectoral value-added distribution, at the global level.

Acknowledgements

This PhD Thesis has been formally in the making for less than three years. Informally though, the idea of completing my PhD had been haunting my thoughts for almost a decade. Unfortunately, an earlier attempt to initiate a PhD research project at the University of Athens was abandoned after the completion of my military service in 2012. However, I feel the need to express my gratitude to those who supported me during that first attempt, and particularly the members of my advisory committee, Nicolas Theocharakis and Heather Gibson, as well as, the former Director of the University of Athens Doctoral Program, Georgios Chortareas.

The idea for the current PhD project was initiated in October 2017 after a long phone call with Dr Giorgos Galanis. I was in Brussels at the time, working at the European Parliament as an Economic Policy Advisor, and I was becoming extremely impatient about my future. Following an academic career was still my long-lasting ambition, and what Dr Galanis proposed to me that day was a well-designed plan for achieving that goal. The next act of my academic journey was in April 2018 in London, when I first met Dr Ashok Kumar and discussed about the possibility of doing a PhD at Birkbeck College, with him as a principal supervisor. I had already devoured a draft paper that Dr Kumar and Dr Galanis had written on governance structures in Global Value Chains, which provided me with the necessary insights for forming my PhD research questions. And after a while a research proposal was agreed with my PhD supervisors, Dr Kumar, and Dr Galanis, formally submitted to the Department of Management, Birkbeck College.

Conducting the necessary research for a PhD Thesis is not an easy task. You have to spend endless days and nights, searching the literature, writing draft chapters, finding, and evaluating your data, with the danger of pointlessness always lurking in the

background. In my case, though, writing this Thesis became much easier and meaningful, because I had the invaluable supervision and guidance of these two brilliant researchers, Dr Ashok Kumar, and Dr Giorgos Galanis. To them, I would like to express my sincere gratitude. Their assistance all those years was irreplaceable, and I will be forever indebted to them for their advice and recommendations. They supported my research project from day one and they taught me to think critically and ‘out-of-the-box’, without compromising scientific rigorousness. Their encouragement and constructive criticism allowed me to grow as a researcher and become an economist who is able to cope with complex analytical questions.

I would also like to extend my appreciation to the many people who have read and commented parts of the present research, including Lilit Popoyan, Karsten Köhler, Xiaming Liu, Karin Shields, Wendy Hein, Horen Voskeritsian, Frederick Guy; but most importantly to Giorgos Gouzoulis for his invaluable help during the final stages of this thesis. I am also grateful to the many conference and seminar participants at the Forum for Macroeconomics and Macroeconomic Policies, the Workshop on Economic Science with Heterogeneous Interacting Agents, the Society for the Advancement of Socioeconomics, Historical Materialism, Birkbeck PhD Seminars, for their comments and suggestions. Moreover, I would like to give special thanks to Birkbeck College for funding my participation to international conferences and seminars. Last, but definitely not least, I would like to thank my partner Danai Kyrli-Florou for supporting me all those years and believing in me for completing this Thesis. Without her this project would not be at all feasible.

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Chapter 1: Introduction

The present PhD thesis consists of three research papers that investigate the theoretical and empirical linkages between, on the one hand, the network structure of global production and. GVCs, and on the other, the a) conceptualization of market power at the global level of production, b) the assessment of functional income distribution within countries that participate in GVCs, and c) the hierarchical distribution of value-added contributions among cross-country sectoral buyers-suppliers in global production.

The expansion of trade and the rise of international fragmentation of production – what is dubbed in the literature of international economics as the rise of Global Value Chains (GVCs) - has markedly changed, not only the world production and trade patterns, not only the growth trajectories of both advanced and developing countries, but also the way economists and social scientist alike, understand and theorize the mechanisms and outcomes of economic globalization. The present thesis attempts to contribute to a diverse array of literatures, combining elements from complex analysis and network theory, in order to unravel the structural/topological properties of global economic networks and provide new insights into the analysis of market power, functional income and sectoral value-added distribution, at the global level.

The methodology that I use in this thesis is multidisciplinary. On the one hand, my thesis focuses on analytical frameworks and theoretical approaches that investigate market power, income distribution, globalization, and the structures of GVCs. On their own merit, these approaches draw heavily on a variety of literatures ranging from international economics, political economy, and economic geography, highlighting a diverse array of underlying factors in the exploration of global production. On the other hand, I introduce analytical tools borrowed from complex and network theory, and input-output analysis, in order to explore the structural properties of the economic relations between economic actors, quantitatively and empirically. In particular, I employ various databases of global input-output tables and express the world economy in terms of configurations of economic networks. Each node in these global networks represents an industrial sector, located in a specific country and each link the value (either nominal or value-added) of their respective international transactions.

The present Thesis is structured around three research papers and one additional chapter that provides a simple, but necessary, introduction to the methodologies of Input-Output Analysis and Network Theory. This introductory chapter (Chapter 2) is imperative for the Thesis in order to avoid the repetition of basic terms and formulas that are relevant to the empirical analysis. Input-Output Analysis was developed by Wassily Leontief (1936) in the 1930s, who envisaged the structure of an economy as a system of linear equations linking producing and demanding sectors of the economy. With Input-Output Analysis, we are able to quantitatively assess the inter-sectoral structure of an economy and estimate how every sector of the economy is affected by external economic shocks. Network Theory, on the other hand, is a branch of mathematics that explores the abstract notion of *structure* found in many natural and social systems (Barabási, 2016; Estrada and Knight, 2015). With the Network Theory, we are able to explore the architectural characteristics of networks, and as a consequence, uncover their governing principles and tame the complexity of the systems under question.

In Chapter 3, I focus on the issue of sectoral market power in global production. As market power, the economics literature defines that ability of market participants to influence the price of a commodity, or any other market outcome linked to the allocation of resources. The chapter starts with an extended critical review of the literature on market power, beginning with theoretical approaches at the micro- and meso-level and moving to models and analytical frameworks that concentrate on the exploration of the global economy and international trade. In particular, I first review the three main theoretical traditions regarding the analysis of market power and competition, ranging from neoclassical perfect competitive markets to Kaleckian and Marxian/Classical theorizations. Next, I move to the assessment of the theoretical approaches of neoclassical trade models (Ricardian model and Heckscher-Ohlin-Samuelson model), the New Trade Theory school and the various heterodox attempts to formulate an alternative trade theory inspired by the Kaleckian and Classical traditions. Lastly, I review the interdisciplinary frameworks of GCCs, GVCs and GPNs, which shed light on the economic and non-economic implications of governance structures and globalization organization of production, and I engage with the literature of econophysics that incorporates analytical tools from SNA and IOA to the understanding of the complexity of internationally fragmented production.

Each of the above approaches has its own merits, along with important limitations with respect to the presence of a conceptualization of market power that will be meaningful for the analysis of global production, in the age of GVCs. For example, heterodox approaches to the conceptualization and exploration of market power and competition, stemming from the Kaleckian and Marxian traditions, have emphasized the importance of power relations between economic actors, highlighting the influence of oligopolies and oligopsonies on the formation of prices and the outcome of distributional conflicts. Nevertheless, even these approaches do not fully capture the complexities and scope of buyer-supplier relations. Whilst Kalecki's income distribution equation takes note of the importance of input materials costs – and consequently of the capitalist who produce and sell these input materials – the proposed measurement of the degree of monopoly, does not take into account the direct and indirect effects that the upstream and downstream partners of a firm might exert on it, with respect to its ability to influence prices and distributional outcomes.

Likewise, many international trade theoretical models, either from a neoclassical or post-Kaleckian perspective, have investigated the effects of globalization and offshoring, conceptualizing the international fragmentation of production, as the share of foreign inputs in total intermediate consumption of each sector. However, the lack of data on imported inputs at the sectoral level, has forced the adoption of additional restrictive assumptions (proportionality assumption) that heavily distort the picture of international fragmentation of production and obfuscate the relevant global industry-level buyer-supplier relationships that define the sectoral market power.

To address these issues, in this chapter, I draw on the literatures of political economy of trade focusing on a sectoral analysis and heterodox economics, combined with the burgeoning literatures of econophysics and Social Network Analysis (SNA), and provide a new conceptualization of market power in global production. In a global economy characterized by increasing geographical and functional fragmentation of production, where firms located in different tiers of complex GVCs, receive and provide inputs to other firms in different tiers, market power cannot be conceptualized with the conventional analytical tools of neoclassical microeconomics or other heterodox approaches (e.g., Kaleckian mark-ups, Marxian competition). Conceptually, I contend that an appropriate measure of sectoral market power within countries taking part in global production processes should take into account the market power dynamics across different levels of production. This is because the relative power of sectors located both upstream and downstream, will eventually determine the market power of the sector under consideration. Consequently, a proper measure of power should account for, not only how well connected one sector is with all the other sectors in an economy, but also how well connected are the other sectors connected to the former are. Moreover, a proper measure of market power should also consider the volume of transactions between sectors. These two key characteristics can be found in direct correspondence to a measure of network centrality that is called, PageRank (Page et al., 1999).

For the empirical analysis of this chapter, I utilise input-output data from the World Input-Output Database (WIOD). The WIOD (Timmer et al., 2015) provides time-series for input-output tables, at the global scale. This means that additionally to the national-level input-output tables, the WIOD provides information about the international trade flows between economic sectors in the world economy. In other words, with WIOD I are able to investigate not only the interconnectedness of an industrial sector with the rest of the economy in a particular country but also the linkages with buyers and suppliers, at the sectoral level, in other countries as well. Based on the information given by the WIOD, I am able to construct the global production network, with each node representing an economic sector within a country and each link representing inter-country and inter-sectoral linkages. The 2016 version, which I use in this chapter, covers 56 economic sectors (ISIC Rev.4) for 44 countries (including an estimate of the RoW), from 2000 to 2014, giving in total 2,408 country-sector observations per year. Additional to the annual input-output tables, the WIOD provides information - among others - about the Gross Operating Surplus (GOS) per sector in each country, as well as sectoral value-added. Based on these two variables, I calculate the yearly distribution of the sectoral relative profits.

The theoretical analysis of this chapter contributes to several literatures. First, it contributes to the Kaleckian/Post-Keynesian (Kalecki, 1938; Lavoie, 2014) and Marxian (Semmler, 1984; Shaikh, 2016; Tsoulfidis, 2015) literatures of market power, which conceptualize market power and theorize about social and distributional conflicts but lack a conceptualization of buyer-supplier power asymmetries. Second, it contributes to the analysis of international trade from the literatures of economics and macro-sociology (Feenstra and Hanson, 1999; Milberg and Winkler, 2013). As I argue, the former literature is dominated by trade models that assume unrealistic assumptions about the nature of the world economy, inspired by neoclassical economic theory. Third, it contributes to the literatures that follow the GVCs/GPNs frameworks (Coe and Yeung, 2015; Gereffi, 2018; Henderson et al., 2002) by highlighting the importance of sectoral level analysis in global production and introducing a measure of market power building on relevant network centrality concepts. These approaches talk about conflicts between actors within supply chains, but they usually underestimate the need for an index that properly captures these conflicts.

On an empirical level, based on a dataset of global input-output tables (Timmer et al., 2015), I observe that the sectoral relative profits and the PageRank centrality across sectors have heavy tails, and the graphs indicate power-law distributions. The distribution of the relative profits highlights that a small number of sectors has a relatively high share of profits and similarly that the (PageRank) centrality of most sectors is low. At the same time, for some, it is relatively high. The regression analysis assessing the power-law relationships between sectoral relative profits and centrality shows an exponent that is close to 4. This empirical observation demonstrates that a strong centralization incentive exists for economic sectors, globally, and hence for the firms that belong to each of these.

Chapter 4 concentrates on the exploration of the relationship between globalization, global production structures, labor bargaining power and income distribution, combining different theoretical approaches to globalization and labor bargaining power and investigating the structure of global production focusing on 40 countries from 1995 to 2009. The chapter starts with the critical assessment of the theoretical and empirical studies that explore the political economy of functional income distribution and the determinants of the labor share, either from an economic, sociological, or political science, perspective. This extensive - in disciplinary scope - literature has emphasized various determining mechanisms with respect to the share in national income, from technological change and automation to the impact of globalization, offshoring, international fragmentation of production and institutional factors, like a fall in the welfare state and the reduction in various dimensions of labor bargaining power.

Overall, there are two broad theoretical approaches to the issues of functional income distribution. In the first group, we find studies that utilize economic models of international trade and explore the effects of trade liberalization, offshoring and international fragmentation of production, on various measures of labor income and labor results. An important theoretical division exists within this group, with neoclassical models stressing the positive or relatively positive implications of globalization for the incomes of workers in advanced and emerging economies, and on the contrary, post-Keynesian and post-Kaleckian models finding evidence of a negative relationship. In the second group, we find studies inspired by the *power resources approach*, that is informed by labor sociology and political science and argues that labor market deregulation, welfare state retrenchment and the fall in union participation are responsible for the observed decreases in the labor income of advanced and emerging economies.

Both perspectives have several shortcomings. Even though they both acknowledge – arguably to a different degree – the explanatory value of labor bargaining power, they do not engage in a theoretical and empirical discussion that would allow the utilization of alternative dimensions of labor bargaining power in the analysis of the effects of globalization and vice versa. For example, the globalization approach tends to investigate technological attributes of economic systems and conceptualize globalization as foreign competition of imported goods and intermediate inputs, or as the degree of international fragmentation of production and supply chains, abstracting from the structural characteristics of global production systems. One implication of this shortcoming is that labor bargaining power is usually conceptualized in a rather narrow scope, proxied by union density rates and strike activity, and as a result failing to recognize alternative dimensions of labor power. Moreover, even if alternative dimensions of labor bargaining power are acknowledged, they are not fully incorporated into the empirical models that investigate the evolution and determinants of labor income shares. Lastly, both approaches seem to under-incorporate the international dimension of labor bargaining power and the fact that national economic systems and social formations become highly integrated into global supply chains.

In this chapter, I combine conceptual elements from the power resources approach and globalization literature to highlight a rather under-developed linkage, between the structural position of labor in production and supply chains and the process of international fragmentation of production. The key insight that is derived from this analysis is that the positional/structural labor bargaining power at the global level, matters for the outcomes of the distributional conflict. Whereas the heretofore literature on the subject, either ignores the role played by labor (see neoclassical theory) or conceptualizes labor bargaining power in a unidimensional way (PRA literature), this chapter draws inspiration from the power resources approach (Korpi, 1978, 1983, 1985; O'Connor and Olsen, 1998) and the globalization (Harrison, 2005; Onaran, 2009; Rodrik, 1997) literatures and reintroduces the notion of positional/structural labor bargaining power, at the global level and offers a practical method to quantify and measure it using international time-series of input-output data.

The research question that chapter 4 addresses with its empirical analysis is whether positional/structural bargaining power and labor outcomes hold a positive relationship at the global level. Applying the notion of positional/structural power of labor in the production process, that was introduced by the work of labor sociologists (Perrone et al., 1984; Silver, 2003; Wallace et al., 1989; Wright, 2000; Wright and Perrone, 1983), I compute estimates of positional/structural power of labor at the global level, utilizing global input-output tables, from the WIOD (Timmer et al., 2014). Additional to the annual input-output tables, the WIOD provides information - among others - about the labor compensation (LAB) of workers per sector in each country, as well as sectoral value-added. Based on these two variables, I calculated the labor share per country sector by dividing the sectoral LAB with the sectoral Value-Added. For example, in order to calculate the labor share of the chemicals sector in China, I divided the labor-bill (total amount of labor compensation) of the construction sector in China, by its respective value-added. The Socio-Economic Matrix that corresponds to the 2013 version of the WIOD input-output tables, includes information about the skill types of labor, distinguishing between low-, medium- and high-skilled labor. Low-level skill-type corresponds to primary and lower secondary education (ISCED-level 1 and 2), Medium-level skill-type to upper secondary and post-secondary education (ISCED-level 3 and 4), and High-level skill-type to first and second stage tertiary education (ISCED-level 5 and 6).

Building on these estimates I compute the impulse responses of panel data vector autoregressions models, using local projections and I find a strong and statistically significant relationship exists between the positional/structural power of labor and the share it receives as income from the national product, irrespective of the income level of the country under consideration. Controlling for the skills of laborers I also find empirical evidence for the so-called agency hypothesis, that states that workers employed at lower-skilled occupation, will tend to utilize more their positional/structural bargaining power. My results lead to the reinterpretation of many widely held views regarding the determinants of functional income distribution, shedding new light on the impacts of labor bargaining power on labor shares. Reflecting upon the empirical findings in the context of the discussion in the literature review section, the present chapter makes three contributions. The first is that it introduces an alternative dimension of labor bargaining power in the literature of globalization, operationalizing a proper measure of the global positional/structural power of labor. The second is that it extends that conceptualization of positional/structural power of labor accounting for the integration of the national economic and social formation in global supply chains. The third contribution is that I provide empirical evidence, at the global level, for the link between positional/structural labor bargaining power and labor's share of national income, whereas at the same time, controlling for the skill-type of labor, I were able to provide support in favor of the agency hypothesis (Wallace et al., 1989), using sectoral-global data.

In Chapter 5, I concentrate on a new path for the empirical and quantitative investigation of the structures that govern the value-added distribution among sectoral buyers-suppliers in global production. The chapter begins with an overview of the burgeoning literature that investigates structures of the phenomenon of international fragmentation of production and rise of GVCs. On the one hand, we find approaches that draw on the analytical tools of input-output analysis and graph-network theory, macroeconomists and trade economists focus on the trade relationships between national sectors and highlight the value-added that is captured in exports and imports of intermediate goods. Measuring how much of the value-added of a commodity or service, has been produced in other countries, gives important information regarding the depth of vertical specialization and which sectors and countries have the power to capture amounts of value-added. Countries that exhibit a decreasing share of domestic value-added in their exports will tend to be heavily integrated in internationally fragmented production processes and become members of complex GVCs. On the other hand, there are studies that concentrate on the analysis of the network structure of global production, conceptualizing the world economy as interrelated and interconnected production network, with sector-countries represented as nodes and their transactions as links, and experiment with measures of network statistics that shed light on the structural position of economic actors, such as, centrality, assortativity, clustering, interrogating economic theoretical research questions, regarding the identification of key sectors in the economy or the propagation of economic shocks within an economic network.

Informed by the growing literature on economic network and complex analysis, and particularly the methodology of global value trees proposed by Zhu, et al. (2015), I analyze the topological characteristics of GVCs with respect to the hierarchicality of the structures of sectoral buyer-supplier relationships. Whereas the latters' work is an invaluable, methodological, and empirical, contribution to the analysis of the hierarchicality of sectoral buyer-supplier relations, we still lack a cross-border, inter-sectoral and inter-temporal examination of the topological properties of global supply chains. Utilizing a dataset of Global Multi-Regional Input-Output Tables (Lenzen et al., 2013), I estimate a global network of value-added transfers, with each node representing a different sector in a specific country, and each link the value-added contribution of the supplier to the final demand of the buyer. The latter, define a Global Value Tree (GVT), which is a subgraph of GVCs, connecting value-added flows from the supplying (upstream) industries to the buying (downstream) industries. Within this context, three configurations of GVCs topologies are considered: a) a star-like topology in which suppliers feed-in their value-added included into their input goods and services into one assembly, b) a chain-like topology in which value-added is transferred sequentially into the final use and c) a tree-like topology that combines elements from both star- and chain-like topologies and its structure is arranged like the branches of a tree.

The research questions this chapter addresses are two. First, is a tree-like topology a universal attribute of GVCs that characterizes the structure of their supply chains across space and time. Second, what is the geographical distribution of the hierarchicality of global supply chains in the world economy and how it has evolved in the last decades. Does the hierarchicality of GVCs show a clear trend across time and space? The empirical observations highlighted in this chapter provide evidence for a clear decreasing trend in the global degree of hierarchicality that characterizes the totality of GVCs in the world economy. In other words, the topological structures of GVTs and consequently of the supply chains and the buyer-supplier relationships, become less hierarchical. Moreover, the results show that the tree-topology of the supply-chain structure of the GVCs is a universal attribute across time, since the degree of hierarchicality fluctuates only between the boundaries of a tree-topology, for the last 25 years.

The contributions of this paper are twofold. First, it expands the scope of the literature of complex system analysis and social-economic network analysis, by empirically investigating the evolution of the topological characteristics of GVCs, based on a large database of global input-output data. Whereas previous research has assessed the topological characteristics of GVCs using global input-output tables covering 40 countries and a proxy for the rest of the world, the present study utilizes a richer data source, the EORA MRIO, which comprises of sectoral data covering 190 countries. Second, the paper provides empirical evidence for the universal scaling behavior of GVTs, which follows a tree-like topology, as well as the spatiotemporal evolution of the hierarchicality of sectoral buyer-supplier relationships.

Chapter 2: Fundamental Concepts of Input-Output Analysis and Network Theory

This chapter offers a brief introduction to the fundamental concepts and analytical tools of Input-Output Analysis and Network Theory. Input-Output Analysis (IOA) provides the framework for the exploration of inter-industry relations in an economy. Developed by Wassily Leontief (1936) in the 1930s, the fundamental structure of IOA consists of information regarding the production (output) and consumption (inputs) of goods and services in a specific economy. In turn, this information composes the Input-Output Table (IOT), which is a system of linear equations distinguishing economic transactions between their uses, that is the demand for commodities/services, and their sources, the supply of commodities (Miller & Blair, 2009).

Network Theory is the branch of mathematics that investigates the abstract notion of *structure* found in many natural and social systems. According to Barabási (2016) “the architecture of networks emerging in various domains of science, nature, and technology are similar to each other, a consequence of being governed by the same organizing principles” (2016, p. 27), implying that with the appropriate mathematical tools we will be able to explore the architectural characteristics of networks, and as a consequence, uncover their governing principles and tame the complexity of the systems under question. Network theory, building upon the mathematical base of *Graph Theory* and *Topology* and borrowing the analytical toolkit of *Statistical Physics*, provides scientists with a plethora of quantitative and qualitative measurements, regarding the structural properties of natural and social networks. Formally, as a network we define “a collection of points joined together in pairs by lines” (Newman, 2010, p. 1), where each point (also known as a *node* or a *vertex*) represents an object of interest, for instance, a social subject, a biological unit or a physical object, and each line (also known as a *link* or an *edge*) expresses the relationship that 'joins together' the respective points.

2.1 The Input-Output Structure of an Economy

		Consuming Industries	Final Demand	Total
		Sector 1 Sector 2 Sector 3 Sector 4 ... Sector n-1 Sector n	Consumption Investment Government Expenditures Net Exports	
Producing Industries	Sector 1 Sector 2 Sector 3 Sector 4 ... Sector n-1 Sector n	Intermediate Demand	Final Demand	Gross Output
Value - Added	Wages Profits Taxes	Value-Added	GDP	
Total		Gross Output		

Figure 2-1 Schematization of an Input-Output Transactions Table

Source: Adopted by (Miller & Blair, 2009, p. 3)

In Figure 2-1, I present an exemplified version of an IOT. Each row depicts the sources of economic activity, that is the value of goods and services produced by each sector and then used either as an input for the production of other commodities or as final products for consumption. Likewise, each column represents the uses of economic activity or the number of inputs demanded from all the other sectors in an economy, as well as, the number of labour and capital used for production. Naturally, we can envision the IOT as the combination of four sub-matrices: the Intermediate Demand

(***Z***), which consists of the inter-industry transactions between sectors; the Final Demand (***F***), which records the sales of products and services to final markets, breaking the respective amounts into the final demand components of Consumption, Investment, Government Expenses and Net Exports; the Value-Added (***V***), which accounts for the non-industrial inputs of the production process; and the Gross Output (***X***), which expresses the total output of the economy, produced and consumed, in gross terms.

Denoting n the number of sectors in an economy, i the supplying and j the demanding sectors, we can compute the value of gross output of each sector by appropriately summing row-wise or column-wise the respective matrices. For instance, taking into account the demand-side of the economy, we can calculate the value of gross output of sector i as the row-wise summation of the intermediate demand matrix, Z_{ij}, plus the value of sector i's products purchased in the final market, as demand F_i:

$$X_i = Z_{i1} + Z_{i2} + \dots + Z_{in} + F_i = \sum_{j=1}^{n} Z_{ij} + F_i \qquad (2\text{-}1)$$

Likewise, computing the value of gross output of sector j from the supply-side of the economy, we sum the intermediate demand matrix, Z_{ij}, column-wise, and we add the value of non-industrial inputs, captured by the components of Value-Added, V_j, that is wages, profits and taxes:

$$X_j = Z_{1j} + Z_{2j} + \dots + Z_{nj} + VA_j = \sum_{i=1}^{n} Z_{ij} + V_j \qquad (2\text{-}2)$$

Equations (2-1) and (2-2)can be also written in matrix form. Assuming that lower-case bold letters represent column-vectors and upper-case bold letters matrices, the following definitions apply:

$$\boldsymbol{x} = \begin{bmatrix} x_1 \\ \vdots \\ x_n \end{bmatrix}, \quad \boldsymbol{Z} = \begin{bmatrix} Z_{11} & \cdots & Z_{1n} \\ \vdots & \ddots & \vdots \\ Z_{n1} & \cdots & Z_{nn} \end{bmatrix}, \quad \boldsymbol{f} = \begin{bmatrix} f_1 \\ \vdots \\ f_n \end{bmatrix}, \quad \boldsymbol{v} = \begin{bmatrix} v_1 \\ \vdots \\ v_n \end{bmatrix} \tag{2-3}$$

with $\boldsymbol{x}$ being the column-vector of gross output (with its transpose, $\boldsymbol{x'}$, being the respective row-vector), $\boldsymbol{Z}$ the matrix of intermediate demand, $\boldsymbol{f}$ the final demand vector, and $\boldsymbol{v}$ the value-added vector. Then the demand-side and supply-side equations of the input-output framework can be written as:

$$\boldsymbol{x} = \boldsymbol{Zi} + \boldsymbol{f} \tag{2-4}$$

and

$$\boldsymbol{x}' = \boldsymbol{i}'\boldsymbol{Z} + \boldsymbol{v}' \tag{2-5}$$

The column-vector $\boldsymbol{i}$ (and the respective row-vector $\boldsymbol{i'}$), is the appropriately sized summation vector, a vector of 1's, which is used in linear algebra for row-wise (column-wise) summation processes. For instance, if we post-multiply the matrix $\boldsymbol{Z}$, in (2-4) with the summation column-vector $\boldsymbol{i}$, we find a column-vector with each element being the sum of rows of $\boldsymbol{Z}$. Equally, if we pre-multiply matrix $\boldsymbol{Z}$, in (2-5) with row-vector $\boldsymbol{i'}$, we find a row-vector with each element being the sum of the columns of $\boldsymbol{Z}$.

Dividing each column of the intermediate demand matrix, $\boldsymbol{Z}$, by the gross output of the consuming sectors, we find the matrix of Technical or Input or Direct Requirements Coefficients, $\boldsymbol{A}$. This matrix is composed by the quantities (in monetary values) of goods and services that an economy needs in order to produce one unit of output. In other words, with the technical coefficients' matrix, $\boldsymbol{A}$, we have a clear picture of the shares of inputs that have been used in the multiple production processes consisting of a particular economy. Similarly, we can divide each row of $\boldsymbol{Z}$, by the value of gross output of the producing sectors, in order to construct the Output or Allocation Coefficients matrix, $\boldsymbol{B}$, which shows the quantities of goods and services that have been produced by sector i and purchased by sectors j as inputs in their respective production processes. In other words, matrix $\boldsymbol{B}$ concentrates all the information for the distribution of sector *i*'s production among all the other sectors, *j*, of an economy. Mathematically, we can express the input and output coefficients matrices, as:

$$\boldsymbol{A} = \left\{a_{ij} = Z_{ij}/X_j\right\} = \boldsymbol{Z}\hat{\boldsymbol{x}}^{\boldsymbol{-1}} \qquad (2\text{-}6)$$

and

$$\boldsymbol{B} = \left\{b_{ij} = Z_{ij}/X_i\right\} = \hat{\boldsymbol{x}}^{\boldsymbol{-1}}\boldsymbol{Z} \qquad (2\text{-}7)$$

where, $\hat{\boldsymbol{x}}^{\boldsymbol{-1}}$ is the inverse of the diagonal matrix, whose all off-diagonal elements are equal to zero, and all the elements on the main diagonal are equal to $1/x_i$:

$$\hat{\boldsymbol{x}}^{\boldsymbol{-1}} = diag\left\{\frac{1}{X_i}\right\} = \begin{bmatrix} {}^{1}\!/_{X_1} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & {}^{1}\!/_{X_n} \end{bmatrix} \qquad (2\text{-}8)$$

This inverse diagonal matrix has a very nice property that is extensively used in input-output analysis for the computations of column- or row-wise division of a matrix. In particular, if we want to divide each column of matrix $\boldsymbol{Z}$, by the gross output of the consuming sectors, we simply have to post-multiply $\boldsymbol{Z}$ with $\hat{\boldsymbol{x}}^{\boldsymbol{-1}}$, as in (2-6). Equally, as in (2-7), if we want to divide each row of $\boldsymbol{Z}$ by the gross output of producing sectors, we have to pre-multiply $\boldsymbol{Z}$ with $\widehat{\boldsymbol{x}}^{-\mathbf{1}}$.

Based on the aforementioned matrices of input *(**A**)* and output *(**B**)* coefficients, the literature of input-output analysis has developed two different, but comparable, approaches: the Demand-Driven (or Standard Leontief) and the Supply-Driven (or Ghoshian) models. The demand-driven model asserts that sectoral output is determined by the demand for intermediate and final goods and services, assuming that the input coefficients matrix is constant. In the supply-driven model, on the other hand, sectoral output is being determined by the supply of intermediate inputs, as well as, the supply of the primary inputs, namely labour and capital, assuming that the output coefficients matrix is constant. Formally, the demand-driven approach is represented by the combination of equations (2-4) and (2-6), as:

$$\boldsymbol{x} = \boldsymbol{A}\boldsymbol{x} + \boldsymbol{f} \tag{2-9}$$

Equation (2-9) can be solved for the gross output vector $\boldsymbol{x}$, assuming that $\boldsymbol{I}$ is the identity matrix and $(\boldsymbol{I} - \boldsymbol{A})^{-\mathbf{1}}$ is non-singular, thus invertible. The solution, then, is given by:

$$\begin{gathered}(\boldsymbol{I} - \boldsymbol{A})\boldsymbol{x} = \boldsymbol{f} \\ \boldsymbol{x} = (\boldsymbol{I} - \boldsymbol{A})^{-1}\boldsymbol{f} = \boldsymbol{L}\boldsymbol{f}\end{gathered} \tag{2-10}$$

where $(\boldsymbol{I} - \boldsymbol{A})^{-\mathbf{1}} = \boldsymbol{L} = \{l_{ij}\}$ is the Leontief Inverse matrix. The supply-driven approach can be represented by the combination of equations (2-5) and (2-7), as:

$$\boldsymbol{x}' = \boldsymbol{x}'\boldsymbol{B} + \boldsymbol{v}' \tag{2-11}$$

The solution of equation (2-11) for the gross output vector, assuming that $(\boldsymbol{I}-\boldsymbol{B})^{-\mathbf{1}}$ is non-singular, is given by:

$$\boldsymbol{x}'(\boldsymbol{I}-\boldsymbol{B})=\boldsymbol{v}'$$

$$\boldsymbol{x}'=\boldsymbol{v}'(\boldsymbol{I}-\boldsymbol{B})^{-\mathbf{1}}=\boldsymbol{v}'\boldsymbol{G} \tag{2-12}$$

where $(\boldsymbol{I}-\boldsymbol{B})^{-\mathbf{1}}=\boldsymbol{G}=\{g_{ij}\}$ is the Ghoshian Inverse matrix. Building on the Leontief and Ghoshian inverse matrices, the behaviour of gross output can be analysed, given some exogenous change in either the final demand or the primary inputs (capital and labour). For example, according to equation (2-13), if final demand increases by 1 unit, it will induce an increase not only in the production of final products (which is captured by the term $\boldsymbol{I}\cdot\boldsymbol{\Delta f}$), but also in the demand for inputs (captured by the term $\boldsymbol{A}\cdot\boldsymbol{\Delta f}$), which in turn induces the production of those inputs from the input-producing sectors of the economy (captured by the term $\boldsymbol{A}^{\mathbf{2}}\cdot\boldsymbol{\Delta f}$), and so on. The result will be a total increase of $\boldsymbol{L}\%$ in the gross output of the whole economy.

$$\boldsymbol{\Delta x}=\boldsymbol{L\Delta f}=(\boldsymbol{I}-\boldsymbol{A})^{-\mathbf{1}}\boldsymbol{\Delta f}=(\boldsymbol{I}+\boldsymbol{A}+\boldsymbol{A}^{\mathbf{2}}+\boldsymbol{A}^{\mathbf{3}}+\cdots)\boldsymbol{\Delta f} \tag{2-13}$$

Similarly, the Ghoshian inverse matrix captures the direct and indirect effects of a change in the value of primary inputs on gross output. An increase of 1 unit in the value of, for example, labour, induces, through the higher valued sales of producing sectors to consuming sectors, a $\boldsymbol{G}\%$ increase in the economy's value of gross output.

$$\boldsymbol{\Delta x}'=\boldsymbol{\Delta v}'\boldsymbol{G}=\boldsymbol{\Delta v}'(\boldsymbol{I}-\boldsymbol{B})^{-\mathbf{1}}=\boldsymbol{\Delta v}'(\boldsymbol{I}+\boldsymbol{B}+\boldsymbol{B}^{\mathbf{2}}+\boldsymbol{B}^{\mathbf{3}}+\cdots) \tag{2-14}$$

In other words, the Leontief and Ghoshian inverses represent the sector-to-sector multipliers for the input (demand) and output (supply) models discussed above. In particular, each element of the Leontief inverse, l_{ij}, measures the multiplying effect of one-unit change in the final demand of sector j (columns) on the gross output of sector i (rows). Equally, each element of the Ghoshian inverse, g_{ij}, measures the multiplying effect of one-unit change in the primary inputs of sector i (rows) on the gross output of sector j (columns). If we add the elements of each column in the Leontief and respectively each row in the Ghoshian, we get the vectors of output and input multipliers for the whole economy.

$$\boldsymbol{L} = \begin{bmatrix} l_{11} & \cdots & l_{1n} \\ \vdots & \ddots & \vdots \\ l_{n1} & \cdots & l_{nn} \end{bmatrix} \ \textit{and} \ \ \boldsymbol{G} = \begin{bmatrix} g_{11} & \cdots & g_{1n} \\ \vdots & \ddots & \vdots \\ g_{n1} & \cdots & g_{nn} \end{bmatrix} \qquad (2\text{-}15)$$

Many economists have proposed extensions to the fundamental input-output framework, introducing sophisticated analytical tools in order to understand the complexities and the interconnected nature of capitalist economies. One such interpretation of the Leontief and Ghoshian matrices was given by the analysis of the inter-industry linkages and economic connectedness (Chenery & Watanabe, 1958; Dietzenbacher, 1992; Hirschman, 1958; Jones, 1976; Laumas, 1976; Rasmussen, 1956; Yotopoulos & Nugent, 1973). Defining as *Backward Linkages* (BL) the degree of dependence of sector j on the input-producing sectors i and conversely as *Forward Linkages* (FL) the dependence of sector i on the input-consuming sectors j, scholars in the IOA tradition have proposed various measures for identifying important sectors in an economy.

The identification, in turn, of those key-sectors allows for an in-depth analysis of the structural characteristics of an economy and, consequently, the design of more effective and targeted macroeconomic and investment policies. For example, policies that focus on the expansion of sectors with high BL and/or FL become more beneficial for the national economy, since they induce higher economic activity both upstream (through input demand) and downstream (through input supply). Several measures have been proposed in the literature, summarized in **Table 2-1**. Whereas early approaches to the measurement of BL and FL were concentrating on the column- and row-wise manipulation of either the Input Coefficients or the Leontief Inverse matrices, since Jones' (1976) article in the *Quarterly Journal of Economics*, a consensus has been reached in the literature as to define backward and forward linkages in a symmetrical way, employing both the Leontief (backward) and Ghoshian (forward) linkages.

Table 2-1 Measures of Backward and Forward Linkages

Authors	Backward Linkages	Forward Linkages
(Rasmussen, 1956) (Hirschman, 1958)	$\boldsymbol{BL} = \boldsymbol{i}'\boldsymbol{L}$	$\boldsymbol{FL} = \boldsymbol{L}\boldsymbol{i}$
(Chenery & Watanabe, 1958)	$\boldsymbol{BL} = \boldsymbol{i}'\boldsymbol{A}$	$\boldsymbol{FL} = \boldsymbol{A}\boldsymbol{i}$
(Hazari, 1970) (Laumas, 1976)	$\boldsymbol{BL} = \boldsymbol{i}'\left(\boldsymbol{L} \circ \frac{\boldsymbol{f}'}{\boldsymbol{i}'\boldsymbol{f}}\right)$	$\boldsymbol{FL} = \left(\boldsymbol{L} \circ \frac{\boldsymbol{f}'}{\boldsymbol{i}'\boldsymbol{f}}\right)\boldsymbol{i}$
(Jones, 1976)	$\boldsymbol{BL} = \boldsymbol{i}'\boldsymbol{L}$	$\boldsymbol{FL} = \boldsymbol{G}\boldsymbol{i}$
(Dietzenbacher, 1992)	$\boldsymbol{BL} = \frac{\boldsymbol{1}}{\boldsymbol{\lambda_{max}}}\boldsymbol{i}'(\boldsymbol{A} \circ \boldsymbol{BL})$	$\boldsymbol{FL} = \frac{\boldsymbol{1}}{\boldsymbol{\lambda_{max}}}(\boldsymbol{B} \circ \boldsymbol{FL})\boldsymbol{i}$

Source: Own Illustration

2.2 Network Theory

I denote a network as $G(N, L)$, with N being the number of nodes, L the number of links and G representing the function of the collection of nodes and links forming a particular network. We usually distinguish between *directed* and *undirected* networks, with the former having links that point to a direction, and the latter having links that simply connect nodes, without any directional characteristic. Another important analytical distinction in network theory is between *weighted* and *unweighted* networks. In weighted networks, the links connecting two nodes have some relative importance or weight, giving to some connections a higher relative value compared to others. In the case of unweighted or *binary* networks, the links simply represent the presence of a connection between two nodes. Mathematically, a network can be expressed through the *Adjacency Matrix*. As an adjacency matrix we define the square, non-negative, matrix, with N rows and N columns, that takes the value of 1, whenever a link exists that connects node i with node j, and the value 0, otherwise:

$$A_{ij} = \begin{cases} 1, if\ there\ is\ a\ link\ between\ i\ to\ j \\ 0, otherwise \end{cases} \tag{2-16}$$

An adjacency matrix of that binary form will represent an unweighted network, since the elements of the matrix take only the values of 1 and 0, according to the presence or absence of a link connecting the respective nodes. In the case of a weighted network, where links represent the relative importance and value of the connection between two nodes, the element of the adjacency matrix reflect these values:

$$weighted\ A_{ij} = W_{ij} \tag{2-17}$$

where matrix W_{ij} is the weighted adjacency matrix, with elements the weights w_{ij}, representing the relative importance of the connection between node i and j. The properties of the adjacency matrix also vary in the cases of directed and undirected networks. When we are dealing with an undirected network the square adjacency matrix is also a symmetric matrix, meaning that $A_{ij} = A_{ji}$, a property that does not hold in directed networks, in which the element A_{ij} represents, if there exists, the directed connection from node i to node j, while element A_{ji}, the directed connection from node j to node i, hence $A_{ij} \neq A_{ji}$.

The adjacency matrix acts as the mathematical counterpart of a network that might have thousands of nodes and millions of links. In the form of a mathematical matrix, the shape and consequently the properties of any network can be easily stored and analyzed. Network theory offers a multitude of empirical tools for the analysis of the structural properties of complex systems that take the form of a network. Among the most basic parameters of a network are the *Path*, the *Distance* (or *Shortest Path* or *Geodesic Path*), the *Diameter*, the *Average Path Length* (APL) and the *Degree* (Barabási, 2016; Estrada, 2011; Newman, 2010). With path we define the "route across the network that runs from vertex to vertex along the edges of the network" (Newman, 2010, p. 136) and with *Path Length* the number of the links of the path. The shortest of the paths between two nodes i and j is the distance (*dist*). Then the diameter is defined as the largest distance found in the network and the *APL* as the average distance, that is:

$$APL = \frac{\sum_{i \neq j} dist(i,j)}{N(N-1)} \tag{2-18}$$

with $dist(i,j)$ measuring the distance (shortest path) between nodes i and j. The number of links of each node is measured by degree, perhaps the most important measurement of network characteristics. Denoting with k_i the number of links connected to node i, degree is calculated as:

$$k_i = \sum_{i=1}^{N} A_{ij} = \sum_{j=1}^{N} A_{ij} \tag{2-19}$$

This formula measures the total number of links that are connected to node *i*, in the case of an undirected network. It is obvious that since we are indifferent for the direction of the links connecting the nodes, we are allowed to calculate the degree of a node by summing the adjacency matrix, either row-wise or column-wise. For directed networks, we have to distinguish between incoming and outgoing links and thus introduce two types of degrees, the *In-Degree*, that counts all the links that point to node *i*, and *Out-Degree*, which counts the outgoing links from node *i*. Equally, *Total-Degree* is simply the sum of the two-directional measures of the number of links:

$$k_i^{in} = \sum_{j=1}^{N} A_{ij}\,, \qquad k_j^{out} = \sum_{i=1}^{N} A_{ij}\,, \qquad x_i^{total} = x_i^{in} + x_j^{out} \tag{2-20}$$

The total number of links, L, in a network with N nodes, is proportional to the sum of degrees of all the nodes. However, in the case of undirected networks, it is reasonable to control for the fact that each pair of nodes is only connected with one link. Thus, for undirected network, the total number of links is given by half the sum of nodes' degree, as in (2-21):

$$L_{undirected} = \frac{1}{2}\sum_{i=1}^{N} k_i = \frac{1}{2}\sum_{j=1}^{N} k_j = \frac{1}{2}\sum_{ij}^{N} A_{ij} \tag{2-21}$$

On the contrary, in the case of a directed network, the total number of links is either the sum of nodes' in-degree reflects or that of out-degree, like (2-22):

$$L_{directed} = \sum_{i=1}^{N} k_i = \sum_{j=1}^{N} k_j = \sum_{ij}^{N} A_{ij} \tag{2-22}$$

Similarly, the average degree of a network can be computed for the two cases of undirected and directed networks, given (2-21) and (2-22), as:

$$\bar{k} = \frac{\sum_{i=1}^{N} k_i}{N} = \frac{2 \bullet L_{undirected}}{N} \tag{2-23}$$

and

$$\bar{k}^{in} = \bar{k}^{out} = \frac{\sum_{j=1}^{N} k_j}{N} = \frac{\sum_{i=1}^{N} k_i}{N} = \frac{L_{directed}}{N} \tag{2-24}$$

Another group of measures focuses on the relational properties formed between the nodes of a network. In this group, we find *Transitivity*, *Reciprocity, Connectance* (or *Density*) and *Homophily.* With transitivity we simply define the situation in which 'the friend of my friend is also my friend', meaning that whenever a node *i* is linked with node *j*, and node *j* is connected with node *k*, then there is also a link connecting nodes *i* and *k*. Transitivity in other words expresses the likelihood to find highly connecting nodes in a network and can be quantified with a measure called *Clustering Coefficient* (Newman, 2010). The literature distinguishes between three forms of clustering coefficient, the *Local Clustering Coefficient (*C_i*)*, which is defined at the level of a node as the ratio of the number of paired neighbouring nodes of node *i*, that are linked, the *Average Clustering Coefficient (*$C_{average}$*)*, and the *Global Clustering Coefficient (*C_{global}*)*, which generalizes the local clustering coefficient to the whole network, by measuring the "frequency with which loops of length three—triangles—appear in a network" (Newman, 2010, p. 204). Equations (2-25), (2-26) and (2-27) give the formal expressions of the three forms of clustering coefficient:

$$C_i = \frac{\#\ connected\ paired\ neighbors\ of\ i}{\#\ paired\ neighbors\ of\ i} \tag{2-25}$$

$$C_{average} = \frac{\sum_{i=1}^{N} C_i}{N} \tag{2-26}$$

$$C_{global} = \frac{3 \bullet (\#\ triangles)}{\#\ connected\ triples} \tag{2-27}$$

where the symbol *(#)* is the number of paired nodes neighbouring node i, the *triangle* is a path that links three nodes and the connected *triples* are "an ordered set of three nodes ABC such that A connects to B and B connects to C" (Barabási, 2016, p. 70). A property very similar to transitivity is that of reciprocity, which measures how often we observe reciprocal relationships formed between the nodes of a network, or in network theory terminology, how often we see the formation of *doubles*, pairs of nodes that point to each other with directed links. Mathematically, reciprocity, denoted with r, is measured with the following expression:

$$r = \frac{\sum_{ij} A_{ij} A_{ji}}{L} \tag{2-28}$$

where L is the total number of links in the network and the expression $A_{ij}A_{ji}$ takes the value of 1, whenever a directed link connects node i to j and at the same time node j to node i, and 0, otherwise. Connectance, or density, measures how many links exist in a network compared to the maximum possible links that can be formed with a given number of nodes. Density reflects how much connected a network's nodes are and is calculated as:

$$desnity = \frac{L}{L_{max}} = \frac{L}{\frac{1}{2}N(N-1)} = \frac{2L}{N(N-1)} \tag{2-29}$$

where L is the number of links, N is the number of nodes and L_{max} is the maximum number of links for a given number of nodes, $L_{max} = \binom{N}{2} = \frac{1}{2}N(N-1)$.

The property of homophily (or *Assortative Mixing*) reflects situations found in networks where particular nodes have the "strong tendency to associate with others whom they perceive as being similar to themselves in some way" (Newman, 2010, p. 222). For example, we might find social situations with people forming closer economic and political relationships with other people that belong to the same racial, ethnic, or other groups. The opposite tendency, that of forming relationships with nodes that do not share similar characteristics to yours, is called *Disassortative Mixing.* We usually measure assortativity with Modularity, Q, which takes the following mathematical expression:

$$Q = \frac{1}{2L}\sum_{ij}(A_{ij} - \frac{k_i k_j}{2L})\delta(c_i, c_j) \qquad (2\text{-}30)$$

where A_{ij} is the adjacency matrix of the network, L is the number of links, k_i and k_j the degree measurements for nodes i and j, c_i and c_j, are the communities in which nodes i and j belong, respectively, and the expression $\delta(c_i,c_j)$ is *Kronecker's delta*, which takes the value of 1 whenever nodes i and j belong to the same community, that is when $c_i = c_j$.

