The complexity of international supply networks and their influence on global income distribution

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Abstract. This paper shows how industries and countries benefit from diversified participation in global production networks as intermediate inputs suppliers. Using input-output matrices, we also developed a method to assess the relative importance of specific industries in the distribution and concentration of value-added. Our results show that, as complex systems, the international supply networks evolved from 2000 to 2014 and that these changes affected income distribution.

Keywords. Trade, Income inequality, input-output, complex systems.

1. Introduction

Income distribution in neoclassical theory, at the aggregate level, is the result of a given equilibrium between the supply and demand of inputs factors. Although ignoring how the choice of production techniques could change income distribution patterns and ignoring how such a choice implies a set of relations among industrial sectors, neoclassical theory concludes that real wages and capital compensations would equal the marginal productivity of each factor.

Sanabria et al. (2009), Robson et al. (2021), and Dragulescu and Yakovenko (2000), among others, using network theory, show that income inequality could result from complex transaction networks. Class formation mainly results from the number of partners every agent could trade with, assuming a given amount of wealth. Wealthier individuals have more trade partners or links than poor agents.

Robson et al. (2021) also considered the possibility of aggregation or fragmentation processes in the exchange networks. This means that markets, as complex networks, can evolve according to collisions or shocks, resulting in several agents' fusion (or fragmentation). The sources of such collisions could be economical and financial crises, technological change, or significant changes in economic policy. Consequently, income distribution patterns could also evolve with changes in the network, even if there are no significant variations in productivity levels. On the other hand, the main limitation of these models is that they assume a given amount of wealth to be distributed. Therefore, we need a theory to understand how production (value-added) occurs in a complex system and how income and wealth are distributed and accumulated.

Markey-Towler & Foster (2013) define the market as a complex trade network where firms create value from their interactions with other firms and the contracting relationships with their employees. In this network, every individual agent represents either a firm, a household (workers or entrepreneurs), or other agents such as the government or non-profit organizations. The number of nodes in the system is the total number of individuals in the network exchanging income for final goods, labor, capital, public services, and intermediate inputs. The total interactions in one period create the total gross output (nominal total transactions and economic value) in the system by combining primary factor inputs with intermediate goods and raw materials. The larger the number of edges for every node, the larger share of income they can

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create, distribute, or concentrate. The authors also explain why some nodes will have more connections in the network. They argue that the presence of "preferential attachment" is the main reason some firms will have more customers and, therefore, more income, regardless of the relative price of their products. Following Simon (1959), preferential attachment results from bounded rationality. If individual agents cannot optimally process all the available information, they tend to make practical decisions and maintain the trade relationship with their business partners.

Moreover, firms with more customers are more prominent in the market. They have an established reputation, making it more difficult for new participants to enter the market and get a significant share of the revenues. Therefore, the degree of each node (firm or individual) explains its income level not just as a distributive phenomenon but as the capacity of each firm to create economic value. Finally, wage inequalities could also be explained by a certain level of centrality within firms and not just because of measurable differences in productivity.

Additionally, Shiozawa (2017) has proposed a return to *à la* Ricardo-Sraffa theories, highlighting that a new theory of international values should consider that "production plays a major role in determining wages and prices." In his view, the choice of techniques sets the complex interdependence among industrial sectors, which implies that, in some countries, some firms could select processes labor-intensive for the same kind of products. They could choose different proportions and types of inputs like capital, labor, and intermediate inputs to produce one good. Moreover, each country's economic development level limits the choice of techniques. For instance, in the 21st century, there are several ways to produce a chair. It can be made using wood, nails, and glue, or we could create a chair using cushions, wheels, fabrics, and metal structures instead of wood. The first type of chair requires fewer intermediate input suppliers than the second; furthermore, a chair made from aluminum, plastics, fabrics, etc., also requires more indirect intermediate input suppliers, such as the firms in the extractive sectors. Therefore, following Markey-Towler and Forster's (2013) preferential attachment argument, once the firm has selected how it will produce its goods, it forms its supplier network and contracting relations with its employees. The preferential attachment also results from an established routine in the production processes because the cost of adjustment or technological upgrading could be perceived as more expensive than the cost of opportunity for "attaching" the firm to the procedures they already know.

Neilson, J., Pritchard, B. & Yeung, H. (2014), on the other hand, consider that the complexity of the international exchange networks also involves an "increasingly complex regime of global corporate governance," which means that firms do not just adapt to shocks driven by changes in economic policy or "exogenous" technological change: firms influence the system while states define their policies. In particular, the emergence of Global Value Chains (GVCs) and Global Production Networks (GPNs) conceptualization implies a model for outsourcing total or fragmented production processes that require a certain level of coordination by a leading firm or a particular market. For Gereffi et al. (2005), the governance and change of GVCs can be explained mainly by how easy it is to move production from one location to another; considering that, even if most production processes can be split into several stages, some tasks require a higher level of coordination and control than others. Therefore, the form of GVC governance depends on the products and the choice of techniques, i.e., there is a close relationship between the production processes, the complexity of the supply networks, and the pattern of the income distribution.

