Journal of World-Systems Research

SN: 1076-156X | Vol. 27 Issue 1 | DOI 10.5195/JWSR.2021.1006 | jwsr.pitt.edu

Investigating the Asymmetric Core/Periphery Structure of International Labor Time Flows

A New Network Approach to Studying the World-System

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Abstract

This paper studies the core/periphery hierarchy of the capitalist world-economy in the current globalization era. The central and novel argument is that the network of international labor time flows reveals the core/periphery hierarchy of the world-economy with regard to the international division of labor. Based on the analysis of the labor time network of forty economies from the world input-output table, I find that the core/periphery structure of the world-economy has in large part remained unaltered for 1995-2009, though the asymmetry of international labor time flows decreased slightly between 2003-2009. Through regression analysis, I find that per capita income of a country is strongly associated with its command over global labor time. The regression analysis also lends evidence to the existence of oligarchic wealth. This wealth is not available to all countries, implying that the struggle of a country to improve its position in the capitalist world-economy tends to put downward pressure on the income of other countries.

Keywords: World-systems theory, labor time flows, core/periphery hierarchy, network analysis, oligarchic wealth

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Recent decades have seen a period of rapid globalization, with intensifying international trade and capital flows while labor mobility across national boundaries is still restricted (Rodrik 2012). Integral to the current phase of globalization is the emergence of a new international division of labor and the rise of global commodity or value chains (Gereffi, Humphrey and Sturgeon 2005; Gereffi 1996). Many believe that they represent opportunities for the economic development of developing countries, with emphasis being placed on building up manufacturing capacity, and increasing higher-skill and formal employment and income (Ignatenko, Raei and Mircheva 2019; World Bank and World Trade Organization 2019). However, other scholars emphasize the asymmetric power relations embedded in global value chains, which may inhibit the advancement of developing countries (Abdulsamad, Frederick, Guinn et al. 2015; Clelland 2014; Smith 2012). Particularly, world-systems analysts argue that the simultaneous upgrading along global value chains by all developing countries is impossible (Brewer 2011). Others have argued that the prospect of national development itself is an illusion (Arrighi 1990; Arrighi, Silver and Brewer 2003; Wallerstein 1988). Since the capitalist world-economy has a hierarchical structure with a pyramidal distribution of wealth, upward mobility of some countries must be accompanied by either the incorporation of new peripheral areas into the world-economy or downward mobility of some other countries (Arrighi 1990; Wallerstein 1988).

This study follows Giovanni Arrighi's conceptualization of the core/periphery hierarchy of the capitalist world-economy in relation to the international division of labor and tries to quantitatively examine the persistent struggle among states to improve their positions along this hierarchy (Arrighi and Drangel 1986; Arrighi 1990; Arrighi et al. 2003). The central question is whether the core/periphery hierarchical structure of the capitalist world-economy has changed in the current globalization era. First, I argue that building the analysis around a labor time flow network improves our understanding of the hierarchical structure of the capitalist world-economy. It reveals this hierarchy more clearly than studies of international trade networks can. Subsequently, I construct and analyze the network of international labor time flows for forty economies over the period 1995-2009. The key finding is that despite some amelioration in the asymmetry of labor time flows, the core/periphery structure of the capitalist world-economy has in large part remained unaltered. The core countries that consumed (or imported) most of foreign labor time were large wealthy countries such as the United States, Germany, Britain, France, and Italy. In contrast, poor populous countries such as China and India supplied (or exported) lots of labor time to other countries. Furthermore, regression analysis suggests that this pattern of international labor time flows matters for the determination of a country's level of (per capita) income, while controlling for standard variables such as capital intensity and years of schooling. These results lend credence to the hypothesis of oligarchic wealth. Oligarchic wealth is not available to all countries and is subject to crowding out (Arrighi 1990). It implies that the struggle of a country to improve its position in the capitalist world-economy tends to reduce the chance of upward mobility, or even squeeze the income, of other countries.

It is necessary to note that the sample of economies analyzed in this paper is small although they covered more than 85% of world gross domestic product in 2008 (at current exchange rates).

Strictly speaking, the results thus obtained are the features of the particular sub-system of the whole capitalist world-economy. Nevertheless, the analysis clearly shows a highly asymmetrical pattern of international labor time flows and a pyramidal international hierarchy, which is consistent with the world-systems perspective. This type of analysis can be further applied when more data are available.

The remainder of the paper is organized as follows. The next section reviews empirical studies on the hierarchy of the capitalist world-economy. Next, I argue that the network of labor time flows reveals the hierarchical structure of the capitalist world-economy. Then, I introduce the footprint calculation through which the network of labor time flows is derived and the type of network analysis through which the asymmetric core/periphery structure is detected. The results are presented following the introduction of the analytical methods. Afterwards, I examine the relationship between GDP per capita and my measure of the world-system position through regression analysis. The final section concludes.

The Hierarchy of the Capitalist World-economy: Key Concepts and Empirical Literature

The capitalist world-economy is a world-system with a single division of labor and multiple political/cultural systems, in which the main motive of production is to realize maximum profits (Wallerstein 1974). Through several waves of geographical expansion, the capitalist world-economy has encompassed the whole earth (Chase-Dunn and Lerro 2016). States and populations in this capitalist world-economy are arranged in a hierarchy of a small core, a middle-sized semiperiphery, and a large periphery. According to Arrighi and Drangel, "core activities are those that command a large share of the total surplus produced within a commodity chain and peripheral activities are those that command little or no such surplus" (1986: 11-12). Core states enclose within their jurisdictions predominantly core activities; semiperipheral states enclose a more or less even mix of core/peripheral activities; peripheral states enclose predominantly peripheral activities. Core and peripheral activities are subject to "creative destruction." As more and more states try to capture a larger proportion of the total surplus by engaging in core activities, those activities tend to become peripheral due to the increasing competitive pressures. Through profit-oriented innovations, however, core states can shift to new areas of activities that grant them new monopolist positions within commodity chains, and the erstwhile core but now peripheral activities are left to semiperipheral and peripheral states. The core/periphery hierarchy is thus maintained (Arrighi and Drangel 1986).

Many world-systems scholars attempt to demarcate core, semiperiphery, and periphery of the capitalist world-economy. In general, there are two approaches to doing so: the *attribute approach* and the *network approach* (Mahutga, Kwon and Grainger 2011; Smith 2017).

For the attribute approach, states are classified based on their attributes, e.g., GDP, GNP per capita, military spending, etc. Arrighi and Drangel's (1986) work is very influential here, using GNP per capita as the proxy for assigning a position to a state. They find that the population distribution along the logarithm of GNP per capita (i.e., the size of population on the vertical axis, and log GNP per capita on the horizontal axis) has a tri-modal shape for the periods 1938–1950, 1960–1970 and 1975–1983, implying that the world population distribution has a persistent hierarchy of a large periphery, a middle-sized semiperiphery, and a small core. Babones (2005) refines Arrighi and Grangel's method by introducing a kernel smoother. Using the same method, Grell-Brisk (2017) discusses the implications of the rise of China for the whole capitalist world-economy. In addition, following the attribute approach, Kentor (2008) classifies countries based on three attributes: GDP, GNP per capita, and total military expenditures.