The importance, power or influence those certain nodes acquire due to their particular position they hold in relation to the whole network structure, is conceptualized and analyzed, through the notion of *'node centrality'.* Centrality is a critical concept in the analysis and understanding of the structural characteristics of a network and network theory offers a variety of definitions and measures, each shedding light on "different aspects of the position that a node has, which can be useful when working with information flows, bargaining power, infection transmission, influence and other sorts of important behaviors on a network" (Jackson. 2008, p. 62).

The most commonly used centrality measure is that of *Degree Centrality*, which simply assigns high centrality scores to those nodes that have larger degrees. So, for instance, if node *i* has a higher degree than node *j*, then it is the former that is characterized as more central than the latter. It is obvious that the distinction of degree measurements between undirected and directed networks (in-degree and out-degree), applies in the case of degree centralities, as well. In case that the network under examination happens to be weighted, then degree centralities become *Strength* centralities and measure the weighted sum of the links a node has formed with other nodes in a network. Consequently, if we denote the centrality measurement of node *i* as x_i, we have degree centralities expressed by (2-31), and strength centralities by (2-32):

$$x_i^{in} = \sum_{j=1}^{N} A_{ij} \,, \qquad x_j^{out} = \sum_{i=1}^{N} A_{ij} \,, \qquad x_i^{total} = x_i^{in} + x_j^{out} \tag{2-31}$$

$$x_i^{in} = \sum_{j=1}^{N} W_{ij} \,, \qquad x_j^{out} = \sum_{i=1}^{N} W_{ij} \,, \qquad x_i^{total} = x_i^{in} + x_j^{out} \tag{2-32}$$

Another family of centrality measures, while building on the notion of degree and strength centralities, it also concentrates on the 'relative influence' of the nodes with which each node establishes relations through links. In other words, these 'influence measures' focus on "the premise that a node's importance is determined by how important its neighbours are" (Jackson, 2008, p.65). The logic behind these measures is simple. These centrality measures quantify the importance of each node by counting the degree/strength centralities of each node and then adding an extra component that reflects the relative importance of the nodes with which the initial node has formed links. In this family of centrality measures, we find the *Eigenvector*, the *Katz*, the *PageRank* and *Kleinberg's* centralities. Eigenvector centrality is defined as the sum of the number/weight of links of node i, weighted by the centrality of the neighbouring node j:

$$x_i = \frac{1}{\lambda_{max}} \sum_{j=1}^{N} A_{ij} x_j \qquad (2\text{-}33)$$

Thus, node i gains more weight in terms of centrality scores, if it is connected to more connected nodes, which themselves have higher centralities. The name 'eigenvector' comes from the fact that in matrix notation the formula of eigenvector centrality can be written as a classical eigenvector-eigenvalue problem. An eigenvector-eigenvalue problem takes the form $Ax = \lambda x$, with A being a squared matrix, x a vector and λ a scalar. The vector and scalar that satisfies the equation, are called eigenvector and eigenvalue, respectively. In our context, the vector x expresses centrality scores and matrix A is the adjacency matrix of the network. According to the Perron-Frobenius Theorem, since the adjacency matrix A is, by definition, a non-negative matrix, since all its elements are either zero or positive, it is guaranteed that the largest eigenvalue, λ_{max}, corresponds to a unique and positive eigenvector. This eigenvector was introduced by Bonacich (P. Bonacich, 1987) as the eigenvector centrality score of node i, in a network. In the case of directed networks, we have to distinguish between the left- and the right-eigenvectors, each expressing the directional characteristics of node's i, neighbours. The left-eigenvector ($x'A = x'\lambda$) takes into account the centrality scores of those neighbouring nodes that have established outgoing links, that is they receive from node i. On the other hand, the right-eigenvector ($Ax = \lambda x$) focuses on the centrality scores of those neighbouring nodes that point towards node i, namely, they have established outgoing links. In the literature, it is the right-eigenvector that is usually used for the calculation of the eigenvector centrality in directed networks.

A variant of the eigenvector centrality is Katz centrality. Katz centrality simply adds to eigenvector centrality a constant, in order to overcome the problems arising with eigenvector centrality definition in directed networks. According to Newman (2010), in directed networks, if a node has only outgoing links and no incoming, then based on (2-33), that node will be assigned with zero centrality, since no other node points to that. Katz centrality 'corrects' this deficiency of eigenvector centrality, by assigning to each node, not only the normal eigenvector score but also a constant, β. Specifically, Katz centrality is defined as:

$$x_i = \alpha \sum\nolimits_j A_{ij} x_j \ + \beta \tag{2-34}$$

where x_i is Katz centrality of node i, x_j the centrality score for node j, A_{ij} the adjacency matrix and a and β the constant parameters. A very similar reformulation of the eigenvector centrality was introduced by the founders of Google search engine, Larry Page and Sergey Brin, who developed, along with Rajeev Motwani and Terry Winograd, a computer algorithm for rating and ranking webpages based on their importance (Page et al., 1999). PageRank centrality is very similar to Katz centrality, but instead of calculating a centrality score proportional to the centrality of neighbouring nodes, it normalizes the effects of those nodes that have a large number of outgoing links. In particular, PageRank changes the way eigenvector term is calculated by dividing the centrality score of neighbouring nodes with their respective out-degree:

$$x_i = \alpha \sum\nolimits_j A_{ij} \frac{x_j}{deg_j^{out}} \ + \beta \tag{2-35}$$

with x_i and x_j being the centralities of nodes i and j and a and β the constant parameters. In that way, PageRank centrality reduces the amount of centrality that large out-degree nodes transfer to the centrality score of node i.

The last centrality measure from the 'influence' family that I will focus on is Kleinberg's, Authorities and Hubs, centralities. Kleinberg thought of the problem of measuring node centralities in terms of the directional characteristics of the links in a network. For that reason, he distinguished between nodes that many other nodes point to, which he called Authorities, and nodes in a network that have the characteristic to point to other nodes, the Hubs. Based on the aforementioned distinction, Kleinberg (Kleinberg, 1999) introduced two types of centrality measures, the authority and hubs centralities, calculated as the proportional sum of each other. More specifically, he defined authority and hubs centralities of node i, as:

$$x_i = a \sum\nolimits_j A_{ij} y_j \qquad (2\text{-}36)$$

$$y_i = \beta \sum\nolimits_j A_{ij} x_j \qquad (2\text{-}37)$$

where x_i and y_i represent the authority and hubs centrality scores of node i, x_j and y_j the authority and hubs centrality scores of node j, and a and β are constants. The calculation of Kleinberg's centralities boils down to an eigenvector-eigenvalue problem, in which authority and hubs centralities are the eigenvectors of the AA' and $A'A$ matrices, respectively, sharing the common maximum eigenvalue.

The last centrality measures that I will explore, that is *Closeness* and *Betweenness* centralities, belong to a family of measures that focus on the distance characteristics of the linkages formed between a network's nodes. Closeness centrality measures the average distance (shortest path) between a node and all the other nodes in a network, giving a higher centrality score to those nodes that belong, on average, closer to the vast majority of the network's nodes. If $dist_i^{average}$ is the average distance of node *i*, from all the other nodes of in a network and *dist(i,j)*, the distance, that is the shortest path, between nodes *i* and *j*, then closeness centrality is formally defined as:

$$x_i = \frac{1}{dist_i^{average}} = \frac{N}{\sum_{j \neq i}^{N} dist(i,j)} \tag{2-38}$$

where, x_i is closeness centrality score of node *i* and *N* is the number of nodes in the network. Betweenness centrality, on the other hand, measures "the fraction of all shortest paths that pass-through a given node or in simple terms it quantifies the number of times a node acts as a bridge along the shortest path between two other nodes" (Arif, 2015, p. 890). So, if function b_{xy}^{i} takes the value of 1 whenever node *i* is found in the shortest path between nodes *x* and *y*, and 0, otherwise, then betweenness centrality can be calculated as:

$$x_i = \sum_{xy}^{N} b_{xy}^{i} \tag{2-39}$$

Chapter 3: Sectoral Market Power

3.1 Introduction

For economics market power captures the ability of market participants to influence the price of a commodity, or any other market outcome linked to the allocation of resources. Neoclassical economics has developed an idealized form of the market - the perfectly competitive market – that generates optimal outcomes for both producers and consumers, through the maximization of their respective welfare (Mas-Colell et al., 1995; Varian, 1992). Any deviation from the standard set of neoclassical assumptions will allow certain market participants to accumulate market power and restrict the optimality of the market mechanism for their own interest. In turn, these deviations define special cases of market imperfections, which have been the theoretical and empirical focus of alternative approaches, like for example the Keynesian and Kaleckian analytical frameworks and the Marxian tradition (Baran & Sweezy, 1966; Lavoie, 2014; Shaikh, 2016). These approaches investigate the notion of market power and the role of monopolies, oligopolies and oligopsonies, on the determination of prices, income distribution, resources allocation, etc. Furthermore, these approaches directly link market power with class conflict and socio-economic outcomes, hence combining economic insights with insights from other social sciences disciplines, like sociology and political science.

A similar distinction between neoclassical and non-neoclassical theoretical approaches is also present in the analysis of global markets and global production. Conventional economics views global production through the lens of international trade between countries, with the Ricardian Principle of Comparative Advantage (PCA) being the main explanation of the observed international trade patterns and the related global allocation of resources (Feenstra, 2004; Stolper & Samuelson, 1941). Alternative approaches within the neoclassical tradition, like the New Trade Theory (NTT), emphasize the importance of distinguishing between trade in intermediate and final goods, incorporating into their analytical frameworks the view of a disintegrated production process that unites geographically scattered means of production (Krugman, 1979; Krugman & Obstfeld, 2003). The latter view is usually enhanced with insights from non-economic literature in the areas of international political economy, economic sociology, and geography, that explore *firm-to-firm*, *firm-to-labor*, and *firm-to-governments* relations (Gereffi, 2018; Milberg & Winkler, 2013).

For these approaches, firms' power in global production translates into the ability of lead firms to shape governance structures to dominate their respective value-chains or production-networks, and consequently capture the highest possible amount of value-added. Several analytical frameworks have been proposed, emphasizing on different dimensions of power relations and levels of production. For example, the Global Commodity Chains (GCC) framework (Gereffi, 1994) focuses on the technological differences of production processes to explain the birth and evolution of global commodity chains, driven by either large and powerful producers (Producer Driven, PD) or sizeable and dominant buyers (Buyer Driven, BD). On the other hand, the Global Production Networks (GPN) framework (Henderson et al., 2002) stresses the bidimensionality of power, which is perceived as both a topological characteristic of the position (positionality) each actor holds in the production network, as well as a relational attribute of the exchange relations between network participants. The more recent GPN 2.0 framework (Coe & Yeung, 2015) goes one step further, arguing that power relations and asymmetries are latently embedded into specific configurations of global production networks.

However, in the above-mentioned frameworks of global production the conceptualization and operationalization of market power becomes much more complex. Each firm is receiving inputs from a firm at a lower tier in the production process and providing inputs to firms at a higher tier. This leads to the question of how can – or should – market power be thought and conceptualized when firms operate within global value chains. Depending on the level of analysis, one can investigate the market power of a firm, a sector or a supply chain. While acknowledging that the specific choice of a level of analysis comes with both advantages and drawbacks, the focus on the firm-level can provide detailed insights regarding the dynamics of specific firms, it lacks both the data availability and the generality of the policy implications that come when choosing to focus on a more aggregate level. At the same time, possible analyses of power on the sectoral level across countries where more data are available, lack a theoretical notion of power that is needed for concrete (quantitative) research.

In this paper, I draw on the literatures of heterodox economics and the political economy of trade focusing on a sectoral analysis, as well as the burgeoning literatures of econophysics and Social Network Analysis (SNA), to address these issues. More specifically, I develop a new framework for analyzing inter-sectoral competition and market power and I present relevant empirical observations based on this framework. On a conceptual level, I argue that a proper measure of sectoral power within countries that take part in global production processes should consider the market power dynamics across different levels of production. As I discuss in detail, this is because the market power of a sector is a function of the relative power of sectors located both upstream and downstream, and the same holds for all sectors. Hence an appropriate measure of power should have account for: (i) not only how connected one sector is, but also how well connected are the other sectors connected to the former are, and (ii) the volume of transactions. These two key characteristics can be found in direct correspondence to the measure of PageRank centrality.

On an empirical level, I first observe that the sectoral relative profits and the PageRank centrality across sectors have heavy tails, and the graphs indicate power-law distributions. The distribution of the relative profits highlights that a small number of sectors has a relatively high share of profits and similarly that the (PageRank) centrality of most sectors is low. At the same time, for some, it is relatively high. Given this observation, I then investigate whether there is an association between the logarithms of the two variables, hence indicating a power law relationship between the two. I observe a relatively strong correlation and find that a statistically significant relationship between the logarithms of the two variables exists. The regression analysis assessing the power-law relationships between sectoral relative profits and centrality shows an exponent that is close to 4. This empirical observation demonstrates that a strong centralization incentive exists for economic sectors, globally, and hence for the firms that belong to each of these.

My theoretical analysis contributes to several kinds of literature. First, it contributes to the Kaleckian/Post-Keynesian and Marxian literatures of market power, which conceptualize market power and theorize about social and distributional conflicts but lack a conceptualization of buyer-supplier power asymmetries. In other words, how oligopoly and oligopsony power interacts and influences economic outcomes. Second, it contributes to the analysis of international trade from the literatures of economics and macro-sociology. As I argue, the former literature is dominated by trade models that assume unrealistic assumptions about the nature of the world economy, inspired by neoclassical economic theory. Other approaches in international trade are more realistic, recognizing the existence of market imperfections and developing a fruitful discussion about the power conflicts of economic agents, but they tend to rely on gross conceptualizations of buyer-suppliers' relationships that ignore the complexity of sectoral heterogeneity of these interconnections at the global level. The latter, whereas highlights the structural complexities of international trade patterns, focusing on the positionality of countries in trade networks and employing network statistics and metaphors, they also fail to account for the sectoral heterogeneity of these linkages, abstracting from the inter-industry relationships developed in global supply chains, without distinguishing between trade in final and intermediate goods.

Third, it contributes to the GVCs/GPNs literatures by highlighting the importance of sectoral level analysis in global production and introducing a measure of market power building on relevant network centrality concepts. These approaches talk about conflicts between actors within supply chains, but they usually underestimate the need for an index that properly captures these conflicts. Furthermore, by showing the power law properties of this market power measure, my paper is related to the empirical literature that focuses on power law (and more specifically, Zipf's law) patterns in economic geography. Due to the interesting properties of power laws, such as scale invariance[1], power law relations have been of a key interest across natural scientists who saw them emerging from collective action and transcending individual specificities. Soon power laws, also called scaling laws, migrated to economics forcing economists to write new theories investigating so far, the patterns involving cities, firms, international trade and financial markets (see Gabaix, 2016).

The structure of the rest of the paper is as follows. Section 3 provides a critical review of the market power literature, focusing on a variety of theoretical approaches, from economic theory proper, to international economics, the frameworks of GCCs, GVCs and GPNs and the investigation of global production with tools from Input-Output Analysis (IOA) and SNA. Section 4, in turn, introduces my framework of sectoral market power in global production and corresponds it to PageRank centrality. In

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[1] Scale invariance is expressed in the relative change in one variable is associated with a relative proportional change in the other variable, independent of the value of each of the two variables.

Section 5, I discuss the data and my methodology and in Section 6, I present the empirical results and some general patterns found in my data. Finally, Section 7 concludes the paper.

3.2 Literature Review

In the next sub-section, I critically review the three main theoretical traditions regarding the analysis of market power and competition, ranging from neoclassical perfect competitive markets to Kaleckian and Marxian theorizations. First, I review the standard neoclassical model of perfect competition. Next, I focus on the literature of imperfect competition, developed by the post-Keynesian, Kaleckian and Marxian *monopoly capital school*. The third part of this sub-section is dedicated to the classical political economy approach. In the sub-section that follows, I move my focus to global production and globalization, critically reviewing literature that investigate global production, from different perspectives and disciplines. First, I review the literature of international economics, exploring the theoretical approaches of neoclassical trade models (Ricardian model and Heckscher-Ohlin-Samuelson model), the NTT school and the various heterodox attempts to formulate an alternative trade theory inspired by the Kaleckian and Marxian traditions. Second, I present the interdisciplinary frameworks of GCCs, GVCs and GPNs, which shed light on the economic and non-economic implications of governance structures and globalization organization of production. Lastly, I engage with the literature of econophysics that incorporates analytical tools from SNA and IOA to the understanding of the complexity of internationally fragmented, but functionally integrated, production processes of the globalized economy.

3.2.1 Market Power in Economic Theory

3.2.1.1 Neoclassical Perfect Competition

Within neoclassical economics, the notion of power has been primarily used at micro-level analysis, and particularly in microeconomics and industrial organization, to describe, on the one hand, the market power of firms in imperfectly competitive markets, and on the other, to illustrate the interaction between employees and employers in the labor market (Carlton & Perloff, 2004; Dunlop & Higgins, 1942; Tirole, 1988). However, it can be argued that even those two cases are quite restrictive, not only in the sense of defining the subject matter (i.e., power equal to market power), but also in their capacity to provide a conception of power that contains analytical strength to effectively capture the dynamic and conflictual nature of economic phenomena in contemporary capitalism.

Bartlett (1989), criticizes neoclassical economics for leaving the concept of power outside its analytical scope and notes that even in those few cases that the discipline has managed to talk about power, like in the analysis of oligopolies, exchange economies, externalities and games, it has failed considerably, rendering the study of power in economics in a Kuhnian ‘prescientific’ state. According to Ozanne (2016), the roots of such neglect can be found in the theoretical and methodological developments initiated by the Marginal (neoclassical) Revolution of the 19th century. Mainly through the work of Jevons (2013), Walras (2013) and Menger (2007), the Marginalists introduced the concept of marginal utility and emphasized the subjective determination of the value of commodities via the influence of consumer choices and their utilities. Applying their marginal techniques to the investigation of income distribution, the neoclassical scholarship managed to question the orthodoxy of classical political economy and considerably water down the socially and politically charged research agendas of Smith, Ricardo, and Marx (Backhouse, 2008).

Contrary to classical political economy, which was concerned with the analysis of antagonistic social classes and the distribution of wealth and income, neoclassical economists focused on "the study of price determination and allocation of resources in anonymous markets rather than the study of human relationships" (Ozanne, 2016, p. 7), limiting the analytical scope of economics. By doing so, they proposed an unrealistic, highly abstract, and idealized form of market economy, which moves quickly to equilibrium where firms do not interact with each other, ignoring the contradictory nature of capitalism, its inclination towards crises and inequalities and the conflictual dynamics of income distribution (Mirowski, 1989; Shaikh, 2016; Varoufakis, 1998). Consequently, the neoclassical scholarship has failed considerably to address important everyday economic problems, like market imperfections, unemployment, and income inequalities, partially due to the analytically restrictive effects of the mathematical formalism of general equilibrium models.

The benchmark model of market analysis for neoclassical economics is perfect competition. Whilst perfect competition is a theoretical case of an ideal market for which very restrictive and unrealistic assumptions have to be made, it is widely used in modern economics textbooks and economic policy institutions, because of its desirable welfare and efficiency properties (Shepherd & Shepherd, 2003). According to neoclassical theory, in perfectly competitive markets an infinite number of small and powerless firms, with identical scales of production, cost structures and access to information – but with no interaction with each other - sell all the product they want at the prevailing market price (Church & Ware, 2000). The latter is the result of the interaction of consumers and producers in an idealized form of a market economy, with supply and demand always being in equilibrium in a frictionless, timeless, and moneyless way (Varoufakis, 1998). It is only under perfectly competitive markets, the neoclassical scholars contend, that producers and consumers can benefit from optimal allocation of resources and incomes, and consequently from maximum welfare, measured as the sum of consumers' and producers' economic surpluses.

The fundamental assumptions for a perfectly competitive market are of a: a) large number of both buyers and sellers in the market; b) absence of entry and exit barriers for firms, consumers and resources; c) price-taking behavior for producers and consumers; d) absence of transaction costs for participating in the market; e) full information shared by producers and consumers about the price, quantity, and quality of the products in the market; f) commodities are identical and homogeneous, g) firms' cost structures are similar and scale of production small (Carlton & Perloff, 2004; Church & Ware, 2000). Although it is almost impossible to find a real-world market that satisfies all of them, the logic behind these assumptions is straightforward. A large number of sellers and buyers and the free entry and exit from the market, guarantees that no market participant will be able to influence the price of the product (Carlton & Perloff, 2004, p. 57).

For example, if a producer decides to increase the price of the product above the market price, then consumers will prefer to buy from other producers that sell at the market price. This will lead the initial producer to either reconsider the price strategy or to economic losses and eventually an exit from the market. The same applies to consumers. If a consumer wants to buy the product at a price lower than the market price, it is impossible to do so since all producers sell at the market price. Consequently, the economic behavior of market participants in perfectly competitive markets is bounded by the fact that they are price-takers and thus extremely - almost infinitely - sensitive to price changes. This assumption was initially introduced by Cournot (1897), linked the assumption of price-taking firm, to a horizontal demand curve. For a demand curve to be horizontal, each firm should be a minuscule contributor of supply. This led Cournot to his second assumption of infinite many suppliers. Later on, it was Jevons who added into the corpus of neoclassical markets the assumption of perfect knowledge, whereas Edgeworth introduced into the model the assumption of product divisibility and suppliers' self-seeking behavior. Walras, systematized and mathematized perfect competition into a static framework of General Equilibrium, in which an abstracted actor – the *auctioneer* – through a process of trial and error – *tâtonnement* – guarantees that all markets will be in equilibrium, and demand will meet supply (Shaikh, 2016, pp. 340–344).

Based on the above assumptions the neoclassical model of perfect competition analyzes the behavior of a typical firm selling its commodities to the market. The idealized competitive market portrayed by the neoclassical model has been the subject of extensive criticism. First, if we embrace the basic assumptions of perfect competition and allow the market to reach its equilibrium point, then we end up with a situation in which there is no actual competition (Varoufakis, 1998) but also no profits. When the market supply equals the market demand, the price is stable, and the producers' profits are equal to zero[2]. With zero profits there is no incentive for any market participant to change his/her behavior, thus there is no incentive for them to compete.

Another point of critique concentrates on the assumption of instantaneous price and quantity equilibration, which is assumed to follow a smooth and continuous process towards the equilibrium point, without persistent phases of disequilibrium (Semmler, 1984, p. 13). In real markets, price and production movements take a long time to reach their (theoretical) point of equilibrium. A similar unrealistic assumption of the neoclassical perfect competition is the direct linkage between the intensity of

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[2] For this derivation see the Appendix.

competition in a market and the number of firms. It is almost impossible to find a market with an infinite number of firms, each of which contribute only a minuscule amount to total market supply, rendering the ability to influence market price null (horizontal individual demand curves). In the first place, technology and intensity of capital vary across firms and particularly across industries and sectors. This implies that the cost structure of firms will differ considerably assuming similar cost structures invalid. Moreover, a multitude of other factors such as the existence of regulations and licensing processes, sunk costs to initial investments or property rights to a resource or a patent, and restrictions on the free entry and exit of firms to and from a market and thus make the assumption of an infinite number of firms in a market simply unrealistic. Shepherd and Shepherd (2003), for example, have noted that the degree of concentration in US markets is around 50% - 60%, highlighting important cases of industrial sectors in which leading firms have dominated their respective markets for decades.

3.2.1.2 Market Imperfections and Non-Neoclassical Alternatives

The theoretical frameworks stemming from the post-Keynesian and Marxist traditions, have emphasized the importance of power relations between economic actors and investigating real world market phenomena, like the influence of monopolies, the degree of oligopoly and oligopsony power on prices and income distributions or the persistence of unemployment, even in the long run. These approaches offer a more realistic view of the typical capitalist firm, expanding the conceptual space of power, in order to include, not only economic factors, like prices and costs but also the political and social environment (Baran & Sweezy, 1966; Lavoie, 2014). For example, post-Keynesians, contrary to their neoclassical colleagues, assume that the main objective of the firm is not the simple maximization of profits, in the sense of a linear programming exercise that minimizes costs and maximizes profits, but the maximization of power, defined as the ability of a firm, notwithstanding its size, to “have control over future events, its financial requirements, the quality of its labour force, the prices of the industry, the possibility of takeovers" (Lavoie, 2014, pp. 128–129).

For the Marxian monopoly capital school, analytical emphasis was given to the fact that production within capitalism, especially after the 19th century, was heavily centralized and concentrated in the hands of giant firms, forming cartels and multi-market conglomerates. The processes of concentration (the increase in the size of firms) and centralization (the joining together of various individual capitals under one unit) that gave birth to these giant firms - the argument goes - put an end to the era of 'free competition' and undermined the Marxian theoretical edifice regarding the labor theory of value, the transformation of values into prices and the long-run dynamics of capital accumulation (Foster, 1986; Sweezy, 1942; Zoninsein, 1990).

Mainly developed through the work of Sweezy (1942) and Sweezy and Baran (1966) this approach argues that a new stage of capitalist development emerged in the late 19th century, which combines four characteristics, distinct from the competitive stage that Marx explored in Capital: a) the emergence of the giant corporation as a new organizational form, b) market prices are determined by the monopoly power of each firm and not by the law of value, c) the tendency toward a uniform average rate of profit gives its place to a hierarchy of profits and d) the rate of introduction of new equipment is reduced, in order to protect the existing value of constant capital, and so is the rate of accumulation (Baran & Sweezy, 1966; Howard & King, 1992; Sweezy, 1942).

Focusing on the Keynesian tradition, Sraffa (1960) was one of the first to question the neoclassical model of perfect competition, by noting that most firms, instead of increasing cost, face decreasing costs in the long-run and a downward-sloping demand curve that gives each firm some monopoly power over its customers (Carter &

Lazzarini, 2013; King, 2002). Later on, Chamberlain (1933) and Robinson (1969), independently introduced their approaches to the analysis of monopolistic and monopsonistic competition, with capitalist firms becoming price setters instead of price takers (Shaikh, 2016, p. 358). However, it was Kalecki's notion of *monopoly power* (and the degree of monopoly power) that provided the most sophisticated anti-neoclassical theory of market price formation and influenced to a great extent the post-Keynesian literature.

For Kalecki (1938; 1968), capitalist firms are price-setters and not price-takers. The prices that producers charge to their products typically differ even for relatively homogeneous commodities and are a function of the cost structure of the company. Firms, in the Kaleckian world, set their prices by applying a stable monopoly markup over their average costs, which in turn is determined and constrained by market structural factors, like the concentration of the market, the degree of unionization of labor and its militancy and the risk of rival capitals to enter the market (Lavoie, 2014; Sawyer, 1985). The Kaleckian approach contends that any deviation of a real-world market from the strict assumptions of neoclassical perfect competition is an indication of the presence of monopoly power or some sort of a social, political, and economic factor that reduces the elasticity of demand for the market participants.

Based on Kalecki's work, this scholarship, along with Institutionalists, has offered a more realistic view of the typical capitalist firm. Competition, according to many post-Keynesians, occurs not only with price rivalry, but more importantly with non-price means that might reduce unit costs and increase profit margins, like advertising, research and development of new product varieties, access to cheap finance and credit, etc. Lavoie (2014) establishes that based on the Kaleckian approach firms' objective is not merely the maximization of profits, but rather a multidimensional process that targets the growth of "power over its suppliers of materials, over its customers, over the government, over legislation, and over the kind of technology to be put it use" (Lavoie, 2014, p. 128). Even though our focus here has been the work of Kalecki who can be seen as a common point of reference between post-Keynesians and Marxians from the Monthly Review School, there have been other authors and schools of thought who had similar insights regarding market phenomena. For example, the Institutional School inspired by the work of Veblen (1904), Hamilton (1919) and Commons (1931), argues that market phenomena are the result of intricate interactions between economic and non-economic institutions and actors. Other notable representatives of the institutional school of thought are Galbraith (1993) and Heilbroner (1982). For an exposition of the institutional school of thought, see O'Hara (2001).

However, Kalecki's analysis of market power is not without limitations and criticisms. For start, a number of Marxists that draw inspiration from the analysis of competition in the work of Smith, Ricardo, and Marx, have argued that perfect and imperfect competition approaches are two sides of the same 'coin', with a 'coin' representing the fundamental assumption about economic behavior made by neoclassical theory. Insofar as the number of firms increases in a market, then the pricing behavior of the firm will resemble that of a neoclassical perfectly competitive firm, setting its price as close as possible to its marginal cost (Moudud, 2013; Shaikh, 2016; Tsoulfidis, 2015).

Another point of critique, which is also prevalent to the deficiencies of the neoclassical theory of perfect competition, is the importance of buyer-supplier considerations. Whereas Kalecki's income distribution equation takes note of the importance of input materials costs – and consequently of the capitalist who produce and sell these input materials – this does not happen in the case of the measure of the degree of monopoly. The latter, in both the firm, sectoral and economy version, reduces the influence of the other sectors into a – more or less – stable competition-sensitivity coefficient, without elaborating on the structural interdependencies among producing and consuming firms, among buyers and sellers, in both firm-, industry- and sectoral-levels[3]. In other words, the Kaleckian degree of monopoly is not able to capture all the direct and indirect effects that the upstream and downstream partners of a firm might exert on it, with respect to its ability to influence prices and distributional outcomes.

3.2.1.3 Classical Political Economy: Social Conflicts and Dynamic Competition

The issues of power, class conflict, property relations and income distribution, are closely linked to the analysis of market structure and economic behavior within the tradition of classical political economy. McNulty (1967) - commenting on Stigler's (1957) article on the history of perfect competition underlines that Smith's notion of competition radically differentiates from the equilibrating conceptualization of competition that dominated economics after the marginal revolution of the 1870s. In particular, McNulty (1967) notes that Smith introduced competition as a "necessity for the individual seller or buyer to raise or lower his price or offer in response to market conditions" (1967, p. 397), forming the basis for a price-setting behavior. Hence, for Smith (1982, 1999) competition did not imply a situation in which firms were simple passive receivers of price information, whereas the intensity of competition in the market was determined by the number of firms. On the contrary, Smithian competition involves firms who are active economic actors that respond to market conditions, competing with each other in a rivalry sense.

Ricardo and Marx, conceptualized the competitive process in a similar way, paving the way for a classical theorization of markets and competition, as a dynamic process of unrestrained movement of capital and labor between markets leading to the tendential equalization of wages, profits, and prices, through their short-run

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[3] See Appendix for the mathematical exposition of the competition-sensitivity coefficient with respect to the degree of monopoly and the other contributing factors.

movement, around their long-run averages, which are ultimately determined by a socially-determined technological environment (Tsoulfidis & Tsaliki, 2013). Instead of assuming a price-taking behavior, the classical view of markets and competition assumes that firms are price-setters that employ an aggressive cost-cutting behavior with the development and introduction into the production process, of new techniques that require large investments in fixed capital (Shaikh, 1980).

The classical view of markets and competition defined a distinct area of research within the Marxian tradition that emphasized the dynamic attributes of capitalist competition, both theoretically and empirically. For Marx (1990, 1992, 1991), commodity capitalist production is a social conflict expressed in multiple dimensions. In particular, the Marxian approach asserts that capitalists participate in a twofold battle, on the one hand with workers in the workplace, in order to extract as much surplus-value as possible, and on the other, with other capitalists within and between industries. In more detail, the battle of capitalist firms is concentrated on two objectives: a) increase the rate of exploitation of labor (labor productivity) in order to extract the highest possible surplus-value, and b) reduce the cost per unit of output gaining a price edge over their competitors (Shaikh, 1978, p. 231). For firms within the Marxian framework, these tasks are accomplished through the constant introduction of technology that increases labor productivity, cuts units costs, and eventually gives capitalists a competitive edge. As a result, firms strive to control their relationship with the three main components of their cost structure, namely wages, materials purchased by other capitalists, and the depreciation of fixed capital, in order to be able to reduce – at will – the prices of their commodities. The nature of this competition is inherently antagonistic, putting capitals into a collision course and setting aggressively prices in such a way as to eliminate any advantage of their competitors (Shaikh, 2016).

The two dimensions through which Marxian competition takes place are within and between industries. Within industries, the competitive battle forces firms to introduce cost-cutting technologies and strategies, leading to a tendency towards a common price. Between industries, competition forces firms to move their capitals to those spheres of production that accrue the highest profit-rate, generating a tendency towards profit-rates equalization. However, this process of capital flows does not imply that in the long run the profit rates will be equalized between industries. As in the work of Smith and Ricardo, the tendencies of equalization are far from smooth and quick. Equalization happens through erratic, never-ending and ceaseless fluctuations of prices (within industries) and profit-rates (between industries), around their long-run averages, which in the Marxian framework take the form of *prices of production* and *average profit-rates*. As Tsoulfidis and Tsaliki (2013) note "in this turbulent equalization the profit rates orbit around the economy's average rate of profit and only over a long period of time, the positive and negative deviations cancel each other out, and, therefore, equalize the interindustry profit rates to the economy's average" (2013, p. 271).

A conceptual note on the distinction between sector, industry and markets is required at this point. Statistical authorities divide the economic activity of a country into sectors, industries and firms or business establishments/entities (BEA, 2017; UN, 2008). In particular, a sector is a combination of industries which produce similar products and/or services. In turn, within industries, we find productive entities, usually taking the form of a firm, which produce more specialized goods and services, defining at the same time, a particular market. For example, the financial sector consists of several industries, like banking, insurance, real estate, central banks. Each of these industries produces a number of products/services for their customers, defining a specific market, for instance, the market of consumer loans or insurance products. Whereas statistical authorities classify economic activity using the taxonomy of sectors-industries-markets, economic theory, especially in the 19th and early 20th centuries, was not so keen to make such distinctions. Within the context of Marx's theoretical arguments, the industry is a collection of capitals that produce similar products, experience similar cost structures, and are characterized by – on average – similar capital intensity (or in the Marxian jargon, technical composition of capital). Consequently, an industry for Marx and the classical tradition, is what a market is for a neoclassical economist. In the rest of the paper, I will use the terms sector, industry, and market inter-changeably, in order to draw comparisons between different theoretical approaches. When necessary, as for instance in the case of the analytical frameworks of GVCs and GPNs, which focus on firm-level relations, proper distinctions between sectors, industries, and businesses, will be made.

Building on the theoretical work of Marx on competition and market structures, a new scholarship emerged in the late 1970s and early 1980s, that elaborated on the former's framework and introduced empirical and quantitative insights. For scholars inspired by the work of Marx (Dumenil & Levy, 2011; Foley, 1986; Moudud, 2013; Semmler, 1984; Shaikh, 1978, 1980, 2016), commodity production in capitalism is far away from the equilibrating process of perfect and imperfect competition envisaged by neoclassicists and post-Keynesians. The latter, despite their differences, follow a conceptual path that emphasizes the centrality of price-cutting and cost-cutting behavior of capitalist firms, irrespective of their size and/or the number of firms in a market. Semmler (1984), for instance, underlines that for Marx competition is a "derivative concept" in the sense that the starting point of capitalist production is "the production of surplus-value and the self-expansion of capital" (Semmler, 1984, p. 22). Consequently, Semmler argues, any quantity theory of competition is completely absent from Marx's theoretical corpus, with competition being "a lasting struggle which is connected with the downfall of old capital and thus with the centralization and concentration process, but simultaneously with the creation of new capitals and of new disequilibria [...] competition affects the production, realization, distribution and accumulation" (1984, p. 23) of surplus.

Likewise, Clifton (1977) highlights that for the Marxian conceptualization of competition as a process, increasing the scale of the firm will only intensify competition. Shaikh (2016), links Ricardo's theory of agricultural differential rents with Marx's theorization of competitive dynamics, in order to address the contradiction of having at the same time a tendency that dis-equalizes profit rates within industries (competition within industries) and a tendency that equalizes profit rates across industries (competition between industries). In his model of *real competition*, Shaikh introduces the concept of regulating capital, defined as "the set of capitals representing the best generally reproducible condition of production in that industry" (2016, p. 265), to argue that only the profit rates of those sets of capital enter the competitive battle between industries, as they become the targets of new investment from other industries. In other words, inter-industrial competition does not equalize (tendentially and gravitationally over the long run) the average rates of profit across industries, but only the profit rates of the regulating capitals, and even these over the long run in a tendential and gravitational way. In the end, real competition will have produced a hierarchy of profit rates within and across industries, even between countries (Shaikh, 2016, p. 265).

An important strength of the classical theories of competition is that they are supported by a significant body of empirical exercises and historical firm-level surveys. Moudud (2010, 2013) cites the survey study of the Oxford Economics Research Group (OERG) on the microeconomic foundations of the behavior of the firms, which validates that real-world corporations do not equate marginal costs to prices, but set their prices according to their costs, taking into consideration that "because a firm's capital stock lasts a relatively long time, entrepreneurs necessarily take a long-run view in their price-setting policies in an attempt to remain profitable, given potential competitive threats" (2010, p. 6). More recently, empirical works have successfully confirmed the hypothesis that regulating profit rates do fluctuate gravitationally over the long run for advanced capitalist economies. Shaikh (2016) uses data from the 1994 OECD International Sectoral Database (ISDB) – the precursor of OECD's Input-Output Databases – for 8 countries, as well as data from BEA for the US economy for the period from 1987 to 2005. In a similar vein, Tsoulfidis and Tsaliki (2013) verify the hypothesis that regulating profit rates tend to equalize in the long run, using input-output data for the Greek economy.

The identification of competition as a conflict between capitals and between capital and labor, that is promoted by classical and Marxian political economy, seems to ignore one important dimension, that of buyer-supplier relationships. In particular, the above approaches assume that capitalist competition is manifested in three dimensions. The first dimension is the shopfloor struggle where the capitalist asserts control of the production and labor process by introducing cost-cutting technologies and processes and exploiting living labor and to extract more surplus value. The second dimension is the marketplace at the level of the industries. Capitalists that produce similar products compete in the market for greater market shares, generating an equalization tendency for the prices. Since each capital has different access to technology and thus different cost structures, competition within industries leads to a hierarchy of profit-rates. The third dimension is competition between industries, which is manifested with the flow of capital from industries with low profit rates to industries with higher profit rates. Within this dimension, the conflicts between those capitals that sell and/or buy products and services from other capitals for use in the production process, are absent.

This is a rather undeveloped area in the theoretical frameworks of competition, not only in the Marxian and classical tradition but also within the neoclassical and post-

Keynesian literatures. I argue in this paper that buyer-supplier tensions are important for the better understanding of capitalist competition. Since capital competes with capital for the control of the market and flows from one industry to another in search of higher returns, there is no reason why capitals will not compete for the magnitude of input costs. Afterall, what is considered as input cost for one group of capitalists functioning as producers, is considered as revenue for the other group of capitalists that functions as suppliers.

3.2.2 Power and Market Power in Global Production

3.2.2.1 International Trade Theory and Globalization

The standard neoclassical view of international trade is structured around general equilibrium models that require the usual assumptions of the perfectly competitive market. For these models there is no room for market imperfections, strategic behavior of firms, governments and other institutions and class struggle is either absent or carefully muted. The most characteristic family of trade models in the neoclassical tradition are the classical Ricardian model of foreign trade and its contemporary neoclassical counterpart, the Heckscher-Ohlin-Samuelson (HOS) model. David Ricardo (2004), writing in the early 19th century, proposed a two-good, one-factor model of international trade, concluding that the patterns of trade between countries can be explained by differences in the technology of production. He claimed that two countries producing the same two goods with only one factor of production (labor), but with different technologies, will eventually engage in a mutually beneficial trade, exchanging those commodities that each produces relatively cheaper. This assertion, also known as the Ricardian PCA, is so strong, that even if one firm produces in absolute terms more dearly than another, free trade in comparative terms will be beneficial for both of them. Whereas this process might produce imbalances in the trade balance between the countries, free trade will eventually equate imports and exports through the adjustment of the so-called Terms of Trade, that is the relative prices of exported and imported commodities.

A contemporary variant of the Ricardian model is the HOS model, formulated by Samuelson and Stolper (1941), based on the previous work of Swedish economists Heckscher and Ohlin (Feenstra, 2004, p. 31). The HOS model is a factor endowment model, with two-goods and two-factors (capital and labor), which asserts that differences in the factor endowments of countries can explain the patterns of international trade. In other words, each country will tend to export the commodities which are produced with the production factor that has in abundance. For example, if country A is abundant in capital, then it will probably export capital-intensive commodities, whereas if country B is abundant in labor, will export goods and services that require relatively more labor.

For the Ricardian and HOS models to work properly and generate the 'desirable' results, strict assumptions have to be taken. First, perfect competition has to be premised for all the countries under consideration. In that way all countries will fully employ their available resources in land, capital, and labor and no unemployment will be present. A second set of assumptions requires "identical technologies across countries; identical and homothetic tastes across countries; differing factor endowments; and free trade in goods" (Feenstra, 2004, p. 32). Other assumptions include the absence of transportation costs, constant returns to scale, quick adjustment mechanisms that change the terms of trade in such a direction that a balance of trade is guaranteed, and perfectly mobile factors of production between national industries, but not between countries (Kierzkowski, 1987; Krugman, 1979). Having said that, two are the main claims of the HOS model: a) with free trade the countries with abundance in capital will have a comparative advantage in producing capital-intensive goods and services and thus will tend to specialize in their production, and b) since markets are perfectly competitive and there are not impediments to the free trade and no unemployed factors, the prices of those factors, of land, labor, and capital, will equalize across countries.

As with the neoclassical model of perfect competition that has influenced the design and implementation of economic policy, the Ricardian and HOS models of international trade have played a decisive role in the development and dissemination of the neoliberal free trade agenda. According to the narrative of free trade policies, the liberalization of product, labor and capital markets will be beneficial for all countries and social classes, because unrestricted trade will optimally allocate commodities and resources, globally. This process, the theory admits, might initially generate some negative effects in the form of unemployment in certain sectors or persistent imbalances in foreign accounts and the macroeconomy of a country. But these negative aspects of free trade are only temporary and can be corrected with suitably designed and implemented social policies (Milberg & Winkler, 2013; Shaikh, 2016). However, the aforementioned view of the effects of free trade downgrades the fact that both the Ricardian and the HOS models are unable to provide a theoretically consistent explanation of the observed historical and modern patterns of international trade and the effects on the welfare of economic actors (Feenstra, 2004; Milberg & Winkler, 2013; Shaikh, 2016).

As a response to the above theoretical and empirical inconsistencies of the fundamental neoclassical trade models, the NTT approach emerged in the early 1980s. The most prominent example of this approach is the work of Krugman (Krugman, 1979; Krugman & Obstfeld, 2003), who draws inspiration from the Keynesian tradition and relaxes some of the strict assumptions of the neoclassical HOS trade models. An important assumption that was modified by Krugman is increasing returns to scale.

The latter is closely related to the presence of oligopolistic conditions in the market and the possibility of product differentiation. With increasing returns to scale in national markets, firms are usually able to influence the market prices and exercise their oligopoly power to increase their market shares. Moreover, producers with oligopoly power can design product varieties to expand their market dominance, and also engage in strategic planning. With these points in mind, the NTT trade models predicted more realistic outcomes with respect to trade, outcomes that were observable in the real-world trade patterns. Production specialization in varieties of goods, instead of industries, intra-industry trade (intermediate goods and services) between countries that share similar factor endowments, product differentiation, room for state interventions in the form of strategic subsidies and trade policy, persistent disequilibrium in the international factor prices, to state a few (Krugman & Obstfeld, 2003; Milberg & Winkler, 2013; Shaikh, 2016).

NNT theory sparked a vivid debate within the international economics literature. According to Milberg and Winkler (2013), three decisive factors that reduced the theoretical and political attractiveness of the NNT models: the political implications of the NTT approach that allows, if not promotes government intervention in the design of trade policy; the sensitivity to the assumptions and the mathematical form of the utility functions that were used in the NTT models that were usually generated non-robust results; the new trend of rising wage inequalities in advanced economies and rising imports from low-wage countries, observed in the world economy in the mid-1980s, that needed a theoretical explanation that NTT[4] models could not provide.

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[4] Other notable studies within the NTT tradition are Trefler and Zhu (2000), Hakura (1999), Melitz (2003) who introduces firm heterogeneity, Thompson (2002) who relaxes the full employment assumption, and Antràs and Helpman (2004).

A new generation of neoclassical models attempted to overcome these issues, reintroducing the fundamentals of the Ricardian and HOS trade models, with appropriate modifications and re-specifications. One modification was to include into the HOS models the distinction between high- and low-skilled labor and investigate whether the observed wage inequalities in advanced countries were attributed to the openness of trade and the import of cheap goods from low-cost countries, or skilled-biased technological change, concentrated inside manufacturing industries. A heated debate erupted in the late 1980s and early 1990s in the international economics discipline about the sources of income inequalities. One strand of the literature emphasized the negative impacts of globalization and import competition from international trade on the wages and employment of high-skilled labor relative to low-skilled labor (Leamer, 1998; Murphy & Welch, 1995; Reich, 1991; Wood, 1995), whereas another part of the literature, emphasized the effects of skill-biased and labor-saving technological change (Berman et al., 1994; Bound & Johnson, 1992; Lawrence & Slaughter, 1993).

Another modification of the HOS framework models was the recognition of the importance of production fragmentation and offshoring. The new structure of global production was heavily and at an increasing rate, relying on a geographically scattered base of suppliers for the purchase of intermediate goods and services. With this in mind, a new generation of models emerged that interpreted offshoring and production fragmentation, as the result of trade liberalization, technological advancements in transportation and telecommunications and the international distribution of factor endowments. The main claim of these approaches was that increase of international trade in both final and intermediate goods and with the influence of offshoring, will have the standard HOS effects on the relative factor price: increase in the wages of high-skilled laborers in countries with abundance and intensive use of high-skilled labor[5] (Bhagwati et al., 2004; Feenstra & Hanson, 1995, 1996, 1997, 1999; Grossman & Rossi-Hansberg, 2006).

Responding to the arguments presented in the *technology-vs-trade* debate, Feenstra and Hanson (1995, 1996) argue that rising imports reflecting higher degrees of outsourcing and offshoring acted as a contributing factor for the reduction of relative employment and wages of unskilled labor in the 1980s. Comparing the US and Mexican economies, the authors investigate how capital mobility affects the ratio of high-to-low skilled labor in both countries. They find that outsourcing/offshoring transfers capital and skilled-labor intensive activities abroad, but transfers less than those remaining at home, increasing the relative demand for high-skilled labor in both countries and an undetermined outcome for the welfare of low-skilled laborers, which will eventually depend on the direction of terms of trade (Feenstra & Hanson, 1995, p. 3). Later, in a series of papers (Feenstra, 1998; Feenstra & Hanson, 1997, 1999), they find that both outsourcing and high-technology expenditures (measured by expenditures in computer systems) explain a substantial amount of the increase in relative high-skilled labor employment/wages. However, when endogeneity of industry prices is allowed then technological change in high-tech is the dominant factor (Feenstra & Hanson, 1999, p. 908).