Finally, Reich (2018) describes how input-output analysis can be applied to the problem of income distribution and income inequality from a macroeconomics perspective. Since input-output models provide comprehensive information about how firms in specific industries create economic value by combining primary input factors with intermediate goods, we can trace how value-added is distributed and mutually determined by the final demand through the economic structure, i.e., to the choice of techniques and the rest of socio-economic factors that influence income distribution.

The rest of the paper is organized as follows: Section 2 describes the method used to characterize international supply networks and their influence on global income distribution as part of a more complex economic global system. In section 3, we present our estimations results from the WIOD data from 2000 to 2014 and show that industries and countries with a broader range of supply edges (relations with other sectors/countries) tend to get a higher share of value-added, regardless of the structure of the final global demand and value-added coefficients.

2. Methodology

The proposed model in this paper combines the standard input-output analysis *à la* Leontief with some basic concepts of complex systems and network theory. Significant limitations are the well-known assumptions for the input-output model, such as the constant returns to scale and the firm homogeneity within industrial sectors.
On the other hand, input-output matrices also represent an ex-post income distribution model (Timmer et al., 2013, Fujii & Cervantes, 2017) that allows thinking about income distribution due to multiple interactions among heterogeneous agents (at least at the industry level) in a complex economic system. For instance, one essential interaction will be the interdependence between final demand and value-added vectors, which depend on income distribution, labor market institutions, technological change, and international trade.

In the model, we assume that no critical technological progress or significant changes occur in the final demand structure that alters the trade network between sectors and countries in one year. From the technical coefficients matrix, A, we have the choice of techniques in each industry and country. Also, this matrix represents the model for one direct interaction or exchange among industries by one dollar of gross output. Any element $a_{i,j}^{m,n}$ in the A matrix accounts for the sales of intermediate inputs from sector i, in country m to sector j, in country n:

$$\mathrm{A} = \begin{pmatrix} a_{1,1}^{1,1} & a_{1,2}^{1,2} & \dots & a_{1,J}^{1,N} \\ a_{2,1}^{2,1} & a_{2,2}^{2,2} & \dots & a_{2,J}^{2,N} \\ \vdots & \vdots & \ddots & \vdots \\ a_{J,1}^{N,1} & a_{J,2}^{N,2} & \dots & a_{J,J}^{N,N} \end{pmatrix} \tag{1}$$

A is a square matrix of JN dimension, where J is the total number of industries, and N is the total number of countries. When $\mathrm{a}_{i,j}^{m,n} = 0$, it means that sector i in country m does not sell inputs to sector j in country n. Domestic submatrices of A with more elements equal to zero will create less domestic value-added for any given amount of final demand.

For a final demand vector, $\mathbf{f}$,the total transactions (gross output) vector, $\mathbf{x}$, will be:

$$\mathbf{x} = (\mathrm{I} - \mathrm{A})^{-1}\mathbf{f} \tag{2}$$

$(\mathrm{I} - \mathrm{A})^{-1}$ is the well-known Leontief inverse or total requirement matrix but also represents a transaction matrix that measures how much income sector i gets for each dollar of final demand in sector j.

Since final demand for each sector equals the total gross output minus the intermediate demand:

$$f_k = x_k - d_k \tag{3}$$

And, for the same k_{th} sector, its value added equals the total gross output minus intermediate consumption:

$$va_k = x_k - c_k \tag{4}$$

For sector k, from equations 3 and 4, its final demand and value-added are mutually determined by the following relations:

$$f_k = va_k + c_k - d_k \tag{5}$$

$$va_k = f_k + d_k - c_k \tag{6}$$

In equation (5), final demand, f_k, rises with an increase in the value-added of the sector k, but also with higher intermediate consumption in sector k, through higher sales in the rest of the sectors. Still, final demand in sector k will have to be less if this sector "has" to supply more intermediate inputs to the rest of the sectors[3]. On the other hand, in equation (6), value-added will rise with final and intermediate demand in sector k but decreases with intermediate consumption, which should increase final demand for equation (5). Therefore, both value-added and final demand are mutually determined and intensely dependent on the interactions among the sectors. Furthermore, the system's complexity implies that all variables are endogenous at the same time. Every element in the technical coefficient matrix and the final demand and value-added vectors are explanatory variables.

Hence, income distribution results from multiple interactions between individuals, firms, and institutions within a global production structure comprising domestic transactions and participation in Global Value Chains. Besides, in the productive system, development paths are also explained by labor market institutions and the amount and level of skills of labor supplied by households and the education systems. Equation 7, then, represents how at the sector level, total income is distributed:

$$\mathrm{V}\hat{\mathrm{f}} = \hat{\mathrm{v}}(\mathrm{I} - \mathrm{A})^{-1}\hat{\mathrm{f}} \tag{7}$$

$\mathrm{V}\hat{\mathrm{f}}$ is a square matrix that displays income (as the sum of labor plus capital compensations) in sector i country m given the final demand in sector j, country n. $\hat{\mathrm{v}}$ and $\hat{\mathrm{f}}$ are the diagonal

[3] To have equations 5 and 6 in balance.

matrices of value-added coefficients and final demand. Therefore, V is a value-added multiplier matrix with elements indicating how much value-added each sector i and country m gets by a one-dollar increase in final demand in sector j country n.