The attribute approach is often criticized for ignoring the interactions among states (Mahutga et al. 2011; Smith 2017). Indeed, the interactions among states make the world-economy operate as a whole and lead to structural patterns (Lloyd, Mahutga, and De Leeuw 2009). The network approach focuses on these interactions and relations among states when studying the structure of the capitalist world-economy, and thus is considered to be the preferred method. Snyder and Kick's (1979) work is pioneering in this regard. The authors investigate four networks including trade flows, military interventions, diplomatic relations, and conjoint treaty memberships. Based on the concept of "structural equivalence," they classify 118 nations into ten blocks that correspond to various positions in the world-economy. As well using structural equivalence, Breiger (1981) and Nemeth and Smith (1985) look into multiple commodity trade networks among countries, and Kick and Davis (2001) further examine trade, political, military, cultural and technical networks. Smith and White's (1992) work has also proven influential. They classify traded commodities into five categories (High Technology/Heavy Manufacture, Sophisticated Extractive, Simple Extractive, Low Wage/Light Manufacturing, and Food Products) and investigate those commodity trade networks. Using regular equivalence, they obtain the similarity scores between pairwise countries and divide 63 countries into five blocks. Smith and White's (1992) work becomes relatively standard for the network approach regarding the selection of networks and network analytical tools. The world-systems theory emphasizes the importance of analysis rooted in economic basis, and trade flows are clearly one of the most important economic relations among countries. Regular equivalence emphasizes the *role* an actor has in a network/networks and does not require actors to have identical ties to identical other actors as required by structural equivalence (Wasserman and Faust 1994:473). For example, children are regularly equivalent because they have relations to their parents, but they are structurally equivalent only if they are siblings. Therefore, regular equivalence is considered to be able to discern the *role* a country has in the world-economy. Based on those considerations, subsequent research generally focuses exclusively on trade flows, using regular equivalence (Lloyd et al. 2009; Mahutga 2006; Mahutga and Smith 2011; Prell, Feng, Sun et al. 2014).

In addition, using the triad-census method that also captures "role" equivalency, Rossem (1996) examines five networks of imports, exports, trade in major conventional weapon systems, the presence of foreign troops, and the presence of diplomatic representation. He obtains four blocks among 163 countries and finds that the world-system role was a function of the absolute size of the economy rather than of level of development. Other works that use the network approach but deviate from the above methods are Clark and Beckfield (2009) and Clark (2010), which study the network of aggregate trade flows and use an analytical method of detecting the continuous core/periphery structure proposed by Borgatti and Everett (1999).

All of these world-system empirical studies have produced pivotal insights regarding the structure of the capitalist world-economy, which world-system position a certain country occupies, and the relationship between the world-system position and economic performance. However, since these studies try to capture different aspects of the world-economy, they tend to reach different results. Here I shall offer critical comments from three separate angles.

First, and importantly, these various studies are built upon different concepts of a core/periphery structure. Some conceptualize the core/periphery structure in a network as having a dense, cohesive core and a sparse, unconnected periphery (e.g., Clark and Beckfield 2009; Clark 2010). Others try to evaluate a country's position in the interstate system based upon the strength of a country (e.g., Kentor 2008), or various types of international dependency (e.g., Kick and Davis 2001; Rossem 1996; Snyder and Kick 1979). For these two related strands, the position of a country in the world-economy tends to be strongly correlated with the absolute size of the economy rather than the level of development, as stated explicitly in Rossem (1996). Therefore, a poor but populous country that stands at the lower end of the international division of labor can possibly be assigned to a core position.

For Wallerstein, in contrast, the defining feature of the core/periphery hierarchy in the capitalist world-economy is the appropriation of surplus from the rest of world by core states.

> Once we get a difference in the strength of the state machineries, we get the operation of "unequal exchange" which is enforced by strong states on weak ones, by core states on peripheral areas. Thus capitalism involves…an appropriation of surplus of the whole world-economy by core areas. (Wallerstein 1974: 401)

Unequal exchange and the appropriation of surplus are realized through the international division of labor. Expounding this line of thinking, Arrighi and Drangel point out that there is a "confusion between the position of a state in relation to the world division of labor and its position in the interstate system" (1986:15). Strictly speaking, the structure and functioning of the core/periphery hierarchy should be understood in terms of the international division of labor. Arrighi and Drangel's (1986) examination of GNP per capita is based upon this premise. The studies that look into multiple commodity trade networks also follow this line (e.g., Mahutga 2006; Mahutga and Smith 2011; Nemeth and Smith 1985; Prell et al. 2014; Smith and White 1992).

Second, all studies based on the network approach include trade network(s), since trade flows represent centrally important economic ties among states. Although I shall demonstrate that the rise of global value chains has not altered the core/periphery hierarchy of the world-economy, this new development does render standard trade statistics problematic (Hummels, Ishii, and Yi 2001; Hummels, Rapoport, and Yi 1998; Johnson and Noguera 2012; Koopman, Wang, and Wei 2014). In a nutshell, intermediate inputs can cross borders multiple times, as different stages of production are carried out in different countries. As a result, trade statistics tend to suffer from a double-counting problem (Koopman et al. 2014). In response, the trade literature increasingly focuses on the value-added content of exports.

This double-counting problem becomes more serious when countries participate in global value chains to different degrees and in different forms. In 2005, for example, according to the OECD's Trade in Value Added database, the total foreign value-added content as a percentage of total gross exports of manufacturing goods was 16.5% for the United States, 12.1% for Japan, 22.7% for Germany, 28.4% for China, 49.7% for Mexico, and 25.2% for India.[1] Therefore, the positions of China, Mexico and India are elevated relative to the United States and Japan in both the aggregate gross trade network and multiple commodity gross trade networks. In consequence, the mere focus on those gross trade networks tends to obscure the contemporary international division of labor.

Third, the commonly used regular equivalence algorithm "REGE" still unduly emphasizes an economy's size. To begin, and as already argued above, regular equivalence better captures the concept of "role" than structural equivalence. But, conceptually, two nodes can be regularly equivalent even though the degrees or strengths of their ties are different. Borgatti and Everett (1993), for example, point out that REGE's measure of similarity can fail whenever otherwise equivalent nodes have different degrees. A close examination of REGE's formula indicates that the strengths of ties also affect the measure of similarity.[2] As a result, the REGE algorithm tends to perceive two countries that have similar magnitudes of trade flows as more regularly equivalent. Therefore, the absolute size of an economy—which critically determines the overall magnitude of trade flows—is factored into the REGE treatment of multiple commodity trade networks (Mahutga 2006; Mahutga and Smith 2011; Prell et al. 2014; Smith and White 1992). Consequently, the position of a poor but large country in the world-economy is likely to be inflated.

For example, following Smith and White (1992), Prell et al. (2014) designate China as a core country in the multiple commodity trade networks for 2007. Still, they do treat China as an anomaly because China has a high level of emissions relative to value added, relies on cheap labor, and encourages foreign investment that allows foreign firms to claim the lion's share of profits

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[1] Organization for Economic Co-operation and Development, TiVA December 2018: Origin of value added in gross exports, https://stats.oecd.org/Index.aspx?DataSetCode=TIVA_2018_C2#

[2] The REGE formula is

$$M_{ij}^{t+1} = \frac{\sum_{k=1}^{g} max_{m=1}^{g} \sum_{r=1}^{R} M_{km}^{t} ({}_{ijr}M_{kmr}^{t} + {}_{jir}M_{kmr}^{t})}{\sum_{k=1}^{g} max_{m}^{*} \sum_{r=1}^{R} ({}_{ijr}Max_{kmr} + {}_{jir}Max_{kmr})}$$

where M_{ij}^{t+1} is the estimate of the degree of regular equivalence for actors i and j at iteration t+1, ${}_{ijr}M_{kmr}^{t} = \min(x_{ikr}, x_{jmr}) + \min(x_{kir}, x_{mjr})$, ${}_{ijr}Max_{kmr} = \max(x_{ikr}, x_{jmr}) + \max(x_{kir}, x_{mjr})$, x_{ikr} is the strength of the tie from *i* to *k* on relation *r*, g is the number of actors (Wasserman and Faust 1994: 479-481). Though the formula is complicated, a comparison between ${}_{ijr}M_{kmr}^{t}$ and ${}_{ijr}Max_{kmr}$ indicates that the formula tends to generate the maximum similarity if $x_{ikr} = x_{jmr}$ and $x_{kir} = x_{mjr}$. Therefore, the strengths of ties matter for the REGE measure of similarity. I have experimented with a hypothetical network in which actors are conceptually regularly equivalent but have ties with different strengths. The REGE result shows that two actors are more regularly equivalent if their ties have more similar strengths.

from China's industrial exports. Those features are more characteristic of a peripheral or semiperipheral country.