An interesting innovation of the approach of Feenstra and Hanson is that they experiment with the use of offshoring, as alternative proxies to trade liberalization and openness to trade, which theretofore was operationalized and measured with foreign imported input prices and terms of trade estimates. They combine import data with disaggregated data from the Census of Manufacturers, which are the raw data and

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[5] This effect is known as the Stolper-Samuelson Theorem, which formally states that "an increase in the relative price of a good will increase the real return to the factor used intensively in that good, and reduce the real return to the other factor" (Feenstra, 2004, p. 15).

basic component of the national input-output data, in order to construct industry-by-industry estimates of foreign outsourcing, which they define as the share of imported intermediate inputs in the total purchase of non-energy materials (Feenstra & Hanson, 1996, 1999).

In a similar fashion Campa and Goldberg (1997, p. 7) develop a measure of offshoring, which they call "imported inputs to production", that takes into account the number of intermediate inputs used in local production systems, at the standard sectoral level of input-output tables, as a share to the value of total production, using national input-output data (industry-by-industry transactions) for the US, Canada, the UK and Japan. Likewise, Amiti and Wei (2004, 2005, 2009) explore the scope and impacts of the offshoring of materials as well as services, concentrating on the economies of the UK and the US. These studies paved the way for a variety of theoretical and empirical approaches for the investigation of the extend of offshoring and its implications with respect to international trade, income distribution and the labor market (see among others Crinò, 2009; Egger & Egger, 2005; Grossman & Rossi-Hansberg, 2006, 2008; Morrison Paul & Siegel, 2001; Slaughter, 2001).

Whereas this new generation of trade models can be characterized as an improvement of the HOS counterparts, since they take into account the fact that modern trade involves exchanges in intermediate goods and services and a geographically disintegrated supply chain, they still do not pay much attention to market condition, such as the oligopolistic and oligopsonistic power asymmetries between international market participants. Although they develop a much more sophisticated toolkit for quantifying offshoring and its penetration in local production processes, their behavioral models assume the standard neoclassical assumptions (full employment in local labor markets), leaving no room for the analysis of social conflicts or the theorization of strategic behavior on behalf of firms, states, and labor unions.

Moreover, since full employment is assumed, the only mechanism left for the adjustment of the economy in case of market imbalances and shocks is wages and exchange rates. However, data on the persistence of long-term unemployment and trade imbalances, abound (Lapavitsas et al., 2010; Stockhammer et al., 2015). Another characteristic of the neoclassical trade models is that contrary to the identification of the firm as the prime analytical subject matter in microeconomics, in macroeconomics and international trade, neoclassical theory ignores its existence. From Ricardo's approach of comparative advantage to the HOS models developed by the scholarship, it is usually countries with specific factor endowments that engage in trade, not firms (Milberg & Winkler, 2013; Shaikh, 2016).

Against this background, theoretical approaches in international economics that draw inspiration from the work of Kalecki, have questioned the optimistic claims that trade liberalization and the new pattern of production disintegration and coordination through GVCs are beneficial for the overall welfare and wages, profits, and employment, in advanced and emerging countries alike. These approaches break with the neoclassical paradigm in three ways: a) introduce market imperfections into their analytical frameworks, b) highlight the importance of absolute, along with comparative advantages for explaining the direction of international trade (Milberg, 1994) and, c) incorporate non-economic actors and institutions into the analysis of trade, as the latter becomes "important determinants of competitiveness and welfare" (Milberg & Winkler, 2013, p. 101).

One of the main issues that distinguishes the Kaleckian approaches from the mainstream neoclassical trade models that might incorporate markup pricing and other constraints and market imperfections in their frameworks (Edmond et al., 2015; Feenstra & Weinstein, 2017; Macedoni, 2021), is that the former manages to link markups with macroeconomic outcomes. As highlighted previously, markups influence the functional income distribution, expressed through wage and profit shares, which in turn determine the decisions for consumption and investment spending, affecting the overall macroeconomic outcomes (Blecker, 1989, 2012).

A prime example of these approaches is the work of Milberg and authors (Milberg et al., 2007; Milberg & Houston, 2005; Milberg & Winkler, 2009, 2010, 2011), which culminated in the book Outsourcing Economics, co-written with Winkler (2013). In this study, they focus on the changing structure of international trade, what they call the New Wave of Globalization, which for the last three decades has increasingly relied on and organized in complex, geographically diversified, but functionally integrated, supply chains. The latter has been thoroughly analyzed by the literatures of GCC, GVC and GPN, which investigate globalization through the perspectives of international political economy, sociology, geography, business studies and international relations. These literatures study the various factors of the supply chain governance like for instance the characteristics of contracting with suppliers, the extent of technology sharing, the presence and length of the barriers of entry, etc. (Milberg & Winkler, 2013, p. 17).

Milberg and Winkler (2013) draw upon these interdisciplinary literatures and acknowledge the dominant role that GVCs play in the organization of global production and the coordination of international trade. Within the context of GVCs analysis, they identify a decisive shift in corporate strategies towards offshoring, seeking to transfer phases of production to lower cost regions that offer greater flexibility and the ability to implement processes of mass customization, while these corporations concentrate on the core activities that maximize shareholder values and financial assets returns (Milberg & Winkler, 2013, p. 12). Employing a Kaleckian pricing framework (see Appendix) they link the corporate strategy of offshoring with oligopoly power, markups, and profits, with firms having three ways to increase their profits: either raise the prices of the products they sell or increase the productivity of production (reducing production costs) or apply pressures to their suppliers and reduce the cost of inputs. Having established this theoretical link between offshoring and profits, they empirically investigate the static and dynamic gains that international trade and offshoring are generating with respect to functional income distribution.

Their key findings are that offshoring has increased corporate profits, mainly due to weaker growth in wages and to cheaper imports of final and intermediate goods and services. Moreover, their empirical evidence shows that financialization, through the channels of shareholders' value maximization and the trend of investing in financial assets, has resulted in a crowding-out effect, since profits are not invested in the production process creating new jobs, but are leaked towards the financial sector (2013, pp. 223–231). For labor, offshoring has resulted in lower employment and labor-share for advanced economies, although there are variegated results, when institutional factors, like labor protection legislation, are taken into consideration (2013, pp. 187–206).

An important limitation stands out from the above discussion of the various international trade theoretical models, which is related to the conceptualization and empirical operationalization of the structures of global production and the relationships between buyers and suppliers. All major studies investigating the effects of globalization and offshoring, either from a neoclassical or post-Kaleckian perspective, conceptualize the fragmentation of production as the share of foreign inputs in total intermediate consumption of each sector. However, data on imported inputs at the sectoral level is not available for the majority of countries and thus additional restrictive assumptions have to be made. It is a common practice for these studies to follow the OECD technique of assuming that every sector in a national economy imports inputs at the same proportion as the whole economy does (also known as the *proportionality assumption* or the *import comparability assumption*).

For example, if Italy's imports of iron are equivalent to the 15% of domestic production of iron, then it is assumed that each sector of Italy that uses iron as an intermediate input, will have imported 15% from foreign suppliers. This assumption poses an important bias to the empirical studies that investigate the effects of globalization and offshoring on national economies and has been criticized by a National Research Council report (2006) investigating the foreign content of US exports and imports, as well as by Winkler and Milberg (2012), Feenstra and Jensen (2012) and more recently, Baldwin, et al. (2017). The former found a significant bias between an offshoring measure based on the proportionality assumption and on based on detailed imported input data per sector, for the German economy between 1995 and 2006.

A probable solution to the shortcoming of the proportionality assumption was proposed by Feenstra and Jensen (2012), who used firm-level import data for the US economy and transformed them into sectoral equivalents within the US input-output framework. On the other hand, Winkler and Milberg (2012) relied on the import matrices of one country (Germany), which incidentally are also constructed with the use of the proportionality assumption, applied however at a more detailed level of aggregation. Whereas both solutions are able to reduce the proportionality assumption bias, they suffer from a data unavailability bias, since only a small number of countries provide either import matrices or firm-level imported inputs data. In this paper, I address this shortcoming with the use of global input-output data from the World Input Output Database (WIOD) project, which utilizes national data on imports, as well as bilateral trade statistics (taken from the UN COMTRADE database) to estimate shares of imported goods and services according to their uses, as intermediate, final and investment consumption. In that way, the WIOD input-output tables provide detailed mappings between products (six-digit Standard International Trade Classification) and their sectoral use per country (Timmer et al., 2015, p. 592). In other words, with the WIOD input-output tables, we can identify the country-of-origin, as well as the sector-of-origin, for every input used in the production of each sector-country covered in the dataset, allowing for a full-scale analysis of the structure of global production.

3.2.2.2 Global Production Analytical Frameworks

Since the early 1990s, new analytical frameworks that combine insights from different disciplines of social sciences, like international political economy, economic geography, sociology, and political studies, have emerged. Focusing on the economic and non-economic dimensions of the relationships of buyers and suppliers in global production and investigating the phenomenon of outsourcing and offshoring, the frameworks of GCCs, GVCs, and GPNs, offer an alternative understanding of globalization and power relations. Sometimes conflicting and divergent, and others complementary and synthesizing, these approaches attempt to highlight the inner mechanisms that allow multinational corporations to coordinate, and eventually, dominate a geographically dispersed, and functionally specialised, complex global supply system.

The founding stone of the 'chain' and 'network' approaches can be found in the World Systems Theory (WST) of Wallerstein and Hopkins (1986, 1994). In the mid-1980s, they introduced a theoretical model for the genesis, expansion, and reproduction of capitalism, based on the notion of the *commodity chain*, which they defined as the "network of labor and production processes whose end result is a finished commodity" (1986, p. 159). Upon these commodity chains a three-tiered hierarchical system of *core*, *semiperiphery* and *periphery* countries was erected. Countries that manage to monopolize the most profitable activities along the sequence of a commodity chain, and consequently accrue more wealth and power, form the core group of the capitalist world economy. On the contrary, countries that concentrate on low value-added activities for which a considerable amount of competitors exists, assemble the periphery groups of poor, underdeveloped and highly exploitable countries of the world (Wallerstein, 2004). The most interesting prediction of world-systems theory was that some periphery countries, based on their resources and the degree of integration into the world economic and political system, will manage to escape from poverty and underdevelopment and locate themselves into the semiperiphery group (Gereffi, 2018).

Global Commodity and Value Chains

Building upon the WST tradition a new perspective emerged in the early 1990s, under the title of *global commodity chains* (Gereffi, 1994; Gereffi et al., 1994). GCCs focus on the "organization of contemporary global industries and how power asymmetries of MNC lead firms affected the prospects for national development" (Gereffi, 2018, p. 14) and are formally defined as the "sets of interorganizational networks clustered around one commodity or product, linking households, enterprises, and states to one another within the world-economy" (Gereffi et al., 1994, p. 2). Central in the analytical framework of GCCs, is the concept of governance structures. As governance structures, Gereffi defines (1994) the "authority and power relationships that determine how financial. material, and human resources are allocated and flow within a chain" (Gereffi, 1994, p. 97). He identifies two types of governance structures – *producer-driven* and *buyer-driven* - characterizing global industries, based on the level of manufacturing activity that takes place in-house compared to the activity that is outsourced to suppliers. In producer-driven chains, we find capital- and technology-intensive industries (e.g., automotive, aircrafts, computers, electric machinery), usually in the institutional form of large hierarchically integrated firms and multinationals.

Table 3-1 Governance Structures of Global Value Chains

Governance Structure	*Transactions Complexity*	*Transactions Codifiability*	*Supply-base Capabilities*	*Degree of: -Explicit Coordination -Power Asymmetry*
Market	Low	High	High	Low
Modular	High	High	High	↕
Relational	High	Low	High	
Captive	High	High	Low	
Hierarchy	High	Low	Low	High

Source: Own Illustration, adopted by Gereffi et al. (2005)

These ‘lead firms’ are able to exploit efficiencies brought on by scale economies and advanced technology and play an important part in the coordination and control of the production and distribution systems. On the other hand, in buyer-driven chains we find labor-intensive, low-capital, and low technology industries (e.g., garment, footwear, toys, furniture), dominated and disciplined by large retailers, brands, and trading companies. Through branding and supply chain management, these companies exert their power and control of the backward linkages in the supply chain (Gereffi, 1994). In his empirical work, Gereffi identified automobile and garment global industries as the prime examples of producer-driven and buyer-driven global commodity chains, with capital-intensive automobile industry exerting control over global production lines, and, likewise, powerful retailers dominating and disciplining the labor-intensive garment industry.

However, Gereffi’s governance dichotomy between PD and BD governance structure was raising important questions regarding its static and narrow approach, its inability to explain the transformation of governance structures (Gibbon et al., 2008), as well as, the simultaneous existence of varieties of governance linkages reflecting the fact that “formerly producer-driven industries were taking on some of the characteristics of buyer-driven chains” (Dallas et al., 2019, p. 669). Informed by the work of Sturgeon (2002) on the modularity of the organizational structures of the US electronics manufacturing, a new framework was initiated by Gereffi, Humphrey and Sturgeon (2005), that of *global value chains*. GVCs focus on the creation and distribution of value in global supply chain and study "the full range of activities that firms and workers perform to bring a product from its conception to end use and beyond" (Gereffi & Fernandez-Stark, 2016, p. 7). As far as the governance structures are concerned, Gereffi, et al. (2005) proposed a fivefold typology of governance structures dependent upon three factors: the *complexity of transactions*, the *codifiability of information*, and the *capabilities of the supply-base*. In turn, the three determining factors, taking only two values (low and high), give birth to 5 types of governance structures[6], the market, modular, relative, captive, and hierarchical (see Table 3-1).

Market governance structures are characterized by simple transactions, easy to transmit product specifications and minimal inputs. The cooperation between producers (characterized by relatively high capabilities) and buyers are kept to a minimum and thus the cost of switching partners is low, implying a low degree of explicit coordination and power asymmetry. Modular structures, on the other hand, comprise of highly complex, but easy to codify, transactions between customers who want specificity for their products and producers who wish to exploit the capability advantages offered by modular production systems. In relational governance structures the complexity of transactions and supply-base capabilities are high, but the fact that transactions are not easily codified implies that the linkages between buyers-supplies will require "trust ... reputation, social and spatial proximity, family and ethnic ties..." (Gereffi & Fernandez-Stark, 2016, p. 11).

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[6] The maximum possible outcomes from the combination of three determining value taking only two values is eight ($8 = 2 \bullet 2 \bullet 2$), of which, Gereffi, et al. (2005) considered only five, as theoretically meaningful.

Inter-firm configurations characterized by a small number of suppliers, with significantly low supply-base capabilities, intensely controlled by powerful buyers monitoring the highly complex and easily codifiable transactions, constitute captive value chains. Lastly, the cases of vertically integrated multinational corporations, with subsidiaries all over the world, distinguish the so-called hierarchical GVCs, implying a very high degree of explicit coordination and power asymmetry. This fivefold categorical typology, however, does not imply that every global industry studied by the GVCs framework assumes one and only governance structure. On the contrary, it has been clearly underlined by the respective literature's research studies, that global industries exhibit multiple governance structures along their value chains, notwithstanding the fact that do not stay fixed over time (Gereffi et al., 2005; Gereffi & Lee, 2012, p. 29).

Global Production Networks: GPNs 1.0 and GPNs 2.0

In parallel with the frameworks of GCCs and GVCs, an alternative approach – the global production networks - was flourishing within the discipline of economic geography, focusing on those aspects of global production that the former frameworks were missing, like the explanatory power of the geographical, social and institutional specificities of global production (Bair, 2008). Another issue of critique coming from the GPN literature was the fact that the GCCs/GVCs frameworks viewed global production as a linear and vertical system, instead of taking into account "highly complex network structures in which there are intricate links – horizontal, diagonal, as well as vertical – forming multi-dimensional, multi-layered lattices of economic activity" (Henderson et al., 2002, p. 442). In other words, the primary goal of the GPNs approach was to analyse and understand the complexities of contemporary global economies, by highlighting the relational networks that economic and non-economic actors (labour, states, international financial institutions, etc.) form with each other (G. Yeung, 2016, p. 266).

Responding to the critique, the GPNs literature added much-needed complexity by understanding global governance as a multifactorial and contingent process. Building upon the theoretical traditions of Actor-Network Theory[7] and Varieties of Capitalism[8], GPNs propose a "relational framework which conceptualizes the networking nature of the global economy as a tangled web of production circuits and networks of interconnected economic processes that are grounded and embedded in specific locations" (G. Yeung, 2016, p. 266). A GPNs is defined as "the nexus of interconnected functions, operations and transactions through which a specific product or service is produced, distributed and consumed" (Coe et al., 2008, p. 272). Having said that, the GPNs approach is able to transcend global-regional-local dichotomies found in the GCCs/GVCs methodology, since the network methodology that it utilizes, transforms topological characteristics into comparable measurements (Dicken et al., 2001).

The first version of a GPNs analytical framework – the GPNs 1.0 - was introduced by Dicken, et al. (2001) and Henderson et al. (2002). They define a GPNs as the "the nexus of interconnected functions and operations through which goods and services are produced, distributed and consumed" (Henderson et al., 2002, p. 445) and structured their theoretical apparatus over three "conceptual categories": a) the creation, enhancement and capturing of *value*, b) the corporate, institutional and collective forms of *power*, c) the territorial, network-like and societal *embeddedness* of linkages.

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[7] Actor-Network Theory (ANT) is a methodological approach which puts emphasis on the inseparability of "economic actors from their actions, as the latter are embedded in multiform and multi-scalar relationships" (Aoyama et al., 2011, p. 184). In the GPN context the actor-network method points out that in order to understand the actions of economic and non-economic actors, we ought to analyze their connections with other actors and socio-economic structures, as well.

[8] Varieties of Capitalism (VoC) literature highlights the historical and institutional determinants of the creation, evolution and change of capitalist states (Aoyama et al., 2011).

These categories, in turn, were expressed through four "conceptual dimensions": *firms*, *sectors*, *networks* and *institutions*. Both the conceptual categories and the conceptual dimensions formed the GPNs methodological architecture which was used as a "heuristic device" for the analysis of global production in a great number of empirical and theoretical studies (Henderson et al., 2002; Hess, 2018, p. 2).

The conceptualization of the global capitalist economy as a network that connects, in a multidimensional way, different economic and non-economic actors, allows the GPN scholars to develop a more thorough and concise discussion around the notion of power. According to Dicken, et al. (2001), power in a global production network is the ability of actors to "drive networks and make things happen" (2001, p. 93), based on the "control of key resources" (2001, p. 93), expressed in a bi-dimensional way, as both structural and relational power. In particular, we observe power as both reflecting the topological-positional characteristics of network actors (structural dimension), usually quantified by node centrality, and the qualitative characteristics of the linkages in a production network (relational dimension). Hence, the power that an actor renders from the possession of a particular asset, reveals, not only its position in a global production network but also the normalization and legitimization processes that allow the holder of such a position to exert its power upon the other actors of the network.

The succeeding version of GPNs 2.0 proposed a more dynamic model of governance structures, providing a "causation mechanism" for the explanation of the production network configurations. This new methodology, introduced in the literature by Coe and Yeung (2015; 2015), underlined the importance of "actor-specific strategies", which were constructed by the interaction of network actors *vis-à-vis* an environment of "competitive dynamics". For the GPNs 2.0 theory, contrary to the GCCs and GVCs traditions, it is not solely governance structures and inter-firm relations that matter for the analysis power in the world economy. More importantly for the GPNs 2.0

theory, it is the behavior of economic and non-economic actors within the competitive environment of contemporary capitalism and the strategies those actors form and implement, that matters. As Hess underlines, “economic processes of production, distribution, and consumption are not simply driven by lead firms in GPNs...[but]...are embedded in wider systems of sociospatial relations and shaped by nonfarm actors operating with their own spatial logical according to their own specific goals and priorities” (Hess, 2018, p. 5).

Table 3-2 The Categories of Governance Structures and Firm Strategies

	GCCs	GVCs	GPNs 2.0
Hierarchicality ↓	Buyer-Driven Producer-Driven	Market Modular Relational Captive Hierarchy	Interfirm Partnerships Interfirm Control Intrafirm Coordination
Determining Factors	Capital Intensity Technology	Information Complexity Information Codifiability Supply-Base Capabilities	Cost-Capabilities Ratio Market Development Financial Discipline Risk and Uncertainty

Source: Own Illustration. *Notes*: The GPNs 2.0 framework includes four actor-specific strategies. The fourth strategy is extrafirm bargaining, which highlights the developmental strategies initiated mainly by non-firm actors, such as, global economic and financial institutions, national states, regional and labor actors. According to Coe and Yeung (2015), extrafirm bargaining is conceptually fused within the other three strategies. That is why it is not depicted as a separate strategy in the Table.

Formally, the GPNs 2.0 model underlines the importance of three variables expressing competitive dynamics (optimization of the cost-capabilities ratio, development of markets, financial discipline under risk and uncertainty), that will eventually determine which strategies firm and non-firm actors will follow and how they will shape the organizational, geographical, and institutional configuration of global production networks. The actor-specific strategies that GPN 2.0 introduced were i) *intra-firm coordination,* ii) *inter-firm control,* iii) *inter-firm partnerships* and iv) *extra-firm* *bargaining*, the combination of which will eventually determine the characteristics of the global production network under question. The GPN 2.0 approach incorporates the same conceptualization of power as GPN 1.0, with its bi-dimensionality reflecting both the position of an actor in a production network, as well as, the "relational practice embedded in the structural position within a network" (Coe & Yeung, 2015, p. 65). However, contrary to GPN 1.0, in which the conceptual categories of value, power and embeddedness, materialize through the conceptual dimensions of firms, sectors, networks and institutions, the GPN 2.0 puts more emphasis on the analytical role played by network configurations, as the reflection of the actor-specific strategies.

Despite the analytical differences between the frameworks of GCCs, GVCs and GPNs - as for example is the case with the emphasis of the latter on firm-level and actor-specific empirical analysis - there is common ground with respect to the hierarchicality and power differentials of governance structures. In Table 3-2, the governance structures of the three frameworks are presented and compared to the degree of hierarchicality or power asymmetry, that each approach assumes. For the GCCs approach, buyer-driven chains imply less hierarchical relations of production and trade among suppliers and buyers, compared to producer-driven chains, that insinuate a vertical and hierarchical chain of production sequences. By the same token, the fivefold governance typology of GVCs explicitly assumes a continuum of power asymmetry, starting from low, in the case of market governance, and ending with high, in the case of hierarchy governance. For the case of the GPNs 2.0, we can trace an implicit correspondence between GCCs/GVCs governance typologies and those GPNs actor-specific strategies that are characteristic of economic transactions. In that way, intra-firm coordination strategy denotes the most hierarchical governance structure found in vertically integrated MNCs, like the case of hierarchy; inter-firm control implies hierarchical types of organization resembling captive governance structures; inter-firm partnership will express the most non-hierarchical governance structures, like modular and market (Werner, 2017).

A significant number of empirical qualitative studies, within the GCCs, GVCs, and GPNs, has shed light on the properties and dynamics of the governance structures and power relations in specific industries. In the context of the commodity-chains framework, Gereffi (1994) explored the power asymmetries underlining the relationships between large retailers and buyers in the global apparel sector. Following Gereffi's governance structures dichotomy and empirical research path, an important number of studies, located in the intersection of economic geography and international political economy, have been proposed for the analysis of particular global industries, regional economies and upgrading trajectories. For instance Gereffi (1999) investigates the linkage between international trade and upgrading trajectories, focusing on the apparel sector in Asia, whereas Bair and Gereffi (2001) explore the role played by US large buyers for the structure of blue jeans industry in Torreon, Mexico. Similarly, Dolan and Humphrey (2000) interrogate the power relations developed between large UK retailers and fresh vegetables producers located in Africa.

A turning-point in the course of the 'chain' framework was the work of Sturgeon (2002) on the modularity of the organizational structures of the US electronics manufacturing, which paved the way for the emergence of the global value chains framework and the fivefold typology of governance structures. Gereffi, Humphrey and Sturgeon (2005) investigate of the governance structures of bicycles, electronics and vegetables, global sectors, while Sturgeon and contributors (Sturgeon et al., 2008, 2009; Sturgeon & Biesebroeck, 2011; Sturgeon & Florida, 2000) focus on the automobile sector. Pietrobelli and Rabelloti (2011), in their thorough review of the literature on innovation systems and GVCs governance typology, highlighted important industry-specific case studies that identify particular sectors and countries with one of the GVCs governance structures. Quantitative studies by Schmitt and Van Bieserbroeck (2017a, 2017b), and Ashenbaum (2018), use firm-level transaction and survey data to test whether there is a causal correspondence between the fivefold typology of governance structures, on the one hand, and the explanatory power of the three determining factors of information complexity, codifiability and supply-base capability. Their empirical exercises validated the assumptions of the theory of GVCs governance structures, at least for the industries that they focus on, namely the automobile industry for the former, and the electronics, chemicals, and food industries for the latter.

As far as the tradition of the GPNs framework is concerned, Rutherford and Holmes (2008) analyze the Canadian auto-industry, highlighting the power relationships between large TNCs and smaller suppliers located in industrial clusters, Yang and Coe (2009) investigate the governance structures of the Taiwanese personal computer production network and Grabs and Ponte (2019) study the evolution of power relations in global coffee GPNs.

Extensions of the GCCs, GVCs and GPNs Approaches

Recently, Dallas, et al. (2019) summarized the discussion of power relations in the extended literature of value-chains and production networks, proposing a new power typology. This new typology incorporates the diverse multidimensionality that have been found in the literature and proposes a ‘systematic framework that draws from the varied implicit usages of power in GVCs and GVC-adjacent literatures’ (Dallas et al., 2019, p. 667). The new typology distinguishes between the main *actors* that possess and exercise power and the *transmission mechanisms,* through which power is spread. This leads to the identification of four types of power, namely *bargaining*, *institutional*, *demonstrative,* and *constitutive.* These power-types are not mutually exclusive. They can co-exist, and their boundaries are porous. This typology is also dynamic, in the sense that it allows for one type of power to transform into another.

Bargaining power is the most common aspect of power found in political economy usually referring to the *firm-to-firm* (or more generally to actor-to-actor) relationships. It is based on resources and structural characteristics of the firm actors and can be operationalized by market concentration ratios, barriers to entry, and economies of scale, scope, and network. The second type - institutional power - is exercised by formal collectives, such as business associations and states, in order to design and establish worldwide regulations, rules and standards. Demonstrative power focuses on how actors exercise power through the transmission of requirements, inducing imitation of actions, products, tastes, and preferences. Lastly, constitutive power emerges from the uncoordinated, but collective actions of individuals and collectives, with respect to the establishment of norms and best practices.

Dallas, et al. (2019) provide three informative examples on the applicability of their proposed power typology, with respect to the wine, apparel and mobile telecommunications GVCs, whereas, Grabs and Ponte (2019) focus on the global coffee value chain. Focusing on the wine GVCs, Dallas, et al. (2019) underline that the power of the global industry, once concentrated in the hands of winemakers, has been consolidated in large retailers that have the ability to offer a wider variety of wine quantities and qualities, compared to specialized shops. Institutional power in the wine GVCs is exercised by both public actors through regulations (e.g., geographic indication labels), and multi-stakeholder initiatives designed by the industry's associations. In turn, demonstrative power reflects the ability of specialized actors, like wine tasters and scorers, to shape wine styles, aesthetics, and preferences, and thus affect how primary producers are positioned in the wine market. Lastly, constitutive power in the wine GVCs is conceptualized as the generalization of the styles, aesthetics and preferences found in demonstrative power, culminating in a well-constructed group of global “new wine consumers” (Dallas et al., 2019, pp. 682–684).

Mahutga (2012), from a macro-sociology perspective, combines the BD-PD chains with the fivefold typology of GVCs, stressing that the determining factor of governance structures in a value-chain is the height of entry barriers to manufacturing. In particular, he underlines that capital-intensive industries with high entry barriers, which constitute the lead firms in producer-driven chains, will tend to establish either modular/relational governance structures in the global north or captive/hierarchical structures in the global south. The geographical diversity of producer-driven chains comes as a result of the highly complex nature of the goods they produce and the variations in the strength of supply-base capabilities, found along the north-south. For instance, in the global north, we usually find industries with high supply-base capabilities for highly complex products, implying that modular and relational governance structures are more compatible for such cases. On the contrary, in the global south, we usually find industries with low supply-base capabilities for highly complex products, a situation that commands captive and hierarchical governance structures. Likewise, labor-intensive industries with low entry barriers are more likely to develop market/quasi-market or modular governance structures, established in the global south, which is characterized by high supply-base capabilities for low-tech products and services (Mahutga, 2012).

In a series of papers Mahutga (2012, 2014a, 2014c) synthesizes the GCCs, GVCs and GPNs approach, borrowing from the literatures of sociology and network theory, in order to conceptualize power in terms of *positionality*, namely the particular positions that actors hold in economic and production networks. Initially, his 2012 paper, combines the BD-PD chains with the fivefold typology of GVCs, stressing that the determining factor of governance structures in a value-chain is the height of entry barriers to manufacturing. In particular, he underlines that capital-intensive industries with high entry barriers, which constitute the lead firms in producer-driven chains, will tend to establish either modular/relational governance structures in the global north or captive/hierarchical structures in the global south.

Later, Mahutga (2015) unifies both the GCCs/GVCs and the GPNs frameworks, building upon the sociological approach of Power-Dependence Theory (Cook et al., 1983; Cook & Emerson, 1978; Emerson, 1962) and introducing the concept of positionality, in order to depict the power attributes of firm actors in an economic network. In the GCCs/GVCs frameworks the power of lead firms stems from the fact that the possession of, tangible (technologies for PD) or intangible (brand names for BD), resources erect entry barriers to their respective industries. The existence, in turn, of such resource-based entry barriers, is decisive for the generation of power asymmetries, due to the fact that PD and BD industries have the ability to restrain the number of competitors in their markets and thus become the irreplaceable producers/buyers for their dependent partners. At this point, the network logic comes into the fore. By taking simple examples of inter-firm relations taking the form of an economic network, Mahutga shows that producer- and buyer-driven lead firms that erect entry barriers tend to hold more central positions in the production network. Therefore, firms that possess valuable and important resources (dependency-power theory), can erect entry barriers to their competitors (GCCs/GVCs framework), hold central positions in the production network (GPNs framework), and consequently, dominate over their partners.

In Mahutga (2014a, 2014c) the world economy is expressed in the form of a global trade network, where each node represents a country and each link its trade relations. Assuming that country-specific trade patterns rightly reflect the economic behavior of the lead firms in BD and PD networks, he measures the positional power of countries participating in the most characteristic examples of buyer- and producer-driven networks (garment and transportation equipment industries), utilizing imports and exports data from UN Comtrade database, from 1965 to 2000. In this way, the positional power of a country in a BD trade network will depend on the import content of its exports, implying that the higher the share of its imports to the exports of its trading partners, the higher the number of business relationships with many "dependent import partners" (Mahutga, 2014a, p. 167).

The exact opposite is expected for countries in a PD trade network. There the positional power of a country will depend upon the share of its exports to the imports of its trading partners, reflecting the dependency of buyers from the large producer. Based on estimations of country-specific positional power, Mahutga builds panel data econometric models and assesses the explanatory power of positional power, with regards to the wage differentials and manufacturing specialization observed in the garment and transport equipment global industries (Mahutga, 2014c, 2014a). The results of Mahutga's econometric analysis are extremely promising for the concept of positional power since he finds that the latter has a strong explanatory power to explain both variations in wages and manufacturing specialization patterns, for countries participating in the respective, buyer- and producer-driven trade networks.

In the empirical part of his work, Mahutga envisions the world economy as a global trade network, with each node representing a country and each link its trade relations. Mathematically, this trade network takes the form of a matrix, with an equal number of rows and columns (squared matrix), expressing the amount of exports and imports traded between countries. So, the element *(i,j)* of the trade matrix gathers information about the exports of country *i*, towards country *j*, and symmetrically, the imports of country *j*, purchased from country *i*. Assuming that country-specific trade patterns rightly reflect the economic behavior of the lead firms in BD and PD networks, Mahutga measures the positional power of countries, participating in the most characteristic examples of buyer- and producer-driven networks, the garment and transportation equipment industries, utilizing imports and exports data from UN COMTRADE database, for selected years, from 1965 to 2000. He does so by calculating, for the positional power of country j in the buyer-driven network, the import share to its i trading partners' exports, and for the positional power of country i in the producer-driven network, the export share to its j trading partners' imports. Hence, the positional power of a country in a buyer-driven trade network will depend on the import content of its exports, implying that the higher the share of imports in its exports, expresses the establishment of business relationships with many "dependent import partners" (Mahutga, 2014a, p. 167). The exact opposite is expected for countries in a producer-driven trade network. There the positional power of a country will depend upon the export content of the imports of its trading partners, reflecting the dependency of buyers from the large producer. Based on the calculations of country-specific positional power, Mahutga builds panel data econometric models and assesses the explanatory power of positional power, with regards to the wage differentials and manufacturing specialization observed in the garment and transport equipment global industries, finding a positive association (Mahutga, 2014c, 2014a).

3.2.2.3 Quantitative Empirical Analyses from Leontief to Econophysics

In parallel with the scholarship of GCCs, GVCs and GPNs that focuses on the *firm-to-actor* relationships developed in global production, an empirical literature has emerged in the recent years, that combines elements of Input-Output Analysis and Network Theory, in order to investigate the structural properties of Global Value Chains. For the latter GCCs, GVCs, GPNs and in general global supply chains, are conceptualized and empirically analyzed at the sectoral level.

The seminal work of Hummels, Ishii and Yi (2001) has had considerable impact within academic research and research institutions on investigating production fragmentation at the international level, through the concepts of trade in value-added (Daudin et al., 2011; De Backer & Miroudot, 2013; DeBacker & Yamano, 2007; R. C. Johnson, 2018; R. C. Johnson & Noguera, 2012; Koopman et al., 2012; OECD, 2012). The logic behind trade in value-added is to use the Leontief inverse multipliers, at the international level, in order to compute the foreign value-added content of the exports of a country and equally the domestic value-added content of the imports of foreign countries. In particular, if $\boldsymbol{V} = diag\{VA \cdot \hat{x}^{-1}\}$, is a diagonal matrix which contains on the main diagonal the sectoral shares of value-added to gross output and $\boldsymbol{L}$ is the Leontief inverse, then by calculating the following matrix $\boldsymbol{VL}$, we obtain the value-added contribution matrix:

$$\boldsymbol{VL} = \begin{bmatrix} \frac{v_1}{x_1} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \frac{v_n}{x_n} \end{bmatrix} \begin{bmatrix} l_{11} & \cdots & l_{1n} \\ \vdots & \ddots & \vdots \\ l_{n1} & \cdots & l_{nn} \end{bmatrix} = \begin{bmatrix} \frac{v_1}{x_1} l_{11} & \cdots & \frac{v_1}{x_1} l_{1n} \\ \vdots & \ddots & \vdots \\ \frac{v_n}{x_n} l_{n1} & \cdots & \frac{v_n}{x_n} l_{nn} \end{bmatrix} \tag{3-1}$$

Each element of the value-added contribution matrix represents the share of value-added contribution of sector i (rows) in sector's j (columns) final demand. For example, the element VL_{36} shows the share of sector *3* value-added contribution in sector *6* final demand. In turn, each column of the VL matrix denotes the shares of value-added contribution of all the sectors i of the economy in sector's j final demand. Now, if we compute the VL matrix for an international IOT, in which each element represents a sector-country, we will have in our hands the value-added contribution shares of each sector in each country of our database. Moreover, if we aggregate with respect to sectors and transform the international IOT in such a way as to reflect the value-added contributions of countries, we will be able to distinguish between domestic and foreign shares, in the following way: The elements of VL matrix on the main diagonal

$(i = j)$ will express the domestic value-added shares, while all the other off-diagonal $(\boldsymbol{i \neq j})$ elements the foreign value-added shares, with respect each column. Informed by the above methodology, a voluminous literature has used information from value-added contribution matrices, in order to compute the foreign content of value-added in exports or in gross output or in final demand, in monetary terms. To do so, they simply post-multiply the VL matrix, with the correspondent vector. In equation (3-2), I present the formula for the calculation of the foreign value-added content of exports:

$$\boldsymbol{VLE} = \begin{bmatrix} \frac{v_1}{x_1} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \frac{v_n}{x_n} \end{bmatrix} \begin{bmatrix} l_{11} & \cdots & l_{1n} \\ \vdots & \ddots & \vdots \\ l_{n1} & \cdots & l_{nn} \end{bmatrix} \begin{bmatrix} EX_1 \\ \vdots \\ EX_n \end{bmatrix} \tag{3-2}$$

An alternative approach for analyzing the structures of global production, focusing on the 'depth' of the backward and forward linkages or the "Upstreamness" and "Downstreamness" of global production processes, was proposed by Antràs and authors (2012; 2018). In a series of papers, they defined "Upstreamness" and "Downstreamness", respectively, as the distance of an input from final demand and equally the distance from the primary inputs, that is the value-added components. They argued that "a sector that sells disproportionately to final consumers would appear to be downstream in value chains, while a sector that sells little to final consumers is more likely to be upstream in value chains" (Antràs & Chor, 2018, p. 6). The method that they used is quite simple. They write the Leontief and Ghoshian inverses as an infinite power series expansion and then they count the number of stages each sectoral output needs to take in order to reach final demand (upstreamness) or the number of stages that sectoral output is used as an input (downstreamness). Mathematically, their upstream $(\boldsymbol{u})$ and downstream $(\boldsymbol{d})$ measures take the following form, with each stage's distance from the previous one taking the *ad hoc* value of one:

$$\boldsymbol{u} = \frac{(1\times\boldsymbol{I} + 2\times\boldsymbol{A} + 3\times\boldsymbol{A}^2 + 4\times\boldsymbol{A}^3 + \ldots)}{\boldsymbol{x}}\boldsymbol{f} \tag{3-3}$$

and

$$\boldsymbol{d} = \boldsymbol{v}'\frac{(1\times\boldsymbol{I} + 2\times\boldsymbol{B} + 3\times\boldsymbol{B}^2 + 4\times\boldsymbol{B}^3 + \ldots)}{\boldsymbol{x}} \tag{3-4}$$

with $\boldsymbol{A}$ and $\boldsymbol{B}$, being the input and output coefficient matrices.

From a Network Theory perspective, the analysis of global production can be divided into two groups, depending on the underlying data used. The first group focuses on trade networks, constructed with the use of trade data, that is data on imports and exports of goods and services at the national level. Several theoretical approaches have been developed on trade networks, from macro-sociological attempt to test the basic claims of World-Systems Theory, using blockmodeling techniques (Kim & Shin, 2002; Nemeth & Smith, 1985; Rossem, 1996; D. A. Smith & White, 1992; Snyder & Kick, 1979); to the Ricardian-based notion of economic complexity developed by Hausman and Hidalgo (Hausmann & Hidalgo, 2011; C. A. Hidalgo et al., 2007; C. A. Hidalgo & Hausmann, 2009; César A. Hidalgo, 2009, 2011); to the econophysics approaches that analyzed the topological characteristics of those networks (Duan, 2007; Fagiolo et al., 2009; Garlaschelli & Loffredo, 2005; Li et al., 2003; Reyes et al., 2008; Serrano & Boguñá, 2003).

The second group focuses on production networks, utilizing novel datasets of global inter-country and inter-industry relationships. In this group we find mainstream neoclassical approaches of *general equilibrium* models, that explore the aggregate fluctuations in an economic system coming from micro-level shocks influencing heterogeneous firms, and traditional econophysics analyses shedding light on structural properties of global production (Blöchl et al., 2011; Campbell, 1972, 1974; Cerina et al., 2015; McNerney, 2009; McNerney et al., 2013; Tsekeris, 2017; Xu et al., 2011).

Each of these literatures sheds light on different aspects of the multifaceted nature and structure of global production. Despite their differences, there are research areas of theoretical intersection and conceptual overlap, with respect to the investigation of the evolution, structure, and resilience of the geographically fragmented and functionally integrated production. However, the literature has not engaged with either the literature on global production or with the heterodox economics literatures that highlight important aspects of political economy, like for instance power relations.

3.3 Centrality and Market Power in Global Production

In this section I formulate a model of competitive structures in global production, highlighting the tensions between buyers and suppliers. I draw inspiration from the Kaleckian, and classical political economy analyses of the competitive process in capitalism, combining elements from the discussion in the literatures of international economics and the scholarship of GVCs and GPNs. Analytically, I engage with the conceptual tools of network theory, and particularly the notion of centrality, to capture the relative influence of buyers and suppliers in global production structures.

3.3.1 Dynamic Competition and Market Structures in Global Production

Capitalist competition compels firms to employ a variety of strategies to survive and grow. Complex pricing tactics, innovations, and product differentiation, along with marketing and advertising policies which aim at exploiting a loyal consumer base. Equally, the introduction of new technologies, with the application of scientific management, and the spatial flexibility of production through offshoring and outsourcing, increases productivity, lowers costs, and creates price competitive edges. Moreover, the motive of profitability forces firms to act in such a strategic way as to limit the competitive advantages of their competitors and thus solidify their market position and maximise profits. Likewise, labor organises itself to resist its subordination to capital. This is accomplished through trade unions or by organising campaigns for better working conditions and higher wages. Labor demands can put pressure to national, regional, and international political organizations and institutional fora to seek binding regulations that guarantee a degree of protection and security against the power of capital. Eventually, competition will reward the most competent and cost-effective firm with higher profits and higher shares of value.

The success of a capitalist firm is dependent on its ability to remain competitive. Competitiveness is contingent on the firm's capacity to forge new technologies, discover innovative techniques, or devise organizational structures to increase productivity. The more competitive it becomes, the more power it accumulates. In the context of the present framework and following what has been discussed in the Kaleckian and Marxian approaches, I define power as the ability of capital to control economic and non-economic factors that affect its profitability. In that sense, power is linked to both cost and revenue dimensions of the firm, including labor wages, input costs, productivity of production and technology, as well as price and non-price competition. With more power, the firm can increase its market share against its competitors within the same market, by introducing more productive, cost-cutting techniques of production. Equally, with more power it can suppress the aspiration of labor for wage increases, as well as pressure suppliers for reducing input costs, resulting in greater value capture. So, the power of the firm is conditional on two struggles: a) within the

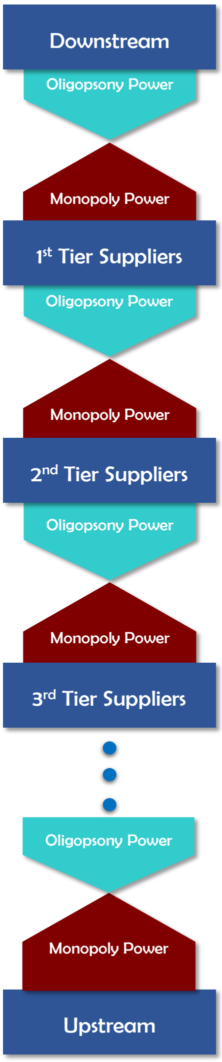

Figure 3-1 Buyer-Supplier Power Asymmetries
Source: Own Illustration.

firm between labor and suppliers, b) within the market with the other firms that immediately competes with.

The first struggle can be explored through oligopsony power, whereas the second through oligopoly power. Depending on their profitability, firms manage to accumulate power in the form of oligopoly and oligopsony power. It follows that every time an exchange takes place between firms in different levels of production, the oligopoly power of the seller confronts the oligopsony power of the buyer. The conflict arises from the buying or selling of a commodity and the attempt by each respective actor (buyer and seller to capture the greatest possible value in the transaction. As shown in Figure 3-1, each link corresponds to a market interaction of different capitalist firms that exert power to each other. I call the difference between the oligopoly power of the sellers and the oligopsony power of the buyer, Buyer-Supplier Power Asymmetry (BSPA).

Successful firms with large market power tend to capture more value from their partners, both backwards (suppliers) and forwards (customers). For example, a large and powerful buyer (e.g., retailer) will have greater oligopsony power compared to numerous geographically dispersed suppliers. The BSPA between them will be high. Consequently, the large buyer captures more value from weaker suppliers, which leads to higher profits. At the same time, supplying firms, which are also capitalist firms that aim at producing goods and services for profits, are struggling for survival in the "life-or-death" competition. On the one hand, they compete within the same market for market shares with other supplier firms. On the other, they compete for value capture with the other capitals that act either as retailers (downstream) or suppliers (upstream).

The opposite forces will apply in the case of powerful manufacturers (e.g., automakers) and supplying companies that manage to gain market power, due to, for example, the introduction of more productive techniques, greater exploitation of labour or the elimination of horizontal competition. If the supplier is more powerful than the buyers, then they will be able to exert oligopoly power over the buyer, set prices with higher profit margins and thus capture more value from the transactions. The power asymmetry between each buyer firm and its supplier will be determined by the balance of power of their respective oligopoly and oligopsony power, which in turn will allocate the produced value added to the more powerful and cost-effective firm in the chain. In the following sub-section, I formulate this distinction in a model of centrality and market structures, focusing on the sectoral level.

3.3.2 Centrality of Sectors and Market Structures

I assume that each firm (*f*) is characterized by two key variables: the type of task that it performs in the production process, call this task t^i, and the country that it resides, call this c^j, where $i = \{1, 2, ..., N\}$ and $j = \{1,2, ..., M\}$ capture *N* different production processes in *M* countries respectively. If for example t^1 is construction and c^{17} is India, then any construction firm in India can be denoted by $f(t^1, c^{17})$. Each firm can have its own characteristics which would differentiate it compared to other firms with the same $\boldsymbol{t^i}$ and $\boldsymbol{c^j}$, hence we can denote by $f^k(t^1, c^{17})$ a specific construction firm in India. When I refer to a *sector* $S(t^i, c^j)$ - the set of all firms $f^k(t^i, c^j)$ characterized by a task t^i and located in country c^j. Note that the geographical characteristic in our simplified framework captures a number of institutional and other influences, for example, legal framework, variety of capitalism, national economic characteristics etc. Each firm $f^k(t^i, c^j)$ competes with other firms within $S(t^i, c^j)$ but also with firms in other sectors with different tasks of the production process. The competition between different levels of production defines various market forms and their related types of market power, i.e., oligopoly/monopoly and oligopsony/monopsony. Hence, I can look at market power at a sectoral level such that sectors with the same t^i and different c^j compete in a similar (though not the same) way as firms within a national economy.