So, from equation (7), the pattern of income distribution among sectors and countries is given by: 1) the structure of the final demand vector mutually determined by the structure of the value-added vector; 2) the value-added coefficients vector, which reflects all the supply conditions that set the profit margins and wage rates; and 3) the choice of techniques in the technical coefficient matrix.

Reich (2018) shows that the complex relationship between the choice of techniques and how the final demand and value-added vectors are mutually determined is also related to income inequality from a macroeconomic perspective. He sets the standard input-output analysis as a "circuit" of income, not just as the "circulation of products among different industries and households." From his proposal, we must further decompose value-added and final demand vectors to understand the importance of income inequality better. Since value-added equals the sum of the payments to primary inputs (labor and capital) and final demand vectors are the result of the aggregation of household consumption, gross capital formation, government expenditure, and exports, he developed a method to directly associate the income flows from households, firms, government, and the foreign demand to the payments received by primary inputs. In this way, there is a better understanding of how the system works as a complex network of trade and income flows. Nonetheless, for this paper, we will isolate the complexity of international supply networks and their influence on global income distribution, assuming that an equal increase in the final demand for all sectors in each country has a specific pattern of income distribution between industries and countries due to structure of the production system. Then, we will present estimations for labor compensation inequality as a rough attempt to connect the complexity of the global production system with the rest of the socio-economic factors that influence income distribution and wage inequality.

A production system is complex because individual agents are heterogeneous; they do not tend to behave equally in response to the same stimulus nor have the same economic power, means of production, skills, and education levels. Regarding the preferential attachment argument at the industry and country levels, this heterogeneity relates to differences in the know-how to produce the same kind of products and set the business network for each firm and then attaching to it through legal contracts or due to the unknown or unperceived opportunity costs.

GPNs are also complex because it is self-organized and depend on initial conditions and paths. There is feedback, emergence, and criticality, that leads to the fact that as economic systems GNPs are dynamic and evolve[4]. Therefore, global income distribution patterns will change according to variations in the production system triggered by technological change, economic policy, and other socio-economic conditions emerging from the same system.

In this regard, equation (7) also represents a network of income flows from one sector to another in domestic transactions or international trade of intermediate inputs. Each node represents an industry in a specific country in the directed graph. Or as can be seen in Figure 1, each node represents a country, and the income flows for intermediate inputs trades are the edges (arrows)

[4] See Alatriste et al. (2019) also for models to assess structural change due to technological progress.

pointing to the exporting country. To evaluate the properties of this network of income flows, we propose two matrices that weigh the relative importance of the sectors and countries:

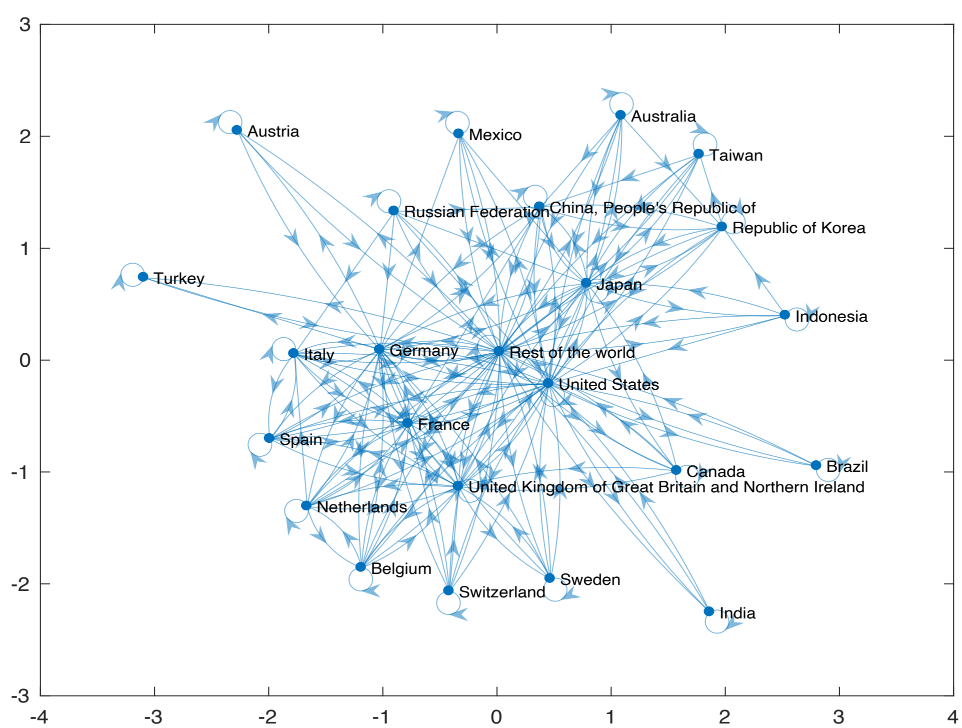
$$\mathrm{P} = \mathrm{V}^T\mathrm{V} \quad (8)$$