The Network of International Labor Time Flows

The previous section discussed concepts and prior empirical results regarding the core/periphery hierarchy of the capitalist world-economy. The purpose of this section is to motivate the use of an international labor time flow network as the lens through which to analyze said hierarchy. Labor time is embodied in all commodities and services that people produce and consume. Therefore, a network of producers and consumers in which these labor time flows connect everyone is embedded in the human world. Based on world input-output tables, we can locate the source countries of the labor time embodied in the final products that destination countries consume. The network of international labor time flows shows how living labor devoted in a year is allocated among countries. Intuitively, core states should be net importers of labor time, peripheral states should be net exporters, and semiperipheral states should approximately balance export and import of labor time. In this sense, the network of international labor time flows can *reveal* the hierarchical structure of the capitalist world-economy. This intuition is supported by several theoretical considerations.

First, Arrighi and Drangel (1986) argue that core states claim a larger share of surplus produced within commodity chains than semiperipheral and peripheral states. As a result, they can use GNP per capita as a proxy for differences in command over world economic resources in order to demarcate core, semiperiphery, and periphery (Arrighi and Drangel 1986; Arrighi 1990). In their conceptualization, GNP per capita as an attribute of a country in effect reflects networks of world economic resource flows. Labor or labor time is one of the most important economic resources, and the network of international labor time flows explicitly shows a country's command over labor across the world.

Further, following the tradition of Marxian political economy, Emmanuel (1972) argues that unequal exchange occurs when two countries with different wage rates (unequal exchange in the strict sense) and different organic composition of capital (unequal exchange in the broad sense) exchange in the world market in which there is a uniform rate of profit. In other words, surplus value or surplus labor is transferred from the low-wage and low-organic-composition-of-capital country to the high-wage and high-organic-composition-of-capital country. Such a directional transfer of surplus is one of the main mechanisms that reproduce the core/periphery hierarchy of the capitalist world-economy (Chase-Dunn 1998: 228-255). In essence, unequal exchange of labor can be expected to manifest itself in asymmetric international labor time flows.

Third, in contrast to Arrighi and Drangel (1986), Chase-Dunn (1998) defines core activities as the production of relatively capital-intensive commodities which employ relatively skilled, relatively highly paid labor. Core states are those in which relatively capital-intensive production is concentrated. Chase-Dunn argues that "a better indicator of my concept would be the amount of product divided by the number of hours worked, because capital intensity is very nearly the same as labor productivity" (1998: 216). In general, either higher labor productivity or higher capital intensity corresponds to a lower amount of *living* labor per unit of value added.[3] When two countries with different capital intensities exchange in the world market, the two labor time flows should be unequal.

Last but not least, there is a fundamental reason why the labor time flow network is worth studying. In discussing the fetishism of commodities, Karl Marx points out,

> The mysterious character of the commodity-form consists therefore simply in the fact that the commodity reflects the social characteristics of men's own labour as objective characteristics of the products of labour themselves, as the socio-natural properties of these things. Hence it also reflects the social relation of the producers to the sum total of labour as a social relation between objects, a relation which exists apart from and outside the producers. (Marx 1976: 164-165)

Therefore, a mere focus on the international trade network tends to obscure the social relations of the producers across countries that is latent in the trade network. A direct study of the international labor time flows is aimed at lifting the veil.[4]

Of course, world-systems scholars that study international trade network(s) have long recognized these issues. Nemeth and Smith (1985), for example, argue that network analysis of the capitalist world-economy would best build on international profit flows. Such data is, however, not available. I agree that a network of profit flows would be preferable to a network of trade flows—but the argument made here is that living labor expended in global commodity production still gets closer to the underlying social relations and hierarchies. The surplus appropriated from the rest of world by core states is shared between workers and capitalists in the form of wages and profits respectively. Since *living* labor is the source of *new* value (which is realized as the sum of wages and profits), an analysis of the flows of *living* labor among countries seems to be ideal to studying the core/periphery structure of the world-economy.

In conclusion, the network of international labor time flows can *reveal* the hierarchical structure of the capitalist world-economy. The verb "reveal" is used here intentionally, because the network of international labor time flows is a result of potentially *various* mechanisms that reproduce the core/periphery hierarchy of the world-economy. No claim is made that it necessarily corresponds to one specific mechanism or another such as "unequal exchange"—only that the asymmetry of labor time flows provides crucial insights into the persistent hierarchy of the world-economy.

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[3] I do not deal with the issue of complex labor and simple labor in this paper because there is no good justification for the claim that one labor hour in a country equals multiple labor hours in another country (Hagiwara 2017). Moreover, even if one labor hour in a core country does equal multiple labor hours in a semiperipheral or peripheral country in terms of "effectiveness," one labor hour in different countries should be treated as equal in the network of international labor time flows for the purpose of demarcating core, semiperiphery, and periphery.

[4] An emphasis on the international labor time flows does not preclude the study of international trade. They are different aspects of the international division of labor and the former is realized through the latter.

Constructing and Analyzing the Network of International Labor Time Flows

Footprint Calculation: Constructing the Network of International Labor Time Flows

In order to locate the origins of labor time embodied in goods or services consumed in a destination country, I adopt the standard footprint calculation using the world input-output table and the satellite labor time input data.

Before presenting the generalized footprint calculation, a simple case will suffice to illustrate the basic idea. Suppose there are two countries, each country has one sector, and they produce different products. To produce \$1 gross product, country 1 has to use \$$a_{11}$ domestic product and \$$a_{21}$ foreign product as intermediate inputs and devote l_1 labor hours. Similarly, to produce \$1 gross product, country 2 has to use \$$a_{12}$ foreign product and \$$a_{22}$ domestic product as intermediate inputs and devote l_2 labor hours. Therefore, in order to meet a final demand \$$y_1$ for the product from country 1, gross output \$$x_1$ from country 1 and gross output \$$x_2$ from country 2 have to be produced, such that

$$\begin{cases} a_{11}x_1 + a_{12}x_2 + y_1 = x_1 \\ a_{21}x_1 + a_{22}x_2 = x_2 \end{cases} \tag{1}$$

The first equation is the balanced condition in country 1, and the second in country 2. Both follow the principle that intermediate input plus final demand equals gross output, though the final demand for country 2's product is zero in (1). Solving for $x_1$and x_2, we obtain

$$\begin{cases} x_1 = \dfrac{y_1(1 - a_{22})}{(1 - a_{11})(1 - a_{22}) - a_{12}a_{21}} \\ x_2 = \dfrac{y_1 a_{21}}{(1 - a_{11})(1 - a_{22}) - a_{12}a_{21}} \end{cases} \tag{2}$$

Therefore, $x_1 = \frac{y_1(1-a_{22})}{(1-a_{11})(1-a_{22})-a_{12}a_{21}}$ has to be produced in country 1 and $x_2 = \frac{y_1 a_{21}}{(1-a_{11})(1-a_{22})-a_{12}a_{21}}$ in country 2 in order to satisfy the final demand \$$y_1$ for the product from country 1. As a result, $l_1 x_1 = l_1 \frac{y_1(1-a_{22})}{(1-a_{11})(1-a_{22})-a_{12}a_{21}}$ labor hours have to be expended in country 1, and $l_2 x_2 = l_2 \frac{y_1 a_{21}}{(1-a_{11})(1-a_{22})-a_{12}a_{21}}$ labor hours in country 2.