In this way, I extend the different market power notions to a sectoral/geographical level such that sectoral oligopoly (monopoly) refers to a market where few sectors-sellers are (one seller) able to define up to some extent the price at which the goods produced are sold. Along these lines, oligopolists can acquire higher than normal profits or rents by selling to a price higher than the one in a “perfect market”. Similarly, sectoral oligopsony (monopsony) refers to a market where few sectors-buyers are (one buyer is) able to exploit producers by paying a lower price for the production of a good. Within a production chain where the production of a final good includes a number of different tiers which correspond to tasks (t^i), oligopoly and oligopsony power capture the market power asymmetries between different levels of production. Based on this, I distinguish four different power possibilities for a sector at a tier *k* with respect to sectors in tiers *k-1* and *k+1*, which capture the combination of power relations between the two different levels. For example, assume three levels of production, then:

1) Between levels 2 and 1:
    a) Sectors at 2 have oligopsony power with respect to sectors at 1
    b) Sectors at 1 have oligopoly power with respect to sectors at 2
2) Between levels 2 and 3
    a) Sectors at 3 have oligopsony power with respect to sectors at 2
    b) Sectors at 2 have oligopoly power with respect to sectors at 3

From the above combinations only in the case where 1a and 2b hold, it is rather straightforward to see that sectors on level 2 will be able to exploit their market power to have high profits. Similarly, in the situation where both 1b and 2a hold, sectors on level 2 have no overall market power. However, in the other two cases, it is not clear whether a sector on tier[9] 2 will have market power or not. Furthermore, while in the previous example, sectoral market power at levels 1 and 3 depends on the competition of each with sectors at level 2, sectors at levels 1 and 3 also indirectly compete with each other. Using the same logic in a more realistic production process with more tiers,

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[9] I use the term level and tier interchangeably.

the sectoral market power will depend on the structure of the whole of the production network.

Hence an appropriate measure of market power should consider the whole production process and also the extent of interactions of each exchange. Put it differently, a measure of sectoral market power should take into account both the specific network structure of the global production process and the weight of each of the links. Both of these conditions are satisfied if I use the measure of PageRank centrality. PageRank centrality is an extension of the eigenvector centrality measure, which is defined as the sum of the links connecting a sector with its neighbours (Newman, 2010). In eigenvector centrality, each link connecting the node under consideration with the neighbouring nodes has a different weight, based on the centrality of the latter. That is, the centrality of a node depends not only on the number of links it has established with other nodes, but also on the number of links those other nodes have established with their neighbours, as well. Thus, for example, a sector has higher eigenvector centrality if it is connected to more connected sectors. Mathematically, eigenvector centrality is defined as the sum of the number/weight of links of sector i, weighted by the centrality of the neighbouring sector j with which it has established economic relations. Formally, if Z_{ij} is the weighted adjacency matrix for the economic network, eigenvector centrality is defined as:

$$x_i = \frac{1}{\lambda_{max}} \sum_{j=1}^{N} A_{ij} x_j \tag{3-5}$$

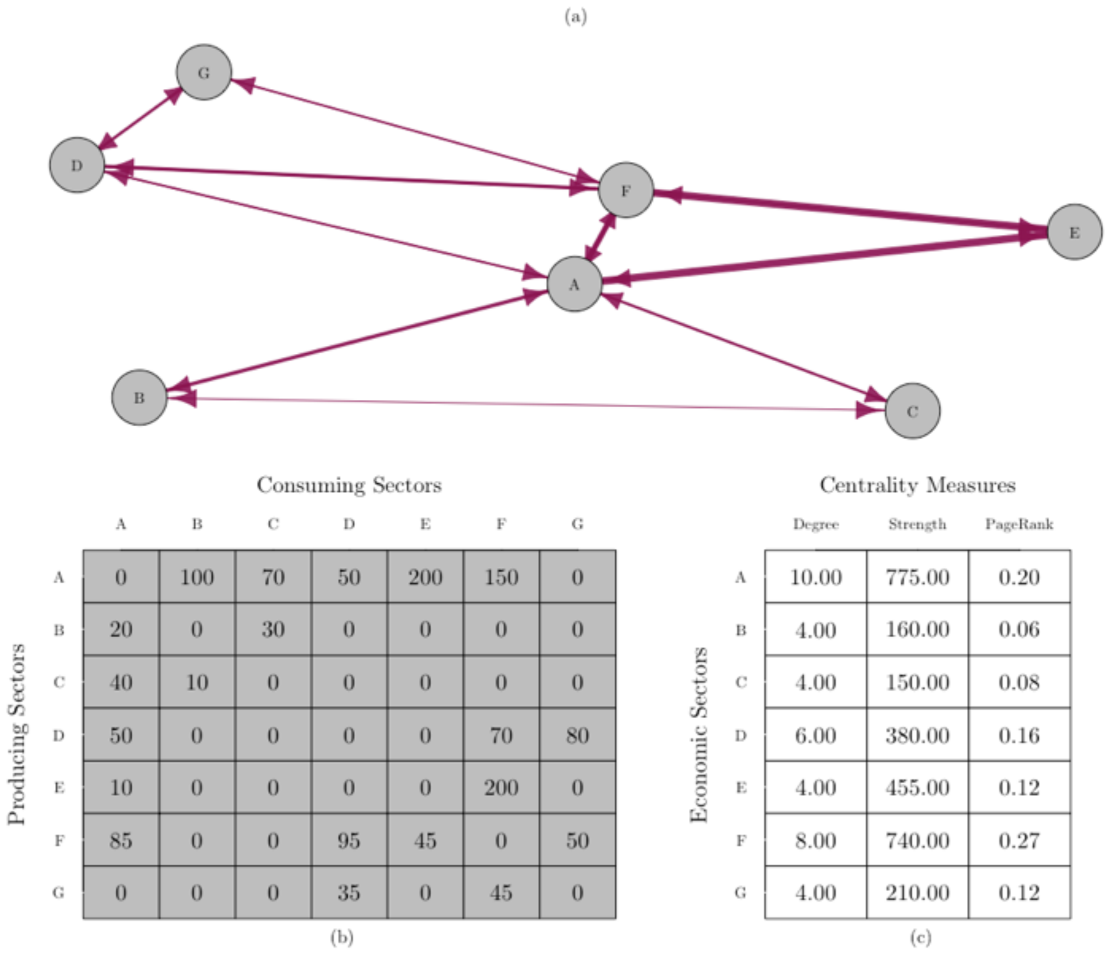
where, x_i is centrality for sector i and x_j the centrality of sector j that sells goods and services to sector i, while λ_{max} is the maximum eigenvalue of A_{ij}. Thus, sector i gains more centrality, if it is connected to more connected sectors, which themselves have higher centralities.

For PageRank centrality instead of calculating a centrality score proportional to the centrality of neighbouring nodes, it scales the effect of those nodes that have a large number of outgoing links. In particular, PageRank is calculated by:

$$x_i = \alpha \sum\nolimits_j A_{ij} \frac{x_j}{deg_j^{out}} + \beta \tag{3-6}$$

with x_i and x_j being the centralities of sectors i and j and a and β the constant parameters. In that way, PageRank centrality gives each sector i an equal share of the centrality of high out-strength economic sectors. Moreover, with the inclusion of the constant parameter β assigned to every sector in the economic network, PageRank centrality accounts for those cases of economic sectors that are not well connected with the vast majority of sectors-nodes in an economic network and thus probably assign zero centrality scores to their neighbours.

Regarding the present framework, this means that a sector will be highly central in terms of the PageRank centrality if it is connected to highly connected sectors that have gained their importance, although they have a large number of out-going links. Thus, PageRank centrality controls for those cases of economic sectors, which under the eigenvector centrality measure, would have accumulated high scores of centralities, merely since they have established business relationships with large input providers, for example, energy, transportation and financial intermediation services. In order to demonstrate the key intuition of this type of sectoral market power, consider the following example.



Consuming Sectors

Producing Sectors

	A	B	C	D	E	F	G
A	0	100	70	50	200	150	0
B	20	0	30	0	0	0	0
C	40	10	0	0	0	0	0
D	50	0	0	0	0	70	80
E	10	0	0	0	0	200	0
F	85	0	0	95	45	0	50
G	0	0	0	35	0	45	0

(b)

Centrality Measures

Economic Sectors

	Degree	Strength	PageRank
A	10.00	775.00	0.20
B	4.00	160.00	0.06
C	4.00	150.00	0.08
D	6.00	380.00	0.16
E	4.00	455.00	0.12
F	8.00	740.00	0.27
G	4.00	210.00	0.12

(c)

Figure 3-2 Centrality Measures in a Hypothesized Production Network

Source: Own Calculation. *Notes:* Sub-graph (a) is the visualization of a production network. Each node represents one of the sectors of our hypothesized economy. The thickness of each link is indicative of the volume/value of the transaction. In sub-graph (b) I have plotted an input-output table of intermediate goods of the hypothesized economy. The rows show the producing sectors and the columns the consuming sectors. Each element of the input-output table expresses the value of transactions between sectors. In sub-graph (c) I have calculated the Degree, Strength and PageRank centralities for every node-sector of the economy. Degree is the most widely used centrality measure, defined as the number of links (connections) a node has with the rest of the nodes. Strength centrality takes into account the volumes of inflows and outflows of inputs and outputs, between sectors in an economy.

In Figure 3-2 I have plotted a hypothesized production network, with each node expressing an economic sector, and the links connecting them, the value of transactions between them. The sub-graph (b) shows the input-output intermediate goods/services table that functions as the 'recipe' of the production network. This is the intermediate demand matrix, which is explained in Chapter 2. Each row shows how much each sector's output has been distributed to the economy and used as inputs. Likewise, each column shows how much inputs each sector will purchase from the other sectors of the economy to produce its respective output. Based on the information of the input-output table, I calculate, in sub-graph (c), the centralities of every sector in the economy. As we can see, each measure highlights the different properties of the structure of the production network. For instance, with degree centrality, we get the information that the most important (central) sectors are A and F, while sectors B, C, E, and G, share the same amount of positional power. A different picture is given when we consider the measure of strength centrality. Here we observe that the value of transactions between the sectors of a production process matters for their relative positional power. Whereas in the previous example of degree centrality, we could not make any conclusion regarding the relative power of sectors B, C, E and G, now with strength centrality, we have a clear ranking of power asymmetries. On the other hand, PageRank centrality takes into account how central the neighbours of a node are and thus modifies the ranking output of strength centrality analogously.

3.4 Empirical Observations

In this section, I investigate the properties of PageRank centrality in global production. For our investigation I use input-output data from the World Input-Output Database (WIOD). The WIOD (Timmer et al., 2015) results from an international scientific project aiming to combine, harmonize and reconcile economic data from national accounts, national input-output tables, and international trade statistics. More specifically, the WIOD project provides time-series for global input-output tables giving detailed information about the production processes of national economic sectors on a global scale, as well as data on the components and incomes of the value-added components. All data have been obtained by official national statistics and are structured as a unified global input-output table, with the block diagonal reflecting the national input-output tables. The WIOD comes into two versions, at basic prices in millions of US dollars. The 2013 version covers $M = 35$ economic sectors (ISIC Rev.3), for $N = 40$ countries and a proxy for the Rest-of-the-World (RoW), from 1995 to 2011. The 2016 version of the WIOD, on the other hand, covers $M = 56$ economic sectors (ISIC Rev.4) for $N = 44$ countries (including an estimate of the RoW), from 2000 to 2014. In this paper, I employ the second version as it is the most recent one and has higher dimensions (more country-sector observations). Given the values of N and M, the database corresponds to 2,408 sectors $S(t^i, c^j)$.

Table 3-3 Hypothesized two-country, two-sector, global Input-Output Table

<table>
<tr><th colspan="2" rowspan="2">Supply/Demand</th><th colspan="2">Economy 1</th><th colspan="2">Economy 2</th><th colspan="2">Final Demand</th><th rowspan="2">Total Output</th></tr>
<tr><th><i>Ind. 1</i></th><th><i>Ind. 2</i></th><th><i>Ind. 1</i></th><th><i>Ind. 2</i></th><th><i>Economy 1</i></th><th><i>Economy 2</i></th></tr>
<tr><td>Economy 1</td><td><i>Ind. 1</i></td><td colspan="4" rowspan="6">Intermediate Demand</td><td colspan="2" rowspan="6">Final Demand</td><td rowspan="10"></td></tr>
<tr><td></td><td><i>Ind. 2</i></td></tr>
<tr><td></td><td></td></tr>
<tr><td>Economy 2</td><td><i>Ind. 1</i></td></tr>
<tr><td></td><td><i>Ind. 2</i></td></tr>
<tr><td></td><td></td></tr>
<tr><td>Value Added</td><td><i>Wages</i></td><td colspan="4" rowspan="3">Value-Added</td><td colspan="2" rowspan="4"></td></tr>
<tr><td></td><td><i>Taxes</i></td></tr>
<tr><td></td><td><i>Profits</i></td></tr>
<tr><td colspan="2">Total Output</td><td colspan="4"></td></tr>
</table>

Source: Own Illustration

The structural composition of the global input-output tables follow the usual structure of the national input-output table, with some important additions. Schematically, a global IOT looks like the one in Table 3-3, with the four distinct, but interconnected sub-matrices of Intermediate Demand, Final Demand, Value-Added and Total Output. For the purposes of this paper I focus on the intermediate demand matrix, which presents the productive interdependent relationships among countries and sectors in a world economy, which will be used for the construction of the respective adjacency matrices.

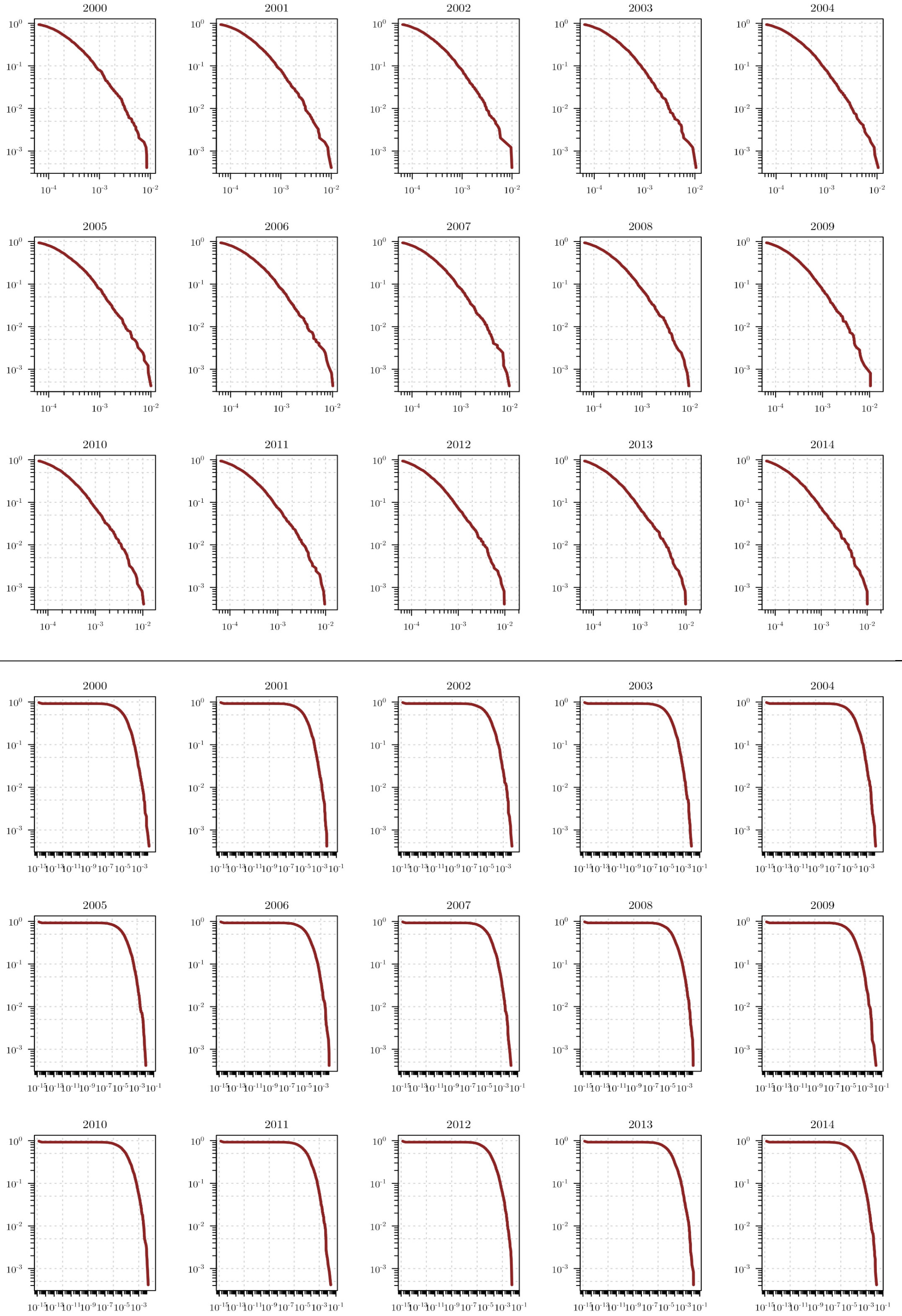


Figure 3-3 Distributions of PageRank Centrality and Sectoral Relative Profits

Source: Own Calculation. Data: WIOD. *Note*: Counter-Cumulative Distribution Function (CCDF) plots in log-log scales. Panel (A) corresponds to PageRank. Panel (B) corresponds to Sectoral Relative Profits.

The empirical analysis is in three steps. First, I present the distribution of PageRank centralities for each of the years available. Then I introduce the yearly distribution of the sectoral relative profits, which are computed by dividing the Gross Operating Surplus (GOS) component of the Value-Added of each sector, in each country, over the total amount of GOS generated in the global economy. Finally, I show that there exists a statistically significant power-law relationship between the two variables.

Figure 3-3, panel A, shows the Complementary Cumulative Distribution Function (CCDF)[10], plots for PageRank centrality for each year of the database. Our findings indicate that national sectors are asymmetrically connected to each other, as captured by the distribution of PageRank centrality. The distributional characteristic of our centrality measure is consistent with empirical exercises that investigate similar heavy-tail properties in real-life networks (Barabási, 2016; Newman, 2010), as well as production networks (Cerina et al., 2015; Tsekeris, 2017). A common technique used in the network theory literature for, at least visually, identify the presence of a power-law distribution in a sample is by plotting the CCDF, in log-log scales and checking whether it becomes linear in the high-value region (right-tail) (Clauset et al., 2009; Gabaix, 2016). Hence our plots indicate the possibility of the presence of a power law distribution for most years. Similarly, in Figure 3-3, panel B, we observe the right-skewed distribution of sectoral relative profits in the world economy, which implies how unequal the global distribution of profits among national sectors is, among both countries and sectors. Here the linear part, thus the indication of a power law distribution appears more clearly than in the previous figure and in most graphs the linear part is longer. Next, I plot the logs of the two variables and observe a clear correlation between the two variables possibly indicating a power law relationship. In order to get a more concrete idea regarding the relationship of the two variables, I

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[10] A complementary cumulative distribution function measures the probability of a variable taking values higher than a particular level and is formally defined as $\bar{F}_x = P(X > x) = 1 - P(X \leq x)$.

regress the logarithms of the two variables, and find a statistically significant relationship, with an exponent γ being on average around 4. In order to estimate the exponent of the relationship $Profits \sim PageRank^{\gamma}$, I run the regression $\ln Profits = Constant + \gamma \ln\ PR$, with Profits being the sectoral relative profits and PR the PageRank centrality. The results of the regressions are gathered in Table 3-4.

But what does it mean for the PageRank centrality is related to the relative sectoral relative profits, with a power law relationship? In our context, PageRank centrality captures the relative market power at the sectoral level, taking into account the whole structure of global production, whereas the sectoral relative profits are the proportion of profits that each sector accrues compared to the total global portion of profits. The power law relationship between the two implies that a relative change in the quantity of sectoral market power (PageRank) will give rise to a proportional relative change in the quantity of sectoral relative profits, independent of the initial size of each variable. In other words, if the logarithm of market power increases by 1%, then the logarithm of sectoral relative profits will increase 4 times more, namely 4%. Given that higher market power leads, on average, to higher profits, then our empirical observation of a power law relationship between PageRank centrality and sectoral relative profits, provides strong evidence for the appropriateness of such a measure. Moreover, the power law relationship between sectoral centrality and sectoral relative profits, implies that there is a strong *sectoral centralization incentive* in global production. In other words, irrespective of whether we observe a high or low distribution of relative profits in a particular global sector, there is a strong incentive for the latter to become more central sectors with respect to global production structures and thus acquire proportionally higher profits.

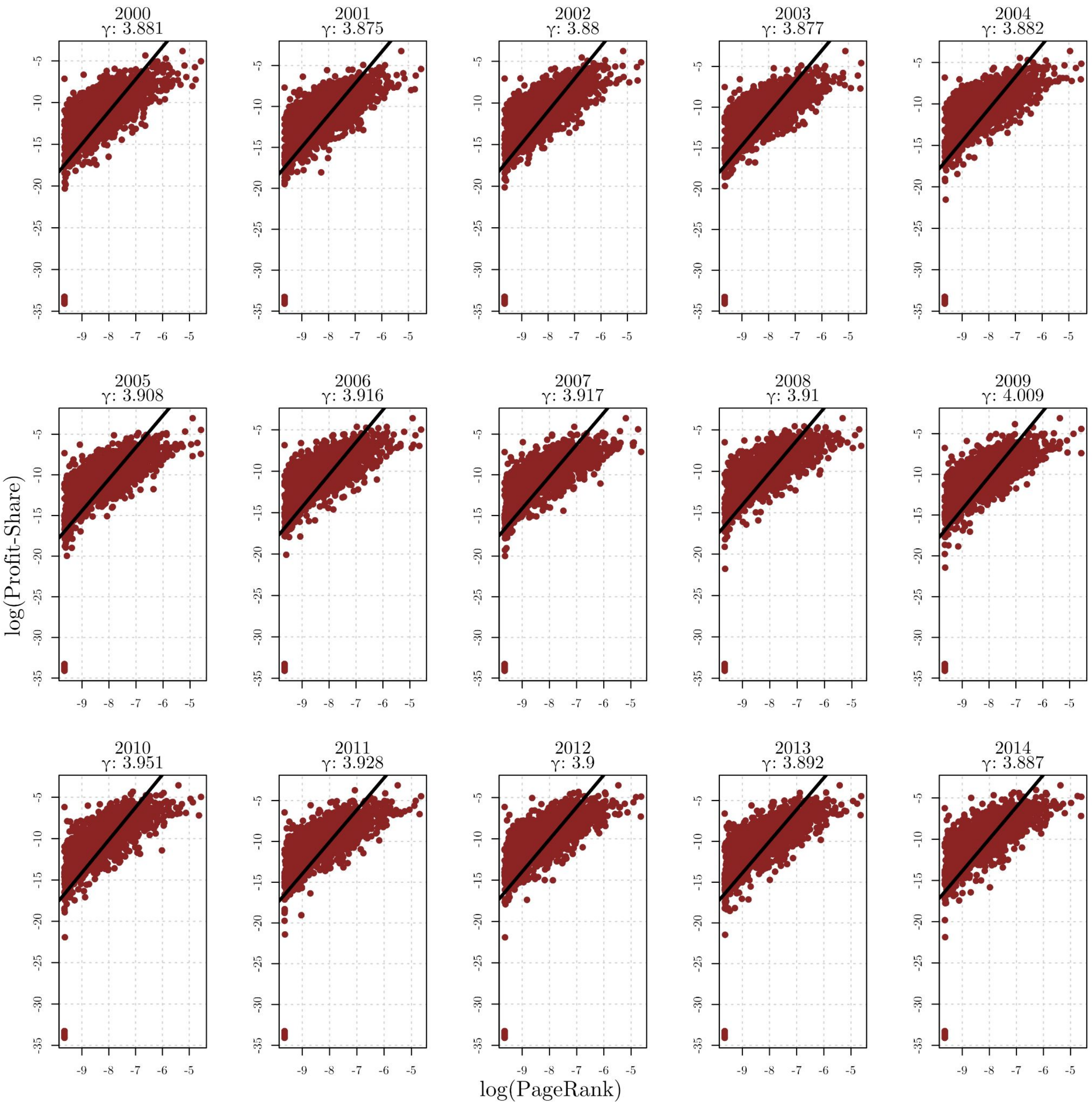

Figure 3-4 Power Law Relationship between PageRank and Sectoral Relative Profits (log-log)

Source: Own Calculation. *Data*: WIOD. *Notes*: Plots in log-log scales. In order to estimate the exponent of the relationship $Profit\ Shares \sim PageRank^{\gamma}$, I run the regression $\ln Profits = Constant + \gamma \ln\ PR$, with Profits being the sectoral relative profits and PR the PageRank centrality. The results of the regression are in Table 1 of the Appendix.

3.5 Conclusions

The objective of this paper has been to study the notion of inter-sectoral competition and market power at the global level. Drawing on the literatures of heterodox economics, political economy of trade, econophysics and social network analysis, the paper introduces a framework for analyzing inter-sectoral competition and market power, highlighting the empirical observation of the power law relationship between sectoral centrality and sectoral relative profits.

Table 3-4 Regression results for identifying power-law relationship

Year	γ	p-value	R-squared
2000	3.881	0.000	0.357
2001	3.888	0.000	0.360
2002	3.880	0.000	0.363
2003	3.877	0.000	0.359
2004	3.882	0.000	0.387
2005	3.908	0.000	0.356
2006	3.917	0.000	0.354
2007	3.017	0.000	0.351
2008	3.910	0.000	0.349
2009	4.009	0.000	0.360
2010	3.951	0.000	0.355
2011	3.928	0.000	0.351
2012	3.900	0.000	0.347
2013	3.892	0.000	0.346
2014	3.887	0.000	0.345

Source: Own Calculations. *Data*: WIOD.

Critically reviewing the different theoretical approaches to the analysis of market power and competition, I highlighted their limitations as well as common areas of interest. The notion of market power is central in a number of frameworks that analyse global production. For economics, market power is usually conceptualized at the micro-level focusing on the ability of firms and consumers to influence, with their behavior, the formation and evolution of prices. Non-neoclassical theoretical traditions, like post-Kaleckian and Marxian models of competition, analyze market power through the conceptual categories of monopolies, oligopolies and oligopsonies, and investigate how the latter are able to affect the determination of prices, income distribution, resources allocation, drawing a direct link between market power and social conflicts. At the global level, market power is either ignored, as with the conventional view of global production in economics literature that focuses on international (gross) trade between countries, governed by the principle of comparative advantage, or relatively understudied and undertheorized, as with the new trade theory and heterodox traditions, and the macro-sociology and GVCs and GPNs literatures.

For the latter, the focus has been primarily on firms incorporating a micro-level conceptualization of market power and market structures without properly taking into account the fact that firms belong to national sectors, and hence sectoral power is a possibly important factor to take into account. For these approaches, the market power is usually translated into the ability of lead firms to shape and dominate governance structures and thus be able to capture higher proportions of the produced value-added along the various stages of the value chain. Moreover, the complexity of conceptualizing and operationalizing market power at the global level is higher compared to the micro-based approaches of the heretofore literature. Global production integrates firms that belong to different sectors, geographies and institutional environments and consequently own different levels of market power with respect not only to their customers downstream, but also to their suppliers upstream. Ignoring the dimension of the global production structure and how it influences market power poses significant difficulties in our understanding of power relations, at the global level. Apart from the significance on a theoretical level, given the availability of sectoral level input-output data, a sectoral analysis is able to allow for empirical investigation of market power.

The present paper aims to contribute to this direction at both a theoretical and an empirical level. Drawing on the literature of heterodox economics and international political economy, I combine elements from social network theory and econophysics, to identify the competitive tensions between buyers and suppliers within global production and highlight how the latter reflect upon the market power of sectoral actors. Formulating a global framework for the analysis of inter-sectoral competition and market power, I argue that PageRank centrality is a proper measure of sectoral power within countries that take part in global production processes. Doing so, I contribute to three relevant literatures. First, I contribute to the post-Kaleckian and Marxian literature of market power and competition, introducing a network-based conceptualization of buyer-supplier power asymmetries. Second, I contribute to the analysis of international trade, enhancing their understanding of market imperfections and global competition. Third, I contribute to the literature that incorporate the analytical frameworks of GVCs and GPNs, by underlining the importance of sectoral level analysis in global production and proposing a measure for quantifying the competitive conflicts between buyers and suppliers in global supply chains.

Empirically, using input-output data, I provided a preliminary investigation of the properties of PageRank centrality and its relationship with relative sectoral profits. In sum, I find that the distribution of both variables has heavy tails and evidence of power law distributions and also some evidence showing a power law relationship between the two variables. This implies that a relative increase in the quantity of sectoral market power, measured by the PageRank centrality, will translate into a proportionally higher increase in the distributed global sectoral profits. This observation provides strong evidence that PageRank centrality is an appropriate measure for quantifying sectoral market power, given that higher market power with respect to the whole structure of production, will lead to higher profits. Moreover, the fact that sectoral relative profits and sectoral centrality are related with a power law relationship implies that no matter how high or low are the relative profits of one sector, and consequently of the firms within it, there is a strong incentive for the latter to become more central, since higher centrality translated into proportionally higher distribution of profits.

Given that the results are for national, but globally interconnected sectors, seveeral possible geography-related questions are raised. For example, which are the countries and regions where most central sectors are located? Would the same observations still hold if the analysis was conducted on a global level where national sectors would be aggregated? While the empirical investigation is preliminary, this paper sets the ground for further and more complete analysis regarding the importance of PageRank centrality as a measure of sectoral market power in global production. There are several possible research questions towards this direction. For example, one can analyse in more detail the different power law properties and/or the relationship between PageRank and various measures of sectoral profitability. As I have discussed, the sectoral level analysis can provide both theoretical and empirical insights. However, keeping in mind that sectors are sets of firms, it will be important to analyse the relationship between firms within key sectors. For example, one other direction of future research is to see whether there are different patterns of firms' profits within sectors with very different centralities.

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3.6 Appendix

The neoclassical model of perfect competition

The objective of the firm is to maximize its profits, so it will decide how much output it will produce, based on this objective. If the profits of the firm are π, the price and quantity of the product p and q, respectively, and the total cost for producing q units of product is $C(q)$, then the profit maximization objective boils down to the following optimization problem:

$$\max_{q} \pi = pq - C(q) \tag{3-7}$$

Maximum profits for the firm are achieved when the difference between the total revenues, pq, and total costs, $C(q)$, is the greatest. Since the firm is by assumption a price-taker, it cannot influence the price of the product (p), but only the quantity produced (q). Solving (3-7), gives us the necessary condition for profit-maximization under perfect competition. The perfectly competitive firm will produce so much output, q, up to the point that $p = MC$; the price of the product, p, is equal to the marginal cost (MC).

These profits, however, which the competitive firm has just maximized, act as an incentive for other producers to enter, invest and produce in the market, at the current equilibrium price. The influx of new producers to the market increases the market supply, which in turn exerts a downward pressure to the price of the product. The entry of new producers to the market - in the absence of entry barriers - will eventually end, when the market equilibrium price is so low that will make firms' profits equal to zero. When that happens, the market will have reached its long-run equilibrium, with the market price being equal to the marginal cost for each producer, who makes zero profits and has no incentive to leave the market (Carlton & Perloff, 2004). Under these circumstances “the socially optimal amount of output is produced at minimum resource cost” (Church & Ware, 2000, p. 25), achieving for the economy optimal efficiency and for market participants maximum welfare, measured by surplus that each gains from the difference of market price and their willingness to buy and sell.

The Kaleckian model of imperfect competition

The Kaleckian imperfect competition model can be formally expressed as following. Market power is defined as the “ability to profitably set price above competitive levels (MC) or the Lerner index is positive” (Carlton & Perloff, 2004, p. 92). According to Carlton and Perloff (2004), the price-taking behavior, the perfectly elastic (horizontal) individual demand curve and the infinitely large number of market participants, are equivalent assumptions, that indicate how powerless firms are to influence the price of the product under conditions of perfect competition. If the number of firms, though, becomes smaller, then each firm will must serve a larger portion of the market demand and thus its individual demand curve will become less elastic (less horizontal). This means that each firm will now have some influence over the price of the product it sells to the market, begging the question of what will happen when, instead of infinitely many firms, there are only a few producers in the market, or even only one. Assuming, as Kalecki did, that each firm acts as a monopolist to its respective market (due to the product heterogeneity assumption) and that the main objective is still profit-maximization, then as in the case of perfectly competitive, profits are maximum when the difference between total revenues and total costs is the greatest, namely:

$$\max_{q} \pi = p(q)q - C(q) \tag{3-8}$$

However, the firm does not face a horizontal demand curve, but an aggregate market demand with a downward sloping shape and inelasticity. This means that the price of the product will not be independent of the quantity and the revenues the firm receives will be dependent on the elasticity of market demand ($p = p(q)$). Solving (3-8), gives us the profit maximization condition for a monopoly. The firm will produce up to the point that the marginal revenue (*MR*) is equal to the marginal cost (*MC*). Formally, the profit maximization condition of $MR = MC$, is found after differentiating (3-8) with respect to quantity, q, which gives us:

$$MR = MC$$

$$p + \frac{dp}{dq}q = p(1 + \frac{1}{\varepsilon}) = MC \tag{3-9}$$

$$\frac{p - MC}{p} = \frac{1}{-\varepsilon}$$

with ε being the elasticity of demand defined as the ratio of the percentage change of quantity over the percentage change of price. From (3-9) we easily conclude that the higher the elasticity of demand, the closer is the price that the firm charges to *MC*, so to the market price under competition. In other words, the more elastic the demand for a product is, even small changes in price induce large changes in quantities. The term $\frac{p-MC}{p}$ is the profit-margin or the price-cost margin or the Lerner index (m), and it is assumed to be a measure of market or monopoly power.

The Lerner index becomes a good approximation for the degree of monopoly power for Kalecki, who proposes, in a series of papers from 1938 to 1971 (Rugitsky, 2013), a theoretical linkage between markup pricing and functional income distribution. In particular, he introduces a pricing equation for a capitalist firm, which is dependent on the degree of monopoly (defined as the Lerner index), the competitive conditions in the other markets and prime costs (average costs consisting of wage and material costs):

$$p = mAC + n\bar{p} \tag{3-10}$$

where p is the price set by a typical Kaleckian firm, m is the degree of monopoly power in the market (Lerner index or profit-margin) which is equal to $m = \frac{p-MC}{p}$, AC is the average cost of the enterprise, $\bar{p}$ is the average price for all firms in the economy, and n is a coefficient that expresses the sensitivity of firm's price to competitive threats from rival capitals. According to Rugitsky (2013), the main logic behind Kalecki's price equation is that firms should set their prices within two limits. On the one hand, they have to take into consideration the cost structure of their company and on the other, the prices of their competitors. In Kalecki's words: "The firm must make sure that the price does not become too high in relation to prices of other firms, for this would drastically reduce sales, and that the price does not become too low in relation to its average prime cost, for this would drastically reduce the profit margin" (as cited in Rugitsky, 2013, p. 451). Building on the firm's price equation, Kalecki calculates the average price of all sectors of an economy, and then (3-10) becomes:

$$\bar{p} = \left(\frac{\overline{m}}{1-\bar{n}}\right)\overline{AC} = k\overline{AC} \tag{3-11}$$

with $k = \frac{\overline{m}}{1-\bar{n}}$ the average economy-wide degree of monopoly, $\bar{p}$ the average price for the whole economy, $\overline{AC}$ the average economy-wide unit prime costs, $\overline{m}$ the average sectoral degree of monopoly and $\bar{n}$ the average sectoral competition-sensitivity coefficient. Given that total output, $Y = pQ$, is divided between wages, W, profits, Π, and material costs, M (that is $Y = \bar{p}Q = \Pi + W + M$), then we can write the share of wages to total output as:

$$Wage\ Share = \frac{W}{Y} = \frac{W}{\Pi + W + M} = \frac{1}{k(1+j)} \tag{3-12}$$

with $j = \frac{M}{W}$ the ratio of material to wages costs and k the average economy-wide degree of monopoly.

From equation (3-12), Kalecki concludes that the average degree of monopoly power will affect the overall nation-wide distribution of functional income (wages and profits), highlighting the inverse relationship between the wage share and the degree of monopoly. A rise in the degree of monopoly or in the factor that positively affect the latter, as well as a rise in the costs of input materials relative to wage cost, will *ceteris paribus* reduce the share of output that goes to wages and subsequently will increase the respective profit share, implying a social class conflict nuance in income distribution. Among the factors that influence the degree of monopoly that Kalecki – and the subsequent literature – discussed were the concentration ratios in each sector, the non-price competition expenditures (i.e., advertising, R&D, product varieties), the share of fixed costs to total costs and the strength of trade unions (Lavoie, 2014; Rugitsky, 2013; Sawyer, 1985; Taylor, 2004). In the long run, profit rates will differ across firms and sectors, due to differences in the cost structure of firms, with the degree of monopoly determining the income distribution and aggregate demand the total level of output.

Table 3-5 The Sectoral Coverage of WIOD Rev.4 (2000-2014)

Sectors of WIOD at ISIC4 level	**WIOD Codes**
Crop and animal production, hunting and related service activities	r1
Forestry and logging	r2
Fishing and aquaculture	r3
Mining and quarrying	r4
Manufacture of food products, beverages and tobacco products	r5
Manufacture of textiles, wearing apparel and leather products	r6
Manufacture of wood and of products of wood and cork, etc.	r7
Manufacture of paper and paper products	r8
Printing and reproduction of recorded media	r9
Manufacture of coke and refined petroleum products	r10
Manufacture of chemicals and chemical products	r11
Manufacture of basic pharmaceutical products and pharmaceutical preparations	r12
Manufacture of rubber and plastic products	r13
Manufacture of other non-metallic mineral products	r14
Manufacture of basic metals	r15
Manufacture of fabricated metal products, except machinery and equipment	r16
Manufacture of computer, electronic and optical products	r17
Manufacture of electrical equipment	r18
Manufacture of machinery and equipment n.e.c.	r19
Manufacture of motor vehicles, trailers and semi-trailers	r20
Manufacture of other transport equipment	r21
Manufacture of furniture; other manufacturing	r22
Repair and installation of machinery and equipment	r23
Electricity, gas, steam and air conditioning supply	r24
Water collection, treatment and supply	r25
Sewerage; waste collection, treatment and disposal activities, etc.	r26
Construction	r27
Wholesale and retail trade and repair of motor vehicles and motorcycles	r28
Wholesale trade, except of motor vehicles and motorcycles	r29
Retail trade, except of motor vehicles and motorcycles	r30
Land transport and transport via pipelines	r31
Water transport	r32
Air transport	r33
Warehousing and support activities for transportation	r34
Postal and courier activities	r35
Accommodation and food service activities	r36
Publishing activities	r37
Motion picture, video and television programme production, etc.	r38
Telecommunications	r39
Computer programming, consultancy and related activities; information service activities	r40
Financial service activities, except insurance and pension funding	r41
Insurance, reinsurance and pension funding, except compulsory social security	r42
Activities auxiliary to financial services and insurance activities	r43
Real estate activities	r44
Legal and accounting activities; activities of head offices; management consultancy activities	r45
Architectural and engineering activities; technical testing and analysis	r46
Scientific research and development	r47
Advertising and market research	r48
Other professional, scientific and technical activities; veterinary activities	r49
Administrative and support service activities	r50
Public administration and defence; compulsory social security	r51
Education	r52
Human health and social work activities	r53
Other service activities	r54
Activities of households as employers; etc.	r55
Activities of extraterritorial organizations and bodies	r56
Total Number of Industries	**56**

Table 3-6 List of Countries

Australia
Austria
Belgium
Brazil
Bulgaria
Canada
China
Croatia
Cyprus
Czech Rep
Denmark
Estonia
Japan
Latvia
Lithuania
Luxembourg
Malta
Mexico
Netherlands
Norway
Poland
Portugal
Finland
France
Germany
Greece
Hungary
India
Indonesia
Ireland
Italy
UK
Tunisia
Rest of the World
Romania
Russia
Slovakia
Slovenia
South Korea
Spain
Sweden
Switzerland
Taiwan
Turkey
USA

Chapter 4: The Positional Power of Labor: Evidence from Global Input-Output Data

4.1 Introduction

One of the most pressing puzzles in international economics is the assessment of the effects of globalization and trade liberalization on the incomes of economic actors and particularly on the distribution between labor and capital. During the last decades globalization, financialization and neoliberalism, have re-shaped national and regional economies towards a new regime of capital accumulation, generating patterns of income distribution and growth trajectories that give birth to interesting research questions for economists and social scientists alike. Is globalization and free trade responsible for the rising incomes of millions of workers in the emerging world? If yes, is this process universal or do we observe – and why – differentiated results among developing countries? Is international trade, technology or distributional struggles, the decisive factors that explain the falling trend of the labor share? The famous Stolper-Samuelson theorem (1941) provides theoretical arguments in favor of globalization, stating that trade liberalization and globalization will tend to increase the labor share of income in developing countries, as labor is the most abundant production factors. On the contrary, Rodrik (1997) underlines that globalization favors the international and mobile class of capital owners at the expense of the working classes in emerging countries which suffer from low levels of bargaining power and thus falling incomes shares.

This puzzle has inspired vivid debates, not only in the field of economics, but also in adjacent disciplines of social sciences that engage with the analysis of the economic sphere and its interconnection with the political, social, anthropological, legal, and geographical dimensions of human reality. This paper focuses on the investigation of the relationship between globalization, global production structures, labor bargaining power and income distribution. Interestingly, there is an impressive volume of theoretical and empirical studies that explore the political economy of functional income distribution and the determinants of the labor share, either from an economic, sociological, or political science, perspective. This extensive - in disciplinary scope - literature has emphasized various determining mechanisms with respect to the share in national income, from technological change and automation to the impact of globalization, offshoring, international fragmentation of production and institutional factors, like a fall in the welfare state and the reduction in various dimensions of labor bargaining power.

Overall, there are two broad theoretical approaches to the issues of functional income distribution. In the first group, we find studies that utilize economic models of international trade and explore the effects of trade liberalization, offshoring and international fragmentation of production, on various measures of labor income and labor results. An important theoretical division exists within this group, with neoclassical models stressing the positive or relatively positive implications of globalization for the incomes of workers in advanced and emerging economies, and on the contrary, post-Keynesian and post-Kaleckian models finding evidence of a negative relationship. In the second group, we find studies inspired by the *power resources approach*, that is informed by labor sociology and political science and argues that labor market deregulation, welfare state retrenchment and the fall in union participation are responsible for the observed decreases in the labor income of advanced and emerging economies.

Both perspectives have several shortcomings. Even though they both acknowledge – arguably to a different degree – the explanatory value of labor bargaining power, they do not engage in a theoretical and empirical discussion that would allow the utilization of alternative dimensions of labor bargaining power in the analysis of the effects of globalization and vice versa. For example, the globalization approach tends to investigate technological attributes of economic systems and conceptualize globalization as foreign competition of imported goods and intermediate inputs, or as the degree of international fragmentation of production and supply chains, abstracting from the structural characteristics of global production systems. One implication of this shortcoming is that labor bargaining power is usually conceptualized in a rather narrow scope, proxied by union density rates and strike activity, and as a result failing to recognize alternative dimensions of labor power. Moreover, even if alternative dimensions of labor bargaining power are acknowledged, they are not fully incorporated into the empirical models that investigate the evolution and determinants of labor income shares. Lastly, both approaches seem to under-incorporate the international dimension of labor bargaining power and the fact that national economic systems and social formations become highly integrated into global supply chains.

In this paper, I combine conceptual elements from the power resources approach and globalization literature to highlight a rather under-developed linkage, between the structural position of labor in production and supply chains and the process of international fragmentation of production. A research question that emerges from this combination is whether positional/structural bargaining power and labor outcomes hold a positive relationship at the global level. Drawing on the notion of positional/structural power of labor in the production process, I estimate the positional/structural power of labor at the global level, utilizing global input-output tables. Our empirical results show that the positional power of labor at the global sectoral level owns significant explanatory power for the labor share, across time, countries, and skills, taking into account sectoral heterogeneity.

My contribution is threefold. First, I introduce a power resources approach problematic in the realm of the globalization literature. Heretofore, the latter has conceptualized the role of labor only through the associational dimension, operationalizing with measurements of union density. Second, I extend the concept of structural/positional power coming from the power resources approach tradition, at the global level. The latter has only investigated research questions at the national level, abstracting or under-exploring the international level of supply chains. Third, I find empirical evidence, at the global level, that supports the agency hypothesis (Wallace et al., 1989), that states that lower skilled workers tend to gain more from their positional power. Fourth, I shed light on the structural dimensions of labor bargaining power at the global level, bringing together analytical frameworks that fall at the intersection of trade economics, international political economy, and sociology. With regard to these fields, despite the wealth of research papers on the determinants of labor share, I argue that there is fertile ground for the development of a labor specific literature that would shed light on the particularities and geographies of their power.

The structure of the rest of the paper is the following. In the next section, I critically assess the literature on the political economy of income distribution, focusing on the globalization debates found in economics and the power resources approach. In the third section, I describe our data and methodology for quantifying positional/structural labor bargaining power and assessing the impact on labor shares, whereas in the fourth section I discuss our empirical results. Finally, in the conclusions section I summarize our analysis.

4.2 The Political Economy of Income Distribution

4.2.1 The Globalization Debates

Research in international economics in the 1980s and early 1990s was heavily motivated by a vivid debate regarding the determining factors of the rising income inequalities observed in many advanced industrialized economies. The *technology-vs-trade* debate was neoclassical in its fundamental theoretical premises and emphasized the role played by both technological and trade factors with respect to the individual income divergences in the advanced economies between high-skilled and low-skilled labor. At the one end of the dividing line within this literature, we find scholars that argue that the most important factors explaining the rising income inequalities and declining trend in the labor share are mainly technological in their nature. According to this argument, capital accumulation promotes labor-saving technical change which reduces the amount of labor employed for every unit of output produced and thus reduces the income of labor.

Autor, Katz and Krueger (1998) examine the effects of computerization, as a form of *skill-bias technological change* on the wage differentials of the US wage earners from 1940 to 1996, for different skill levels. They find that technological progress has increased the relative demand for high-skilled labor. Focusing on the functional income distribution, Bentolila and Saint-Paul (2003) find that the declining trend of the labor share in the OECD countries is attributable to the rise of the capital-output ratio, taking into account sectoral heterogeneity. Similarly, Driver and Munoz-Bugarin (2010), focusing on a panel dataset for the UK and a selection of European countries, they show that capital investment has decreased the labor share, at the sectoral level. Hutchinson and Persyn (2012), apply Bentolila and Saint-Paul's framework in the EU single market and provide an empirical assessment of the importance of several factors, like trade costs, international low-wage competition, industrial concentration and skill-biased technological change (labor-saving), in explaining the evolution of the labor share, finding significant evidence for the latter. More recently, Autor and Salomons (2018) explore the evolution of labor share using harmonized long time-series of cross-country and industry data with respect to the direct and indirect effects of technological change, and they report that "automation displaces employment and reduces labor's share of value-added in the industries where it originates" (2018, p. 1).

At the other end of the debate, we find research studies that explain the observed income trends through the rise of globalization and the increasing import competition. For these approaches globalization tends to shift the production of low-cost and labor-intensive goods and services to new locations abroad. At the same time, capital-intensive production processes are usually less influenced by the pressures of import competition and international trade and tend to locate in capital-abundant countries with large high-skilled workforce. Applying the Stolper-Samuelson effect and Ricardian-based trade models, these approaches argue that the rising income inequalities in the advanced countries are attributable to the globalization-induced structural changes in the industrial base of the respective countries, which shift the labor demand towards industries and tasks that are capital-intensive and require highly skilled labor (G. E. Johnson & Stafford, 1993; Leamer, 1998; Murphy & Welch, 1995; Wood, 1995).