$$\mathrm{R} = \mathrm{V}\mathrm{V}^T \quad (9)$$

V^T is the transpose of the value-added multipliers matrix. P is a symmetric matrix of weighted payments or compensations to direct primary inputs. Each element, $p_{i,j}^{m,n}$, adds up the product of value-added (implicit in the total income flow) that sector i in country m pays to the rest of the sectors times the labor and capital compensations that sector j in country n pays to the rest of the sectors when buying intermediate inputs.

R is a symmetric matrix representing income concentration due to the relative importance of sectors as intermediate input suppliers. Thus, each element $r_{i,j}^{m,n}$ weights the value-added that sector i in country p gets from the rest of the sectors in terms of the income sector j in country q gets from the rest of the world economy, including the direct value-added for supplying one dollar of final demand.

Figure 1. Network of global value-added flows, 2001



Source: Author's preparation with WIOD (Release 2016) data.

Therefore, equations (8) and (9) better represent the degree of interdependence among sectors. For every non-negative value-added coefficient, $p_{i,j}^{m,n}$ is lower when, in combination, expenses made by both sectors, $i,$ and j in countries m and n are relatively low, either because they use few or zero intermediate inputs from the rest of the sectors, or, because the value-added content of the inputs they buy is relatively low. On the other hand, a greater value of $p_{i,j}^{m,n}$ implies that both sectors, i, j in countries m and n, have greater importance in distributing value-added through their demand of intermediate inputs. In network theory, the elements $p_{i,j}^{m,n}$ then measure the quality of a node as a function of the quality of another node.

In equation (9), the sum by rows (or columns), if net taxes are equal to zero and there are no international transportation margins, equals the total income as value-added that each sector will get if there were a one-dollar- increase in final demand for each industry, that is:

$$\mathrm{R}\mathbf{1} \equiv \mathrm{V}\mathbf{1} \tag{10}$$

Therefore, in the $\mathrm{V}\mathbf{1}$ vector, if the total value-added generated in one sector is greater than one, we have that, given certain inter and intra-industry relations of intermediate input transactions, the total increase of labor and capital compensations exceed the growth of the final demand that such a sector directly satisfies; otherwise, the industry will get less value-added per dollar of final demand.

Furthermore, from equation (10), we have that an equal increase in final demand could lead to an unequal value-added distribution among sectors and countries, depending not just on the value-added coefficients but on the number of relations each industry has as a supplier of the other ones.

2.1 Network visualization

We create graphs of the global value-chain networks for several countries based on the weighted income matrix (9) presented in the previous section. The visualization intends to show the relationship between the country's involvement in GVC with the profitability in terms of value-added per capita in 54 sectors of the selected country.

Visualization of networks consists of nodes (vertexes) and linkages between them (edges). In our visualizations, we use sectors[5]of the domestic economy (red circles) and consolidated sectors of foreign economies (green circles) as nodes. The size of each node reflects the value-added generated within a country-industry per capita. The amount of value-added in US$ is derived from the WIOD, and the number of employees in each sector is obtained from the Socio-Economic accounts (SEA) from the WIOD database November 2016 release. Despite any world input-output table being a closed system, which in this database includes values for 43 countries and all other countries grouped under "Rest of the World," the SEA provides figures for 43 individual countries only; that is why we must omit the aggregated group from the calculation of value-added per capita and, hence, it is not included in the calculation of consolidated foreign sectors.

[5] "Activities of households as employers undifferentiated goods- and services-producing activities of households for own use" and "Activities of extraterritorial organizations and bodies" are excluded from analysis since they are not relevant for the study.

Thus, the value-added per capita is calculated for each of 54 industries of the country of interest and each aggregated industry in all other 43 countries. This way, we obtain a vector of value-added per capita length of 108.

The edges represent the flow of weighted revenue from equation (9). The thickness of edges between two nodes reflects the importance of the sectors for each other in terms of revenue allocation. Due to the dense net of linkages, we apply a 50% threshold and show only the top 2 quantiles of weighted revenue flows. Since the matrix in equation (9) is symmetric, we do not need to depict the direction of the flows. For visualization of an individual economy, we extract three matrices out of the matrix (9): the domestic matrix of 54 * 54 for revenue flows within the economy, the domestic export matrix from the domestic industries to consolidate 54 foreign sectors and the domestic import matrix from 54 consolidated foreign industries to 54 domestic sectors. Appending the three matrices, we obtain a matrix of dimension 108 * 108, with a column (row) for each domestic and aggregated foreign sector. The revenue flows between foreign sectors are replaced with *NAs*.