Symmetrically, to meet a final demand \$$y_2$ for the product from country 2, $l_1 \frac{y_2 a_{12}}{(1-a_{11})(1-a_{22})-a_{12}a_{21}}$ labor hours must be expended in country 1, and $l_2 \frac{y_2(1-a_{11})}{(1-a_{11})(1-a_{22})-a_{12}a_{21}}$ labor hours in country 2.

Suppose each year country 1's final demand consists of \$$y_{11}$ domestic product and \$$y_{21}$ foreign product, then $L_{11} = l_1 \frac{y_{11}(1-a_{22})}{(1-a_{11})(1-a_{22})-a_{12}a_{21}} + l_1 \frac{y_{21} a_{12}}{(1-a_{11})(1-a_{22})-a_{12}a_{21}}$ labor hours are expended and consumed domestically in country 1, and $L_{21} = l_2 \frac{y_{11}a_{21}}{(1-a_{11})(1-a_{22})-a_{12}a_{21}} + l_2 \frac{y_{21}(1-a_{11})}{(1-a_{11})(1-a_{22})-a_{12}a_{21}}$ labor hours are expended in country 2 and flow to country 1.

Symmetrically, if each year country 2's final demand consists of $\$y_{12}$ foreign product and $\$y_{22}$ domestic product, then $L_{12} = l_1 \frac{y_{12}(1-a_{22})}{(1-a_{11})(1-a_{22})-a_{12}a_{21}} + l_1 \frac{y_{22}a_{12}}{(1-a_{11})(1-a_{22})-a_{12}a_{21}}$ labor hours are expended in country 1 and flow to country 2, and $L_{22} = l_2 \frac{y_{12}a_{21}}{(1-a_{11})(1-a_{22})-a_{12}a_{21}} + l_2 \frac{y_{22}(1-a_{11})}{(1-a_{11})(1-a_{22})-a_{12}a_{21}}$ labor hours are expended and consumed domestically in country 2.

This simple case demonstrates two important features of international trade involving intermediate inputs. First, a country imports foreign labor time not only by directly consuming foreign products but also by consuming domestic products that require intermediate inputs from foreign countries. Second, a country consumes its own labor time not only by directly consuming domestic products but also by consuming foreign products that require intermediate inputs from this country. Next, I will show how to derive the network of international labor time flows in a world with G countries and N sectors.

Table 1 An illustration of a World Input-Output Table

Outputs / Inputs		Intermediate Use				Final Demand				Total Output
		1	2	⋯	G	1	2	⋯	G	
Intermediate Inputs	1	Z^{11}	Z^{12}	⋯	Z^{1g}	Y^{11}	Y^{12}	⋯	Y^{1g}	X^1
	2	Z^{21}	Z^{22}	⋯	Z^{2g}	Y^{21}	Y^{22}	⋯	Y^{2g}	X^2
	⋮	⋮	⋮	⋱	⋮	⋮	⋮	⋱	⋮	⋮
	G	Z^{g1}	Z^{g2}	⋯	Z^{gg}	Y^{g1}	Y^{g2}	⋯	Y^{gg}	X^g
Value-added		Va^1	Va^2	⋯	Va^g					
Total input		$(X^1)^T$	$(X^2)^T$	⋯	$(X^g)^T$					

Notes: I use the same illustration as Wang et al. (2017). *T* denotes the transpose operation.

Table 1 is an illustration of a world input-output table with *G* countries and *N* sectors. Z^{ij} is an $N \times N$ matrix of intermediate inputs produced in country *i* and used in country *j*; Y^{ij} is an $N \times 1$ vector giving final products (or final demand) produced in country *i* and consumed in country *j*; X^i is an $N \times 1$ vector giving gross outputs in country *i*; and Va^i denotes a $1 \times N$ vector of direct value-added in country *i* (Wang, Wei, Yu et al. 2017). Parallel to the value-added vector, $Lt = (Lt^1, Lt^2, \dots, Lt^g)$ denotes a satellite labor time input vector where Lt^i is a $1 \times N$ vector of direct labor time input in country *i*.

The intermediate input coefficient matrix $A = Z\hat{X}^{-1}$, where $\hat{X}$ is a diagonal matrix with the gross output vector X in its diagonal. Similarly, the labor time input coefficient vector $Lc = Lt\hat{X}^{-1} = (Lc^1, Lc^2, \ldots, Lc^g)$.

Gross outputs X are made up of intermediate and final products, $AX + Y = X$. Solving for gross outputs X given the intermediate input coefficient matrix A and final products Y, we can get $X = (I - A)^{-1}Y$, where $(I - A)^{-1}$ is the well-known Leontief inverse matrix.

Therefore, to satisfy country j's final demand $Y^{\cdot,j}$, gross outputs $X^{\cdot,j} = (I - A)^{-1}Y^{\cdot,j}$ have to be produced.

$$X^{\cdot,j} = \begin{pmatrix} X^{1j} \\ X^{2j} \\ \vdots \\ X^{gj} \end{pmatrix} = (I - A)^{-1}Y^{\cdot,j} = (I - A)^{-1}\begin{pmatrix} Y^{1j} \\ Y^{2j} \\ \vdots \\ Y^{gj} \end{pmatrix} \tag{3}$$

where X^{ij} is an N×1 vector giving gross outputs produced in country i to meet the final demand in country j. Intuitively, all countries combine living labor and intermediate inputs to produce the gross outputs that not only satisfy the final demand of country j but also reproduce the used-up intermediate inputs.

The total labor time embodied in final products $Y^{\cdot,j}$ is $LcX^{\cdot,j} = Lc(I - A)^{-1}Y^{\cdot,j}$ (a scalar). The term to the left of $Y^{\cdot,j}$ is $Lc(I - A)^{-1} = (Lc^1, Lc^2, \ldots, Lc^g)\,(I - A)^{-1}$ (a 1×GN vector), which gives the labor time embodied in the $1 product of each sector in each country (Hagiwara 2017). By twisting the labor time input coefficient vector, we can calculate how many labor hours each country exports to country j.

$$\underset{(G\times 1)}{\begin{pmatrix} L_{1j} \\ L_{2j} \\ \vdots \\ L_{gj} \end{pmatrix}} = \underset{(G\times GN)}{\begin{pmatrix} Lc^1 & 0 & \cdots & 0 \\ 0 & Lc^2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & Lc^g \end{pmatrix}} \underset{(GN\times 1)}{\begin{pmatrix} X^{1j} \\ X^{2j} \\ \vdots \\ X^{gj} \end{pmatrix}} = \underset{(G\times GN)}{\begin{pmatrix} Lc^1 & 0 & \cdots & 0 \\ 0 & Lc^2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & Lc^g \end{pmatrix}} \underset{(GN\times GN)}{(I - A)^{-1}} \underset{(GN\times 1)}{\begin{pmatrix} Y^{1j} \\ Y^{2j} \\ \vdots \\ Y^{gj} \end{pmatrix}} \tag{4}$$

where $L_{ij} = Lc^iX^{ij}$ is a scalar indicating the labor time that flows from country i to country j.

Expanding the final demand vector on the right side of equation (4), we can get the country-to-country labor time flow matrix.

$$\underset{(G\times G)}{\begin{pmatrix} L_{11} & L_{12} & \cdots & L_{1g} \\ L_{21} & L_{22} & \cdots & L_{2g} \\ \vdots & \vdots & \ddots & \vdots \\ L_{g1} & L_{g2} & \cdots & L_{gg} \end{pmatrix}} = \underset{(G\times GN)}{\begin{pmatrix} Lc^1 & 0 & \cdots & 0 \\ 0 & Lc^2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & Lc^g \end{pmatrix}} \underset{(GN\times GN)}{(I - A)^{-1}} \underset{(GN\times G)}{\begin{pmatrix} Y^{11} & Y^{12} & \cdots & Y^{1g} \\ Y^{21} & Y^{22} & \cdots & Y^{2g} \\ \vdots & \vdots & \ddots & \vdots \\ Y^{g1} & Y^{g2} & \cdots & Y^{gg} \end{pmatrix}} \tag{5}$$

The matrix on the left side of equation (5) is the network of international labor time flows. The diagonal elements are labor time used for domestic consumption. The off-diagonal elements are labor time exported to foreign countries.