In the mid-1990s, partly as a response to the technology-vs-trade debate, a new family of sophisticated trade models emerged in the literature, relying heavily on the original or modified versions of the Ricardian framework and its corollaries, the HOS model, and the SS effect. An important innovation of these models is that they recognize the importance of international production fragmentation, offshoring and the rise of a new form of trade along global supply and value chains (Bhagwati et al., 2004; Feenstra & Hanson, 1995, 1996, 1997, 1999; Grossman & Rossi-Hansberg, 2006). These approaches find theoretical support and empirical evidence for the variegated effects of increased trade volumes in final and intermediate goods and the influence of offshoring on relative factor prices, in both advanced and emerging economies.

A prime example of this group of the literature is Feenstra and Hanson (1996, 1997, 1999) who emphasize the adverse effects of capital mobility and technological change on the labor share in both developing and developed countries, revising the traditional claims of Ricardian-based trade theory. In particular, they investigate the effects of capital mobility on the relative demand of high- and low-skilled labor in the US and Mexico, and they find that outsourcing/offshoring leads to an increase in the demand for high-skilled labor in both countries, whereas the effect on the demand and incomes of low-skilled laborers in the two countries, will eventually depend on the direction of the terms of trade (Feenstra & Hanson, 1995, p. 3).

From a non-neoclassical perspective, Kaleckian approaches, and studies inspired by the research agendas of international political economy emphasize the role of institutions, socio-political apparatus, and labor bargaining power. This literature has developed an open and productive dialogue with non-economic approaches found in the literature of macro- and micro-sociology (see power resources approach), economic geography and political science, the extensive literature that employs the analytical frameworks of GCCs, GVCs and GPNs. These approaches emphasize the asymmetry between the powerful position of capital in global production systems, which has the ability to move from place to place and relocate production or outsource parts of the production to low-cost regions of the world economy, minimizing the bargaining power of labor and generating a bias in the distributional outcomes of globalization.

Among the first, was Rodrik (Rodrik, 1997) who questioned the Samuelsson's claim of a zero-sum game for the trade liberalization. A similar argument was promoted by Arrighi, Silver and Brewer (2003) whose findings contradicted the pro-trade economists' claims that trade liberalization and neoliberal policies have reduced the income divide between North and South. They found that in the last four decades since their publication, there is no evidence of convergence in the income levels since the 1960s for the world economy. Harrison (2005) provides empirical evidence that labor in poor countries is disproportionally affected, in terms of the labor share declines, from currency crises compared to advanced countries, trade liberalization reduces labor incomes in both poor and advanced, whereas capital controls are found to be beneficial for labor's income.

Onaran (2009) analyzed the manufacturing sector of three emerging markets economies that follow different development paths (Mexico, Turkey and Korea), empirically assessing the effects of globalization, exchange rates fluctuations and the business cycle, on the labor share. She finds similar results to Harrison (2005) with respect to the impact of the exchange rates crisis on labor income, as well as the net effects of international trade intensification. Stockhammer (2017) uses panel data econometric regression to explore the effects of globalization, financialization, technological change and welfare retrenchment on the labor share of 43 developing and 28 advanced economies. He finds strong negative effects for financialization and welfare retrenchment, mixed results for technical change between advanced and emerging economies, and strong negative effects for globalization for both income groups, in contrast to the Stolper-Samuelson theorem.

4.2.2 The Power Resources Approach and the Positional Power of Labor

The power resources approach (PRA) finds its roots in the 1970s and the pioneering work of Korpi (1974, 1983). The latter argued that labor as a social class can organize and successfully win political and economic battle for its interest through collective mobilization of power resources. The basic premise on which the PRA apparatus is built on can be found in the Weberian conceptualization of power, which is defined as a possibility of an actor to act on his own will despite any resistance from other actors or the social environment, including the mobilization of power resources (Schmalz et al., 2018; Weber, 1968).

According to Korpi (1978) employers have a structural advantage over their employees since they are able to materialize their power resources which come in the form of "potential and actual concentration, ease of mobilization, ease of transformation and range of applicability, capital and control over the means of production" (1978, p. 23). However, in this conflict, laborers are also able to utilize either individual skills that offer them some kind of power in the labor market, or collective resources, usually in the form of trade unions associations and political parties (Refslund & Arnholtz, 2021). Early studies in the PRA tradition investigated the political economy of the emergent welfare state and the expanding scope of social policies, underlying the decisive role played by the organized labor movement and the power resources which mobilized in order to achieve these politico-economic outcomes (Korpi, 1978, 1983, 1985; O'Connor & Olsen, 1998).

In the US, the PRA was formalized and developed by Perrone (1984; 1983), Wright (2000), Arrighi and Silver (1984), Wallace and authors (1993; 1989, 1993), who in a series of empirical and theoretical studies, proposed a complex Marxist class theory that dominated the power resources literature (Schmalz et al., 2018). Within this context, they differentiated labor's bargaining power according to the specific social and economic positions and functions workers hold and engage with. Two concepts emerged from this differentiation, the *structural* power of labor that stems from labor's specific position within an interdependent economic system, and the *associational* power arising from the collective political activity and trade union associations, which laid the foundations for the elaboration and discussion of the labor bargaining power sources.

Historically, Arrighi and Silver (1984) were the first in this tradition to offer a distinction between two types of labor bargaining power, the marketplace and the workplace bargaining power. *Marketplace bargaining power* relates to the bargaining power of labor when workers sell their labor-power to the capitalist, and thus puts emphasis on the specific characteristics of labor's skills and the degree of subjection to capital's authority. On the other hand, *workplace bargaining power* denotes the power of labor stemming from the vulnerability of capital to workers' resistance, due to increased concentration and centralization of labor in large production units and the "connectedness of work roles" (Arrighi, 1982). According to them, capitalist accumulation constantly transforms industrial organization and the labor process, in such a way as to weaken marketplace bargaining power, through the deskilling and homogenization of labor, and at the same time strengthen workplace bargaining power via the concentration of greater volumes of living labor in the same production unit, paving the way for "their association in a struggle against their common exploitation" (Arrighi, 1982, p. 84).

Around the same time, Perrone (1984) identifies the position of labor in the production process of complex interdependent economic systems and the "disruptive potential of workers which is derived from their varying positions within the system of economic interdependencies" (1984, p. 414), as a form of *structural* labor bargaining power. An important novelty of Perrone's work was that he managed to operationalize and empirically measure labor's structural power through the mapping of particular labor positions – or *positional* power - in the interdependent system of the Italian economy. His empirical approach was based on the utilization of Input-Output tables and the assumption that an industrial sectors' positional power, measured by the number of linkages connecting the supplying sectors to the demanding sectors, acts as a proxy for the positional and consequently structural power of labor employed in those sectors.

Input-Output tables represent the interdependent nature of a capitalist economy. Each row of an Input-Output table shows the amount of goods/services produced by every sector in the economy and how much of these commodities are used, either as an input for the production of other goods/services or as a component of final demand, namely consumption, investment, government expenditures and net exports to the rest of the world. Likewise, each column of an Input-Output table expresses the inputs demanded from the other sectors of an economy, as well as, the amount of labor and capital used for the production of goods/services. Perrone (1984) focuses on the 1974 Italian Input-Output table and constructs a *reachability matrix* that measures the frequencies of direct and indirect linkages among the sectors of the economy. Based on the information of the reachability matrix, he produces estimates of the direct and total disruptive potential of each sector, by measuring the outdegrees (divided by the number of employees in each sector) of the reachability matrix, that is the number of linkages connecting supplying to demanding sectors.

Perrone's paper was edited by Wright and published in the *American Sociological Review* after his unexpected death. Unfortunately, this means that he was not able to address any of the assessments and criticisms made by his reviewers. This task was eventually performed by Wallace, Griffin and Rubin (1989), who refined Perrone's conceptualization of labor bargaining power and introduced a more advanced, and analytically exploitable, notion of structural labor power. First, Wallace et al. (1989) extended the understanding of positional power to account for the disruptive potential of the receiving sectors, as well as, the non-systemic, localized "threat of damage" (1989, p. 199) within an industry. This significantly broadened the analytical depth of the concept of positional/structural power of labor, since it embodied cases of disruptive potential for the economic system as a whole and not only for the damage threat directed from input supplying (upstream) sectors to receiving (downstream) sectors. Furthermore, instead of measuring (via the reachability matrix) whether a sector has established direct or indirect input-output linkages with other sectors, they proposed a continuous logarithmic version of the degree centrality of each sector, measuring volumes of transactions between sectors. In that way, they proposed a measurement of positional power that gives "greater weight to industries that send some goods and services to every other industry than to industries that send a large volume to a single industry" (1989, p. 200). Afterwards, they applied their positional power measurement specification to the US Input-Output tables for the benchmark years of 1963, 1967, 1972 and 1977.

In the next decade, the analyses of Wright (2000) and Silver (2003) dominated the PRA literature. Wright (2000) distinguishes between only two dimensions of labor bargaining power, associational and structural. With associational power, he defines the collective power of the working class emerging from representative institutions and labor organizations. The density of unionization, the coverage of the collective agreements or the participation of labor collectives in firm and non-firm decision making, are some of the attributes of associational power. Structural power, on the other hand, represents the "power of workers as individuals that results directly from tight labor markets or from the strategic location of a particular group of workers within a key industrial sector" (2000, p. 962) and their capacity to interrupt the normal functioning of the production process, and in that way pressure employers for concessions. Silver (2003) extensively builds on Wright's work, as well as, previous work conducted by herself and Arrighi (1982; 1984) and reiterates the division between associational and structural bargaining power, whereas the latter is further divided into *structural marketplace bargaining power*, stemming from the "tight labor markets" and *structural workplace bargaining power*, generated by the "strategic location" of labor in the production process.

More recent studies combine elements from labor geography, institutional analysis, and labor union revitalization research, introducing new dimensions of labor bargaining power, along with the traditional structural/positional and associational. Chun (2005), Fine (2005) and Pernicka, et al. (2021) introduce the logic of symbolic power, as the power that workers are able to command through cultural and public debates. Others have highlighted cases in which the labor bargaining power is exercised as logistical power, in the sense of street and transportation blockages (E. Bonacich & Wilson, 2008; Nowak, 2021; Webster et al., 2008). Similarly, Brookes (2013) introduces, along with Silver's variant of structural power, two distinct categories of labor bargaining power, Institutional and Coalition labor power, usually exercised by laboring classes when they act through transnational alliances. Brookes (2013) identifies as institutional power the ability of workers to resort to the legal and institutional framework of their respective nations, in order to hold their employers accountable and influence their behavior and as coalition power the "capacity of workers to expand the scope of conflict by involving other, nonlabor actors willing and able to influence an employer's behavior" (Brookes, 2013, p. 192). A similar categorization has been proposed by Schmalz, Ludwig and Webster (2018), who identify four distinct types of labor bargaining power, associational and structural, as Wright (2000) and Silver (2003), institutional, as Brookes (2013), and societal, in which they encompass the coalition power of mobilizing other non-labor actors and the discursive power of shaping and leading public debates on labor-related issues.

With respect to the empirical investigation of the effects of positional/structural power on labor outcomes and behavior, Perrone (1984; 1983) reports a systematic and strong effect on wages, but a statistically insignificant effect on the levels of strike activity. When positional/structural bargaining power and strike activity are taken together, the regression analysis of Perrone (1984; 1983) on average wages, shows a positive effect bargaining power and a negative effect for strikes, probably because for a given level of positional/structural power of labor, strikes are more likely to happen when wages are low (1984, p. 418). Similar results were found by Wallace, et al. (1989), who assess the explanatory power of positional/structural labor bargaining power on multiple labor outcomes, like union density, strike frequency, duration and volume, average wages and fringe benefits.

An interesting result of the analysis conducted by Perrone (1984; 1983) and Wallace, et al. (1989) is that the positional/structural power of labor is greater when it is defined as the disruptive ability to the upstream sectors of the economy, compared to the downstream sectors. These results can be explained by the higher profit-realization risks that a stoppage in the downstream production process puts input suppliers to face (who have finished products in their hands ready to ship to their customers), compared to the mitigating strategy of products stockpiling that receiving sectors have the ability to untangle, as well as, by the inherent difficulties suppliers face in finding new customers, particularly when the inter-firm relations between buyers-suppliers are of the relational or captive format (Gereffi et al., 2005), which require strict production specifications and customized products and services[11].

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[11] Tomaskovic-Devey (1988) extended the analytical framework of Perrone and the conceptualization of the positional/structural power to firms and the investigation of the sources of industrial productivity.

Wallace, et al. (1993) observe a shift in the notion of positional/structural labor bargaining power from the macro-level of the theretofore studies, to the micro-level. Following a multivariate structuralist approach in the analysis of individual earnings inequalities, they test their previous findings against sociodemographic data and other structural sources of earnings determination in order to investigate whether the positive linking between positional/structural power and labor outcomes holds across social classes, labor occupations and demographic groups. They show that the positive effects of labor positional/structural power on individual earnings still holds across "class, organizations, labor market experiences, and socio-demographic characteristics" (1993, p. 102).

Additionally, they test two micro-level hypotheses about the distribution of labor positional/structural power across class and occupational structures, the *agency hypothesis* against the *social control hypothesis*. The agency hypothesis states that those "workers who possess and utilize positional power are most likely to benefit from its presence" (1993, p. 92), meaning that those occupational groups within the working class of an establishment, like blue-collar workers or low-status white-collar occupations, will have to benefit more from positional/structural power. On the contrary, the social control hypothesis, states that positional/structural power should reward those workers with high occupational and technical skills and managerial occupations since they usually "play a crucial social control function in curbing disruptions of subordinates and cementing a cultural identification with the interests of the firm" (1993, p. 92). The multivariate regression analysis conducted on Wright's (1985) class structure typology and survey-based dataset, finds evidence in favor of

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In particular, he underlined that there is no "logical reason" why the power that workers accrue due the position of their firms in the interdependent economic system, would not equally be extended to the power available to managers and capital holders. In the empirical part of his study, he finds evidence supporting a positive relationship between sectoral position of firms and productivity.

the social control hypothesis showing that earnings gains due to the positional/structural power of labor, are not evenly distributed across occupational structures, with the lower-skilled laborers, whereas holding strategic positions in the production process and having the ability and history to be disruptive and militant, earn less than their colleagues in the upper echelons of labor structures.

With respect to the investigation of the effects of the various dimensions of labor bargaining power on the income distribution between labor and capital, several empirical studies have proved that labor market deregulation, the decline in labor militancy and organization and welfare retrenchment, are responsible for the fall in labor shares. Leslie and Pu (1996), use union density measures to explain changes in personal income inequality in Britain over time and they find that the rising wage inequality in Britain is attributable to the pay settlement arrangement that has been moved towards market-based individualistic forms, weakening the union sector. Wallace, et al. (1999) focus on the US post-War period and test whether changes in union membership and strike activity affects the labor share in national income. Utilizing a quarterly time-series dataset they observe that the positive link between union membership on labor share was much stronger before the 1980s. In the 1980s and afterwards, the linkage seems to have been weakened significantly, whereas for the whole period, they find inconclusive results about the effects of strike activity, either non statistically significant or even negative with respect to the impact on labor income.

Fichtenbaum (2009) builds an analytical model based on assumptions of imperfect competition and assesses empirically long time-series data for the US manufacturing sector, finding significant results for a positive impact of unions on the labor share of income, showing that for “each one percentage point reduction in union density is associated with a 0.2 percentage point reduction in the proportion of income received by production workers, holding other factors constant" (2009, p. 584). Kristal (2010) investigates the period 1960-2005 for 16 industrialized countries and finds a positive effect on labor share coming from union density, unemployment benefits, strikes, left governments and social expenditures. Bengtsson (2014) explores the determinants of labor share for 16 OECD countries for the period from 1960 to 2007, using as explanatory variables the union density, unemployment rates, trade openness, labor productivity, welfare state expenditure and the presence of left-wing governments. He finds a positive association between union density and wage share in the 50 years of his dataset for advanced economies.

The PRA literature has recently re-emerged, emphasizing the revitalization of trade unions and investigating the behavior of labor positioned in strategic sectors of the economy (Moody, 2017). National-level studies on labor militancy episodes and strikes have been also investigated with relation to the balance between dimensions of labor bargaining power. Stillerman (2017) evaluates four strike episodes in MADECO, the largest copper manufacturer in Chile, taking place in 1960, 1965, 1983 and 1993. Each strike represents a different combination of labor bargaining, structural, associational, and symbolic power, leading to different results. Stillerman concludes that the strike outcomes depend, not only on the structural power of labor and its ability to disrupt production (a common factor in all four strike episodes), but also on the "degree of workers' unity, the availability of nearby government allies, and the degree of government and business dependence on foreign capital" (2017, p. 98).

Fox-Hodess (2017) and Fox-Hodess and Santibáñez Rebolledo (2020) focus on the solidarity movement of the International Dockworkers Council towards its affiliates' mobilizations in Portugal, Greece and the UK and the Chilean dockworkers' strike movement, respectively. They emphasize the role of associational and societal dimensions of labor bargaining power, that is the ability of trade unions, even in strategically positioned sectors of the global economy, to oragnize struggles and coordinate nationally and internationally with other labor and non-labor communities. Hui (2021) investigates bottom-up attempts of unioninzatin by rural migrant workers in China, identifying an important shift in their strategies from utilizing associational power to gain economic related outcomes, to – what the author denotes as – workplace institutional power, that is the "ability to shape workplace rules and regulations as well as employment terms and conditions on a regular and organizational basis" (2021, p. 2).

4.2.3 Critical Assessment of the Literature

Given the above discussion of the two main strands in the literature of the political economy of income distribution, I identify several limitations which I attempt to address with the present study. First, whereas the theoretical and empirical approaches originating from economics acknowledge – to some extend – the explanatory opportunities that labor bargaining power offers with respect to the evolution of labor shares, they do not engage with the conceptual and analytical frameworks developed by alternative approaches, like for example the PRA. Studies within the economic literature, irrespective of their theoretical inclination towards neoclassical or non-neoclassical theories, tend to investigate the technological characteristics of economic systems and explore how globalization, either conceived as foreign competition of imported goods and intermediate inputs, or as international fragmentation of production and supply chains, affect labor outcomes. However, in doing so, they conceptualize labor bargaining power in the narrow scope of union density rates and strike activity, failing to acknowledge other dimensions of the bargaining power of labor.

The variables of union density and strike activity, furthermore, are either scarce with respect the time, as well as the country and sector dimension, or have limited or inconclusive explanatory power compared to other dimensions of labor bargaining power (Perrone et al., 1984; Wallace et al., 1989; Wright & Perrone, 1983). Focusing on the individual wage differences of workers in highly unionized sectors as well as the entire workforce in the US, Rosenfeld (2006) finds an insignificant effect of the union density (Rosenfeld, 2006; Wallace et al., 1999). No effects of unionization on labor shares are found by Jaumotte and Tytell (2007) and Checchi and Garcia-Penalosa (2008), whereas Daudey and Decreuse (2006) and Kristal (2010) find positive and significant effects, Stockhammer (2009) positive and significant effects except in countries where unions administrate the unemployment benefit system, and Fichtenbaum (2009) and Kristal (2013) find positive effects of union density on wage shares in US manufacturing industries, only.

Second, notwithstanding the emphasis the PRA literature gives on the analysis of labor bargaining power, it seems that the majority of the recent studies, either neglect the distinctions between the various dimensions of labor bargaining power (Bengtsson, 2014; Fichtenbaum, 2009; Kristal, 2010; Leslie & Pu, 1996; Wallace et al., 1999) or fail to properly measure structural bargaining power as the position of labor in the intersectoral structure of production (Fox-Hodess, 2017, 2020; Fox-Hodess & Santibáñez Rebolledo, 2020; Hui, 2021; Stillerman, 2017). Remarkably, despite the wealth of empirical studies in the area, directly influenced by the work of Perrone (1984; 1983), Wright (2000), Arrighi and Silver (1984), Wallace and authors (1993; 1989, 1993), up to now, and to the best of our knowledge, there has not been any empirical assessment of the relationship between labor's positional/structural power and labor outcomes, at the global level.

Third, both economics and PRA approaches fail to capture the international dimension of labor bargaining power, since they conceptualize and measure it only at the narrow national level. National economic systems become increasingly integrated into global supply chains, whereas international trade has transformed into an important aspect of globally fragmented production systems. In order to understand the dynamics of labor bargaining power and the transmission mechanisms through which it most effectively expresses itself, I need to understand the structural position of labor in the global production chains, in the international division of labor. In other words, I need to understand the position of labor in the national economic formation, as well as the location of national sectors in the global economy.

4.3 The Global Positional Power of Labor

In this paper, I follow the conceptualization of structural labor bargaining power as it was proposed by Perrone (1984; 1983) and Wallace and authors (1993; 1989, 1993), who conceived labor's positional power in an economic system, as the centrality of the normalized by the number of workers. Positional power captures labor's capacity for disruption, such that a better-positioned sector is able to cause more disruption which gives the sector more bargaining power. Given the fact that rise of international trade and the integration of national economic systems with GVCs and internationally fragmented supply chains, I contend that the same idea regarding the positional power of labour, should also hold at the global level. This means that workers in a sector better positioned in global production should also have more bargaining positional/structural power.

I have to note that higher structural power does not necessarily imply higher wages or even higher overall bargaining power. This is because a) structural power captures only one part of the overall bargaining power. This means that even in situations of high structural power, the overall bargaining power can be low, due to low associational power and b) the relationship between bargaining and wages is a stochastic rather than a deterministic one. High bargaining power means, high *probability* for labour gains in situations of conflict rather than directly higher wages. Consequently, if this approach is correct, we would expect to find a positive relationship between the structural power of labor and labor income share, across sectors and across countries and time. In order to be able to check if there is a positive relation between structural power and wage levels in different sectors, I first identify a quantitative measure of the positional/structural power.

Given that global production consists of interconnected networks of production processes, with every node representing a sector and every link the input-output relationships between them, I use insights from network theory which quantify the level of positional power of a node within a network. A fundamental concept in network theory, which concentrates on different aspects of the position that a node has, is the concept of *centrality* (Barabási, 2016; Jackson, 2008). One of the most commonly used measures of centrality is that of *degree*, which simply counts for each node, the number of links it has established with the other nodes of the network under examination. For example, if a node is connected with many other nodes, is considered highly central, compared to a node that is positioned in the periphery of a network.

Applying this concept to labor within global production we would expect that laborers employed in the most centralized sectors of the global economy, will tend to have higher positional/structural power, and hence will have, on average, higher compensation gains and consequently larger labor shares. However, in order to capture the direct and indirect effects of the positional/structural labor bargaining power and its ability to disrupt the production system globally, we need to take into account, not only the number of links between every node-sector, as well as their relative strength, but also the indirect linkages of each sector with the rest of the global economy. An appropriate measure is PageRank centrality, which measures the relative importance of nodes in a network (see Chapter ## for details regarding the various centrality measures).

Having established global positional power of labor as the centrality of labor occupations in the internationally fragmented, but functionally integrated production processes of global value chains, provides us with new insights with respect to the macroeconomic and sociological puzzles reviewed in the previous section. First, global positional power of labor becomes an important determining factor in assessing the effects of globalization on labor incomes both within the labor class in the same country, and between labor and capital within and between countries. Stolper-Samuelson theorem predicts rising incomes for laborers in emerging countries due to the rise of international trade. On the contrary, Rodrik's thesis emphasizes the falling labor shares due to rising bargaining power of the mobile international capitalist class. However, if we take into account the strategic position that labor holds with respect to the structure of global production, we understand that neither the former nor the latter are necessarily right. Whether the working class in advanced or emerging economies will be able to gain from the integration of global production and the rise of international trade, will depend – among other factors - on the global positional power of labor. Consequently, the arguments employed by the two ends of the globalization debate might be mis-specified and the claims of each approach misleading, if we don't introduce into the analysis an understanding of the structure of global production, the position of labor within it and the implications for distributional conflicts. Second, interpreting the empirical literature in the fields of international macroeconomics and the PRA tradition through the lens of global positional power of labor, lead us to the conclusion that their quantitative results might be misleading.

Conceptualizing labor bargaining power as a unidimensional variable that is - most of the times - quantified by union density or strike activity ignores the fact that workers are active agents of production with the ability to interrupt the normal functioning of internationally extended production process, generating supply chains disruptions and system-wide risks. Moreover, having an empirical measure of the positional/structural power of labor is an important tool in performing comparative analyses with respect other dimensions of labor bargaining power and thus assessing their net effects on labor outcomes. For instance, the research agenda of the trade unions revitalization literature, has overemphasized the importance of the non-structural dimensions of power, like associational, institutional, societal, etc., failing to incorporate into its empirical analyses positional/structural power as a quantified measure of the disruptive ability of labor.

4.4 Data and Methodology

4.4.1 Data

For our analysis, I rely on the World Input-Output Database (Timmer et al., 2015), which provides time-series for input-output tables, at the global scale. This means that additionally to the national-level input-output tables, the WIOD provides information about the international trade flows between economic sectors in the world economy. In other words, with WIOD I are able to investigate not only the interconnectedness of an industrial sector with the rest of the economy in a particular country but also the linkages with buyers and suppliers, at the sectoral level, in other countries as well.

Based on the information given by the WIOD, I are able to construct the global production network, with each node representing an economic sector within a country and each link representing inter-country and inter-sectoral linkages. All data in the WIOD are structured around a global Input-Output table, with the block diagonal reflecting the respective national input-output tables. The WIOD comes in two versions at basic prices in millions of US dollars. In this paper, I decided to use the 2013 version of the WIOD database, because it offers additional data regarding the skill types of labor at the sectoral and national levels. This version covers 35 economic sectors, at the ISIC Rev.3 classification system and 40 countries, from 1995 to 2011. Overall, the 2013 version of WIOD is comprised of 16 annual global input-output tables, with 1,400 country-sector observations (rows/columns) each. Since the 2013 version of the WIOD does not provide data for the value-added components (labor and capital compensation), of the two last years (2010 and 2011), I will only use the data until 2009. The list of countries and sectors of the WIOD database are gathered in the Appendix.

Table 4-1 Full Sample Descriptive Statistics

Variable	Mean	Maximum	Minimum	Std. Dev.	Observations
PageRank	0.0007	0.0171	0.0001	0.0009	21,000
Labor Share	0.0007	0.0173	0.0000	0.0008	21,000
Labor Share (High-Skilled)	0.0002	0.0031	0.0000	0.0004	21,000
Labor Share (Medium-Skilled)	0.0003	0.0111	0.0000	0.0004	21,000
Labor Share (Low-Skilled)	0.0002	0.0123	0.0000	0.0004	21,000

Sources: Own Calculations. *Note*: Descriptive statistics are calculated using the full sample. The variables refer to observations at the sectoral level.

Additional to the annual input-output tables, the WIOD provides information - among others - about the labor compensation (LAB) of workers per sector in each country, as well as sectoral value-added. Based on these two variables, I calculated the labor share per country sector by dividing the sectoral LAB with the sectoral Value-Added. For example, in order to calculate the labor share of the chemicals sector in China, I divided the labor-bill (total amount of labor compensation) of the construction sector in China, by its respective value-added. The Socio-Economic Matrix that corresponds to the

2013 version of the WIOD input-output tables, includes information about the skill types of labor, distinguishing between low-, medium- and high-skilled labor. Low-level skill-type corresponds to primary and lower secondary education (ISCED-level 1 and 2), Medium-level skill-type to upper secondary and post-secondary education (ISCED-level 3 and 4), and High-level skill-type to first and second stage tertiary education (ISCED-level 5 and 6). Table 4-1, presents the summary statistics of the full sample of the dataset, whereas Table 4-2, Table 4-3, Table 4-4, Table 4-5, and Table 4-6, summarize the descriptive statistics per country for the variables of sectoral PageRank, sectoral Labor Share, and sectoral Labor Share per skill-type.

4.4.2 Methodology

I use the intermediate demand matrix of our dataset - which expresses the value (in million dollars) of inter-sectoral transactions for goods and services used as inputs in the production process of each sector – and I divide each transaction with the number of workers employed in the producing sector. I then calculate the centralities of all the economic sectors in the database and get an approximation of the positional power of labour for each of the sectors across countries. For each year, I construct the economic network corresponding to the per-worker values transferred between producing and consuming industries, at the global level. I measure centrality with PageRank centrality, which takes into account not only the number and volume of transactions established by a sector with its immediate neighboring sectors, but also the centrality of the neighboring sectors, as well. In other words, a sector will have high PageRank centrality score if it is connected with other highly central sectors. My next step is to empirically assess the relationship between positional/structural bargaining power of labor and the labor share of national income. I do so with the use of a Vector Autoregression (VAR) model with panel data. VAR models have become the standard empirical approach in quantitative analyses in economics and are usually used as an alternative choice to theory demanding econometric structural models (Jordà, 2005). VAR methodology is considered as an a-theoretical empirical tool in the sense that it does not require any prior restriction on the explanatory variables or an ex-ante distinction between exogenous and endogenous variables. Another important advantage of VAR models is that they account for the impact of past variables to any present variable, as well as, for the interaction between variables (Stockhammer & Onaran, 2004).

The standard VAR approach requires to regress all variables on their own lag values and the lags of all other variables, like in the following equation:

$$y_{it} = \alpha_{0t} + \sum_{l=1}^{m} \beta_{lt} y_{it-l} + \sum_{l=1}^{m} \gamma_{lt} x_{it-l} + \delta_t z_i + u_{it} \tag{4-1}$$

where the coefficients a_{0t}, β_{lt} and γlt, are the linear projections of y_{it} onto a constant and the past values of x and y, with lags m, sufficiently large to ensure that the disturbance part, u_{it} is a white noise. The term $\delta_t z_i$ refers to the unobserved individual effects of the cross-section, sectoral, dimension.

Applying VAR methodology to disaggregated panel data is not infrequent. Since Holtz-Eakin, et al. (1988) paper that introduced estimation and testing techniques specifically designed for the application of VAR methodology to panel data, this path has been extensively used in macroeconomic analyses (see among others Autor & Salomons, 2018; Hall et al., 2012; Ramey & Zubairy, 2018). The panel data vector autoregression methodology unfolds in two steps, combining the traditional VAR approach, treating all system's variables as endogenous, with the panel data approach, in which we allow for individual unobserved heterogeneity.

Table 4-2 Summary Statistics for PageRank Centralities

Countries	Mean	Maximum	Minimum	Std. Dev.	Observations
Australia	0.000680	0.004344	0.000115	0.00064	525
Austria	0.000553	0.001572	0.000115	0.00030	525
Belgium	0.000594	0.001923	0.000115	0.00042	525
Brazil	0.000697	0.002321	0.000115	0.00043	525
Bulgaria	0.000376	0.001766	0.000115	0.00028	525
Canada	0.000603	0.002503	0.000115	0.00046	525
China	0.000297	0.002072	0.000115	0.00025	525
Cyprus	0.000380	0.001392	0.000115	0.00030	525
Czech Republic	0.000505	0.001904	0.000115	0.00032	525
Denmark	0.000533	0.001996	0.000115	0.00035	525
Estonia	0.000311	0.000949	0.000115	0.00016	525
Finland	0.000580	0.002271	0.000115	0.00037	525
France	0.001274	0.005506	0.000115	0.00104	525
Germany	0.001946	0.011030	0.000115	0.00180	525
Greece	0.000666	0.002481	0.000115	0.00054	525
Hungary	0.000440	0.001848	0.000115	0.00027	525
India	0.000644	0.002498	0.000115	0.00053	525
Indonesia	0.000475	0.002095	0.000115	0.00033	525
Ireland	0.000454	0.003750	0.000115	0.00044	525
Italy	0.001411	0.005384	0.000115	0.00094	525
Japan	0.001211	0.004243	0.000115	0.00088	525
South Korea	0.000745	0.002958	0.000115	0.00054	525
Latvia	0.000381	0.002417	0.000115	0.00030	525
Lithuania	0.000361	0.001723	0.000115	0.00027	525
Luxembourg	0.000233	0.002853	0.000115	0.00026	525
Malta	0.000291	0.001605	0.000115	0.00020	525
Mexico	0.000597	0.003479	0.000116	0.00065	525
The Netherlands	0.000605	0.002363	0.000115	0.00041	525
Poland	0.000614	0.002521	0.000115	0.00043	525
Portugal	0.000543	0.003012	0.000115	0.00047	525
Romania	0.000474	0.002556	0.000115	0.00035	525
Russia	0.000887	0.005515	0.000115	0.00083	525
Slovak Republic	0.000370	0.001287	0.000115	0.00023	525
Slovenia	0.000378	0.001668	0.000115	0.00023	525
Spain	0.001064	0.008185	0.000115	0.00104	525
Sweden	0.000662	0.002014	0.000115	0.00042	525
Taiwan	0.000428	0.001600	0.000115	0.00031	525
Turkey	0.000750	0.004316	0.000115	0.00066	525
UK	0.001531	0.013339	0.000115	0.00164	525
USA	0.003028	0.017099	0.000115	0.00312	525

Source: Own Calculations. Note: Summary statistics are calculated using the sectoral level observations for each country, for every year of the sample.

Table 4-3 Summary Statistics for Labor Share

Countries	Mean	Maximum	Minimum	Std. Dev.	Observations
Australia	0.000726	0.003782	0.000000	0.000777	525
Austria	0.000798	0.002948	0.000003	0.000731	525
Belgium	0.000801	0.004899	0.000009	0.000923	525
Brazil	0.000619	0.003688	0.000000	0.000714	525
Bulgaria	0.000609	0.004113	0.000000	0.000643	525
Canada	0.000690	0.002684	0.000005	0.000700	525
China	0.000577	0.007280	0.000000	0.000892	525
Cyprus	0.000760	0.004251	0.000000	0.000877	525
Czech Republic	0.000692	0.003275	0.000003	0.000603	525
Denmark	0.000811	0.004729	0.000002	0.000936	525
Estonia	0.000702	0.003216	0.000000	0.000617	525
Finland	0.000776	0.003779	0.000015	0.000793	525
France	0.000748	0.004539	0.000020	0.000881	525
Germany	0.000792	0.003892	0.000013	0.000730	525
Greece	0.000655	0.003248	0.000008	0.000700	525
Hungary	0.000725	0.002866	0.000000	0.000653	525
India	0.000627	0.006776	0.000011	0.000967	525
Indonesia	0.000579	0.005389	0.000000	0.000771	525
Ireland	0.000680	0.003919	0.000002	0.000759	525
Italy	0.000774	0.003548	0.000035	0.000693	525
Japan	0.000683	0.002979	0.000000	0.000700	525
South Korea	0.000906	0.004104	0.000000	0.000912	525
Latvia	0.000641	0.003295	0.000000	0.000630	525
Lithuania	0.000633	0.003656	0.000011	0.000648	525
Luxembourg	0.000663	0.004987	0.000000	0.000919	525
Malta	0.000710	0.003455	0.000000	0.000714	525
Mexico	0.000411	0.001819	0.000013	0.000422	525
The Netherlands	0.000792	0.005030	0.000005	0.000935	525
Poland	0.000899	0.017330	0.000019	0.001749	525
Portugal	0.000789	0.003312	0.000019	0.000816	525
Romania	0.000758	0.012458	0.000000	0.001442	525
Russia	0.000698	0.003935	0.000000	0.000773	525
Slovak Republic	0.000461	0.001752	0.000000	0.000406	525
Slovenia	0.000882	0.005659	0.000003	0.000851	525
Spain	0.000752	0.003366	0.000000	0.000762	525
Sweden	0.000788	0.004245	0.000000	0.000885	525
Taiwan	0.000713	0.003845	0.000020	0.000808	525
Turkey	0.000460	0.004830	0.000012	0.000708	525
UK	0.000812	0.003185	0.000008	0.000766	525
USA	0.000714	0.004522	0.000003	0.000980	525

Source: Own Calculations. Note: Summary statistics are calculated using the sectoral level observations for each country, for every year of the sample.

Table 4-4 Summary Statistics for Labor Share (High-Skilled)

Countries	Mean	Maximum	Minimum	Std. Dev.	Observations
Australia	0.000201	0.001697	0.000000	0.000352	525
Austria	0.000200	0.001670	0.000000	0.000317	525
Belgium	0.000196	0.002556	0.000002	0.000377	525
Brazil	0.000251	0.002357	0.000000	0.000433	525
Bulgaria	0.000110	0.001068	0.000000	0.000192	525
Canada	0.000197	0.001158	0.000001	0.000305	525
China	0.000048	0.000513	0.000000	0.000077	525
Cyprus	0.000341	0.002447	0.000000	0.000500	525
Czech Republic	0.000158	0.001697	0.000000	0.000238	525
Denmark	0.000280	0.002340	0.000001	0.000478	525
Estonia	0.000321	0.002018	0.000000	0.000377	525
Finland	0.000320	0.002230	0.000006	0.000436	525
France	0.000287	0.002831	0.000005	0.000484	525
Germany	0.000286	0.002088	0.000004	0.000353	525
Greece	0.000218	0.002052	0.000003	0.000407	525
Hungary	0.000246	0.001908	0.000000	0.000351	525
India	0.000146	0.001020	0.000001	0.000217	525
Indonesia	0.000094	0.001235	0.000000	0.000161	525
Ireland	0.000258	0.002305	0.000001	0.000404	525
Italy	0.000156	0.001468	0.000002	0.000296	525
Japan	0.000239	0.001504	0.000000	0.000327	525
South Korea	0.000502	0.002845	0.000000	0.000661	525
Latvia	0.000243	0.001721	0.000000	0.000334	525
Lithuania	0.000267	0.002071	0.000003	0.000374	525
Luxembourg	0.000215	0.002890	0.000000	0.000428	525
Malta	0.000164	0.001973	0.000000	0.000340	525
Mexico	0.000111	0.000814	0.000000	0.000162	525
The Netherlands	0.000276	0.003098	0.000001	0.000488	525
Poland	0.000209	0.001641	0.000004	0.000288	525
Portugal	0.000175	0.002211	0.000001	0.000379	525
Romania	0.000098	0.001058	0.000000	0.000155	525
Russia	0.000165	0.001449	0.000000	0.000228	525
Slovak Republic	0.000108	0.001063	0.000000	0.000163	525
Slovenia	0.000286	0.002169	0.000001	0.000414	525
Spain	0.000305	0.001942	0.000000	0.000437	525
Sweden	0.000239	0.002031	0.000000	0.000417	525
Taiwan	0.000270	0.002570	0.000004	0.000455	525
Turkey	0.000111	0.001243	0.000003	0.000200	525
UK	0.000328	0.001932	0.000003	0.000454	525
USA	0.000299	0.002727	0.000001	0.000521	525

Source: Own Calculations. Note: Summary statistics are calculated using the sectoral level observations for each country, for every year of the sample.

Table 4-5 Summary Statistics for Labor Share (Medium-Skilled)

Countries	Mean	Maximum	Minimum	Std. Dev.	Observations
Australia	0.000266	0.001369	0.000000	0.000270	525
Austria	0.000498	0.001699	0.000002	0.000438	525
Belgium	0.000411	0.001968	0.000005	0.000455	525
Brazil	0.000201	0.001207	0.000000	0.000228	525
Bulgaria	0.000105	0.000858	0.000000	0.000119	525
Canada	0.000475	0.001701	0.000004	0.000448	525
China	0.000226	0.000838	0.000000	0.000189	525
Cyprus	0.000257	0.001871	0.000000	0.000342	525
Czech Republic	0.000499	0.002039	0.000002	0.000411	525
Denmark	0.000402	0.001812	0.000001	0.000429	525
Estonia	0.000332	0.001934	0.000000	0.000280	525
Finland	0.000311	0.001547	0.000007	0.000311	525
France	0.000290	0.001231	0.000008	0.000291	525
Germany	0.000430	0.001577	0.000007	0.000374	525
Greece	0.000233	0.001279	0.000002	0.000269	525
Hungary	0.000400	0.001429	0.000000	0.000327	525
India	0.000234	0.001467	0.000004	0.000326	525
Indonesia	0.000157	0.000794	0.000000	0.000172	525
Ireland	0.000260	0.001860	0.000001	0.000292	525
Italy	0.000323	0.001585	0.000014	0.000309	525
Japan	0.000391	0.001592	0.000000	0.000381	525
South Korea	0.000319	0.001665	0.000000	0.000275	525
Latvia	0.000336	0.002164	0.000000	0.000335	525
Lithuania	0.000326	0.002070	0.000006	0.000341	525
Luxembourg	0.000275	0.002951	0.000000	0.000422	525
Malta	0.000140	0.000932	0.000000	0.000173	525
Mexico	0.000220	0.001032	0.000006	0.000228	525
The Netherlands	0.000338	0.001641	0.000002	0.000379	525
Poland	0.000580	0.011110	0.000013	0.001130	525
Portugal	0.000145	0.001056	0.000002	0.000182	525
Romania	0.000101	0.000733	0.000000	0.000096	525
Russia	0.000499	0.002975	0.000000	0.000572	525
Slovak Republic	0.000333	0.001218	0.000000	0.000282	525
Slovenia	0.000489	0.002632	0.000002	0.000415	525
Spain	0.000145	0.000660	0.000000	0.000153	525
Sweden	0.000420	0.002260	0.000000	0.000440	525
Taiwan	0.000228	0.001375	0.000007	0.000283	525
Turkey	0.000097	0.000477	0.000004	0.000094	525
UK	0.000324	0.001302	0.000003	0.000290	525
USA	0.000374	0.002603	0.000002	0.000482	525

Source: Own Calculations. Note: Summary statistics are calculated using the sectoral level observations for each country, for every year of the sample.

Table 4-6 Summary Statistics for Labor Share (Low-Skilled)

Countries	Mean	Maximum	Minimum	Std. Dev.	Observations
Australia	0.000259	0.001086	0.000000	0.000245	525
Austria	0.000101	0.000553	0.000000	0.000103	525
Belgium	0.000194	0.000984	0.000002	0.000191	525
Brazil	0.000167	0.000879	0.000000	0.000187	525
Bulgaria	0.000394	0.004019	0.000000	0.000537	525
Canada	0.000017	0.000147	0.000000	0.000020	525
China	0.000303	0.006960	0.000000	0.000837	525
Cyprus	0.000163	0.001329	0.000000	0.000245	525
Czech Republic	0.000035	0.000147	0.000000	0.000027	525
Denmark	0.000130	0.000831	0.000001	0.000127	525
Estonia	0.000049	0.000613	0.000000	0.000058	525
Finland	0.000145	0.000734	0.000002	0.000142	525
France	0.000172	0.000855	0.000005	0.000177	525
Germany	0.000076	0.000239	0.000001	0.000063	525
Greece	0.000205	0.001695	0.000000	0.000282	525
Hungary	0.000079	0.000742	0.000000	0.000091	525
India	0.000247	0.005223	0.000001	0.000634	525
Indonesia	0.000328	0.004794	0.000000	0.000614	525
Ireland	0.000163	0.001560	0.000000	0.000234	525
Italy	0.000295	0.001311	0.000012	0.000268	525
Japan	0.000054	0.000528	0.000000	0.000067	525
South Korea	0.000085	0.001027	0.000000	0.000106	525
Latvia	0.000062	0.000841	0.000000	0.000098	525
Lithuania	0.000041	0.000574	0.000000	0.000073	525
Luxembourg	0.000173	0.001403	0.000000	0.000224	525
Malta	0.000405	0.002455	0.000000	0.000388	525
Mexico	0.000080	0.000665	0.000000	0.000115	525
The Netherlands	0.000179	0.000893	0.000001	0.000187	525
Poland	0.000111	0.005622	0.000001	0.000554	525
Portugal	0.000469	0.002376	0.000009	0.000509	525
Romania	0.000559	0.012246	0.000000	0.001406	525
Russia	0.000034	0.000288	0.000000	0.000042	525
Slovak Republic	0.000020	0.000171	0.000000	0.000023	525
Slovenia	0.000107	0.002698	0.000000	0.000263	525
Spain	0.000301	0.002090	0.000000	0.000372	525
Sweden	0.000129	0.000559	0.000000	0.000116	525
Taiwan	0.000215	0.001231	0.000006	0.000264	525
Turkey	0.000253	0.004480	0.000002	0.000605	525
UK	0.000160	0.000685	0.000001	0.000133	525
USA	0.000041	0.000257	0.000001	0.000052	525

Source: Own Calculations. Note: Summary statistics are calculated using the sectoral level observations for each country, for every year of the sample.

Table 4-7 Unit-Root Tests for Stationarity of PageRank Centrality (p-values)

Variable PageRank	Levin-Lin-Chu			Im-Pesaran-Shin			Maddala-Wu		
Countries	(A)	(B)	(C)	(A)	(B)	(C)	(A)	(B)	(C)
Australia	0.0012	0.0001	0.0005		0.0001	0.0005	0.0012	0.0001	0.0005
Austria	0.0111	0.0000	0.0001		0.0000	0.0001	0.0111	0.0000	0.0001
Belgium	0.0046	0.0000	0.0003		0.0000	0.0003	0.0046	0.0000	0.0003
Brazil	0.0001	0.0000	0.0000		0.0000	0.0000	0.0001	0.0000	0.0000
Bulgaria	0.0122	0.0001	0.0003		0.0001	0.0003	0.0122	0.0001	0.0003
Canada	0.0049	0.0002	0.0014		0.0002	0.0014	0.0049	0.0002	0.0014
China	0.0003	0.0000	0.0000		0.0000	0.0000	0.0003	0.0000	0.0000
Cyprus	0.0049	0.0000	0.0000		0.0000	0.0000	0.0049	0.0000	0.0000
Czech Republic	0.0045	0.0000	0.0001		0.0000	0.0001	0.0045	0.0000	0.0001
Denmark	0.0044	0.0011	0.0069		0.0011	0.0069	0.0044	0.0011	0.0069
Estonia	0.0089	0.0000	0.0001		0.0000	0.0001	0.0089	0.0000	0.0001
Finland	0.0018	0.0002	0.0013		0.0002	0.0013	0.0018	0.0002	0.0013
France	0.0082	0.0000	0.0000		0.0000	0.0000	0.0082	0.0000	0.0000
Germany	0.0054	0.0000	0.0001		0.0000	0.0001	0.0054	0.0000	0.0001
Greece	0.0028	0.0001	0.0007		0.0001	0.0007	0.0028	0.0001	0.0007
Hungary	0.0007	0.0001	0.0006		0.0001	0.0006	0.0007	0.0001	0.0006
India	0.0021	0.0000	0.0002		0.0000	0.0002	0.0021	0.0000	0.0002
Indonesia	0.0022	0.0000	0.0001		0.0000	0.0001	0.0022	0.0000	0.0001
Ireland	0.0003	0.0000	0.0000		0.0000	0.0000	0.0003	0.0000	0.0000
Italy	0.0012	0.0001	0.0002		0.0001	0.0002	0.0012	0.0001	0.0002
Japan	0.0002	0.0000	0.0000		0.0000	0.0000	0.0002	0.0000	0.0000
South Korea	0.0125	0.0002	0.0017		0.0002	0.0017	0.0125	0.0002	0.0017
Latvia	0.0048	0.0000	0.0002		0.0000	0.0002	0.0048	0.0000	0.0002
Lithuania	0.0019	0.0000	0.0000		0.0000	0.0000	0.0019	0.0000	0.0000
Luxembourg	0.0006	0.0000	0.0000		0.0000	0.0000	0.0006	0.0000	0.0000
Malta	0.0003	0.0000	0.0000		0.0000	0.0000	0.0003	0.0000	0.0000
Mexico	0.0004	0.0000	0.0000		0.0000	0.0000	0.0004	0.0000	0.0000
Netherlands	0.0016	0.0007	0.0025		0.0007	0.0025	0.0016	0.0007	0.0025
Poland	0.0019	0.0000	0.0000		0.0000	0.0000	0.0019	0.0000	0.0000
Portugal	0.0070	0.0001	0.0004		0.0001	0.0004	0.0070	0.0001	0.0004
Romania	0.0007	0.0000	0.0000		0.0000	0.0000	0.0007	0.0000	0.0000
Russia	0.0037	0.0004	0.0018		0.0004	0.0018	0.0037	0.0004	0.0018
Slovak Republic	0.0002	0.0000	0.0000		0.0000	0.0000	0.0002	0.0000	0.0000
Slovenia	0.0003	0.0000	0.0001		0.0000	0.0001	0.0003	0.0000	0.0001
Spain	0.0020	0.0000	0.0000		0.0000	0.0000	0.0020	0.0000	0.0000
Sweden	0.0084	0.0000	0.0003		0.0000	0.0003	0.0084	0.0000	0.0003
Taiwan	0.0134	0.0001	0.0009		0.0001	0.0009	0.0134	0.0001	0.0009
Turkey	0.0018	0.0001	0.0010		0.0001	0.0010	0.0018	0.0001	0.0010
UK	0.0013	0.0000	0.0000		0.0000	0.0000	0.0013	0.0000	0.0000
USA	0.0071	0.0002	0.0015		0.0002	0.0015	0.0071	0.0002	0.0015

Source: Own Calculations. Notes: Column (A) refers to unit-root tests without exogenous variables, column (B) with intercepts and (C) refers to unit-root tests with intercepts and trends.