The graphs were created via the visualization *igraph* package (Csardi and Nepusz, 2006) for the R software.

In the next section, we present some estimations and representations of the complexity of international supply networks using WIOD data for the years 2000, 2007, and 2014. Estimation results from a panel data model showing how the number of significant edges from the supply network explains how income concentrates in specific industries and countries, regardless of their value-added coefficients.

3. Results and discussion.

With information from the World Input-Output Database (WIOD, release2016), in Tables 1 and 2, we present the top five and top-bottom countries that would concentrate more and less value-added from an equal increase in the final demand in all sectors and all countries, in the years 2000, 2007 and 2014 (latest data available). Given the nature of the WIOD tables, it is impossible to get a better picture of the participation of more developing countries. But, from Table 1, it is worth noting that until 2014 China was the only less developed country in the top five countries with more value-added generated for its participation as suppliers in the world production network. The United States and Germany are two economies that get more value-added directly and indirectly for a unitary final demand vector. Since we have 44 economies and 56 industries, with zero taxes and zero international transportation margins, there would be up to 2 464 dollars of final demand equal to the total value-added generated in the economy. So, an equal demand in every sector produces an unequal distribution among industries and countries due not (just) to the value-added coefficients but the number of industries (in the domestic economy or the rest of the world) every sector supplies with intermediate inputs.

Table 1. Top five countries with more value-added as world intermediate inputs suppliers. 2000, 2007 and 2014

2000	Value-added share %	Total value-added $
United States	4.8	102.62
Germany	4.4	92.83
United Kingdom of Great Britain and Northern Ireland	3.2	68.25
Japan	3.0	64.20
France	2.9	62.47
2007	Value-added share %	Total value-added $
Germany	4.5	95.18
United States	4.3	91.02
United Kingdom of Great Britain and Northern Ireland	3.2	68.10
Italy	2.9	61.64
France	2.9	61.30
2014	Value-added share %	Total value-added $
United States	4.6	97.55
Germany	4.5	96.05
China, People's Republic of	3.4	73.05
United Kingdom of Great Britain and Northern Ireland	3.2	67.40
Italy	2.8	60.42

Source: Authors' estimations based on WIOD (release 2016)

The five countries in Table 1 could get from 7.9 to 83.25 percent more dollars in value-added than the final demand they directly supply. Since it is a "zero-sum game," Table 2 shows the five countries that would get the lowest value-added shares than the final demand they face. Given the nature of the sample, we cannot distinguish if the level of development plays a significant role in these results. But it seems that smaller economies are less well integrated into the global economy through the complexity of the supply networks. From Tables 1 and 2, it is worth noting that the US economy would get 3.3 (in 2000) and 3.7 (in 2014) times more income than Luxembourg, even if both countries had the same final demand.

Table 2. Top-bottom countries with less value-added as world intermediate inputs suppliers. 2000, 2007, and 2014

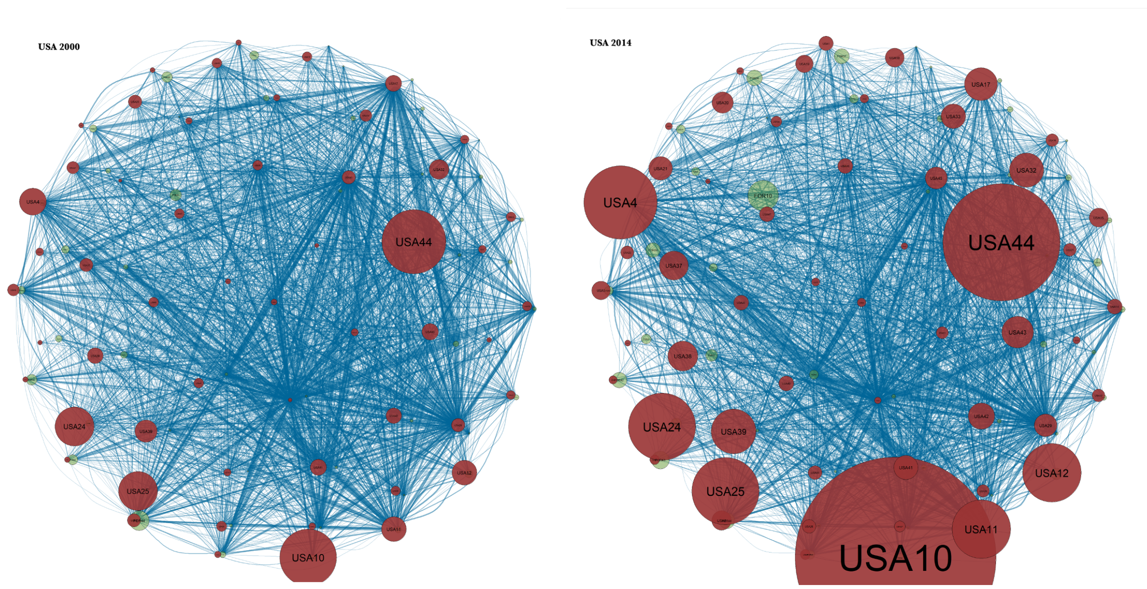
2000	Value-added share %	Total value-added $
Ireland	1.7	36.44
Hungary	1.7	36.21
Estonia	1.7	35.70
Malta	1.5	32.17
Luxembourg	1.5	31.07
2007	Value-added share %	Total value-added $
Cyprus	1.7	35.86
Estonia	1.7	35.01
Bulgaria	1.6	32.97
Malta	1.3	28.12
Luxembourg	1.3	27.57
2014	Value-added share %	Total value-added $
Hungary	1.7	35.72
Bulgaria	1.7	35.29
Estonia	1.6	34.31
Malta	1.3	27.66
Luxembourg	1.2	26.18