I use the term "footprint calculation" to denote the method through which I derive the network of international labor time flows. It can avoid the double-counting problem pertaining to the international trade network(s). This method is widely adopted to demonstrate the decoupling of production and consumption across countries through trade (Wiedmann and Lenzen 2018), uneven distribution of value-added along global value chains (Timmer, Dietzenbacher, Los et al. 2015), ecological unequal exchange (Lenzen, Moran, Kanemoto et al. 2012; Yu, Feng, and Hubacek 2014), and master-servant relationships measured by unequal consumption of employment footprints (Alsamawi, Murray, and Lenzen 2014; Simas, Wood, and Hertwich 2015). These studies contribute to understanding the dynamics of the capitalist world-economy. However, to my knowledge, they rarely examine the network structure of those flows but instead focus on aggregates of those flows.

World input-output tables are from the World Input-Output Database (WIOD), which include 40 economies and a Rest of World (RoW) for the period 1995-2009.[5] The 40 economies cover more than 85% of world gross domestic product (GDP) in 2008 (at current exchange rates) (Timmer et al. 2015).[6] Each economy has 35 sectors. The labor time data (total hours worked by persons engaged) come from the satellite social-economic accounts provided by the same database. Unfortunately, the labor time data for the RoW are not provided. Therefore, I shall examine the international labor time flows of 40 economies for 1995-2009. The resultant labor time flows are expressed in millions of hours.

Network Analysis

The network of international labor time flows is asymmetric in the sense that some countries import more labor than they export and other countries export more labor than they import. Therefore, a network analytical method that can fully utilize the network information such as the strengths of ties to detect the asymmetry of labor time flows will be ideal. The minimum residual singular value decomposition (MINRES/SVD) proposed by Boyd, Fitzgerald, Mahutga et al. (2010) to compute asymmetric continuous core/periphery structures is such a network analytical tool. Here the core/periphery structure refers to a structure of a dense, cohesive core and a sparse, unconnected periphery, which is not necessarily a core/periphery hierarchy with regard to the international division of labor in the world-economy. But this method can serve to reveal the core/periphery hierarchy of the world-economy by detecting the asymmetry of international labor time flows.

Denote the original matrix of labor time flows as L ($G \times G$ matrix where G is the number of countries). Because the labor time flows are highly skewed to large values, I transform the original matrix L by taking the base 10 logarithm, as suggested in Boyd et al. (2010). The new matrix A =

[5] http://www.wiod.org/database/wiots13.

[6] The 40 economies include all 27 members of the EU (as of 1 January 2007) and 13 other major economies: Australia, Brazil, Canada, China, India, Indonesia, Japan, Mexico, Russia, South Korea, Taiwan, Turkey and the USA.

$\log_{10}(L + 1)$, where 1 is added to each element of *L* to avoid negative values and to produce a value of 0 at 0. Since the international labor time flows are of interest, I shall neglect the diagonal elements of *A*.

The basic idea is to use two vectors—*U*, "the tendency to export" or "out-coreness" vector, and *V*, "the tendency to import" or "in-coreness" vector—to approximate the logged matrix of labor time flows *A*. Both *U* and *V* are a $G\times1$ vector. U_i, the *i*th element of *U*, is country *i*'s out-coreness score, and V_i, the *i*th element of *V*, is country *i*'s in-coreness score. To fully approximate the structure of *A*, we need to find the optimal *U* and *V* that minimize the sum of squares of the off-diagonal differences between UV^T and *A*. The resultant *U* and *V* will diverge if *A* is asymmetric. Specifically, the objective function is

$$min \sum_{i\neq j} \left(A_{ij} - U_i V_j\right)^2 \quad (6)$$

Figure 1 illustrates this basic idea. Holding other factors fixed, a higher out-coreness score U_i means that country *i* is likely to export a larger volume of labor time. A higher in-coreness score V_i means that country *i* is likely to import a larger volume of labor time. The number of the unknowns is 80 (40 for *U* and 40 for *V*). I find the optimal *U* and *V* through R programming packages.[7]

Figure 1. An illustration of detecting the asymmetric core/periphery structure. The objective is to minimize the sum of the squares of the off-diagonal differences between the logged matrix *A* and the ideal asymmetric structure UV^T.

Logged matrix *A*

-	A_{12}	A_{13}	⋯	A_{1g}
A_{21}	-	A_{23}	⋯	A_{2g}
A_{31}	A_{32}	-	⋯	A_{3g}
⋮	⋮	⋮	⋱	⋮
A_{g1}	A_{g2}	A_{g3}	⋯	-

⟺

Ideal asymmetric structure UV^T

-	U_1V_2	U_1V_3	⋯	U_1V_g
U_2V_1	-	U_2V_3	⋯	U_2V_g
U_3V_1	U_3V_2	-	⋯	U_3V_g
⋮	⋮	⋮	⋱	⋮
U_gV_1	U_gV_2	U_gV_3	⋯	-

To make the optimal *U* and *V* comparable over time, I remove the magnitude factor by normalizing *U* and *V* such that their norms are 1.

$$UV^T = \frac{U}{\|U\|}\|U\|\|V\|\frac{V^T}{\|V\|} = udv^T \quad (7)$$

where $\|U\| = \sqrt{\sum U_i^2}$, $\|V\| = \sqrt{\sum V_i^2}$, $u = \frac{U}{\|U\|}$, $v^T = \frac{V^T}{\|V\|}$, $d = \|U\|\|V\|$. This paper will only report u and v as standardized out- and in-coreness scores. d is a scaling factor that can enlarge or shrink the elements in the matrix udv^T so that they best approximate the matrix *A*.

[7] Boyd et al. (2010) propose to find the optimal vectors by setting the first-order partial derivatives to 0 in Mathematica. Instead, I find the optimal vectors by using the function "optim" which automatically solves the minimization problem in R.

The proportional reduction of error (*PRE*) is the goodness of fit that assesses how well UV^T approximates A.

$$PRE(UV^T|\bar{A}) = 1 - \frac{\sum_{i\neq j}\left(A_{ij} - U_iV_j\right)^2}{\sum_{i\neq j}\left(A_{ij} - \bar{A}\right)^2} \tag{8}$$

where $\bar{A}$ is the mean of the off-diagonal elements of A. Apparently, minimizing $\sum_{i\neq j}\left(A_{ij} - U_iV_j\right)^2$ is equivalent to maximizing $PRE(UV^T|\bar{A})$. $PRE(UV^T|\bar{A})$ can be interpreted as the proportion of the variation of off-diagonal elements of A around $\bar{A}$ explained by the asymmetric structure UV^T.

By setting $U = V$, we can examine the *symmetric* structure embedded in A. Denote this $G\times 1$ "coreness" vector as W. We use WW^T to approximate A, and the objective function becomes

$$min \sum_{i\neq j}\left(A_{ij} - W_iW_j\right)^2 \tag{9}$$

I will report the normalized coreness score $w = \frac{W}{\sqrt{\sum W_i^2}}$. $PRE(WW^T|\bar{A})$ is the goodness of fit that evaluates how well WW^T approximates A. Its expression is

$$PRE(WW^T|\bar{A}) = 1 - \frac{\sum_{i\neq j}\left(A_{ij} - W_iW_j\right)^2}{\sum_{i\neq j}\left(A_{ij} - \bar{A}\right)^2} \tag{10}$$

We can also assess the performance of UV^T in accounting for the error that WW^T fails to explain. The resultant measure is

$$PRE(UV^T|WW^T) = 1 - \frac{\sum_{i\neq j}\left(A_{ij} - U_iV_j\right)^2}{\sum_{i\neq j}\left(A_{ij} - W_iW_j\right)^2} \tag{11}$$

It can be easily verified that

$$PRE(UV^T|\bar{A}) = PRE(WW^T|\bar{A}) + PRE(UV^T|WW^T) - PRE(WW^T|\bar{A})PRE(UV^T|WW^T) \tag{12}$$

$PRE(UV^T|\bar{A})$, $PRE(WW^T|\bar{A})$, and $PRE(UV^T|WW^T)$ all fall between 0 and 1, and a larger value means a better fit. The latter two measures can be used to judge the degree of asymmetry of the network of international labor time flows.