Table 4-8 Unit-Root Tests for Stationarity of Labor Share (p-values)

Variable Labor Share	Levin-Lin-Chu			Im-Pesaran-Shin			Maddala-Wu		
Countries	A	B	C	A	B	C	A	B	C
Australia	0.0026	0.0011	0.0065		0.0011	0.0065	0.0026	0.0011	0.0065
Austria	0.0019	0.0004	0.0025		0.0004	0.0025	0.0019	0.0004	0.0025
Belgium	0.0006	0.0002	0.0012		0.0002	0.0012	0.0006	0.0002	0.0012
Brazil	0.0000	0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000
Bulgaria	0.0004	0.0001	0.0008		0.0001	0.0008	0.0004	0.0001	0.0008
Canada	0.0023	0.0006	0.0040		0.0006	0.0040	0.0023	0.0006	0.0040
China	0.0000	0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000
Cyprus	0.0012	0.0007	0.0038		0.0007	0.0038	0.0012	0.0007	0.0038
Czech Republic	0.0018	0.0001	0.0010		0.0001	0.0010	0.0018	0.0001	0.0010
Denmark	0.0020	0.0002	0.0013		0.0002	0.0013	0.0020	0.0002	0.0013
Estonia	0.0007	0.0002	0.0014		0.0002	0.0014	0.0007	0.0002	0.0014
Finland	0.0050	0.0025	0.0117		0.0025	0.0117	0.0050	0.0025	0.0117
France	0.0003	0.0000	0.0000		0.0000	0.0000	0.0003	0.0000	0.0000
Germany	0.0007	0.0001	0.0009		0.0001	0.0009	0.0007	0.0001	0.0009
Greece	0.0008	0.0004	0.0026		0.0004	0.0026	0.0008	0.0004	0.0026
Hungary	0.0060	0.0015	0.0070		0.0015	0.0070	0.0060	0.0015	0.0070
India	0.0002	0.0000	0.0002		0.0000	0.0002	0.0002	0.0000	0.0002
Indonesia	0.0007	0.0001	0.0008		0.0001	0.0008	0.0007	0.0001	0.0008
Ireland	0.0000	0.0000	0.0001		0.0000	0.0001	0.0000	0.0000	0.0001
Italy	0.0000	0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000
Japan	0.0005	0.0003	0.0012		0.0003	0.0012	0.0005	0.0003	0.0012
South Korea	0.0021	0.0003	0.0018		0.0003	0.0018	0.0021	0.0003	0.0018
Latvia	0.0019	0.0003	0.0021		0.0003	0.0021	0.0019	0.0003	0.0021
Lithuania	0.0005	0.0001	0.0010		0.0001	0.0010	0.0005	0.0001	0.0010
Luxembourg	0.0000	0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000
Malta	0.0004	0.0002	0.0009		0.0002	0.0009	0.0004	0.0002	0.0009
Mexico	0.0001	0.0000	0.0000		0.0000	0.0000	0.0001	0.0000	0.0000
The Netherlands	0.0014	0.0005	0.0031		0.0005	0.0031	0.0014	0.0005	0.0031
Poland	0.0010	0.0001	0.0005		0.0001	0.0005	0.0010	0.0001	0.0005
Portugal	0.0008	0.0004	0.0029		0.0004	0.0029	0.0008	0.0004	0.0029
Romania	0.0000	0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000
Russia	0.0006	0.0002	0.0015		0.0002	0.0015	0.0006	0.0002	0.0015
Slovak Republic	0.0000	0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000
Slovenia	0.0001	0.0000	0.0001		0.0000	0.0001	0.0001	0.0000	0.0001
Spain	0.0015	0.0001	0.0009		0.0001	0.0009	0.0015	0.0001	0.0009
Sweden	0.0000	0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000
Taiwan	0.0014	0.0006	0.0038		0.0006	0.0038	0.0014	0.0006	0.0038
Turkey	0.0000	0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000
UK	0.0003	0.0001	0.0006		0.0001	0.0006	0.0003	0.0001	0.0006
USA	0.0003	0.0003	0.0019		0.0003	0.0019	0.0003	0.0003	0.0019

Source: Own Calculations. Notes: Column (A) refers to unit-root tests without exogenous variables, column (B) with intercepts and (C) refers to unit-root tests with intercepts and trends.

Table 4-9 Unit-Root Tests for Stationarity of Labor Share, High-Skilled (p-values)

Variable Labor Share (High-Skill)	Levin-Lin-Chu			Im-Pesaran-Shin			Maddala-Wu		
Countries	A	B	C	A	B	C	A	B	C
Australia	0.0003	0.0007	0.0041		0.0007	0.0041	0.0003	0.0007	0.0041
Austria	0.0001	0.0002	0.0007		0.0002	0.0007	0.0001	0.0002	0.0007
Belgium	0.0000	0.0000	0.0003		0.0000	0.0003	0.0000	0.0000	0.0003
Brazil	0.0000	0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000
Bulgaria	0.0000	0.0000	0.0002		0.0000	0.0002	0.0000	0.0000	0.0002
Canada	0.0003	0.0003	0.0023		0.0003	0.0023	0.0003	0.0003	0.0023
China	0.0000	0.0000	0.0002		0.0000	0.0002	0.0000	0.0000	0.0002
Cyprus	0.0002	0.0001	0.0007		0.0001	0.0007	0.0002	0.0001	0.0007
Czech Republic	0.0001	0.0000	0.0003		0.0000	0.0003	0.0001	0.0000	0.0003
Denmark	0.0004	0.0002	0.0009		0.0002	0.0009	0.0004	0.0002	0.0009
Estonia	0.0001	0.0001	0.0008		0.0001	0.0008	0.0001	0.0001	0.0008
Finland	0.0003	0.0002	0.0012		0.0002	0.0012	0.0003	0.0002	0.0012
France	0.0000	0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000
Germany	0.0001	0.0000	0.0002		0.0000	0.0002	0.0001	0.0000	0.0002
Greece	0.0001	0.0001	0.0009		0.0001	0.0009	0.0001	0.0001	0.0009
Hungary	0.0007	0.0007	0.0027		0.0007	0.0027	0.0007	0.0007	0.0027
India	0.0000	0.0000	0.0003		0.0000	0.0003	0.0000	0.0000	0.0003
Indonesia	0.0001	0.0001	0.0009		0.0001	0.0009	0.0001	0.0001	0.0009
Ireland	0.0001	0.0000	0.0003		0.0000	0.0003	0.0001	0.0000	0.0003
Italy	0.0003	0.0004	0.0028		0.0004	0.0028	0.0003	0.0004	0.0028
Japan	0.0000	0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000
South Korea	0.0001	0.0002	0.0011		0.0002	0.0011	0.0001	0.0002	0.0011
Latvia	0.0006	0.0004	0.0030		0.0004	0.0030	0.0006	0.0004	0.0030
Lithuania	0.0005	0.0006	0.0032		0.0006	0.0032	0.0005	0.0006	0.0032
Luxembourg	0.0000	0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000
Malta	0.0000	0.0000	0.0001		0.0000	0.0001	0.0000	0.0000	0.0001
Mexico	0.0000	0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000
The Netherlands	0.0003	0.0002	0.0011		0.0002	0.0011	0.0003	0.0002	0.0011
Poland	0.0000	0.0000	0.0001		0.0000	0.0001	0.0000	0.0000	0.0001
Portugal	0.0001	0.0002	0.0012		0.0002	0.0012	0.0001	0.0002	0.0012
Romania	0.0001	0.0001	0.0004		0.0001	0.0004	0.0001	0.0001	0.0004
Russia	0.0000	0.0000	0.0002		0.0000	0.0002	0.0000	0.0000	0.0002
Slovak Republic	0.0000	0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000
Slovenia	0.0000	0.0000	0.0002		0.0000	0.0002	0.0000	0.0000	0.0002
Spain	0.0000	0.0000	0.0002		0.0000	0.0002	0.0000	0.0000	0.0002
Sweden	0.0001	0.0001	0.0008		0.0001	0.0008	0.0001	0.0001	0.0008
Taiwan	0.0001	0.0001	0.0009		0.0001	0.0009	0.0001	0.0001	0.0009
Turkey	0.0000	0.0001	0.0005		0.0001	0.0005	0.0000	0.0001	0.0005
UK	0.0001	0.0002	0.0017		0.0002	0.0017	0.0001	0.0002	0.0017
USA	0.0001	0.0002	0.0019		0.0002	0.0019	0.0001	0.0002	0.0019

Source: Own Calculations. Notes: Column (A) refers to unit-root tests without exogenous variables, column (B) with intercepts and (C) refers to unit-root tests with intercepts and trends.

Table 4-10 Unit-Root Tests for Stationarity of Labor Share, Med-Skilled (p-values)

Variable Labor Share (Medium-Skill)	Levin-Lin-Chu			Im-Pesaran-Shin			Maddala-Wu		
Countries	A	B	C	A	B	C	A	B	C
Australia	0.0023	0.0005	0.0030		0.0005	0.0030	0.0023	0.0005	0.0030
Austria	0.0011	0.0001	0.0008		0.0001	0.0008	0.0011	0.0001	0.0008
Belgium	0.0009	0.0002	0.0014		0.0002	0.0014	0.0009	0.0002	0.0014
Brazil	0.0001	0.0000	0.0000		0.0000	0.0000	0.0001	0.0000	0.0000
Bulgaria	0.0003	0.0000	0.0003		0.0000	0.0003	0.0003	0.0000	0.0003
Canada	0.0027	0.0005	0.0032		0.0005	0.0032	0.0027	0.0005	0.0032
China	0.0086	0.0010	0.0055		0.0010	0.0055	0.0086	0.0010	0.0055
Cyprus	0.0004	0.0003	0.0023		0.0003	0.0023	0.0004	0.0003	0.0023
Czech Republic	0.0027	0.0002	0.0014		0.0002	0.0014	0.0027	0.0002	0.0014
Denmark	0.0017	0.0001	0.0006		0.0001	0.0006	0.0017	0.0001	0.0006
Estonia	0.0011	0.0002	0.0017		0.0002	0.0017	0.0011	0.0002	0.0017
Finland	0.0007	0.0001	0.0005		0.0001	0.0005	0.0007	0.0001	0.0005
France	0.0000	0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000
Germany	0.0006	0.0001	0.0006		0.0001	0.0006	0.0006	0.0001	0.0006
Greece	0.0014	0.0002	0.0018		0.0002	0.0018	0.0014	0.0002	0.0018
Hungary	0.0039	0.0004	0.0025		0.0004	0.0025	0.0039	0.0004	0.0025
India	0.0003	0.0000	0.0003		0.0000	0.0003	0.0003	0.0000	0.0003
Indonesia	0.0007	0.0000	0.0003		0.0000	0.0003	0.0007	0.0000	0.0003
Ireland	0.0003	0.0000	0.0003		0.0000	0.0003	0.0003	0.0000	0.0003
Italy	0.0000	0.0000	0.0002		0.0000	0.0002	0.0000	0.0000	0.0002
Japan	0.0006	0.0002	0.0013		0.0002	0.0013	0.0006	0.0002	0.0013
South Korea	0.0009	0.0001	0.0005		0.0001	0.0005	0.0009	0.0001	0.0005
Latvia	0.0019	0.0002	0.0014		0.0002	0.0014	0.0019	0.0002	0.0014
Lithuania	0.0003	0.0000	0.0000		0.0000	0.0000	0.0003	0.0000	0.0000
Luxembourg	0.0000	0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000
Malta	0.0007	0.0009	0.0045		0.0009	0.0045	0.0007	0.0009	0.0045
Mexico	0.0000	0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000
The Netherlands	0.0016	0.0004	0.0027		0.0004	0.0027	0.0016	0.0004	0.0027
Poland	0.0001	0.0000	0.0001		0.0000	0.0001	0.0001	0.0000	0.0001
Portugal	0.0005	0.0001	0.0010		0.0001	0.0010	0.0005	0.0001	0.0010
Romania	0.0000	0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000
Russia	0.0001	0.0000	0.0001		0.0000	0.0001	0.0001	0.0000	0.0001
Slovak Republic	0.0000	0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000
Slovenia	0.0001	0.0000	0.0002		0.0000	0.0002	0.0001	0.0000	0.0002
Spain	0.0019	0.0001	0.0009		0.0001	0.0009	0.0019	0.0001	0.0009
Sweden	0.0000	0.0000	0.0000		0.0000	0.0000	0.0000	0.0000	0.0000
Taiwan	0.0019	0.0006	0.0040		0.0006	0.0040	0.0019	0.0006	0.0040
Turkey	0.0002	0.0000	0.0001		0.0000	0.0001	0.0002	0.0000	0.0001
UK	0.0002	0.0000	0.0003		0.0000	0.0003	0.0002	0.0000	0.0003
USA	0.0003	0.0001	0.0010		0.0001	0.0010	0.0003	0.0001	0.0010

Source: Own Calculations. Notes: Column (A) refers to unit-root tests without exogenous variables, column (B) with intercepts and (C) refers to unit-root tests with intercepts and trends.

The first step is to estimate the standard VAR model with the use of a panel data fixed effect linear regression, that captures the individual heterogeneity of the sectoral dimension. A standard practice in VAR analysis is to report and assess the impulse responses. With impulse responses we identify how current and future values of each of the variables of our VAR model respond to a one-unit increase in the current value of one of the VAR errors. Impulse responses are important statistics that are able to identify empirical regularities in an economy and thus give substance to theoretical models.

For estimating the impulse responses of the VAR models, I utilize the local projections technique proposed by Jordá (2005). A local projection runs sequential regressions of the endogenous variables that is shifted forward in time, in predetermined lags. In doing so, the projections become local for each specific time horizon and thus "robust to misspecification of the unknown DGP". Moreover, estimating impulse responses with local projections is preferrable in panel data applications with considerable cross-sectional variations (Adämmer, 2019; Autor & Salomons, 2018; Jordà, 2005). According to Adämmer (2019) "LPs are easier to estimate since they rely solely on simple linear regressions; second, the point or joint-wise inference is easily conducted; and third, impulse responses that are estimated using LPs are more robust when a (linear) VAR is mis-specified" (2019, p. 421).

Having said that, in the second step I use the VAR coefficients and standard errors of the panel data fixed effects model to estimate the coefficients of the local projection, as well as the confidence intervals of the impulse responses It has to be noted that for this paper, the panel data dimensions are two, the sectoral-individual and the time-dimension. Hence, in this exercise I estimate 40 different VAR models, each for every country. All fixed-effects estimators were corrected for cross-sectional and serial correlation, using *panel corrected standard errors estimators* (Beck & Katz, 1995). The selection of the appropriate lag length for each fixed effects regression, was conducted with the comparison of the Akaike (AIC), the Schwarz (SIC) and the Hannan-Quinn (HQ) information criteria.

For examining the presence of stationarity in the panel data, I performed three types of unit-root tests, the Levin-Lin-Chu test (2002), the Im-Pesaran-Shin test (1989), and the Maddala-Wu test (1999), for three cases (no exogenous variables, individual intercepts and intercepts and trends). The results of the unit-root tests are presented in Table 4-7, Table 4-8, Table 4-9, Table 4-10. For the Levin-Lin-Chu test of stationarity, the majority of countries reject the null hypothesis for the existence of a unit root, when the simple case is considered, whereas all the countries reject the null for the cases of intercept and intercept and trend, for all time-series variables. For the Im-Pesaran-Shin and the Maddala-Wu, all countries for all specifications reject the null hypothesis for all time-series variables, denoting the presence of stationarity in the data.

4.5 Empirical Results

In this section I present the empirical results of the analysis of the impulse response. The impulse responses show the effects of an unexpected one unit increase in the global positional power of labor, measured by PageRank centrality, of each country's sectors on the dependent variables, namely sectoral labor share and sectoral labor shares per skill-type. Also plotted are the standard error bands at 90% confidence interval for each impulse response.

In Figure 4-1, I report the individual and cumulative impulse response analysis for labor share after a shock in the positional/structural power of labor, measured by the PageRank centrality. The results show that shocks in the positional/structural power of labor have a strong, statistically significant, and positive effect on the labor share, for all countries, irrespective of their income and development levels. All countries show a positive cumulative and non-cumulative increase in their labor shares that lasts almost a decade after a shock in the PageRank centrality of positional power.

The only exception is Malta, for which the impulse response results are not statistically significant after the third year. An explanation for the case of Malta is that the country is a very small open economy that relies heavily on financial and other business services, with extremely low primary and manufacturing sectors and a small integration to global production networks and supply chains. According to Tagliori and Winkler (2016, p. 89) who assess the OECD measure of GVCs participation, based on the domestic value added embodied in third countries' exports, Malta is one of the countries in the sample of 61 countries that has the lowest index (46th position), whereas according to the domestic value added embodied in foreign final demand, another GVCs participation index used by OECD and Trade in Value Added (TiVA) database, Malta for 2009 is the country with the lowest participation after Iceland, Cambodia and Laos (OECD, 2021).

Overall, the results of the estimated impulse responses show patterns of a persistent common response for all countries, irrespective of their income levels. This observation offers interesting insights with respect to the empirical literature that investigates the determinants of the labor share and its relationship with labor bargaining power. First, the results of the cumulative and non-cumulative impulse responses are consistent with the expectations formed by the work of Perrone (1984; 1983), Wallace, et al. (1989), Wright (2000) and Silver (2003), who identified and explored the positional/structural dimension of labor bargaining power.

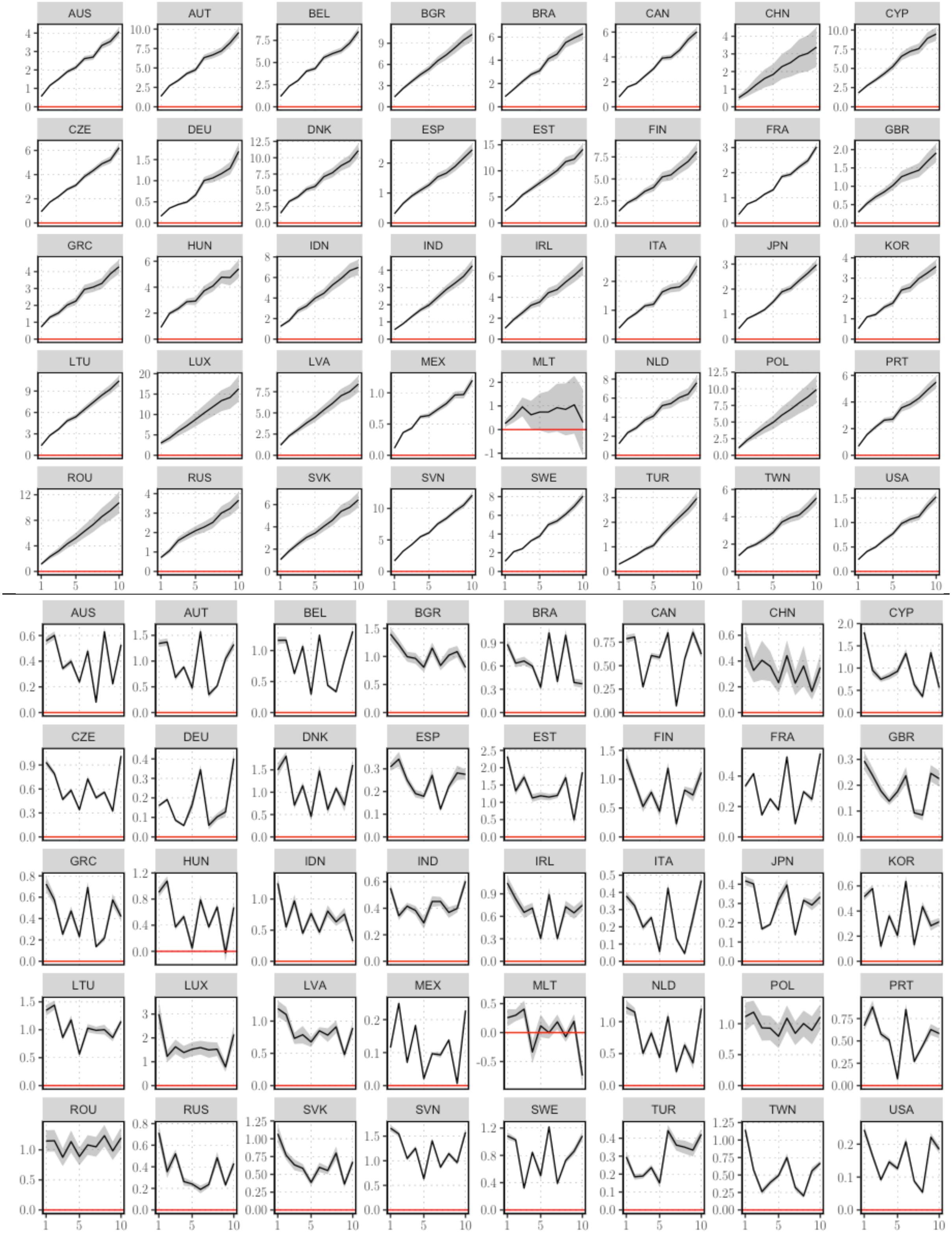

Figure 4-1 Impulse Responses of Labor Share to a PageRank shock

Source: Own Illustration. *Data*: WIOD (1995-2009), Input-Output Tables and Socio-Economic Matrix. Notes: The first panel shows the cumulative effects of the impulse response of labor share to a shock in PageRank centrality. The shadowed area represents the lower and upper confidence bands, at 90% confidence interval, using Local Projections.

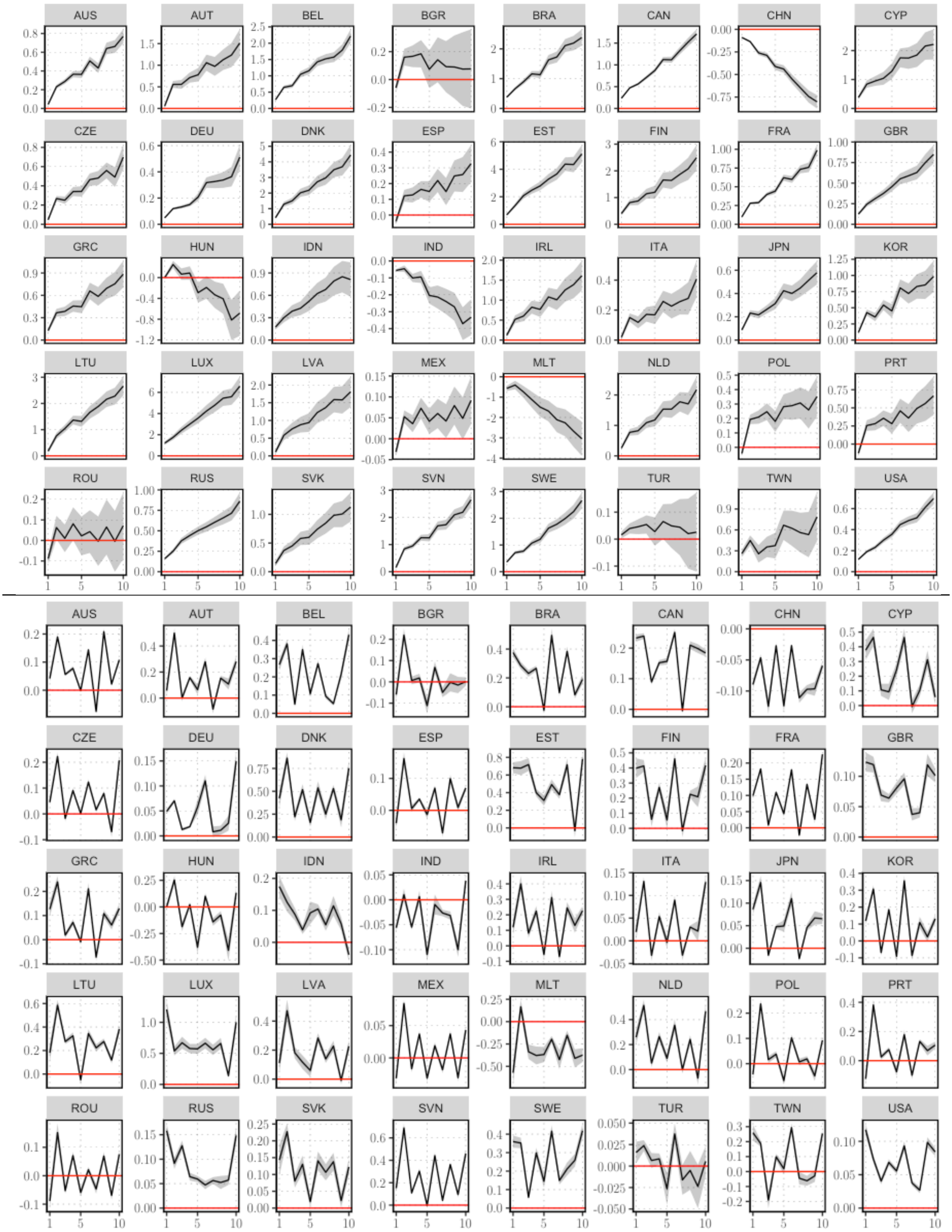

Figure 4-2 Impulse Responses of Labor Share (High-Skilled) to a PageRank shock

Source: Own Illustration. *Data*: WIOD (1995-2009), Input-Output Tables and Socio-Economic Matrix. Notes: The first panel shows the cumulative effects of the impulse response of labor share to a shock in PageRank centrality. The shadowed area represents the lower and upper confidence bands, at 90% confidence interval, using Local Projections.

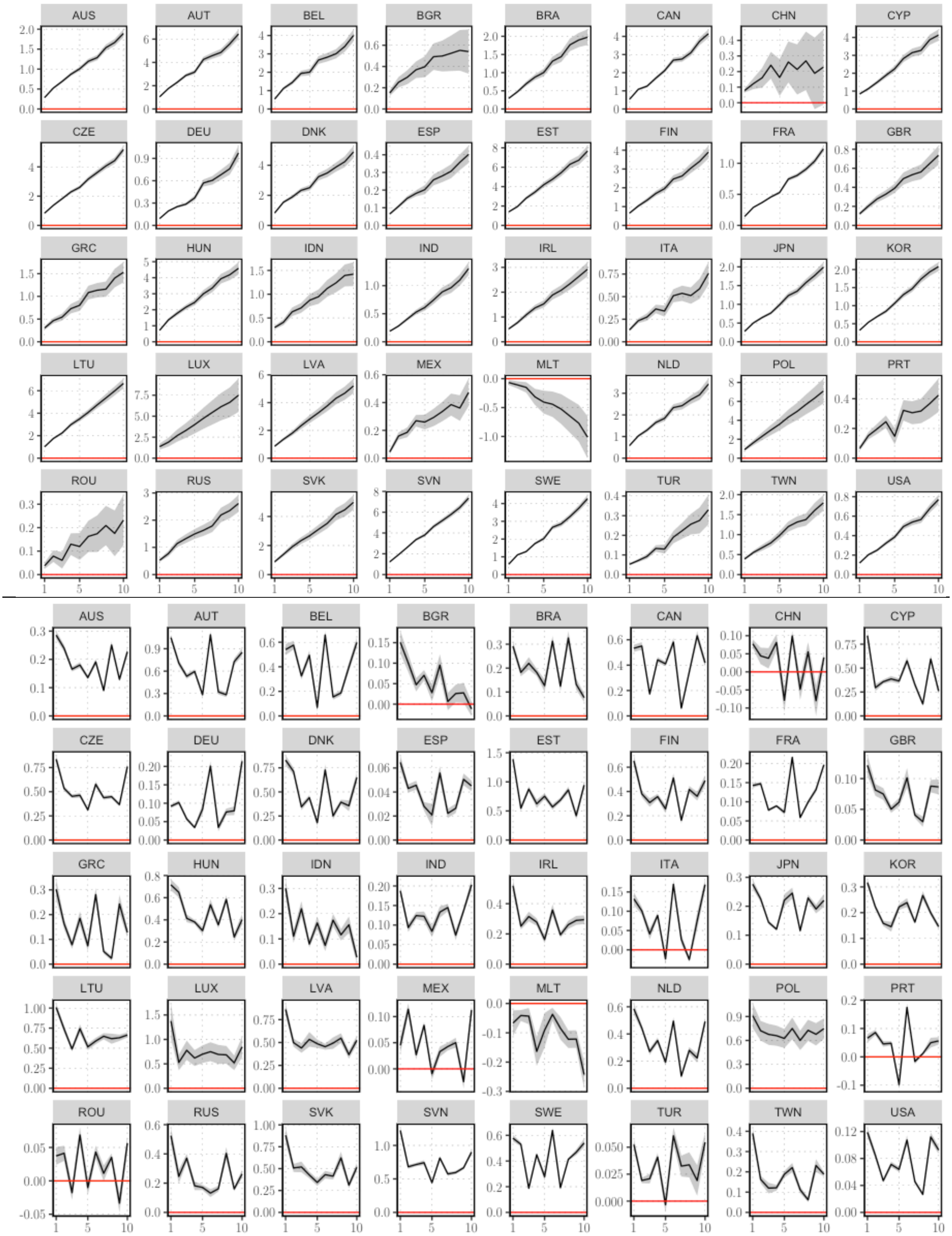

Figure 4-3 Impulse Responses of Labor Share (Medium-Skilled) to a PageRank shock

Source: Own Illustration. *Data*: WIOD (1995-2009), Input-Output Tables and Socio-Economic Matrix. Notes: The first panel shows the cumulative effects of the impulse response of labor share to a shock in PageRank centrality. The shadowed area represents the lower and upper confidence bands, at 90% confidence interval, using Local Projections.

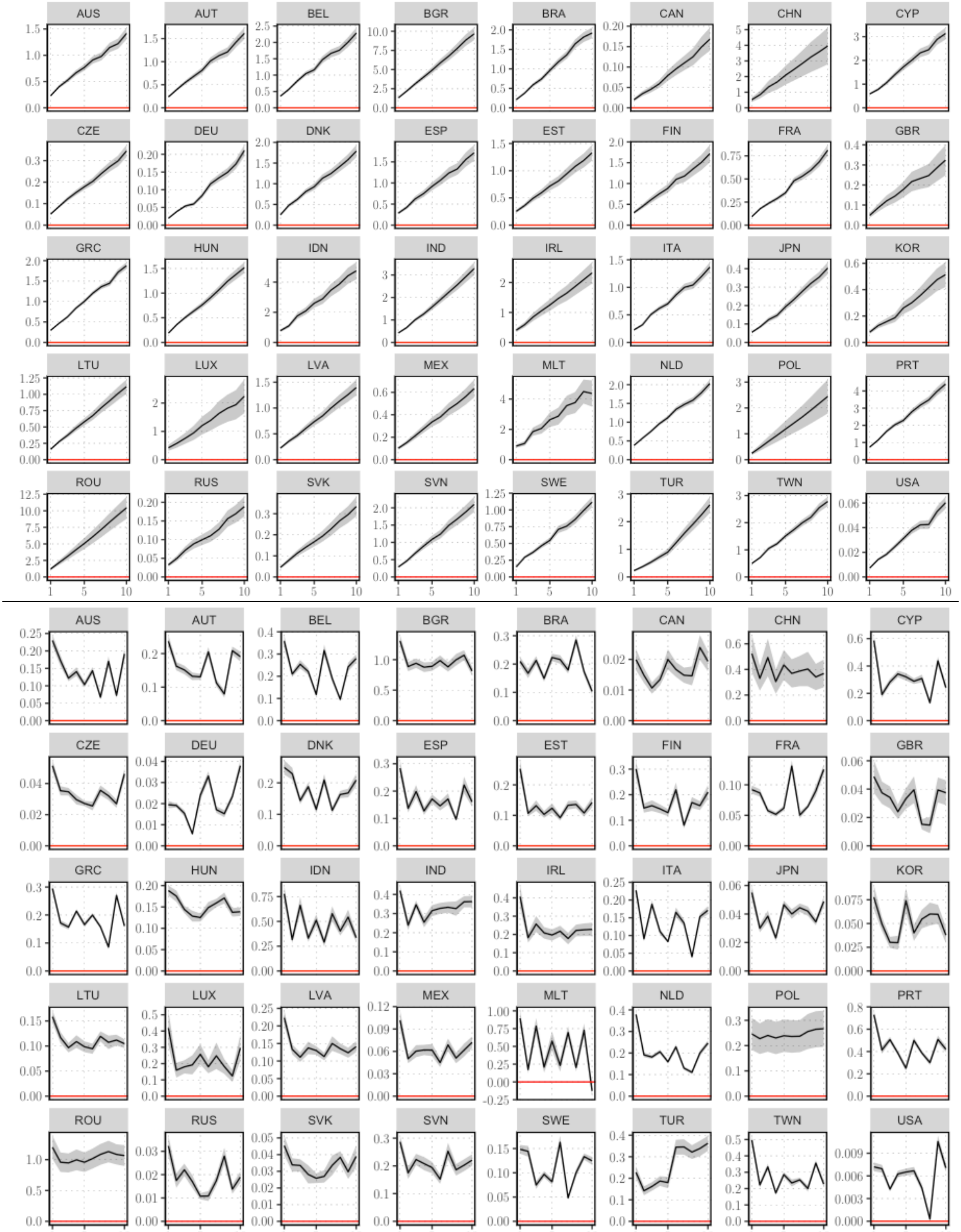

Figure 4-4 Impulse Responses of Labor Share (Low-Skilled) to a PageRank shock

Source: Own Illustration. *Data*: WIOD (1995-2009), Input-Output Tables and Socio-Economic Matrix. Notes: The first panel shows the cumulative effects of the impulse response of labor share to a shock in PageRank centrality. The shadowed area represents the lower and upper confidence bands, at 90% confidence interval, using Local Projections.

In particular, the present empirical analysis speaks directly to the studies of Perrone (1984; 1983) and Wallace, et al. (1989), extending their findings of a causal, statistically significant and important relationship of positional/structural power of labor on income distribution. Whereas the above-mentioned studies find a strong positive effect of positional/structural power of labor on average wages, my analysis takes into account the disruptive ability of labor with respect to the global structure of international production, for 40 countries that account for more than 85% of the world GDP (2014), including both advanced and emerging economies.

Second, the empirical literature on the effects of labor bargaining power on the labor share has provided mixed results, which might be misleading if we don't properly account for the positional/structural dimension of labor bargaining power. For example, Fichtenbaum (2009) reports a statistically significant and positive, although somewhat small, effect of union density on the labor share in the US manufacturing sector, whereas Kristal (2010), focusing on 16 OECD countries from 1960 to 2005, finds a positive effect on labor share coming from union density, unemployment benefits, strikes, left governments and social expenditures, variables that can be considered good candidates for representing the associational dimension of labor bargaining power.

On the contrary, Stockhammer (2017) conducting a panel analysis for 28 advanced and 43 developing and emerging economies from 1970 to 2007, finds no statistically significant effect of labor market institutions on the evolution of the labor share. Similarly, Bentolila and Saint-Paul (2003) find a negative effect of labor conflict rate on labor shares for panel sample of 12 OECD countries, 13 sectors from 1972 to 2003. A common characteristic of these studies is that they conceptualize and quantify labor bargaining power with variables that express either the union membership density or the conflict/strike activity, neglecting the positional/structural dimension.

Third, given that the contemporary literature on the revitalization of trade unions has over-emphasized the importance of non-structural dimensions of labor bargaining power in the analysis of national episodes of labor struggles and strikes, failing to account for the structural dimension of labor bargaining power, my results allow for a constructive interrogation of many of their claims. For instance, Fox-Hodess and Santibáñez Rebolledo (2020), examining the case of the Chilean dockworkers' strike movement and coalistion strategies between 2012 and 2014, argue against economistic interpretations of the strategic position of workers in production, claiming that "the Chilean dockworkers' ability to make use of their structural power has been heavily conditioned by their ability to develop associational and societal power" (2020, p. 223).

Similarly, Fox-Hodess (2017) explains the different outcomes of dockworkers' mobilizations in Portugal, Greece and the UK, through the critical role played by political and coalition strategies developed by the respective national trade unions. These studies rely heavily on a qualitative methodology including the analysis of interview materials, archival documents, news reports etc. However, they do not provide a properly conceptualized (as the dirsuptive ability of labor in inter-sectoral production networks) and quantified (as the centrality of labor in production systems) measure of positional/structural power. In light of the empirical results presented in this section, a deeper understanding and quantitative assessment of the international positional/structural dimension of labor bargaining power is needed in order to provide a meaningful comparative analysis between the several dimensions of labor power.

Since the first version of the Socio-Economic Matrix provides data on the skill-type of labor, I reproduce the impulse responses for each of the available skill categories, namely, high-, medium- and low-skilled labor (Figure 4-2, Figure 4-3, Figure 4-4). With respect to the labor share of high-skilled labor, I observe that four countries do not have statistically significant impulse response results, such as Bulgaria, Hungary, Romania, and Turkey, whereas China, India, and Malta, have negative cumulative and non-cumulative responses to a shock in labor positional power. All the other countries show a strong, statistically significant, positive impulse response to PageRank centrality shocks.

When I focus on the labor share of medium-skilled labor, only China after the 8th period, has statistically insignificant results, but otherwise strong positive, whereas for Malta, a shock in the positional power of labor leads to a cumulative and non-cumulative fall in the labor share for medium-skill labor. On the contrary, for the impact of a positional/structural labor bargaining power shock on the labor share of low-skilled workers, I observe that a persistent, statistically significant, positive effect exists between the two variables, for all the countries in the sample.

Comparing the cumulative impulse responses between skill-types I find four distinct groups of countries. In the first group the cumulative impulse responses for the labor share of low-skilled workers are higher than that for the medium- and high-skilled workforce. In this group I find Bulgaria, China, Greece, India, Indonesia, Italy, Malta, Mexico, Romania, Spain, Taiwan, Turkey. In the second group, I that Australia, Austria, Belgium, Brazil, Cyprus, Hungary, Ireland, Poland, Canada, Czech Republic, Estonia, Finland, France, Germany, Japan, South Korea, Latvia, Lithuania, Luxembourg, The Netherlands, Russia, Slovak Republic, Slovenia, Sweden, and the USA, for which the cumulative impulse responses for the labor share of medium-skilled workers are higher than low- and high-skilled workforce. Denmark and United Kingdom are the only two countries for which the impulse responses of high-skilled labor share are reported as higher than the medium- and low-skilled workforce.

From these results I can assess the empirical validity of the the agency and social control hypotheses that Wallace, et al. (1993), tested with micro-level data for the US alone. The agency hypothesis states that workers with low and medium level skill set and occupations, will tend to utilize more their positional bargaining power, compared to those employed in the higher echelons of a business establishment. On the contrary, the social control hypothesis argues that workers with high occupational and technical skills and managerial occupations, play an important role in social control and diffusing labor conflicts and tensions, for which they usually get a reward in terms of their labor income.

Broadening the geographical and sectoral scope of analysis, as I do in this empirical exercise, I find strong and statistically significant support, in favor of the agency hypothesis at the global level, since the impulse responses for the labor share of low- and medium-skilled workers are considerably much higher than those of the high-skilled workforce. Only two countries in our sample, namely Denmark and United Kingdom, seem to validate the social control hypothesis, with the impulse responses of high-skilled laborers being higher than those of their colleagues with lower and medium level skillset.

4.6 Conclusions

The analysis of the determinants and evolution of the labor share in national income has been the central theme in the literatures of economics, international political economy, and other social sciences. This extensive interdisciplinary literature has shed light on several determining mechanisms and contributing factors regarding the distribution of produced income between capital and labor. For example, empirical studies in the field of economics that employ economic models of international trade to explore the effects of globalization and international fragmentation of production on labor income and distributional conflicts, have emphasized the importance of technological factors, international competition arising from imported goods and services, as well as the impact of labor market institutions and welfare provisions.

On the other hand, the scholarship in the areas of international political economy, economic geography, labor sociology and political sciences - usually inspired by post-Kaleckian theorizations of the distributional conflict or by the power resources approach tradition – finds empirical evidence in favor of factors the manifest dimensions of labor bargaining power. Notwithstanding the fact that both strands of the literature recognize the importance of labor bargaining power for the determination of the observed patterns of income distribution, although to different degrees, there is still fertile ground for developing research agendas that allow the utilization of alternative dimensions of labor bargaining power in the analysis of the effects of globalization.

In this paper, I concentrate on the exploration of the relationship between globalization, global production structures, labor bargaining power and income distribution, combining different theoretical approaches to globalization and labor bargaining power and investigating the structure of global production focusing on 40 countries from 1995 to 2009. The key insight that is derived from my analysis is that the positional/structural labor bargaining power at the global level, matters for the outcomes of the distributional conflict. Whereas the heretofore literature on the subject, either ignores the role played by labor (see neoclassical theory) or conceptualizes labor bargaining power in a unidimensional way (PRA literature), this paper draws inspiration from the power resources approach and the globalization literatures and highlight a rather under-developed link, between the structural position of labor in production and supply chains and the process of international fragmentation of production. In particular, it reintroduces the notion of positional/structural labor bargaining power, at the global level and offers a practical method to quantify and measure it using international time-series of input-output data.

The research question that the paper addresses with its empirical analysis is whether positional/structural bargaining power and labor outcomes hold a positive relationship at the global level. Applying the notion of positional/structural power of labor in the production process, that was introduced by the work of labor sociologists (Perrone et al., 1984; Silver, 2003; Wallace et al., 1989; Wright, 2000; Wright & Perrone, 1983), I compute estimates of positional/structural power of labor at the global level, utilizing global input-output tables. Building on these estimates I compute the impulse responses of panel data vector autoregressions models, using local projections and I find a strong and statistically significant relationship exists between the positional/structural power of labor and the share it receives as income from the national product, irrespective of the income level of the country under consideration. Controlling for the skills of laborers I also find empirical evidence for the so-called agency hypothesis, that states that workers employed at lower-skilled occupation, will tend to utilize more their positional/structural bargaining power.

My results lead to the reinterpretation of many widely held views regarding the determinants of functional income distribution, shedding new light on the impacts of labor bargaining power on labor shares. Reflecting upon the empirical findings in the context of the discussion in the literature review section, the present paper makes three contributions. The first is that it introduces an alternative dimension of labor bargaining power in the literature of globalization, operationalizing a proper measure of the global positional/structural power of labor. The second is that it extends that conceptualization of positional/structural power of labor accounting for the integration of the national economic and social formation in global supply chains. The third contribution is that I provide empirical evidence, at the global level, for the link between positional/structural labor bargaining power and labor's share of national income, whereas at the same time, controlling for the skill-type of labor, I were able to provide support in favor of the agency hypothesis (Wallace et al., 1989), using sectoral-global data.

The present paper can be extended towards different research paths. Typically, it takes some combination of structural and associational power for workers to make genuine gains in terms and conditions. Structural power merely raises the possibilities for workers to assert their associational power. There is considerable room for research for quantifying and measuring associational bargaining power and thus taking into account the heterogeneity of national social formations and local capitalisms. Additionally, the present framework could help provide policy makers, and workers unions, a tool to better understand the relationship between global production, employment relations, development, and trade union strategy.

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4.7 Appendix

Table 4-11 The Sectoral Coverage of WIOD Rev.3 (1995-2009)

Sectors of WIOD at ISIC3 level	**WIOD Codes**
Agriculture, Hunting, Forestry and Fishing	c1
Mining and Quarrying	c2
Food, Beverages and Tobacco	c3
Textiles and Textile Products	c4
Leather, Leather and Footwear	c5
Wood and Products of Wood and Cork	c6
Pulp, Paper, Paper, Printing and Publishing	c7
Coke, Refined Petroleum and Nuclear Fuel	c8
Chemicals and Chemical Products	c9
Rubber and Plastics	c10
Other, Non-Metallic Mineral	c11
Basic Metals and Fabricated Metal	c12
Machinery, Nec	c13
Electrical and Optical Equipment	c14
Transport Equipment	c15
Manufacturing, Nec; Recycling	c16
Electricity, Gas and Water Supply	c17
Construction	c18
Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel	c19
Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles	c20
Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods	c21
Hotels and Restaurants	c22
Inland Transport	c23
Water Transport	c24
Air Transport	c25
Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies	c26
Post and Telecommunications	c27
Financial Intermediation	c28
Real Estate Activities	c29
Renting of M&Eq and Other Business Activities	c30
Public Admin and Defense; Compulsory Social Security	c31
Education	c32
Health and Social Work	c33
Other Community, Social and Personal Services	c34
Private Households with Employed Persons	c35
Total Number of Industries	**35**

Table 4-12 List of Countries

Australia
Austria
Belgium
Brazil
Bulgaria
Canada
China
Cyprus
Czech Rep
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
India
Indonesia
Ireland
Italy
Japan
Latvia
Lithuania
Luxembourg
Malta
Mexico
Netherlands
Poland
Portugal
Rest of the World
Romania
Russia
Slovakia
Slovenia
South Korea
Spain
Sweden
Taiwan
Turkey
UK
USA

Chapter 5: The Sectoral Degree of Hierarchicality in the World Economy

5.1 Introduction

The organization of production and international trade along Global Value Chains (GVCs), implies that the production process of goods and services that in the past used to be performed under the roof of a single factory, located in one specific place, has now been "sliced" (Timmer et al., 2014) or "unbundled" (R. Baldwin, 2016) into a multitude of specialized sub-process, in multiple locations around the world. A broad and all-inclusive definition of GVCs was recently proposed by Antràs (2020), who defines them "as a series of stages involved in producing a product or service that is sold to consumers, with each stage adding value, and with at least two stages being produced in different countries" (2020, p. 553).