Source: Authors' estimations based on WIOD (release 2016)

Figures 2 to 4 show how in 2000 and 2014, the economies of the United States, China, and Mexico were integrated into the domestic and foreign markets as intermediate input suppliers. We use the information from the estimation of the R matrices (Equation 9) and plot the edges in the top 2 quantiles of weighted revenue flows to visualize the complexity of the networks better.

According to our estimations, the US economy is the most integrated as an intermediate inputs supplier. In Figure 2, the size of the nodes represents the value-added per person. In both years, more productive sectors in the United States were the Manufacture of coke and refined petroleum products (10), Real estate activities (44), Electricity, gas, steam, and air conditioning supply (24), Water collection, treatment, and supply (25), Manufacture of basic pharmaceutical products and pharmaceutical preparations (12), and Telecommunications (39).

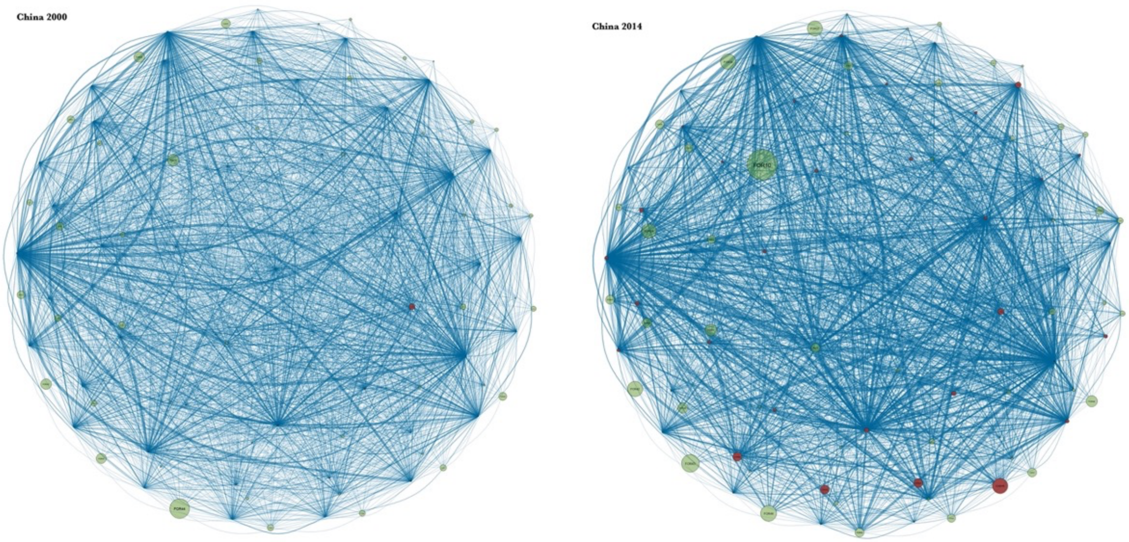
Figure 2. US participation in international supply networks



Source: Authors' estimations based on WIOD (release 2016)

Figure 3 shows how China's integration into the world economy grew significantly in fifteen years, nonetheless that, in current dollars, most productive sectors were in other countries.