Results: Overview of the Socio-Economic Conditions for the Forty Economies

Table 2 summarizes the socio-economic conditions for the forty economies, including the average annual hours worked by persons engaged from two different data sources, GDP per capita measured in PPP, annual growth rates of GDP per capita during the period 1996-2015, and population. Except the growth rates of GDP per capita, all the other indicators are for the year 2005, after China became a member of WTO and before the Great Recession.

Table 2. Socio-economic conditions for countries in the network of labor time flows, 2005

Country	Average annual hours worked by persons engaged, **WIOD**	Average annual hours worked by persons engaged, **pwt91**	GDP per capita, PPP (constant 2011 international $)	Annual growth rate of GDP per capita, 1996-2015	Population
High Income					
Australia	1,797	1,803	38,969	1.87%	20,394,800
Austria	1,652	1,752	41,283	1.36%	8,227,829
Belgium	1,438	1,565	39,803	1.25%	10,478,617
Canada	1,739	1,747	40,557	1.46%	32,243,753
Cyprus	1,856	1,847	33,629	0.92%	1,027,662
Germany	1,434	1,411	37,704	1.35%	82,469,422
Denmark	1,579	1,451	44,568	1.04%	5,419,432
Spain	1,668	1,726	32,902	1.29%	43,653,155
Finland	1,716	1,697	39,116	1.76%	5,246,096
France	1,481	1,527	36,375	1.05%	63,179,351
United Kingdom	1,551	1,670	37,172	1.58%	60,401,206
Greece	2,086	2,136	29,559	0.64%	10,987,314
Ireland	1,883	1,883	46,598	4.22%	4,159,914
Italy	1,819	1,812	37,604	0.17%	57,969,484
Japan	1,814	1,828	35,658	0.77%	127,773,000
Korea, Rep.	2,375	2,351	25,517	3.69%	48,184,561
Luxembourg	1,631	1,550	88,610	1.82%	465,158
Malta	1,895*	2,158*	26,321	2.81%	403,834
Netherlands	1,393	1,434	43,829	1.48%	16,319,868
Portugal	1,843	1,895	26,593	0.99%	10,503,330
Slovenia	1,809	1,697	26,955	2.30%	2,000,474
Sweden	1,605	1,605	41,270	1.94%	9,029,572
Taiwan	2,193	2,128	31,283	3.67%	22,602,886
United States	1,797	1,787	49,513	1.54%	295,516,599
Upper Middle Income					
Czech Republic	1,965	1,817	25,781	2.34%	10,211,216
Estonia	1,951	2,008	22,807	4.54%	1,354,775
Hungary	1,993	1,987	22,464	2.49%	10,087,065
Lithuania	1,871	1,879	18,527	5.45%	3,322,528
Latvia	1,544*	1,906*	17,522	5.24%	2,238,799
Mexico	2,189	2,290	16,159	1.32%	106,005,203
Poland	1,831*	2,079*	17,194	4.11%	38,165,445
Romania	1,853	1,853	14,430	3.48%	21,319,685
Russian Federation	1,920	1,989	19,326	3.30%	143,518,523
Slovak Republic	1,761	1,769	20,021	3.91%	5,372,807
Turkey	1,936	1,936	16,310	3.24%	67,903,469
Lower Middle Income					
Bulgaria	1,659	1,659	12,420	3.56%	7,658,972
Brazil	2,124*	1,783*	12,352	1.47%	186,127,103
China	1,947*	2,192*	5,703	8.69%	1,303,720,000
Indonesia	1,541*	1,954*	6,837	2.76%	226,289,470
Low Income					
India	2,338*	2,097*	3,411	4.89%	1,147,609,927
World	-	-	11,753	2.37%	6,512,602,867

Notes: 1. This table lists two data sources for the average annual hours worked by persons engaged, the WIOD Socio-Economic Accounts Release 2013, and the Penn World Table version 9.1 (pwt91). For the WIOD source, the average annual hours worked by persons engaged are equal to the total hours worked by persons engaged divided by the number of persons engaged. The asterisks highlight the cases in which the data discrepancy is greater than 200 hours. These discrepancies are due to the different assumptions made by WIOD and by pwt91. The results below completely rely on the labor time data of WIOD.

2. The data on GDP per capita, PPP (constant 2011 international $) and population come from the World Development Indicators Database of World Bank. The annual growth rate of GDP per capita for 1996-2015 was calculated by the author. Countries are classified according to the World Bank Analytical Classifications.

There are 40 economies in the network of international labor time flows. As shown in Table 2, in 2005, 24 of those countries were high-income countries, 11 countries belonged to the upper-middle-income group, and 5 countries were lower-middle-income or low-income with large populations. Therefore, this study neglects many other countries due to the lack of data. However, these included countries cover more than 85% of world gross domestic product (GDP) in 2008 (at current exchange rates) (Timmer et al. 2015) and make up 64.8% of the world population in 2005. We should be able to uncover the core/periphery hierarchy through the analysis of these countries.

Table 2 also lists the average annual hours worked by persons engaged from two different data sources, the WIOD Socio-Economic Accounts Release 2013 and the Penn World Table version 9.1 (pwt91). Most of the data points are consistent across those two data sources. The asterisks highlight the cases in which the data discrepancy from those two sources is greater than 200 hours. These discrepancies are due to different assumptions made by WIOD and by pwt91. This paper uses the labor time data from the WIOD Socio-Economic Accounts.

One salient pattern in Table 2 is that the middle-income and low-income countries have faster long-term economic growth than the high-income countries during 1996-2015, which implies economic convergence. However, I shall contend that the hierarchical structure of the capitalist world-economy has in large part remained unaltered through the analysis of international labor time flows.

Results: The Core/Periphery Hierarchy

I apply the MINRES/SVD method to the network of international labor time flows for each year in 1995-2009, and "the tendency to import labor time" (in-coreness) and "the tendency to export labor time" (out-coreness) are derived for each country. Table 3 presents the results for the leading 15 countries on the ladders of in-coreness v, out-coreness u and coreness w in 2005.

According to the ladder of in-coreness, the first 15 countries are all high-income ones except China and Russia. Specifically, the United States, Germany, United Kingdom, France, and Italy are the leading countries that consume foreign labor time. In contrast, many middle-income and low-income countries enter the leading group of out-coreness. China, India, Russia, Brazil, and Germany are the countries that have the strongest tendency to export labor time. The divergence between in-coreness and out-coreness conforms to the theoretical expectation. It reflects the asymmetry of international labor time flows, a result of the current international division of labor. The symmetric "coreness" measure sorts out the countries that heavily participate in the exchange of labor in the world-economy regardless of the direction of labor time flows. Therefore, the coreness ranking mixes the rankings of in-coreness and out-coreness. China is placed ahead of the United States due to its sheer role in exporting labor time.