Historically, this phenomenon can be located in the late 1970s and early 1980s, as the result of the demise of the post-war, Fordist, regime of capital accumulation and the emergence of a new historical phase in the development of capitalism, characterized by globalization and financialization in the economic sphere (Aglietta, 1979; Arrighi, 1994; Boyer, 2000; Silver, 2003). During this period, global capital responded to the systemic capitalist crisis of the 1970s - among others - with relocating parts of the production process to countries in Latin America and Asia, exploiting the low cost of labor. Additional contributing factors were the technological advancements in communication and transportation, which enabled such spatial and functional fragmentation of production.

In recent years, the study of international fragmentation of production has gained prominence among social scientists. There are in general two broad research paths along which this new scholarship is growing. The first research path investigates the political economy of the GVCs, along with the participation of countries and economic actors in them, from the lens of economic development and industrial upgrading (Criscuolo & Timmis, 2017; Galanis & Kumar, 2020; Gereffi, 2018; Milberg & Winkler, 2013; Pahl & Timmer, 2020; Taglioni & Winkler, 2016; World Bank, 2020). Drawing from different theoretical traditions and analytical frameworks, spanning from international economics to economic geography, international political economy and sociology, this research path has produced an impressive set of quantitative and qualitative studies on the matter of globalization and the international organization of production.

A second research path questions the validity of conventional gross trade statistics for the theorization and analysis of the phenomenon of international fragmentation of production (DeBacker & Yamano, 2007; Hummels et al., 2001; Koopman et al., 2014; World Bank, 2020). According to the argumentation developed in this literature, gross trade statistics are unable to differentiate between trade in final and trade in intermediate goods and services and thus cannot capture the amount of value-added produced and transferred within a single production process. This view becomes even more important and relevant for an in-depth analysis of the phenomenon of international fragmentation of production, if we take into account that trade in intermediates has dominated world trade (UNCTAD, 2021). In order to capture the complexity of contemporary trade patterns, these studies incorporate global input-output tables in order to measure the cross-border and inter-sectoral linkages of production, differentiating between the final and intermediate uses of traded goods and services. In particular, these studies employ decomposition techniques of input-output tables and estimate the amount of domestic and foreign value-added that is present in the trade patterns of national economies, identifying in that way the extent of vertical specialization in the world economy (R. C. Johnson & Noguera, 2012; Koopman et al., 2014; Timmer et al., 2015).

A voluminous literature incorporates analytical tools from graph theory and network theory to investigate the structural characteristics of the GVCs, assuming that the cross-border and inter-sectoral linkages between countries and sectors form a world production network, with nodes representing the level of analysis (either country, or sector, or both), and links the economic transactions between them (Amador & Cabral, 2017; Cerina et al., 2015; Cingolani et al., 2017; Masi & Ricchiuti, 2019). A strand within this literature investigates the topology of the networks that emerge from economic networks, highlighting the hierarchicality of these structures that enables certain economic actors – either countries in a trade network or sectors in a production network – to capture higher shares of value-added per unit of final goods and services than others. (Duan, 2007; Garlaschelli & Loffredo, 2005; Lo et al., 2014; Zhu et al., 2015).

Of significant importance for the present study is the work of Zhu, et al. (2015) who propose a novel methodology for the quantitative examination of the topological characteristics of GVCs and the hierarchicality of sectoral buyer-supplier relations in global production. In particular, they define as Global Value Trees (GVTs) the subgraphs of GVCs that capture the value-added flows from the supplying (upstream) industries to the buying (downstream) industries and distinguish between three configurations of GVCs topologies: a) a star-like topology in which suppliers feed-in their value-added included into their input goods and services into one assembly, b) a chain-like topology in which value-added is transferred sequentially into the final use[12]

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[12] A similar conceptualization of the different configurations of the topologies of GVCs is offered by Baldwin and Venables (2013), who distinguish between spider-like and snake-like structures.

and c) a tree-like topology that combines elements from both star- and chain-like topologies and its structure is arranged like the branches of a tree. Whereas the latters' work is an invaluable, methodological, and empirical, contribution to the analysis of the hierarchicality of sectoral buyer-supplier relations, we still lack a cross-border, inter-sectoral and inter-temporal examination of the topological properties of global supply chains.

Within this context two research questions arise. First, is a tree-like topology a universal attribute of GVCs that characterizes the structure of their supply chains across space and time? Second, having said that, what is the geographical distribution of the hierarchicality of global supply chains in the world economy and how it has evolved in the last decades. Does the hierarchicality of GVCs show a clear trend across time and space? This paper attempts to respond to these research questions by empirically investigating the degree of hierarchicality of GVCs, following the growing literatures of complex and social network analysis (Duan, 2007; Garlaschelli et al., 2003; Liang et al., 2016; Zhu et al., 2015). Specifically, taking into account the information of economic transactions between sectors in 190 countries of the world economy, gathered within the structures of the Global Multi-Regional Input-Output Tables of the EORA Database (Lenzen et al., 2012, 2013), I construct a global network of value-added transfers, with each node representing an individual sector in a specific country, and each link the value-added contribution of the supplier to the final demand of the buyer. Based on the empirical methodology of Zhu, et al. (2015), who calculated tree-shaped topologies for value-added networks, I estimate the *degree of hierarchicality* for every GVCs, and explore its evolution across country.

The contributions of this paper are twofold. First, it expands the scope of the literature of complex system analysis and social-economic network analysis, by empirically investigating the evolution of the topological characteristics of GVCs, based on a large database of global input-output data. Whereas previous research has assessed the topological characteristics of GVCs using global input-output tables covering 40 countries and a proxy for the rest of the world, the present study utilizes a richer data source, the EORA MRIO, which comprises of sectoral data covering 190 countries. Second, the paper provides empirical evidence for the universal scaling behavior of GVTs, which follows a tree-like topology, as well as the spatiotemporal evolution of the hierarchicality of sectoral buyer-supplier relationships.

The rest of the paper is structured as follows. Section 2 reviews the respective literature, concentrating on the fields of international economics, econophysics and international political economy. In Section 3, I introduce the methodology used in this paper, as well as some basic information about the data employed in the empirical study. In Section 4, I present the empirical results of the evolution of the degree of hierarchicality in the world economy for the last 25 years, and discuss the implications of these results with respect to economic development and policy. Lastly, Section 6 summarizes the main findings of this paper.

5.2 Overview of the Literature

5.2.1 International Macroeconomics

Drawing on the analytical tools of input-output analysis and graph-network theory, macroeconomists and trade economists focus on the trade relationships between national sectors and highlight the value-added that is captured in exports and imports of intermediate goods (Hummels et al., 2001; R. C. Johnson, 2018; Koopman et al., 2012; OECD, 2018). For instance, when official statistics measure the gross value of exports and imports of a country, they do not take into consideration the amount of value-added included in the intermediate goods necessary for the completion of the final goods, which were imported by other countries and sectors. Measuring how much of the value-added of a commodity or service, has been produced in other countries, gives us important information regarding the depth of vertical specialization and which sectors and countries have the power to capture amounts of value-added. Countries that exhibit a decreasing share of domestic value-added in their exports will tend to be heavily integrated in internationally fragmented production processes and become members of complex GVCs.

The latter observation, according to the literature, has important implications about the growth patterns and developmental paths of participating countries. For instance, Hummels et al. (2001), examining the input-output tables of 10 OECD countries from 1970 to 1990, find that the growth in vertical specialization exports accounts for 30% of the growth of total exports in those countries. In a similar fashion, but different methodology, Koopman, et al (2012) highlight – among others – the fact that the share of domestic value added in China's manufacturing exports for the first 5 years from China's membership in the World Trade Organization (WTO), increased from 51% to 60%, implying that through international trade, the country managed to become more integrated into GVCs. In the same study, we also find important results with respect to the sectoral heterogeneity in the shares of domestic and foreign value-added in exports in China. Those sectors that heavily rely on low-skilled and low-cost labor, tend to incorporate higher shares of domestic value-added, whereas the contrary holds for the high-skilled, and capital- and technology-intensive sectors of China.

Another strand of this literature concentrates on capturing the functional and geographical location of national economies within GVCs, by measuring the number of production segments within which each country and/or sector under analysis is participating into (Antràs et al., 2012; Antràs & Chor, 2018). Estimating the distance between an input sector located in a specific country and a final demand sector located into another (upstreamness), this approach is able to highlight the characteristics of GVCs activities performed by countries and sectors in the world economy and thus investigate the determinants of GVCs formation. In Antràs and Chor (2018), the investigation of various measures of what the authors call upstreamness and downstreamness, reveals important stylized facts about the structures of global production and international trade. As upstreamness and downstreamness, the authors have defined the distance, in terms of the number of sequential segments of a production process, from an input from final demand and equally the distance from the primary inputs, of labor and capital (Antràs & Chor, 2018, p. 6). In other words, a sector is considered to be located downstream in the value chain if it sells disproportionately more output to consumers rather than to other producers and upstream if it sells disproportionately more to other producers rather than to consumers. Employing the global input-output tables from the WIOD (Timmer et al., 2014) for the period from 1995 to 2011, the authors find that GVCs activity has become more complex in terms of the length (number of sequential production stages across sectors and countries) between primary factors of production and final demand, implying a rising trend in both the upstreamness and downstreamness of production processes. Comparing particular countries in the database, Antràs and Chor (2018) report that the most upstream and downstream countries relative to their proximity to final demand, are China, Luxembourg, Czech Republic and Brazil, Greece and Cyprus, respectively.

Linked to this methodological and empirical tradition, is a voluminous literature that explores one the one hand the economic, social, institutional, and political factors that contribute to the participation of countries and national sectors into GVCs, and on the other, the implications of this participation with respect to economic growth across countries, productivity enhancements, and functional income distribution. The main arguments in the first group, is that factor endowments and specialization will play a significant role in the determination of the position of one country and sector in GVCs (Antràs, 2020). For example, countries which are rich in natural resources will have higher levels of forward participation in GVCs in the sense that their exports will be used downstream for the production of other commodities. Likewise, countries that specialize in agricultural products will tend to be closer to final consumption and thus will participate in GVCs with smaller length. Similarly, capital-intensive, and technologically advanced countries, with abundance in high-skilled labor force, will tend to be located either upstream or downstream in the GVCs, depending on the relative intensities with which capital and high-skilled labor is used in upstream and downstream production processes (Fernandes et al., 2021; Taglioni & Winkler, 2016; Zheng et al., 2021).

Another factor identified in the literature is trade costs, ranging from geographical features such as distance and easiness of transportation, to infrastructure barriers, regulatory impediments, like tariffs and quotas and supply chain disruptions (Criscuolo & Timmis, 2017; Fernandes et al., 2021; Taglioni & Winkler, 2016). In this regard, trade agreements and the policy of trade liberalization is an important factor that influences the growth of GVCs and the relative position of each economic actor within it. Criscuolo and Timmis (2017) also mention the degree of integration to global financial markets as a determining factor, whereas Taglioni and Winkler (2016) identify the as determining factors, the quality of the logistics infrastructure and performance, the skill-levels of labor force, geographical distance. In a spatiotemporal empirical exercise, Zhi et al. (2021) employ data from a global input-output database and reflect on the determinants of GVCs participation, finding support for factors such as government efficiency, the rule of law, infrastructures in transportation, natural resources, education levels, and abundance of capital.

In the second group, we find empirical studies that explore the implications of GVCs growth and participation for growth, productivity, and income distribution. At one end of the debate, we find theoretical and empirical arguments that support that GVCs participation leads to greater international division of labor and thus higher gains from specialization in terms of productivity of labor and capital and allocation of available resources, along the theoretical lines of traditional neoclassical trade theories and the Ricardian Comparative Advantage Principle (Antràs & Gortari, 2020; Pahl & Timmer, 2020; World Bank, 2017, 2020). Within this argumentation, factors like the abundance of production factors, geography, institutions, trade openness and market size, also contribute and reinforce the positive impacts of GVCs participation.

At the other end of the debate, we find studies that question the universality of the positive effects of GVCs growth, highlighting the fact that the impacts of globalization, offshoring/outsourcing and the GVCs participation are highly variegated across and within countries, especially with respect to income distribution. From a neoclassical theory perspective, there are studies that argue that the rise of GVCs has shifted the production of low-cost and labor-intensive goods and services to new locations abroad. Applying the Stolper-Samuelson effect, which states that the increased international fragmentation of production will increase the wages of highly skilled labor in advanced countries relative to low-skilled wages, these approaches argue that the growth of globalization and GVCs has precipitated a rise in income inequalities in the advanced countries (G. E. Johnson & Stafford, 1993; Leamer, 1998; Murphy & Welch, 1995; Wood, 1995). Feenstra and Hanson (1997, 1999), take this argument a few steps further, finding empirical support for increases in income inequalities, not only in advanced but also in developing countries, as in the demand for high-skilled labor rises in latter too. From a heterodox point of view, Milberg (2004) underlines that the rise of GVCs might have increased the export-oriented manufacturing activity of the developing countries that participate in them, but since lead firms in advanced countries have only outsourced/offshored the lower value-added activities which usually have low barriers to entry and employ low-cost technologies and labor force, they cannot capture high levels of value added. Milberg and Winkler (2013), in a series of econometric exercises, using a proxy of GVCs participation (offshoring intensity) for 15 OECD countries, find a statistically significant negative effect on labor shares.

More recently, Pahl and Timmer (2020), utilizing an input-output based measure of GVCs participation, combining information regarding the backward and forward linkages of country-sectors, find empirical support for the mixed blessing hypothesis, highlighting the fact that whereas GVCs participation leads to positive effects on productivity growth in the manufacturing sector, there is no empirical evidence for a positive effect on employment growth. In a similar fashion Yanikkaya and Altun (2020), investigate the impact of GVCs growth and countries' participation on sectoral value-added and Total Factor Productivity growth. In their econometric study the find that sectors that are highly integrated into GVCs experience higher outport and TFP growth, however, such GVCs-gains were higher in the period from 1995 to 2011, compared to 2005-2015. Szymczak and Wolszczak-Derlacz (2021), using global input-output tables, investigate the link between the participation of national sectors in GVCs and labor market outcomes. They find a negative relationship between GVCs participation and wages and employment, however, with important heterogeneity across sectors and countries and unevenly distributed gains per labor-skill.

5.2.2 Complex Systems and Network Theory

From a complex systems and socio-economic network perspective, the analysis of global production can be divided into two groups, depending on the underlying data used. The first group focuses on trade networks, constructed with the use of trade data, that is data on imports and exports of goods and services across countries. An early application of this approach can be found in research problems in economic geography and international political economy. For instance, Schmidt (1975) analyzed the spatial characteristics of the linkage structures of seven iron and steel firms in the US[13]. Another example, is the work of macro-sociologists who interrogated the basic premises of the World-Systems Theory, with the application of network analysis (Kim & Shin, 2002; Nemeth & Smith, 1985; Rossem, 1996; D. A. Smith & White, 1992; Snyder & Kick, 1979). In particular, this tradition analyzes data on cross-country trade relations, replicating the basic taxonomies of the World Trade Theory (Core, Semi-Peripheral and Peripheral countries) in order to investigate their explanatory power with respect to the observed developmental paths of the respective countries. The end results of the literature were mixed with some studies finding evidence for a positive relationship between the position within the World System and growth, and others finding no relation at all (Mahutga, 2014b).

From a network-analysis point of view, the literature offers a great number of studies that analyze the topological characteristics of trade networks (Fagiolo et al., 2009; Li et al., 2003; Reyes et al., 2008; Serrano & Boguñá, 2003). For example, Li, Jin and Chen (2003), using trade data from the COMTRADE database, compute a global trade network (called World Trade Web), with nodes countries and links their export and import activity, and examine whether the scale-free (power-law distribution) feature of the degree distribution influences the synchronization of business cycles across countries. Their findings show that the business cycles of 18 out of 21 developed countries in the sample are synchronized with the US economy, verifying the claim that economic dynamics are transmitting through the global trade network, due to the

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[13] For a recent investigation of the literature regarding the use of complex analysis into economic geography, see the special issues of *Environment and Planning A* (O'Sullivan et al., 2006), *Environment and Planning B* (Crawford et al., 2005) and *Journal of Economic Geography* (Gluckler & Doreian, 2016), as well as, Crespo et al. (2014) who concentrate on knowledge networks. For a recent review of the literature, see Ducruet and Beauguitte (2014).

scale-free property of degree distributions. Using the same dataset, Reyes, Schiavo and Fagiolo (2008), investigate the evolution of two groups of countries, namely the high-performing Asian economies and the Latin American region, with respect to their centrality within the global trade network. Their empirical findings show that the Asian group has been more integrated (increased its centrality) within the trade network, whereas the Latin American group, either stay at the same position in the periphery of the network, or even have fallen.

The second group focuses on production networks, utilizing novel datasets of global inter-country and inter-industry relationships. This group conceptualizes global production as an interrelated and interconnected production network, with sector-countries represented as nodes and their transactions as links, and experiments with various measures of network statistics that shed light on the structural position of economic actors, such as, centrality, assortativity, clustering, interrogating economic theoretical research questions, regarding the identification of key sectors in the economy or the propagation of economic shocks within an economic network (Blöchl et al., 2011; Cerina et al., 2015; McNerney, 2009; McNerney et al., 2013; Tsekeris, 2017; Xu et al., 2011). A distinct subset of the network-oriented literature concentrates on the observation that global networks of trade exhibit hierarchical topologies. The hierarchicality of these topologies lies on the existence of a few strong and powerful trade hubs that monopolize the trade routes of the global economy.

The property of hierarchicality of international trade relationships in these studies, is usually identified with the investigation of the distribution characteristics of the particular network variables that measure the degree of connectivity between the nodes of a network. Similar hierarchicality properties have been also found for economic networks that describe the intersectoral relationships at a global level. These studies have examined the power-law distribution of measures of interconnectedness (Xu et al., 2011), as well as the sign and the degree of assortativity (Cerina et al., 2015). Inspired by the work of Garlaschelli, Caldarelli and Pietronero (2003), who highlighted the topological properties of food webs, when the latter form tree-like structures of connections Duan (2007), Shi, Zhang and Luo (2014) and Zhu, Puliga, Cerina, Chessa and Riccaboni (2015), have investigated the hierarchical characteristics of trade and production economic networks. In particular, they have explored how the topologies of economic networks forming a tree structure, scale with the size of the whole network, highlighting the property that "the structure of the whole tree is statistically equivalent to that of any of its branches" (Garlaschelli et al., 2003, p. 166).

Duan (2007) focuses on a global trade network and analyzes the presence of a universal scaling behavior, by estimating the allometric scaling exponents with respect to the topology and flow of the trade network. The results show that the two allometric exponents are fairly stable for the period under consideration (1950-2000), despite the "radical changes in trade institutions, trade environments, and individual trade patterns" (2007, p. 276) in the last 50 years. Shi, et al. (2014) estimate allometric exponents for a trade network in order to investigate the presence of hierarchicality, inequality and monopoly, in trade flow networks. Their findings show that manufacturing products which include high value-added, tend to be more hierarchical, that is with higher allometric exponents:

> "When a product needs more complex production processes, more countries must be involved to form a long value chain, so that more value is added on the product. All of these properties must be reflected in the flow structure of the product trade network. That is the reason why allometric exponent g can be distinct for different products" (2014, p. 5)

Zhu et al. (2015) investigate the topological properties of GVCs, through the concepts of Global Value Networks (GVNs) and Global Value Trees (GVTs). As a GVNs, the authors define an economic network that is established by nodes representing individual sectors, and links measuring the sectoral value-added contribution to the final demand of each sector. A GVTs, on the other hand, is a tree-like network, specifically defined for each sector at a time, which "captures the value-added flows from the leaf industries to the root industry" (2015, p. 4). In order to construct a GVNs, the authors rely on the information of global input-output databases and compute the value-added contribution matrix, which is simply a matrix that measures the value-added contributions of each producing sectors *i* to the final demand of every buying sector *j*. Based on the matrix of value-added contribution matrix, it is possible to construct the GVTs for every country-sector, through the application of a modified version of the Breadth-First Search (BFS) algorithm, which extracts the most important supplying sectors for every buying sector of the database, in terms of their value-added contributions.

5.3 Methodology

5.3.1 Computation of Global Value Trees

Following the methodology of Zhu et al. (2015), I analyze the topological properties of the buyer-supplier relationships at the sectoral level of GVCs, through the concepts of Global Value Networks (GVNs) and Global Value Trees (GVTs). Zhu, et al. (2015) start with the computation of the matrix of value-added contributions of sectors *i*, to the final demand of sectors *j*. So, if $\boldsymbol{VL}$ is the matrix of value-added contributions matrix of global input-output relationships, then we simply have to multiply the diagonal of sectoral shares of value-added to gross output with the Leontief inverse, as in:

$$\boldsymbol{VL} = \begin{bmatrix} \frac{v_1}{x_1} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \frac{v_n}{x_n} \end{bmatrix} \begin{bmatrix} l_{11} & \cdots & l_{1n} \\ \vdots & \ddots & \vdots \\ l_{n1} & \cdots & l_{nn} \end{bmatrix} = \begin{bmatrix} \frac{v_1}{x_1} l_{11} & \cdots & \frac{v_1}{x_1} l_{1n} \\ \vdots & \ddots & \vdots \\ \frac{v_n}{x_n} l_{n1} & \cdots & \frac{v_n}{x_n} l_{nn} \end{bmatrix} \tag{5-1}$$

Zhu, et al. (2015), at this point, substitute the main diagonal of $\boldsymbol{VL}$ with zeros, in order to exclude any economic interactions within the same sector (self-loops). After computing the matrix of value-added contributions ($\boldsymbol{VL}$), they calculate the GVTs for each economic sector, by applying a modified version of the BFS algorithm. In particular, for each node-sector in the matrix $\boldsymbol{VL}$ (or GVNs in their terminology), they assume that is the root of the value tree and successively add supplier nodes and links, based on two conditions: i) the links have a direction from the supplier nodes towards the root, and ii) the weight of the links is higher than a specific benchmark value, a. So, in other words, the BFS algorithm chooses those supplying sectors from the GVNs (the matrix of value-added contributions $\boldsymbol{VL}$), that contribute value-added to the final demand of the root-sector, higher than a.

In order to determine the optimal benchmark value a for the weights of the links, the authors experimented with several values and ultimately concluded that the benchmark weight should, on the one hand, generate a large number of GVTs, and on the other, a large variation of tree size. For the World Input-Output Database (Timmer et al., 2015), the link weight that maximizes the Coefficient of Variation (CV) of tree size and also gives a large number of GVTs (close to the full scope of the database) is $a = 0.019$. Having experimented with various values of the benchmark link weight for the EORA database that is use in this study, I conclude that the CV of the tree size is maximized between values of 0.019 – 0.020, so I also use the a = 0.019 benchmark.

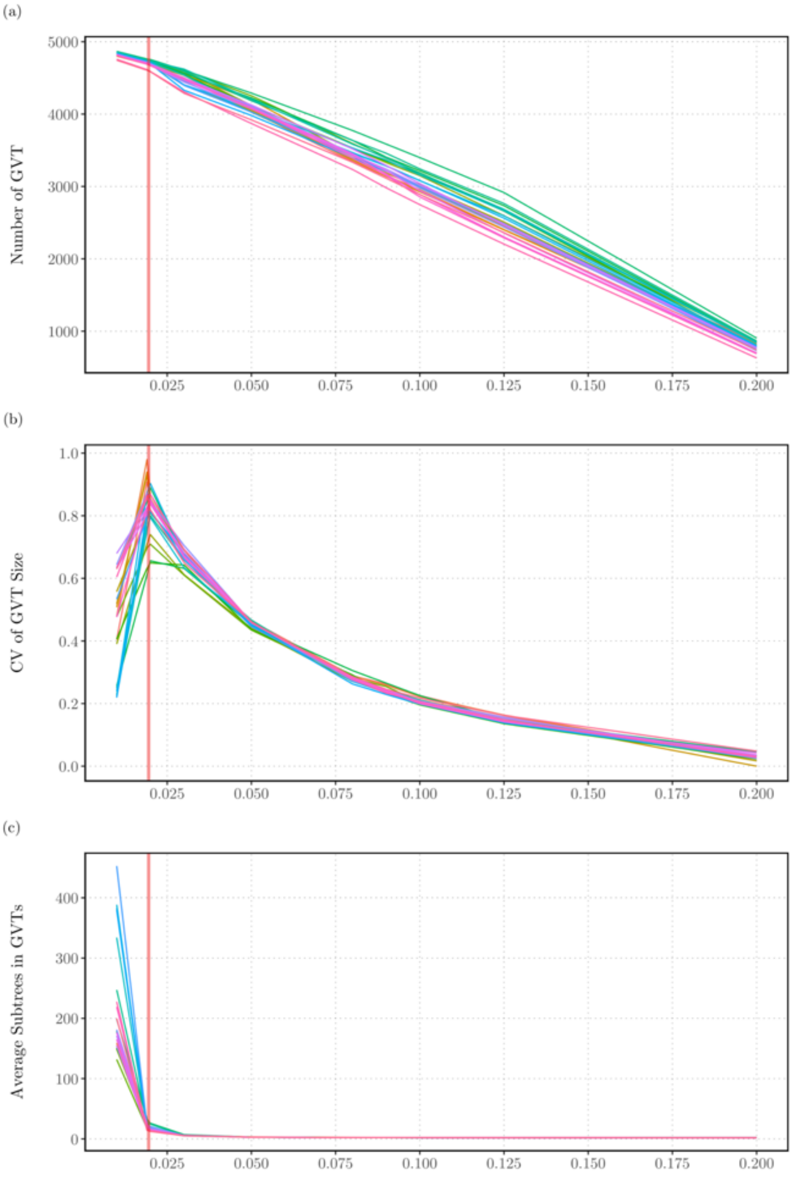


Figure 5-1 CVT characteristics based on various values of α

Source: Own Calculations. Data: EORA Database.

Figure 5-1, summarizes the exercise for finding the optimal value of link weight, based on the comparison of the total number of GVTs and the CV of their size. The CV of the GVTs size is maximized around the values of 0.019 – 0.020 (red strip), for which the number of estimated, by the BFS algorithm, GVTs is approximately close to the total number of country-sector observations in the database, that is 4700 GVTs, out of 4940 total nodes in the GVNs. Computationally, the above exercise is translated into the transformation of the matrix of value-added contributions into a network object, using the *igraph* package in *R* programing language, and then the application of the BFS algorithm for each node-sector (Csardi & Nepusz, 2006), in order to detect each global value tree.

The next step in the analysis of the topological properties of sectoral buyer-supplier linkages in sectoral GVCs, is the investigation of the *degree of hierarchicality* characterizing the topology of a GVTs. As hierarchicality of a tree structure, Zhu, et al. (2015), define the value of the *allometric scaling exponent* that describes the mathematical relationship between the size of a GVTs and the size of the sub-trees consisting the GVTs. Allometry is the mathematical relationship that "holds when the growth of one part of a system (Y) is compared with growth of another part or with the system itself (X)" (Ray et al., 1974, p. 342) expressed as a power law relation. If the allometry coefficient is less than one, then the part grows slower than the whole, whereas if it is more than one, grows faster than the system. In biology, allometric scaling refers to the relationship between the size of the body of a living organism and the size of a body part, as they both grow. It has been shown in numerous empirical studies that allometric scaling patterns are almost universal for both biological systems (Kaitaniemi, 2004; Shingleton, 2010), and other flow systems, such as, transportation networks, food webs, blood circulation, etc. (Garlaschelli et al., 2003; Zhang & Guo, 2010). If the relationship between the size of a body or system and the size of their parts is exponential, then the exponent is called *allometric exponent.* In mathematical terms, the allometric exponent is usually denoted with η and the power law relationship is expressed as:

$$Y_i \sim X_i^{\eta} \tag{5-2}$$

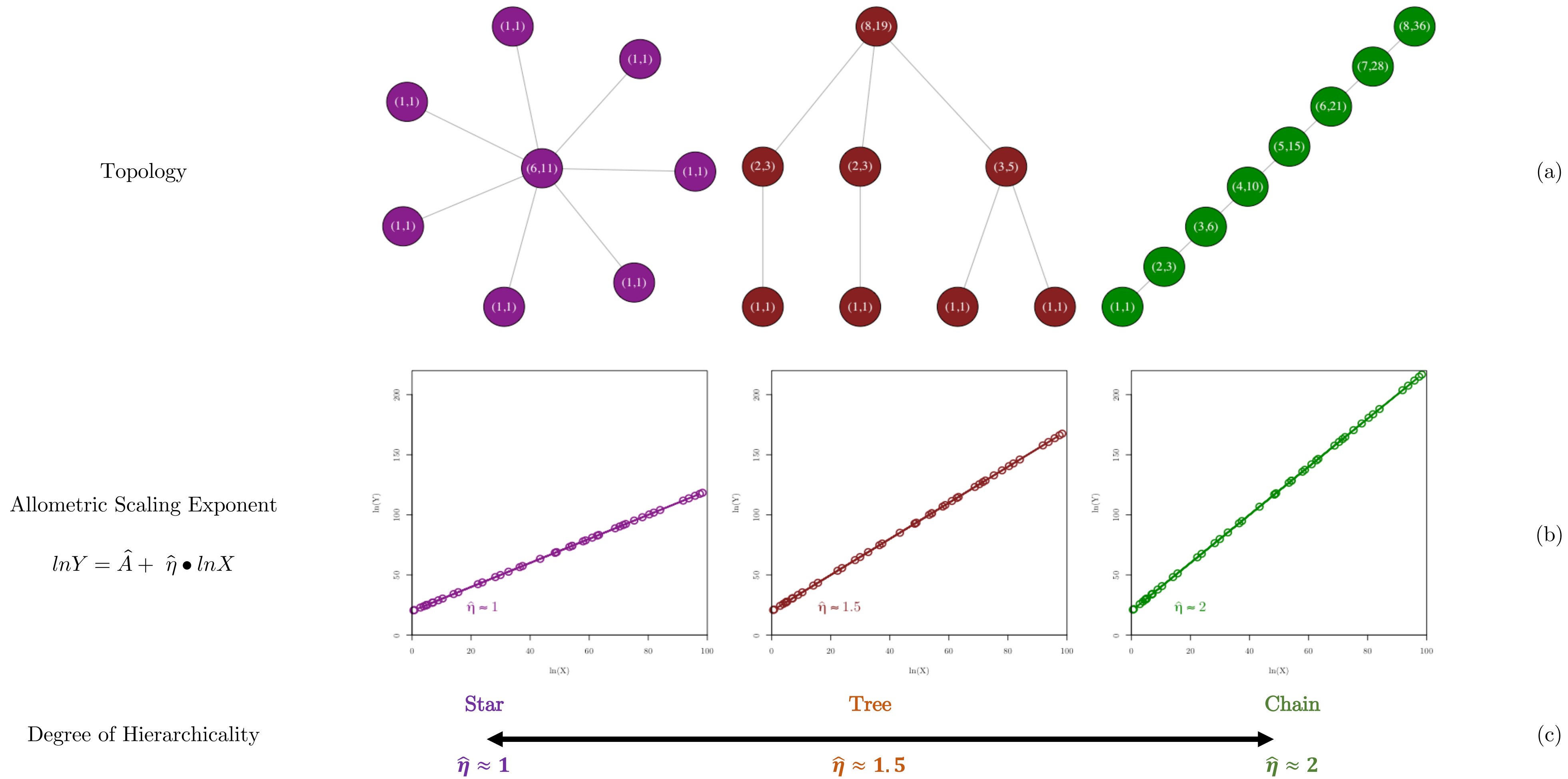
The mathematical relationship between the two variables, X_i and Y_i, is the allometric scaling exponent η. The scaling exponent η takes two extreme values that correspond to specific tree topologies. The lowest theoretical value of the allometric exponent is $\eta = 1$, which corresponds to a star-like topology, with the root-sector being at the center and every supplying industry contributing value-added to the final demand of the root-sector. The highest theoretical value of $\eta = 2$, and corresponds to a chain-like topology, with the root-sector at the one end, and each link connecting sequentially the supplier nodes-sectors, at various tiers. Values of η between the two extreme ($1 < \eta < 2$) theoretical cases, correspond to tree-like topologies.

In order to capture the size of a GVTs and the size of its sub-trees, the authors measure the "total number of nodes in the sub-tree rooted at node i by X_i and the sum of all X_i's in the sub-tree rooted at node i by Y_i" (2015, p. 7), as in subgraph (a) of Figure 5-2. In particular, they compute, for each root-sector, the total number of nodes in every sub-tree component of the value-tree under consideration (X_i), as well as the sum total of all the sub-trees, $Y_i = \sum_i X_i$, which represents the cumulative size of the value-tree. In the subgraph (a), I have reproduced three examples of GVTs topologies, for which I have calculated the values of X_i and Y_i for every node. Inside each node there are two numbers, the first corresponding to the size of the sub-tree (X_i) and the second to the cumulative size (Y_i). The sequence of these X_i and Y_i is characterized by a power-law allometric scaling relationship.

In Figure 5-2, three cases of GVTs topologies are considered; the two extremes of the star and chain topologies and the intermediate cases that resemble a tree topology. The scaling exponent η takes two extreme values that correspond to specific GVTs topologies. The visual results of the allometric exponents estimation are depicted in subgraph (b), with each regression line corresponding to a GVTs topology. The lowest theoretical value of the exponent is $\eta \approx 1$, which corresponds to a star-like topology, with the root-sector being at the center and every supplying industry contributing value-added to the final demand of the root-sector. The highest theoretical value of $\eta \approx 2$ corresponds to a chain-like topology, with the root-sector at the one end, and each link connecting sequentially the supplier nodes-sectors, at various tiers. Values of η between the two extreme theoretical cases ($1 < \eta < 2$), correspond to tree-like topologies. Given the values of the allometric exponent for the GVTs topologies in subgraph (b), a degree of hierarchicality continuum is defined in subgraph (c), allowing for the evaluation of the relationships of value-added contributions of buyers and suppliers in the world economy.

Given the matrices of value-added contributions for every year covered by the EORA database, I have computed 25 configurations of GVNs, with each network containing 4940 country-sector nodes. For each country-sector node, I have estimated the respective global value tree, assuming that each node acts as the 'root' of that tree. Since for the estimation of the GVTs the BFS algorithm has been used, the average number of GVTs cases is smaller than the total number of observations in the database, and specifically on average 4,700, per year.

Figure 5-2 Topological Properties of Global Value Trees and the Degree of Hierarchicality (Allometric Scaling Exponent)



Source: Own Illustration.

In Table 5-1, I have collected the summary statistics for the GVTs and their sizes, for the optimal link weight, $a = 0.019$. On average, each GVTs contains 20 supplying nodes, with the standard deviation ranging from 12.2 to 26.2, and the CV being the maximum (on average 85%), compared to the other values of link weights.

Table 5-1 Summary Statistics of Global Value Trees and their Size ($a = 0.019$)

Year	GVTS	μ	σ	CV	Year	GVTS	μ	σ	CV
1990	4690	21.042	24.978	1.187	2003	4735	21.447	16.134	0.752
1991	4700	18.820	26.234	1.394	2004	4720	20.423	16.067	0.787
1992	4703	23.102	20.637	0.893	2005	4732	23.061	17.601	0.763
1993	4706	20.562	18.677	0.908	2006	4713	19.961	17.450	0.874
1994	4703	20.018	19.607	0.979	2007	4720	21.731	17.667	0.813
1995	4711	19.846	18.650	0.940	2008	4713	23.272	18.461	0.793
1996	4722	20.432	18.978	0.929	2009	4692	21.611	18.859	0.873
1997	4737	17.434	13.944	0.800	2010	4705	16.538	13.675	0.827
1998	4730	19.788	14.032	0.709	2011	4707	24.638	19.846	0.8055
1999	4739	29.900	20.850	0.697	2012	4701	16.288	13.399	0.8226
2000	4762	33.029	20.865	0.632	2013	4690	17.584	14.48	0.8235
2001	4754	28.110	17.198	0.612	2014	4615	14.254	12.215	0.8570
2002	4739	15.954	13.460	0.844	2015	4606	15.38	13.308	0.8653

Source: Own Calculation. *Data*: EORA Database. Notes: GVTs measures the total number of global value trees for each year, taking into account that the link weight benchmark has been set for $a = 0.019$. The mean μ, the standard deviation σ and the coefficient of variation CV, correspond to the number of nodes that each GVTs contains. The CV is defined as the ration of σ/μ and expresses the variability of the data with respect to the mean.

5.3.2 Standardized Major Axis Regression

The degree of hierarchicality of the topologies of GVTs, is computed with the regression analysis of the scaling relationships after a linear transformation (log-log), using the Standardized Major Axis (SMA) approach. The usual option for estimating the exponent of a power law relationship between two variables, is to transform the relation into a linear form and then apply an Ordinary Least Squares (OLS) regression. For example, if we want to estimate the exponent η of the relationship in equation (5-3), we simply have to estimate the OLS coefficient of the following equation:

$$\ln Y_i = A + \hat{\eta} \ln X_i \tag{5-3}$$

with A being the intercept and $\hat{\eta}$ the estimate of the linear regression. However, in the respective literature on the analysis of allometric relations, an alternative method is usually employed, that of Standardized Major Axis (SMA) regression, since the OLS method produces biased results (Kaitaniemi, 2004; Warton et al., 2006; Zhang & Yu, 2010). Whereas, with the OLS regression approach we predict changes in the dependent variable from changes in the independent variables of a linear model, with SMA regression we are able to simply summarize the relationship between two variables. According to Zhang and Yu (2010), with SMA regression we get fitted lines that are placed in the center of the data, since this method attempts to "minimize the total distances from data points to the regression line both from x and y direction; not only the y direction as the OLS method does" (2010, p. 4888).

In other words, for estimating the coefficient of the linear regression under the SMA method, we have to minimize the perpendicular distance of the residuals from the fitted line, while in the OLS regression we minimize the vertical distance of the residuals from the regression model line (Warton et al., 2006, p. 264). Mathematically, the SMA regression estimates for the intercept and the coefficient of a linear regression like the one in equation (5-4) can be computed as:

$$\hat{\eta}_{SMA} = \pm \frac{S_Y}{S_X} \text{ and } \hat{A}_{SMA} = \bar{Y} - \hat{\eta}\overline{X} \tag{5-4}$$

with S_Y and S_X being the estimates of the standard deviations of *ln(Y)* and *ln(X)* and $\bar{Y}$ and $\bar{X}$ the mean values of *ln(Y)* and *ln(X)*, respectively. Computationally, for this paper, I used the *smatr* package in *R* programing language (Warton et al., 2012) in order to estimate the SMA coefficients for the degree of hierarchicality.

5.3.3 Data

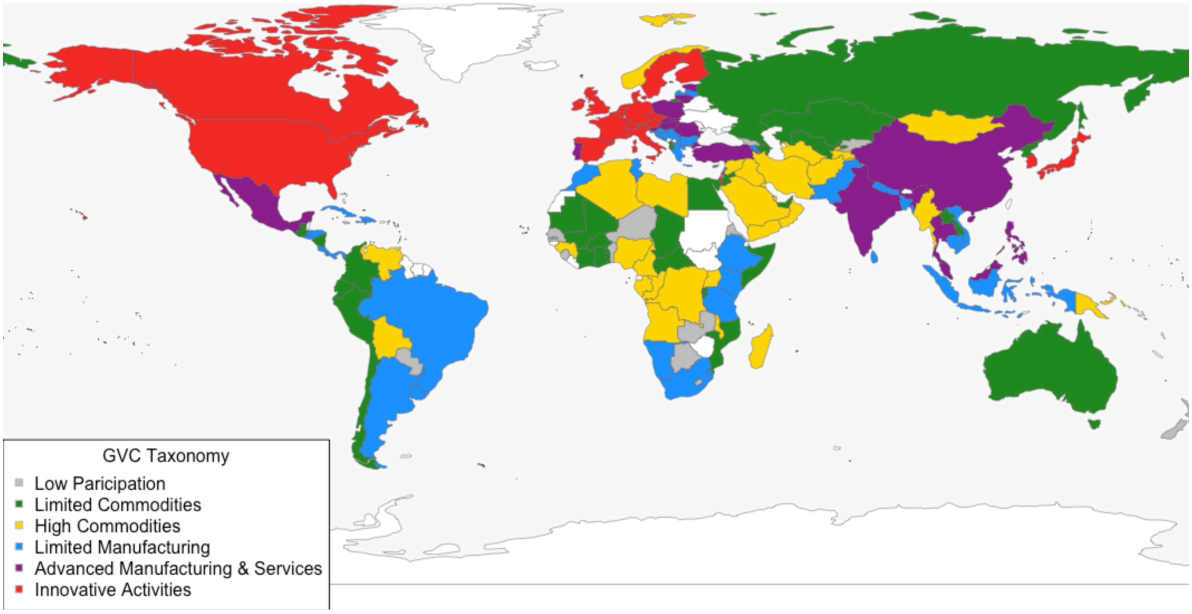


Figure 5-3 The World Bank GVCs Participation Taxonomy

Source: Own Illustration. Note: Adapted from World Bank Report (2020) and modified by the author.

For the calculation of both the GVNs and the GVTs, I take into account the information provided by the EORA Global Multi-Regional Input-Output Database. The EORA MRIO covers 26 economic sectors, at the ISIC Rev.3 classification system, for 190 countries (including a proxy for the Rest of the World), from 1990 to 2015. The database provides time-series of global multi-regional input-output tables, in thousands of US dollars and allows for a complete understanding of the intersectoral linkages between global sectors, in terms of their intermediate inputs consumption, as well as final demand and value-added components. The superiority of the EORA MRIO compared to the other global input-output databases, like the WIOD and the OECD ICIO, lies on the substantially higher coverage of countries. Whereas the latter databases provide time series input-output tables for maximum 65 countries, the EORA database provides for 190 countries, almost the whole world economy. For the present research paper, I used the matrices of intermediate and final demand, as well as, the vector of gross output, in order to compute the Leontief inverse and the matrix of value-added contributions. In the Appendix, there is the full description of the sectoral coverage and the countries included in the EORA database.

For the classification of countries, I use the GVCs participation taxonomy developed and proposed by the World Bank, which distinguishes each country between six different groups, according to three variables: a) the exports' sectoral specialization with respect to the amount of domestic value-added in gross exports, b) the extent of GVCs participation measured by the share of backward linkages (imported embodied imports) to total exports and c) the country's innovative activity, captured by the GDP shares of intellectual property revenues and R&D expenses. The six types of GVCs participation are (see also the map in Figure 5-3):

- Low Participation countries with manufacturing share of domestic value-added in exports less than 60% and primary goods' share less than 20%,
- Limited Commodities countries, with manufacturing share of domestic value-added in exports less than 60% and primary goods' share between 20% and 40%,
- High Commodities countries, with manufacturing share of domestic value-added in exports less than 60% and primary goods' share higher than 40%,
- Limited Manufacturing countries, with manufacturing share of domestic value-added in exports between 60% and 80%,
- Advanced Manufacturing and Services countries, with manufacturing and business services share of domestic value-added in exports more than 80%,
- Innovative Activities, with R&D expenditure higher than 1% of GDP and intellectual property receipts higher than 0.1% of GDP.

5.4 Empirical Observations

In this section, I present the empirical results of the analysis of the degree of hierarchicality of GVTs within GVCs, showing its spatiotemporal evolution and geographical distribution in the world economy. For every case of GVTs originating from one of the country-sectors, I have estimated the degree of hierarchicality η, by computing the allometric scaling exponent of the relationship between the size (X_i) and the cumulative size (Y_i) of each tree, as described above.

Figure 5-4 shows the results of the estimation of the degree of hierarchicality for two selected years, 1990 and 2015. In the scatterplots of subgraphs (a) and (b), the world economy as a whole has been taken into account, with all the cases of GVTs and their respective pairs of X_i and Y_i. The horizontal axis measures the size (X_i) of each GVTs and the vertical axis the cumulative size (Y_i), whereas each point in the scatterplots corresponds to an observed pair of X_i and Y_i. The red line is the regression line estimated with the SMA approach. The scatterplots in the subgraphs (c) and (d), on the other hand, show the allometric scaling relationship between pairs of X_i and Y_i, taking into account the 26 sectors represented in the EORA database, with each sector corresponding to a different color.

In Figure 5-5, the world economy as a whole is taken into account with the degree of hierarchicality showing a decreasing trend for the last 25 years. The values of the degree of hierarchicality are between 1.459 and 1.531. Between 1990 and 2007, the hierarchicality of GVCs in the world economy fluctuated fairly stable between 1.501 and 1.505, showing a small tendency to fall. From 2007 onwards, however, the decrease of the global degree of hierachicality was higher, with the three-year moving average falling -2.19%, from 1.507 to 1.474.

Two preliminary conclusions can be drawn from the above observations:

- First, the global degree of hierarchicality that characterizes the totality of GVCs in the world economy shows a clear falling trend. This fact implies that the topological structures of GVTs and consequently of the supply chains and the sectoral buyer-supplier relationships, become less hierarchical.
- Second, despite the falling tendency in the degree of hierarchicality observed in the last 25 years, the latter seems to fluctuate between the boundaries of a tree-topology. Given the fact that the spectrum of the degree of hierarchicality that corresponds to a star, tree, and chain topology, is from 1 to 2, then we can safely conclude that GVCs are characterized by tree topologies, rendering the other two (star and chain), theoretical extremes. This observation gives empirical support to the claim that the hierarchicality and tree-like topology of global production is a universal attribute across time.

Although the previous results suggest that there is a clear falling trend in the global degree of hierarchicality with respect to the topological characteristics of GVCs, it is likely that an aggregate picture of the world economy hides significant variations between countries. In what follows, I will shed light on cross-country heterogeneities and examine the evolution of hierarchicality of GVCs across countries, highlighting meaningful commonalities and/or differences. Since the computed degree of hierarchicality does not account for the relative economic importance of countries, I will assume that all countries have unequal weights, depending on their share to global GDP. Moreover, I will follow the GVCs participation taxonomy proposed by the World Bank (2020), and group the countries in the following categories: Innovative Activities (Figure 5-6), Advanced Manufacturing and Services (Figure 5-7), Limited Manufacturing (Figure 5-8), High Commodities (Figure 5-9), Limited Commodities (Figure 5-10), and Low Participation (Figure 5-11) countries.