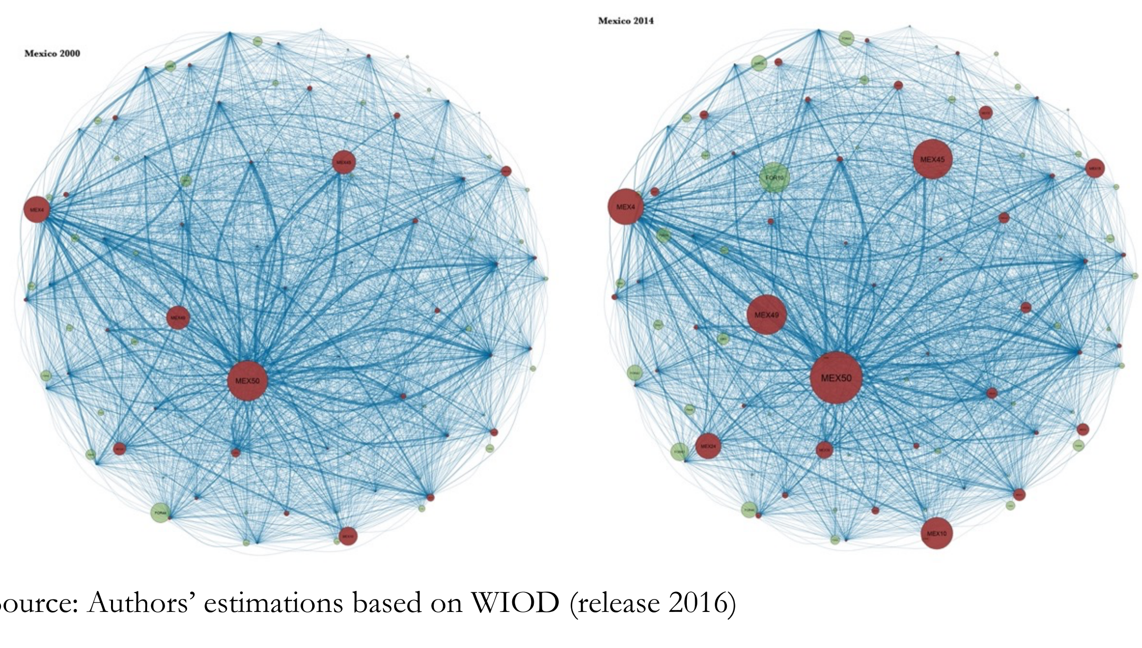
Figure 3. China’s participation in international supply networks



Source: Authors’ estimations based on WIOD (release 2016)

Mexico’s participation in international supply networks is more concentrated in specific sectors. As can be seen in Figure 4, in both years, the industry of Administrative and support service activities (50) is one with the highest levels of productivity and the highest levels of income concentration.

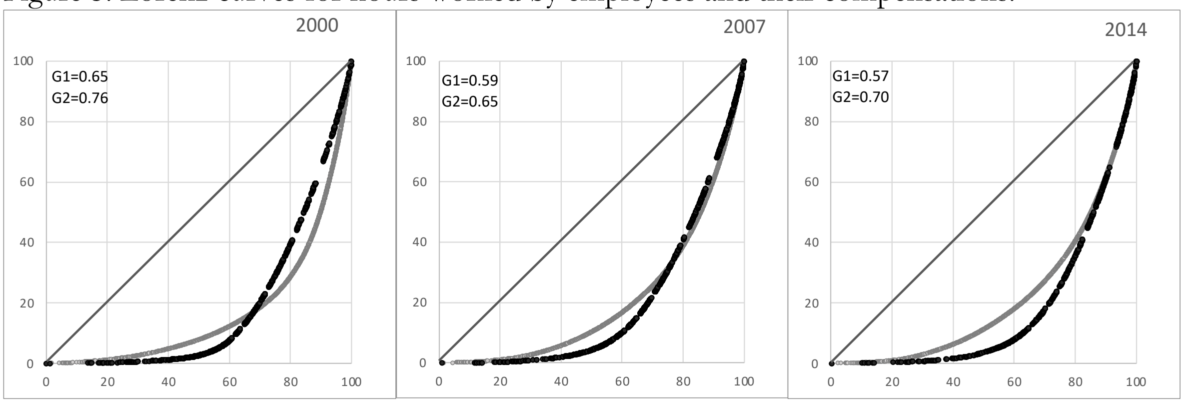
Figure 4. Mexico’s participation in international supply networks



Source: Authors’ estimations based on WIOD (release 2016)

In Figure 5, we plot six Lorenz curves for the shares of labor compensations to employees[6] and the shares of the total hours worked by employees in the world economy. As seen in the first panel from left to right, in 2000, the grey line shows the inequality in labor compensations for an equal final demand among sectors and countries. With an estimated Gini coefficient of 0.65, this result reflects how the choice of techniques plays a significant role in income inequality. Considering the actual final demand (darker line in the graph), wage inequality among industries and countries will be even higher, with a Gini coefficient of 0.75. Then, in 2007 and 2014, the evolution of the network of exchange reduced wage inequality, with Gini coefficients equal to 0.59 and 0.57. From 2000 to 2007, the final demand structure also reduced its impact on wage inequality by hours worked, but it increased again in 2014.

Figure 5. Lorenz curves for hours worked by employees and their compensations.



Source: Authors' estimations based on WIOD (release 2016)

Finally, in Table 3, we present the summary of four panel-model estimations. In all four models, the dependent variable is the total value-added that each sector will get from a one-dollar vector of final demand. If we correlate value-added coefficients with the total value-added that each industry in each country will get by directly and indirectly supplying the final demand, we have a significant positive relationship between both variables; however, the adjusted R^2 coefficient is relatively low (0.1387). On the other hand, if we correlate the number of edges that each industry has in the R matrix with the total value-added (Model 2), for a linear specification, one additional connection in the supply network will increase about four cents the total value-added. Besides, from Model 2 to Model 4, the adjusted R^2 is higher than 0.86. So, in Models 3 and 4, we present results for more variables, and we get that all coefficients are positive, including a dummy variable we use for the level of development of each country, equal to one for highly developed countries and zero for less developed economies.