Table 3. Network analysis of the international labor time flows, 2005

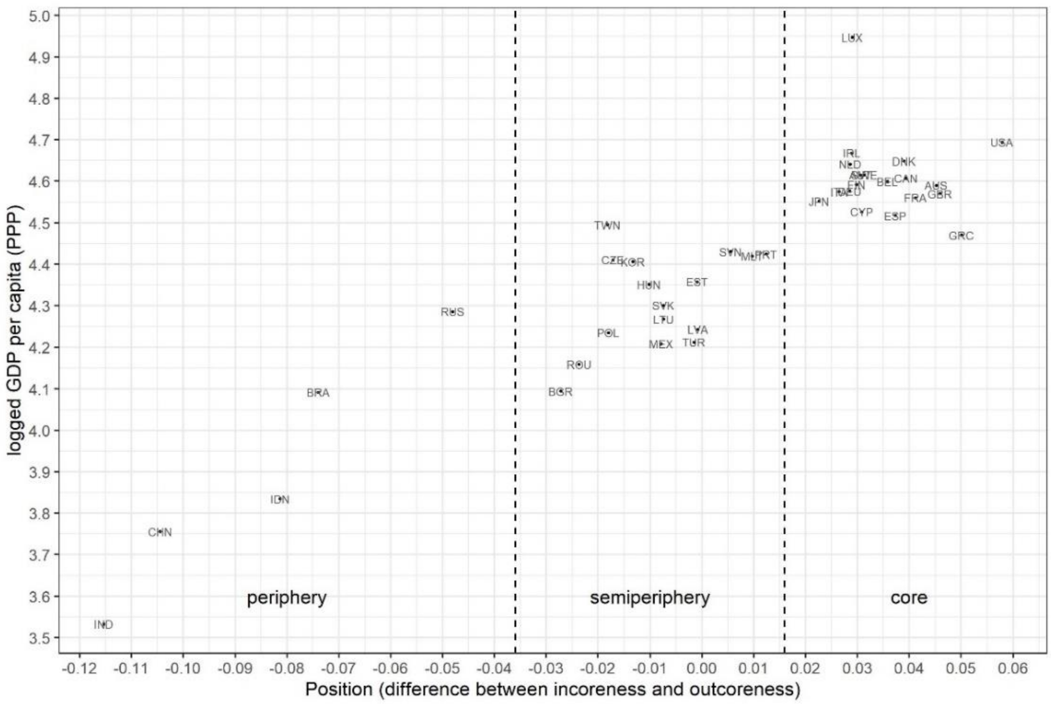
Rank	Country	In-coreness, *v*	Country	Out-coreness, *u*	Country	Coreness, *w*
1	USA	0.2600	CHN	0.3125	CHN	0.2644
2	DEU	0.2417	IND	0.2726	USA	0.2344
3	GBR	0.2283	RUS	0.2285	DEU	0.2303
4	FRA	0.2165	BRA	0.2189	IND	0.2172
5	ITA	0.2148	DEU	0.2132	GBR	0.2077
6	CHN	0.2080	IDN	0.2116	RUS	0.2067
7	JPN	0.2042	USA	0.2021	ITA	0.2036
8	ESP	0.1999	ITA	0.1883	FRA	0.1980
9	NLD	0.1837	KOR	0.1826	JPN	0.1953
10	RUS	0.1805	GBR	0.1824	BRA	0.1839
11	CAN	0.1801	JPN	0.1815	ESP	0.1828
12	BEL	0.1700	POL	0.1756	KOR	0.1780
13	KOR	0.1692	FRA	0.1753	IDN	0.1723
14	AUS	0.1658	MEX	0.1642	NLD	0.1701
15	SWE	0.1619	TUR	0.1633	POL	0.1675
$\boldsymbol{PRE(.\|\bar{A})}$	0.8813				0.7470	
$\boldsymbol{PRE(UV^T\|WW^T)}$	0.5310				-	

Notes: The list of abbreviations of countries is in the Appendix. In-coreness *v* measures a country's tendency to import labor time. Out-coreness *u* measures a country's tendency to export labor time. Coreness *w* is a symmetric measure regardless of the direction of labor time flows.
$PRE(.|\bar{A})$ stands for $PRE(UV^T|\bar{A})$ with respect to *v* and *u* and $PRE(WW^T|\bar{A})$ with respect to *w*.

The PREs are also informative. The symmetry measure $PRE(WW^T|\bar{A})$ is 0.7470, which reflects the fact that the size of an economy is factored into the volumes of both export and import of labor time, rendering the network of international labor time flows somewhat symmetric. However, the asymmetric aspect of those labor time flows is equally evident. $PRE(UV^T|WW^T)$ is 0.5310, implying that UV^T accounts for more than a half of the error that WW^T fails to explain. The ultimate goodness of fit $PRE(UV^T|\bar{A})$ is 0.8813, suggesting that the asymmetric structure UV^T fits the network of international labor time flows exceptionally well.

The theoretical discussions in the previous section suggest that a country's position in the world system can be revealed by the difference in import and export of labor time. Here I shall use the difference between "the tendency to import labor time" and "the tendency to export labor time," namely, $v - u$, as a proxy of a country's world-system position. Figure 2 is the scatterplot of log GDP per capita versus the position measure. It appears that the relationship between log GDP per capita and the position measure is significantly positive. This finding is consistent with the expectation that the income of a country is positively related to its relative command over foreign labor.

Figure 2. Log GDP per capita versus the difference between labor in-coreness and out-coreness, 2005.



Notice that my world-system position measure is a continuous one. As Chase-Dunn argues, “I don’t see any advantage in spending a lot of time trying to define and empirically locate the boundaries between zones because I understand the core/periphery hierarchy as a complex continuum” (1998: 214). It suggests that the boundaries between zones cannot be exactly located and a continuous position measure might be preferable. However, core, semiperiphery, and periphery are still good metaphors (Chase-Dunn 1998). In Figure 2, there seems to be three clusters that correspond to the core, semiperipheral, and peripheral zones. Hence, I draw two vertical dashed lines that are theoretically informed but practically a little arbitrary in order to demarcate the core/periphery hierarchy of the world-economy. The results are summarized in Table 4.

Table 4. A tentative core/semiperiphery/periphery classification of economies in the network of labor time flows, 2005

World-system position	Economies	Population
Core	United States, Greece, United Kingdom, Australia, France, Canada, Denmark, Spain, Belgium, Sweden, Cyprus, Austria, Finland, Luxembourg, Germany, Ireland, Netherlands, Italy, Japan	854,962,232
Semiperiphery	Portugal, Malta, Slovenia, Estonia, Latvia, Turkey, Lithuania, Mexico, Slovak Republic, Hungary, South Korea, Czech Republic, Taiwan, Poland, Romania, Bulgaria	357,335,049
Periphery	India, China, Indonesia, Brazil, Russia	3,007,265,023