Focusing on the group of Innovative Activities (Figure 5-6) countries, we observe that the majority of them has higher than average degree of hierarchicality, reflecting, not only their leading role in the organization of those GVCs, through large and powerful multinational corporations acting as "lead-firms" (Gereffi, 2018; Milberg & Winkler, 2013), but also their ability to capture higher share of value-added from their supply-chain partners, both domestically and internationally. This group consists of technologically advanced economies that have the capacity to expend for research and development investments more than 1% of GDP as well as receive intellectual property receipts that exceed at least the 0.1% of GDP. In other words, the Innovative Activities groups includes countries that produce high-tech and high-valued manufacturing goods and services (World Bank, 2017, 2020).

Within this group, however, we observe interesting variations. First, the degree of hierarchicality for Austria, Belgium, Canada, Switzerland, Germany, Spain, Finland, France, Great Britain, Italy, Japan, the Netherlands, Sweden, and the United States, shows a clear decreasing trend, starting between mid-1990s and early 2000s. This observation, in combination with the respective rise in the degree of hierarchicality of countries and regions that are central in the GVCs geography, such as East Asia and Eastern Europe (see Figure 5-7, Figure 5-8, Figure 5-9), is consistent not only with the empirical data that show the relative rise in world exports and economic significance of countries like China and India in the political economy of GVCs, but also with the literature's metaphors and claims that have dominated the scientific and political discourse, like the rise of the "Global Factory" (Buckley, 2018) or the phenomenon of "Global Shift" (Dicken, 2007). Afterall, it was during that period that India (1995) and China (2001) joined the World Trade Organization, as part of a global agenda of trade liberalization, tariffs' reduction, and growth of GVCS.

Second, there are a handful of countries that belong to the Innovative Activities group that, instead of showing a falling degree of hierarchicality, they have managed to increase it. Countries, such as Korea, Czech Republic, Israel, and Singapore, in the last 25 years have climbed up the ladder of GVCs and located themselves in more centralized positions in the network of international fragmentation of production, capturing higher portions of value-added from their suppliers. Moreover, with the exception of Korea, the latter set of countries, along with Finland, have lower than the global average hierarchicality, which implies that the potential gains from participating in GVCs, are quite low, compared to the rest of the group.

Moving on to the Advanced Manufacturing and Services group (Figure 5-7), we observe that 10 out of 16 countries in this group, have lower than average degree of hierarchicality. In this group we find countries that produce manufacturing goods, which are not necessarily characterized as high-tech, whereas the share of domestic value-added in exports of those manufacturing goods, is higher than 80%. Estonia, Hong Kong, Hungary, Lithuania, Malaysia, Philippines, Portugal, Romania, Slovakia, Slovenia, have degree of hierarchicality that is lower that the global average. The six countries in the group than show higher than average degree of hierarchicality, are China, India, Mexico, and Poland, Thailand, and Turkey, after the early 2000s.

The growth in the degree of hierarchicality for China and India - the two most representative examples of rising GVCs partners (Buckley, 2018; Dicken, 2007; World Bank, 2017) - is impressive, as equally impressive is the rise for Poland and Turkey, reflecting their increasing role in the topology of global supply chains and their integration to global and regional GVCs, especially with respect to the European single market (Cieślik et al., 2021; Dine, 2019; Ozer et al., 2016). Malaysia (electronics, automobile parts) and Philippines (agriculture, fisheries), despite the fact that are below the global average for the whole time-period under consideration, they have significantly increased their hierarchicality of the GVCs located in their jurisdictions, reflecting their rising role in the regional, as well as international supply chains (Andriesse, 2018; Raj-Reichert, 2020; WAD, 2008).

In the Limited Manufacturing group (Figure 5-8), we find countries whose share of domestic value-added in exports of manufacturing goods is lower than 80% but higher than 60%. These are usually low-cost countries that produce simple manufacturing goods, with production processes of low capital and technological intensities. The vast majority of countries within this group have lower than average hierarchicality, implying that they have very low power to capture value-added from their suppliers, along the value chain. The only exceptions are Indonesia, which manages to rise over the global average after the mid-1990s, and Brazil, which is constantly higher than the global average. Both observations are consistent with what the literature that has identified for these countries, an increasing degree of integration into GVCs, especially for the garments and electronics sectors for Indonesia (Kadarusman & Nadvi, 2013) and role of a "regional hub" connecting supply-chains within South America and between the region and the rest of the world (Araújo et al., 2021), for intermedia primary inputs.

In the next groups we find countries whose share of domestic value-added in exports of manufacturing goods is lower than 60%, but they produce and export an important share of primary goods. The vast majority of those countries exhibit lower than average degree of hierarchicality, reflecting their small role in the organization of GVCs and their ability to capture portion of value-added. Moreover, it reflects the fact that since they are primarily producers and exporters of primary goods, such as oil, metals, and agricultural commodities, are characterized by high upstreamness with respect to other countries whose key-sectors and firms are closer to final demand or other high value-added mid-stream and downstream tiers of production (Antràs et al., 2012).

The High Commodities group (Figure 5-9) includes those countries with share of domestic value-added in exports of manufacturing goods is lower than 60%, and primary goods' share higher than 40%. The vast majority of countries within this group show below average hierarchicality, reflecting the complementary role that they play in the capturing of value-added from global production. Here we find, Afghanistan, Angola, Bolivia, Cameroon, Democratic Republic of Congo, Congo, Algeria, Gabon, Guinea, Iran, Iraq, Kuwait, Libya, Madagascar, Myanmar, Mongolia, Malawi, Nigeria, Oman, Papua New Guinea, Qatar, Syria, Tajikistan, Turkmenistan, Trinidad and Tobago, Uganda, Vietnam, Yemen.

In the Limited Commodities group (Figure 5-10), we find countries with share of domestic value-added in exports of manufacturing goods is lower than 60% and primary goods' share higher between 20% and 40%. Lower than average hierarchicality characterizes Albania, Azerbaijan, Burundi, Burkina Faso, Central African Republic, Chile, Cote d'Ivoire, Colombia, Ecuador, Egypt, Chana, Guatemala, Jordan, Kazakhstan, Laos, Mali, Mozambique, Mauritius, Nicaragua, Peru, North Korea, Rwanda, Somalia, Chad, Togo, Uzbekistan. Lastly, in the Low Participation country group (Figure 5-11), we find countries with manufacturing share of domestic value-added in exports less than 60% and primary goods' share less than 20%, such as Benin, Botswana, Eritrea, Georgia, Gambia, Jamaica, Kyrgyzstan, Lesotho, Niger, New Zealand, Paraguay, Palestine, Senegal, Sierra Leone, Zambia, which all exhibit lower than average degree of hierarchicality.

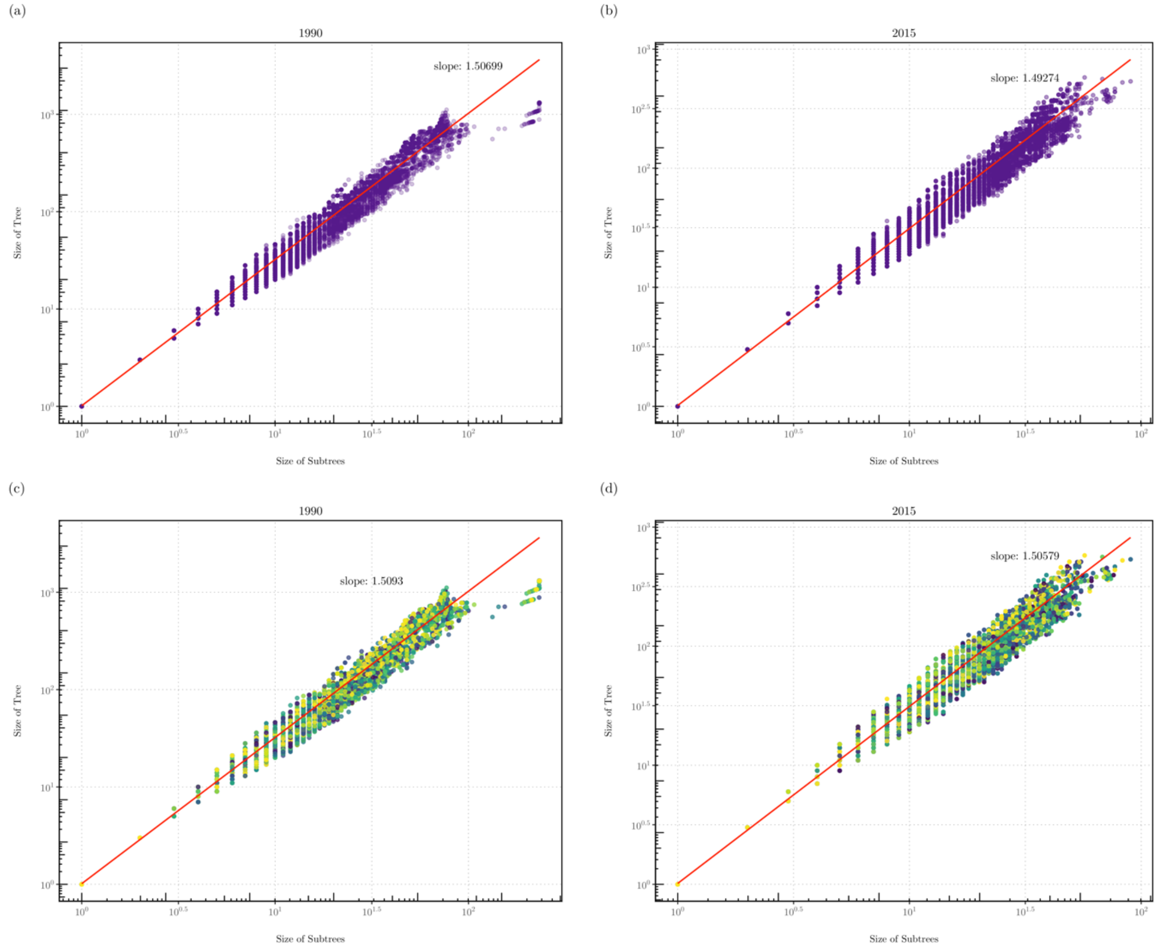


Figure 5-4 Scatterplots of the Size of Subtrees and the Size of Trees for Selected Years.

Source: Own Calculations. *Data*: EORA Database. Notes: The Size of Subtrees is denoted by X_i and the Size of Trees by Y_i. The scatterplots are in log-log scales.

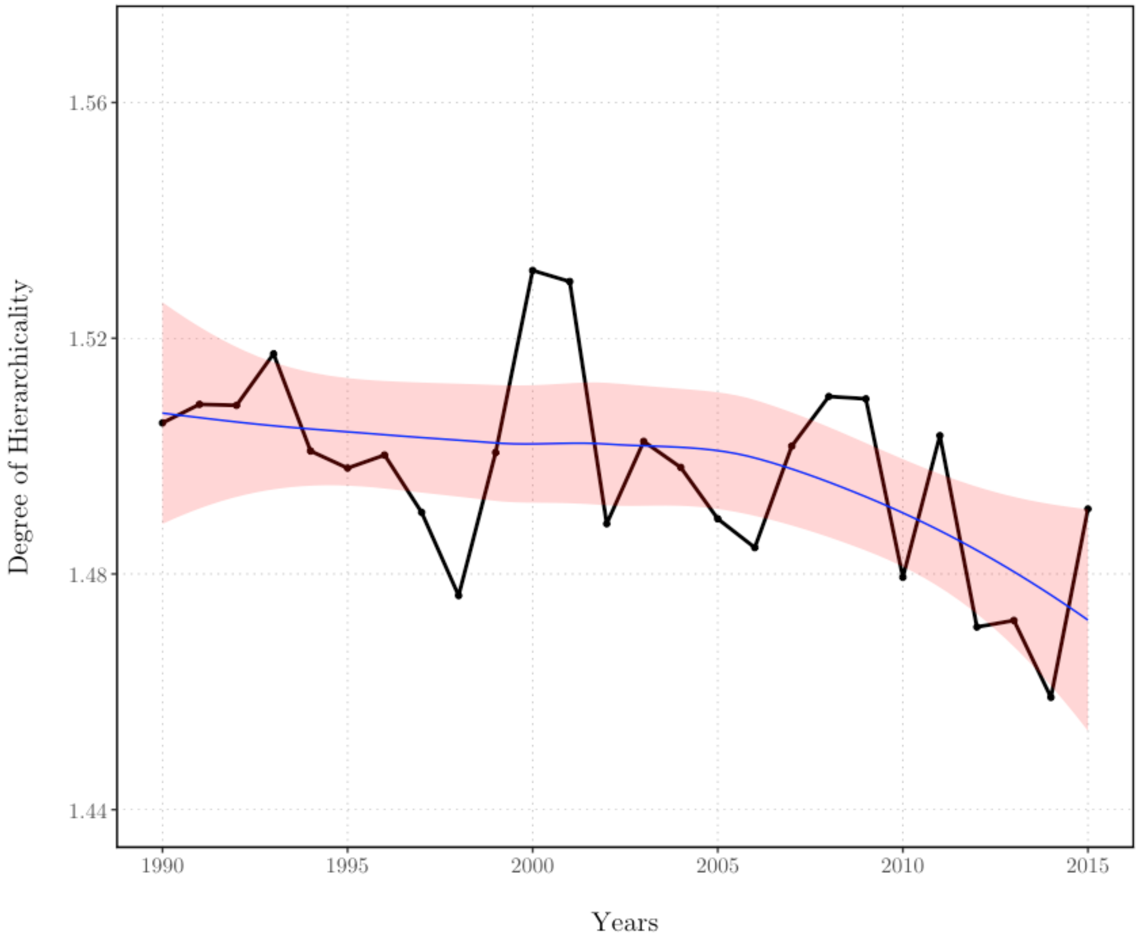


Figure 5-5 Degree of Hierarchicality for the World Economy
Source: Own Calculations. *Data*: EORA Database.

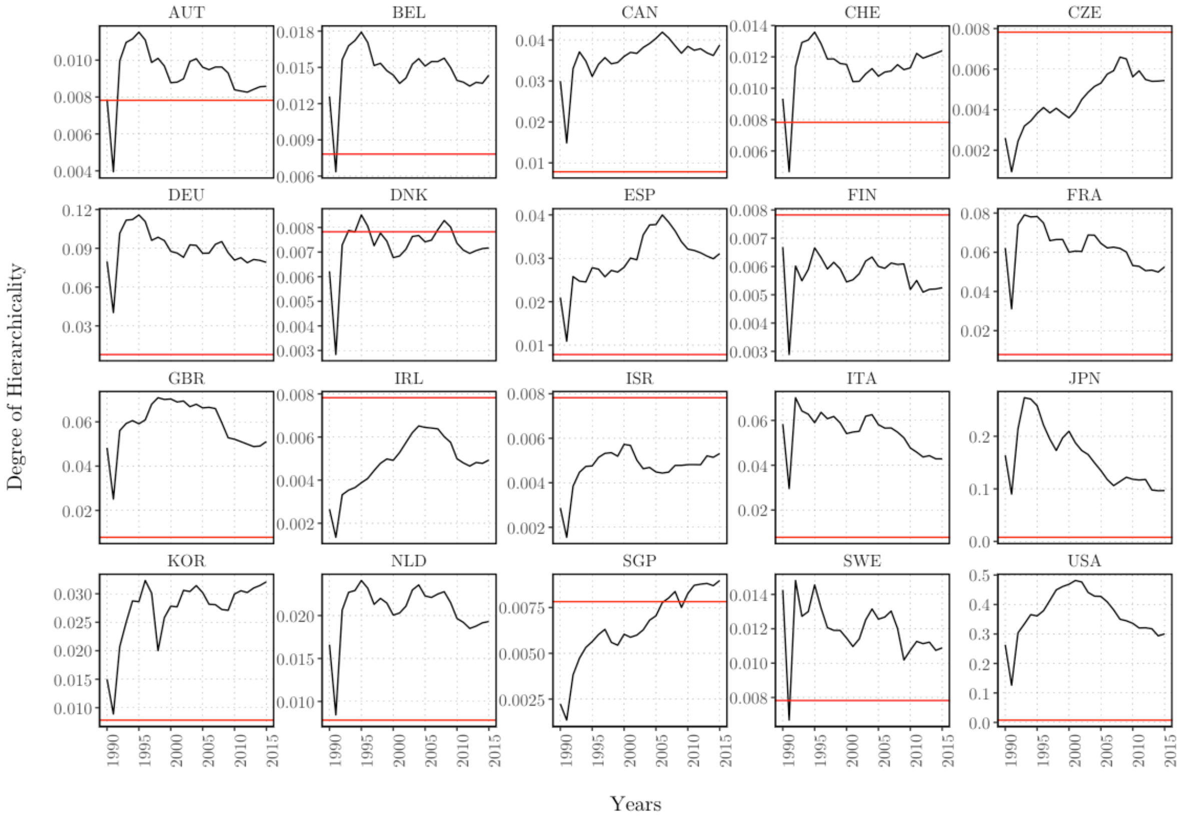


Figure 5-6 Weighted Degree of Hierarchicality for Innovative Activities Countries

Source: Own Calculations. Data: EORA Database, WITS. Notes: The red horizontal line corresponds to the mean value of the degree of hierarchicality weighted by the countries' share to global Gross Output.

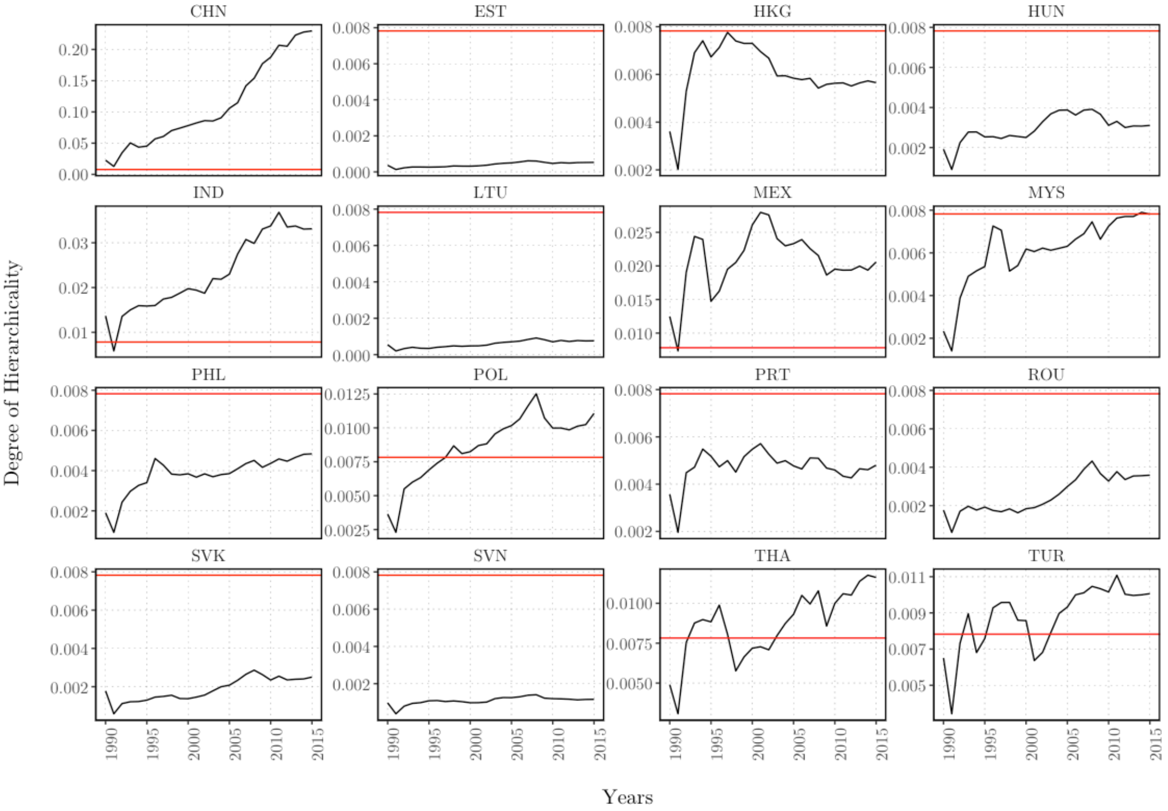


Figure 5-7 Weighted Degree of Hierarchicality for Advanced Manufacturing and Services Countries

Source: Own Calculations. Data: EORA Database, WITS. Notes: The red horizontal line corresponds to the mean value of the degree of hierarchicality weighted by the countries' share to global Gross Output.

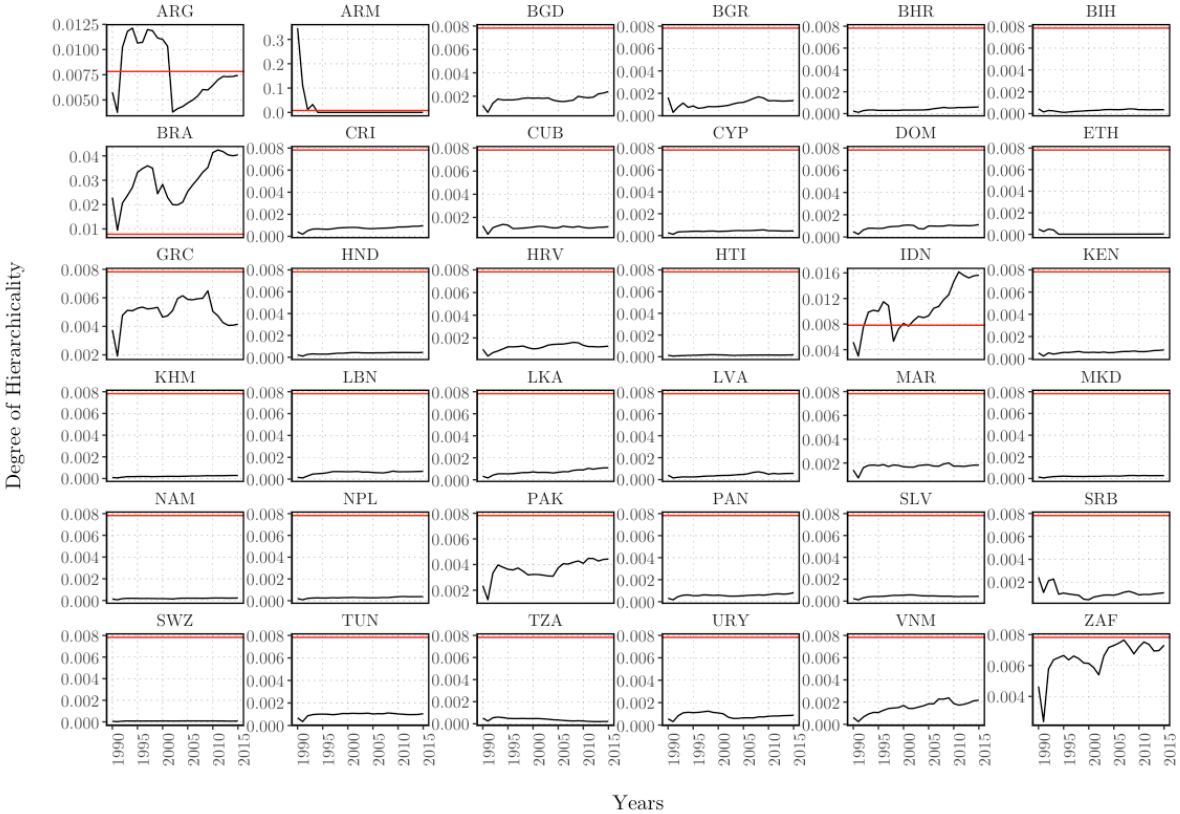


Figure 5-8 Weighted Degree of Hierarchicality for Limited Manufacturing Countries

Source: Own Calculations. Data: EORA Database, WITS. Notes: The red horizontal line corresponds to the mean value of the degree of hierarchicality weighted by the countries' share to global Gross Output.

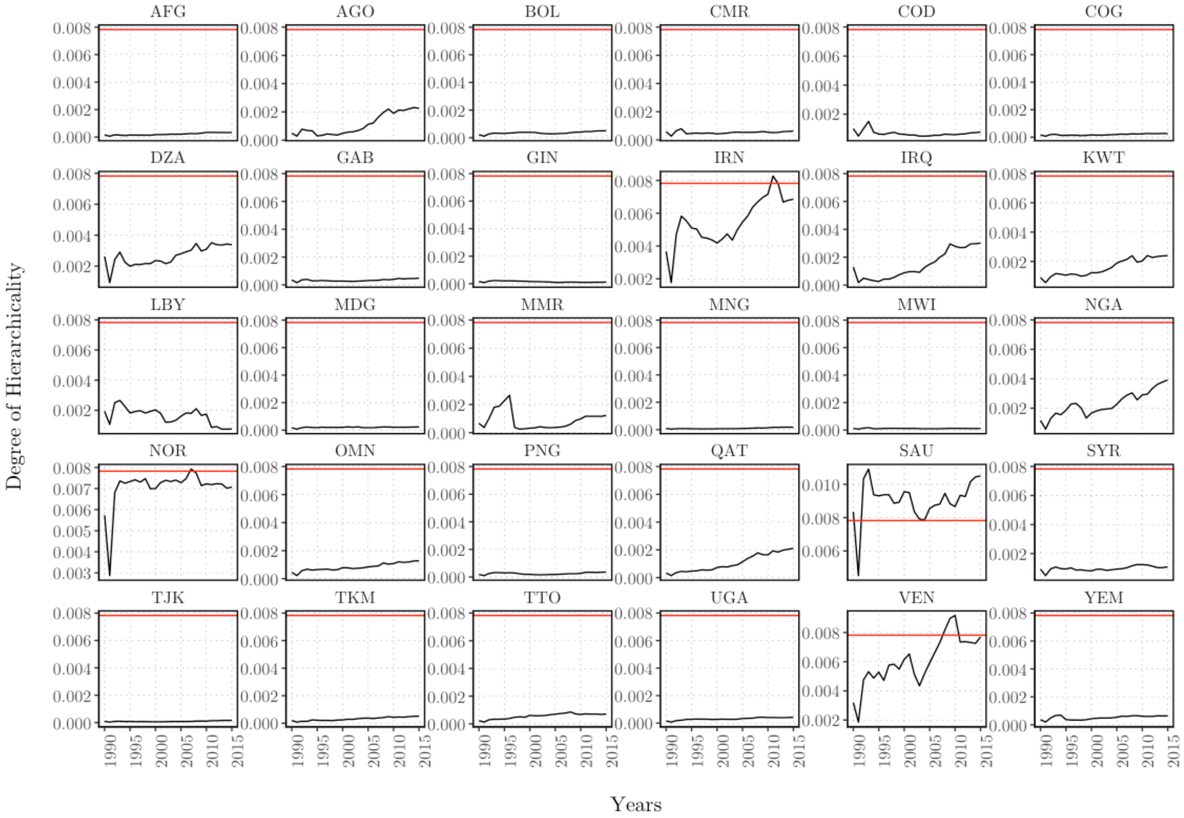


Figure 5-9 Weighted Degree of Hierarchicality for High Commodities Countries

Source: Own Calculations. Data: EORA Database, WITS. Notes: The red horizontal line corresponds to the mean value of the degree of hierarchicality weighted by the countries' share to global Gross Output.

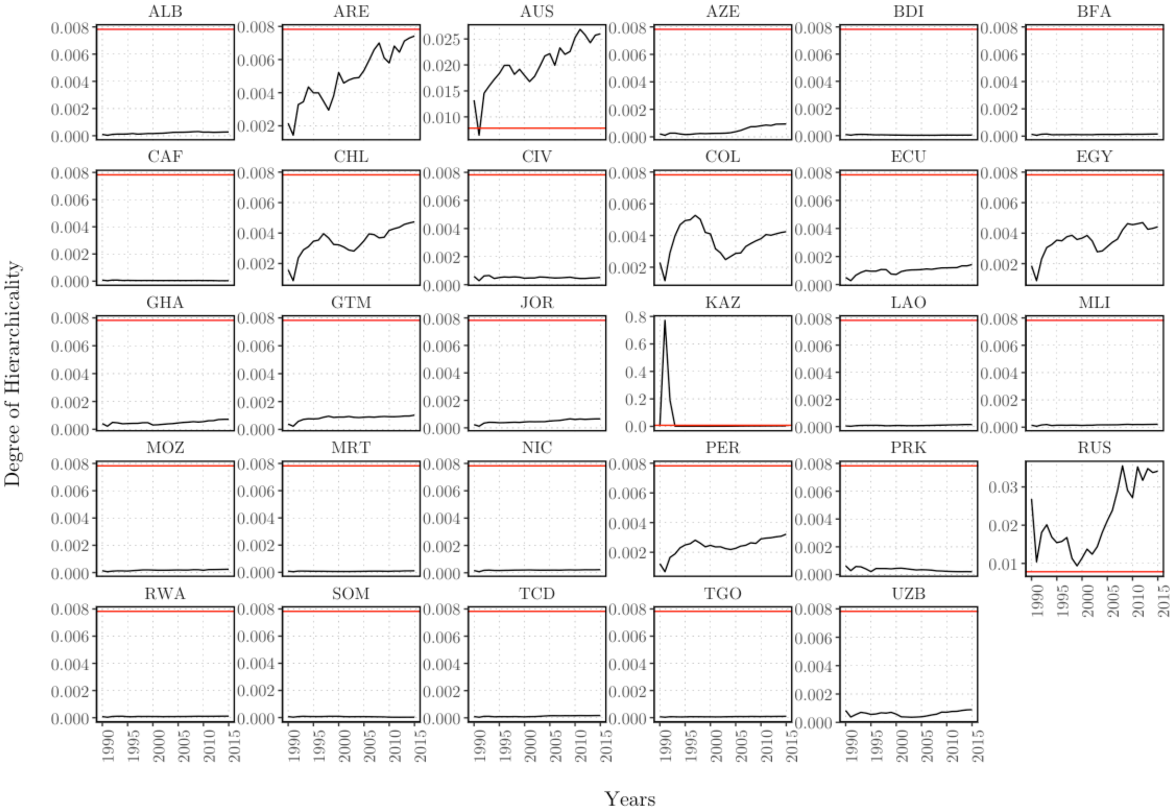


Figure 5-10 Weighted Degree of Hierarchicality for Limited Commodities Countries

Source: Own Calculations. Data: EORA Database, WITS. Notes: The red horizontal line corresponds to the mean value of the degree of hierarchicality weighted by the countries' share to global Gross Output.

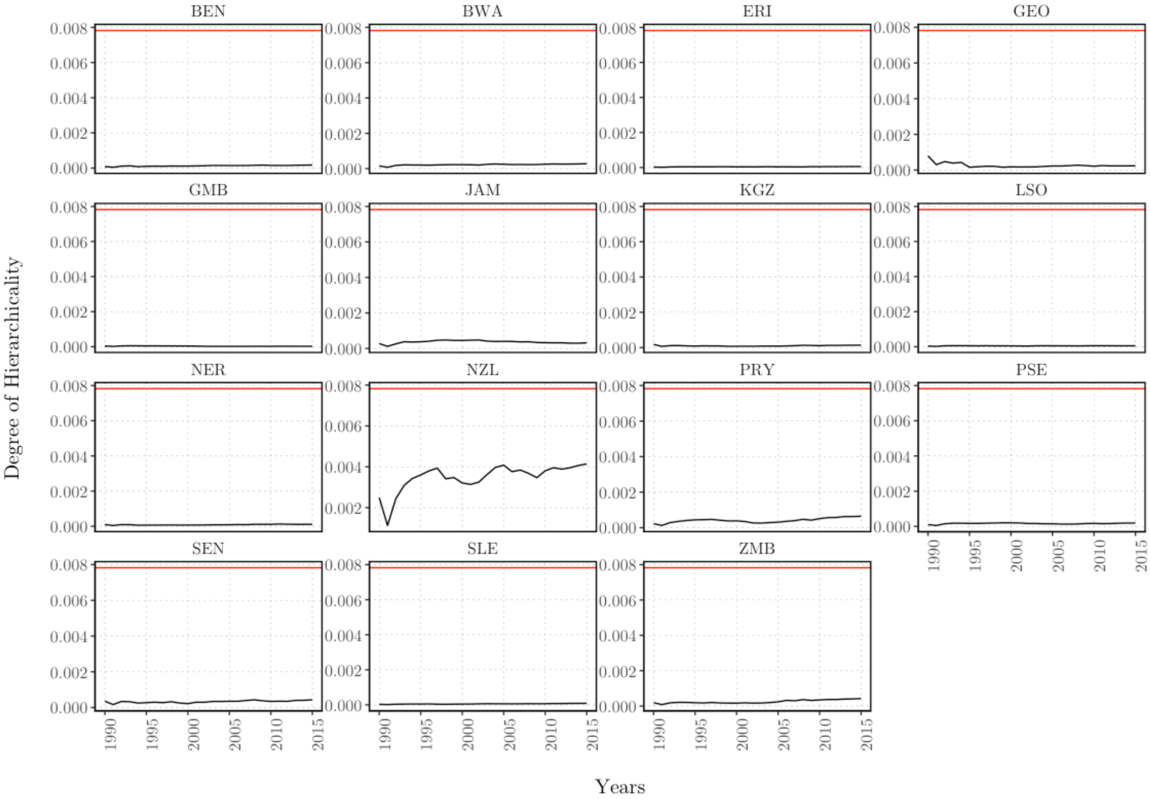


Figure 5-11 Weighted Degree of Hierarchicality for Low Participation Countries

Source: Own Calculations. Data: EORA Database, WITS. Notes: The red horizontal line corresponds to the mean value of the degree of hierarchicality weighted by the countries' share to global Gross Output.

However, within the latter groups, there are a few important exceptions. On the one hand, oil and material producing countries, such as Saudi Arabia, Russia, Australia, and Norway, show higher than average degrees of hierarchicality, although for the latter is below the average, but very close to the global average. This link between oil and materials producing economies and integration into complex global supply chains has been identified by the literature, although it has been pointed out that the high share of primary and energy goods exports is not a guaranteed path for reaping the gains from higher GVCs participation (Karlik et al., 2016; Volgina, 2018). On the other, there are oil and material producing countries, that notwithstanding that exhibit lower than average hierarchicality, they are doing better than the rest of their respective group (Algeria, Angola, Qatar, Nigeria, Libya, Kuwait, Iraq, Azerbaijan, Colombia, Ecuador, Egypt, Peru, Uzbekistan), and some of them showing an impressive increase in the last 25 years (Iran, Vietnam, United Arab, Emirates, Chile).

Given the discussion above, a number of broad economic policy implications can be highlighted. A first, although not completely new lesson on the economic development front is that the integration of a country or a country's sectors, into GVCs, is not unconditionally beneficial. In view of the above results and the methodology of value-trees and the investigation of the topology of GVCs provides scholars and policy makers with valuable information regarding the distribution which sectors and countries have the ability to capture higher portions of value-added.

The rise of GVCs economic activity in the last decades – what Dicken (2007) calls the "Global Shift", Buckley the rise of the "Global Factory" (2018) and Milberg and Winkler (2013) the "New Wave of Globalization" – has had a notable and transformative effect on the structure of global economy, the observed patterns and characteristics of international trade, the development of countries and the distribution of income among factors of production (De Backer & Miroudot, 2013; Gereffi, 2018; Taglioni & Winkler, 2016; World Bank, 2020).

The conventional view of the economic and political elite on the impacts of GVCs participation is that countries will gain, unconditionally from it. GVCs participation, irrespective of the extent, the characteristics, the sectors it involves or even the political, institutional, and social context of the country under consideration, will lead to productivity and technological spillovers, cheaper inputs, growth in domestic value-added, higher profits, investments and eventually (the usual trickle-down effects) higher wages.

There are however controversial case studies and mixed results in the literature, with respect to two dimensions: a) whether the gains are universal for all countries and b) whether the gains are universal for all factors of production (Carballa Smichowski et al., 2021; Milberg, 2004; Milberg & Winkler, 2009; Rodrik, 2013). Within the latter, an important aspect is the structure/architecture of GVCs. That is whether countries and within countries their leading key-sectors, are able to capture portions of value-added, which translates into a specific topology of the network (Criscuolo & Timmis, 2017; Pahl & Timmer, 2020; Yanikkaya & Altun, 2020).

If we want to inform economic policy, we need to have a better understanding of the topology of GVCs, especially for those countries that envisage their future development as part of value-added value chains. The design and implementation of development policies, consequently, require insights and a comprehensive understanding of the structural characteristics of GVCs and the articulation of national economies within them. Mapping the structures through which GVCs are organized and value-added is transferred and captured between components and segments of complex supply-chains, pave the way for an effective participation in a GVCs.

5.5 Conclusions

The assessment of the empirical linkages between sector-country participation in GVCs and the overall economic outcomes in terms of output, productivity, and incomes growth, cannot be achieved without a comprehensive understanding of the structural properties of supply-chains. In this paper I concentrate on a new path for the empirical and quantitative investigation of the structures that govern the organization of global production. Informed by the growing literature on economic network and complex analysis, and particularly the methodology of global value trees proposed by Zhu, et al. (2015), I analyze the topological characteristics with respect to the hierarchicality of the topological structures of sectoral buyer-supplier relationships. Utilizing a dataset of Global Multi-Regional Input-Output Tables, I estimate a global network of value-added transfers, with each node representing a different sector in a specific country, and each link the value-added contribution of the supplier to the final demand of the buyer.

The research questions this paper attempts to address are two. First, is a tree-like topology a universal attribute of GVCs that characterizes the structure of their supply chains across space and time. Second, what is the geographical distribution of the hierarchicality of global supply chains in the world economy and how it has evolved in the last decades. Does the hierarchicality of GVCs show a clear trend across time and space. The empirical observations highlighted in this paper provide evidence for a clear decreasing trend in the global degree of hierarchicality that characterizes the totality of GVCs in the world economy. In other words, the topological structures of GVTs and consequently of the supply chains and the buyer-supplier relationships, become less hierarchical. Moreover, the results show that the tree-topology of the supply-chain structure of the GVCs is a universal attribute across time, since the degree of hierarchicality fluctuates only between the boundaries of a tree-topology, for the last 25 years.

The present paper can be extended at least towards three research paths. The first path could concentrate on the generalization of the current framework. Global value trees have been defined as the tree-like topology shaped by the most important suppliers, with respect to their value-added contribution to the final demand of the buyer. Equally, it would be meaningful to analyze the topology shaped by the value-added contributions of the buyer, with respect to the sectors that itself supplies with intermediate inputs. In that way, both the backward and forward linkages of the sector under consideration would have been analyzed in terms of the hierarchicality of the business relationships.

The second path of future work could focus on the analysis of specific global industries, employing detailed sectoral and firm-level data. This path would allow for a finer analysis of the hierarchicality of governance structures and the spatioeconomic evolution of the respective GVCs. This path could take note of the massive number of country and industry specific case studies found in the literature and reinforce them with an empirical and quantitative counterpart.

The third path of future research is to concentrate on particular countries or groups of countries, for which input-output tables at higher dimensions in terms of sectoral coverage, are provided. The global input-output database used in this paper provides information for 26 economic sectors, whereas other alternative databases, like the WIOD and the OECD-ICIO, stand at 56 and 36 sectoral configurations. However, there are many national statistical institutions that have compiled extremely detailed forms of input-output tables, reaching up to 400 economic sectors, subsectors, and industries.

The advantage of using higher resolution input-output databases, though, comes with the price of taking gross assumptions regarding the foreign content of intermediate inputs, in the absence of detailed concordances between international trade and the end-use of commodities exchanged (Feenstra & Jensen, 2012; Milberg & Winkler, 2013; Winkler & Milberg, 2012). In spite of the above trade off, there is plenty of room for an in-depth analysis of the hierarchicality of topological structures of production networks and value chains, on the one hand, and opening a constructive dialogue with adjacent literatures that use the concept of GVCs from a micro-level and firm-centric perspective, like economic sociology, international political economy and geography (Coe & Yeung, 2015; Gereffi et al., 2005; Henderson et al., 2002).

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5.6 Appendix

Table 5-3 List of Countries

EORA Global Multi-Regional Input-Output

Afghanistan
Albania
Algeria
Andorra
Angola
Antigua
Argentina
Armenia
Aruba
Australia
Austria
Azerbaijan
Bahamas
Bahrain
Bangladesh
Barbados
Belarus
Belgium
Belize
Benin
Bermuda
Bhutan
Bolivia
Bosnia & Herzegovina
Botswana
Brazil
British Virgin Islands
Brunei
Bulgaria
Burkina Faso
Burundi
Cambodia
Cameroon
Canada
Cape Verde
Cayman Islands
Central African Republic
Chad
Chile
China
Colombia
Congo
Costa Rica
Croatia
Cuba
Cyprus
Czech Republic
Cote d'Ivoire
North Korea
DR Congo
Denmark
Djibouti
Dominican Republic
Ecuador
Egypt
El Salvador
Eritrea
Estonia
Ethiopia
Fiji
Finland
France
French Polynesia
Gabon
Gambia
Georgia
Germany
Ghana
Greece
Greenland
Guatemala
Guinea
Guyana
Haiti
Honduras
Hong Kong
Hungary
Iceland
India
Indonesia
Iran
Iraq
Ireland
Israel
Italy
Jamaica
Japan
Jordan
Kazakhstan
Kenya
Kuwait
Kyrgyzstan
Laos
Latvia
Lebanon
Lesotho
Liberia
Libya
Liechtenstein
Lithuania
Luxembourg
Macao SAR
Madagascar
Malawi
Malaysia
Maldives
Mali
Malta
Mauritania
Mauritius
Mexico
Monaco
Mongolia
Montenegro
Morocco
Mozambique
Myanmar
Namibia
Nepal
Netherlands
Netherlands Antilles
New Caledonia
New Zealand
Nicaragua
Niger
Nigeria
Norway
Gaza Strip
Oman
Pakistan
Panama
Papua New Guinea
Paraguay
Peru
Philippines
Poland
Portugal
Qatar
South Korea
Moldova
Romania
Russia
Rwanda
Samoa
San Marino
Sao Tome & Principe
Saudi Arabia
Senegal
Serbia
Seychelles
Sierra Leone
Singapore
Slovakia
Slovenia
Somalia
South Africa
South Sudan
Spain
Sri Lanka
Sudan
Suriname
Swaziland
Sweden
Switzerland
Syria
Taiwan
Tajikistan
Thailand
TFYR Macedonia
Togo
Trinidad & Tobago
Tunisia
Turkey
Turkmenistan
Former USSR
Uganda
Ukraine
UAE
UK
Tanzania
USA
Uruguay
Uzbekistan
Vanuatu
Venezuela
Viet Nam
Yemen
Zambia
Zimbabwe

Table 5-4 Sectoral Coverage of EORA (1990 - 2015)

Sectors at ISIC4 Classification Level	**EORA Codes**
Agriculture	Agr
Fishing	Fsh
Mining and Quarrying	Min
Food & Beverages	Fod
Textiles and Wearing Apparel	Tex
Wood and Paper	Wod
Petroleum, Chemical and Non-Metallic Mineral Products	Pcm
Metal Products	Met
Electrical and Machinery	Mch
Transport Equipment	Tpt
Other Manufacturing	Mnf
Recycling	Rcl
Electricity, Gas and Water	Utl
Construction	Cst
Maintenance and Repair	Mnt
Wholesale Trade	Whl
Retail Trade	Rtl
Hotels and Restraurants	Htl
Transport	Trn
Post and Telecommunications	Pst
Finacial Intermediation and Business Activities	Fin
Public Administration	Pub
Education, Health and Other Services	Edu
Private Households	Pvt
Others	Oth
Total Number of Industries	**26**

Chapter 6: Conclusions

The present PhD thesis - which consists of three research papers - aims to provide new insights on the empirical investigation of the linkages between the network structure of global production and GVCs and the issues of sectoral market power, functional income distribution among capital and labor and the value-added flows among sectoral buyers and suppliers in GVCs.

The first paper studies the concept of inter-sectoral competition and market power at the global level. Drawing on the literatures of heterodox economics, political economy of trade, econophysics and social network analysis, the paper introduces a framework for analyzing inter-sectoral competition and market power, highlighting the empirical observation of the power law relationship between sectoral centrality and sectoral relative profits. The empirical results of the paper provide a preliminary investigation of the properties of PageRank centrality and its relationship with relative sectoral profits. Specifically, they show that a relative increase in the quantity of sectoral market power, measured by the PageRank centrality, will translate into a proportionally higher increase in the distributed global sectoral profits.

The second paper concentrates on the question of whether positional/structural bargaining power and labor outcomes hold a positive relationship at the global level. Drawing on the notion of positional/structural power of labor in the production process, I estimate the positional/structural power of labor at the global level, utilizing global input-output tables. Our empirical results show that the positional power of labor at the global sectoral level owns significant explanatory power for the labor share, across time, countries, and skills, taking into account sectoral heterogeneity.

The third paper, empirically investigates the topological characteristics of the sectoral buyer-supplier relationships in the context of global production, utilizing a unique global input-output database comprising of inter-sectoral data for 190 countries. The essay provides empirical evidence for the existence of a universal scaling attribute with respect to the topology of GVT, as subgraphs of GVCs expressing the topology of sectoral buyer-supplier relationships. Moreover, the spatiotemporal analysis of the evolution of the hierarchicality of the GVT shows a clear decreasing trend in the global degree of hierarchicality that characterizes the totality of GVCs in the world economy.

The key findings of this thesis yield a new research path for the analysis of the complexities of the structure of global production and GVCs. Taking into account the abstract space formed by economic, social, and institutional relationships between actors, this research paves the way for the investigation and explanation of those complexities, opening new areas for future research. For example, the use of quantitative methods and techniques in the investigation of the research questions posed by economic geography, has been a long-lasting endeavor for the discipline (Plummer & Sheppard, 2006; Sheppard, 2001). Complex and network-graph theory, as well as input-output analysis have been the usual methodological candidates for many quantitative and empirical attempts in the field (Crawford et al., 2005; Gluckler & Doreian, 2016; O'Sullivan et al., 2006; Schmidt, 1975; Sheppard & Barnes, 1990). Extending this tradition of quantitative economic geography, into the analysis of global production, will elevate our understanding of contemporary capitalist economies and their coordination failures and/or successes. More importantly, it will allow for a systematization of spatial and social conceptual variables that hitherto have been investigated only in the context of special case-studies.

The present research is not without limitations. The use of high-dimensional input-output data for the world economy in terms of the coverage of countries participating in GVCs and GPNs, comes at the cost of low resolutions in the sectoral coverage. This poses a limitation with respect to the firm-level analysis that characterizes the literature on GCCs, GVCs and GPNs. But at the same time defines new research paths for the future. Investigating the positionality of ‘chain’ and ‘network’ actors using firm-level and sector-level data is a promising strategy for exploring the determining factors and dynamics of buyer-supplier relationships in specific social and spatial contexts. Moreover, highly detailed input-output tables at the national or regional level could be employed in the analysis of production network configurations at higher resolutions, allowing for a better evaluation of the causes and effects pertinent of developmental trajectories.

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