[6] We use labor compensation in current US dollars without any intent to compare power purchasing parities among countries since there is still a long way to get a more precise estimation of wage inequality at the intra-industry and intra-firms' levels. Furthermore, the data available does not include the information for the rest of the world and China, so in these plots, we have information for 42 countries, most of them European and developed economies.

Table 3. Panel models for the generation of value-added through complex supply networks

	Model 1	Model 2	Model 3	Model 4
Constant	0.1076	0.3822	0.0193	- 0.0093
	(0.0108)	(0.0021)	(0.0038)	(0.0040)
VA coefficient	1.7397	-	0.8834	0.8768
	(0.0225)	-	(0.0080)	(0.0080)
Edges	-	0.0450	0.0431	0.0431
	-	(0.0001)	(0.0001)	(0.0001)
Level of development	-	-	-	0.0606
	-	-	-	(0.0032)
Adjusted R^2	0.1387	0.8619	0.8961	0.8971
Standard error	0.894	0.3581	0.3106	0.3091
F	5 952.30	23 0584.94	159 385.98	107 388.14
Observations	36960			

Source: Authors' estimations based on WIOD (release 2016).

4. Conclusions

Although with the proposed method, we cannot have a measure relating the selection of techniques used in the production processes with the rest of the socio-economic factors and institutions that determine how the income is going to be distributed between the primary factors, in this paper, we have shown how the complexity of the international supply networks help to explain how income will be concentrated in some industries and countries, and how this income is going to be distributed to employees. We have also found that diversified participation in GVCs as intermediate inputs suppliers has a more significant impact on explaining the gains of trade than the domestic value-added coefficients; that is, sectors and countries with higher value-added coefficients will not necessarily benefit more from participating in the global economy.

From the three cases shown in this paper, we have demonstrated that, as complex systems, international supply networks evolve. Participation of China has changed in such a way that this country was more integrated in 2014 as an intermediate supplier than in 2000. On the other hand, the Mexican economy seemed more specialized in some specific industrial sectors. While in the US economy, we see the more significant changes in productivity levels.

Using Gini coefficient estimations and Lorenz curves, we could "isolate" the effect of the global economic structure on income distribution. Our results showed that from 2000 to 2014, more diversified sectors and countries as intermediate input suppliers tend to concentrate more income, which will be distributed as labor and capital compensations.

References:

Alatriste-Contreras, M. G., Brida, J. G. y Puchet, M. (2019). Structural change and economic dynamics: rethinking from the complexity approach. Journal of Dynamics and Games, 6(2), 87-106. https://doi.org/10.3934/jdg.2019007

Csardi, G. and Nepusz, T. (2006). The igraph software package for complex network research.InterJournal, Complex Systems:1695.

Dragulescu, A., Yakovenko, V. Statistical mechanics of money. *Eur. Phys. J. B* **17,** 723–729 (2000). https://doi.org/10.1007/s100510070114

Fujii-Gambero, G & Cervantes-Martínez, R (2017) The weak linkages between processing exports and the internal economy. The Mexican case, Economic Systems Research, 29:4, 528-540, DOI: 10.1080/09535314.2017.1351332

Gereffi, G., Humphrey, J. & Sturgeon, T. (2005) The governance of global value chains, Review of International Political Economy, 12:1, 78-104, DOI: 10.1080/09692290500049805

Markey-Towler, B., & Foster, J. (2013). *Understanding the causes of income inequality in complex economic systems* (No. 478). The University of Queensland, School of Economics. http://www.uq.edu.au/economics/abstract/478.pdf

Neilson, J., Pritchard, B. & Yeung, HWC. (2014) Global value chains and global production networks in the changing international political economy: An introduction, Review of International Political Economy, 21:1, 1-8, DOI: 10.1080/09692290.2013.873369

Reich, U-P. (2018) Who pays for whom? Elements of a macroeconomic approach to income inequality, Economic Systems Research, 30:2, 201-218, DOI: 10.1080/09535314.2017.1369395

Robson, D.T., Baas, A., & Annibale, A. (2021). A combined model of aggregation, fragmentation, and exchange processes: insights from analytical calculations. *Journal of Statistical Mechanics: Theory and Experiment, 2021*.

Sanabria, C.H., Huerta-Quintanilla, R., & Rodríguez-Achach, M.E. (2009). Class formation in a social network with asset exchange. *Physica A-statistical Mechanics and Its Applications, 390*, 328-340.

Shiozawa Y. (2017) The New Theory of International Values: An Overview. In: Shiozawa Y.,

Simon, H. (1959). Theories of Decision-Making in Economics and Behavioral Science. The American Economic Review, 49 (3), 253-283.

Timmer, M.P., B. Los, R. Stehrer and G.J. de Vries (2013) Fragmentation, Incomes and Jobs: An Analysis of European Competitiveness. Economic Policy, 28, 613–661.