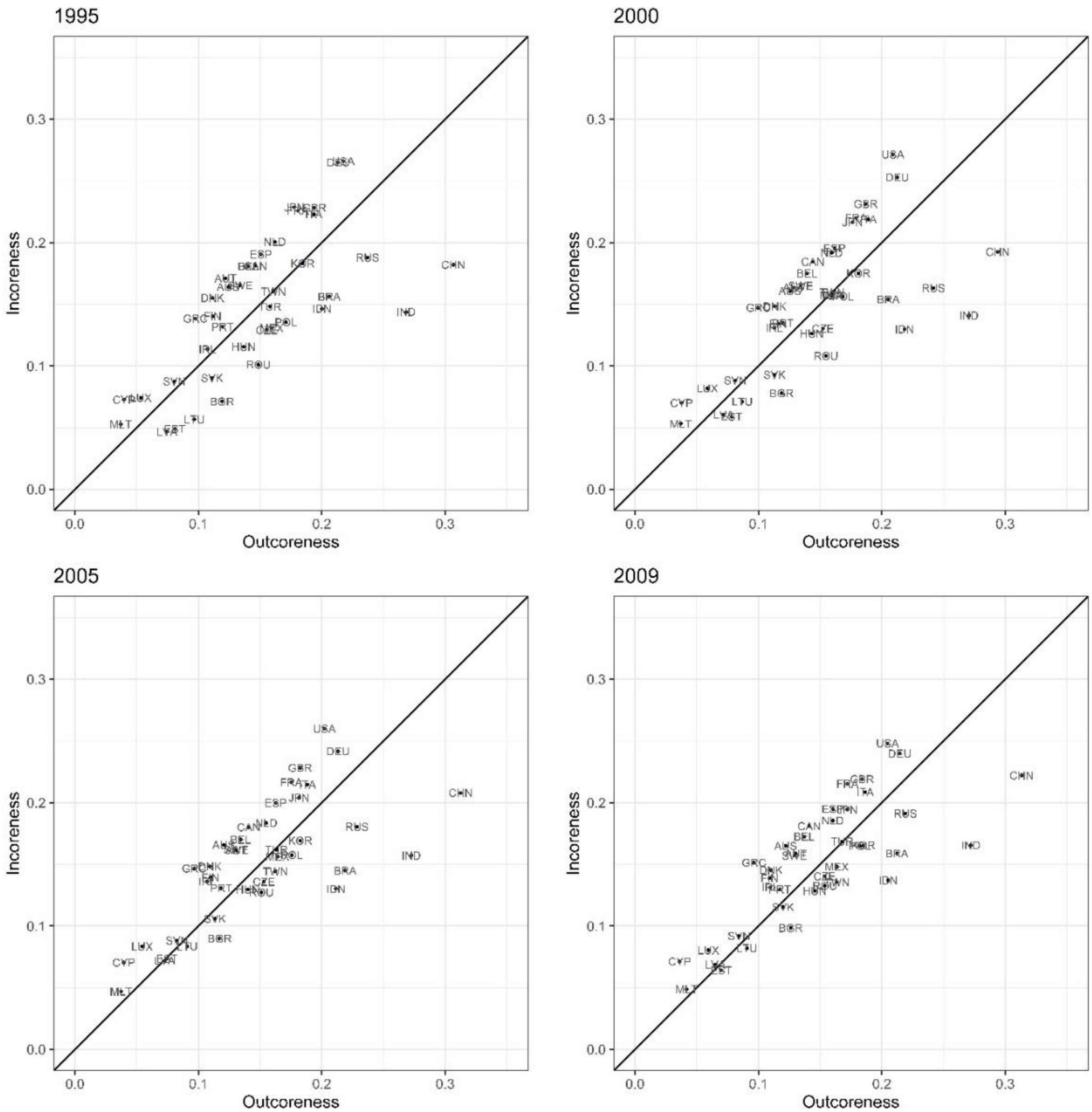
Although the number of economies in the core and semiperiphery is far greater than that in the periphery due to the limited size of the sample, the population in the latter constitutes around 70 percent of the total population of the forty economies. Considering that these forty economies make up 64.8 percent of the world population and that most of the RoW locates in the periphery and semiperiphery, the distribution of world population in terms of labor time flows should have a pyramidal shape.

Results: The Stability of the Core/Periphery Hierarchy

The stability of the world-system core/periphery hierarchy requires that most of the countries do not show significant mobility across core, semiperipheral, and peripheral zones and that the overall hierarchical structure remains intact. Figure 3 shows the evolution of the positions of countries in the out-coreness and in-coreness space for 1995–2009. A 45-degree line is drawn to represent the world average—all countries would fall on the 45-degree line if there was a perfect equality among countries with regard to labor time flows. The position measure ($v - u$) is just the vertical distance between the country and the 45-degree line. A country above the line (a positive $v - u$) has the advantage of commanding more foreign labor time than it exports. A country below the line (a negative $v - u$) is disadvantaged in commanding foreign labor time relative to its export.

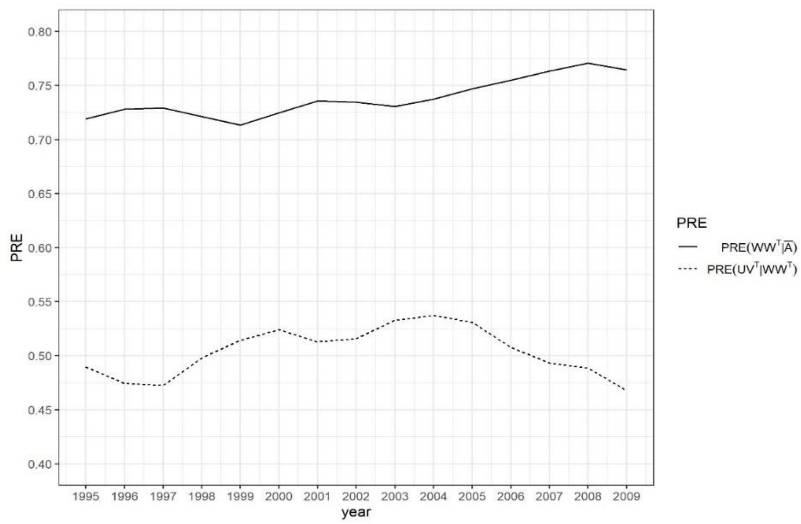
Three salient patterns stand out in Figure 3. First, the relative positions of countries are quite stable, especially those countries that are far away from the origin. Second, many of the Central and Eastern European countries that had belonged to the Eastern Bloc were approaching the 45-degree line during the period 1995-2009 (Poland, Czech Republic, Hungary, Romania, Slovak Republic, Bulgaria, Lithuania, Estonia, and Latvia). They successfully secured their semiperiperal position during this period. Third, China and India were climbing up along the in-coreness ladder while staying at roughly the same points of the out-coreness ladder, and they had remained far away from the 45-degree line by 2009 despite their fast economic growth. China's, and to a lesser extent India's, role of supplying labor time to other countries hadn't changed by 2009. In addition, the world-system position measure ($v - u$) for each country in 2009 is strongly correlated with that in 1995 (Pearson correlation coefficient 0.939), indicating that the hierarchy of countries is stable for 1995-2009.

Figure 3. The evolution of the network structure of international labor time flows in the *u*-*v* space, 1995-2009



However, there is a sign that the asymmetry of international labor time flows has been alleviated slightly. Figure 4 shows two PRE measures $PRE(WW^T|\bar{A})$ and $PRE(UV^T|WW^T)$. The symmetric measure $PRE(WW^T|\bar{A})$ increased from 0.7192 in 1995 to 0.7707 in 2008, and then dropped a bit to 0.7646 in 2009. It implies that the international labor time flows had become more symmetric during 1995–2009. However, most of the increase in $PRE(WW^T|\bar{A})$ occurred after 2003. Furthermore, the asymmetric measure $PRE(UV^T|WW^T)$ rose from 0.4896 in 1995 to 0.5328 in 2003, suggesting that there was no improvement in reducing the asymmetry of labor time flows during 1995–2003. The improvement that occurred after 2003 could be attributed to the fact that many of the Central and Eastern European countries consolidated their semiperipheral position during that period and that China and India kept ameliorating their disadvantaged status within the peripheral zone. Whether this improvement continued after 2009 and whether this improvement would translate into instability and interstate conflicts are the questions worth investigating in the future.

Figure 4. The evolution of the asymmetry of the international labor time flows, 1995–2009. $PRE(WW^T|\bar{A})$ measures how well the symmetric structure WW^T fits the logged labor time flow network A. $PRE(UV^T|WW^T)$ measures the performance of the asymmetric structure UV^T in accounting for the error that WW^T fails to explain.



In a nutshell, there was a slight decrease in the asymmetry of the international labor time flows for the 40 economies during 2003-2009, but the core/periphery hierarchy of the capitalist world-economy in large part remained unaltered by 2009.

Regression Analysis: The Income of Countries and Labor Time Flows

Command over Global Labor Time and the "Oligarchic Wealth" Hypothesis

To begin, I briefly motivate two hypotheses for regression analysis, to further our understanding of the findings on the network of international labor time flows documented in the preceding section. The first hypothesis simply states that a country's income per capita positively correlates with my world-system position measure ($v – u$). As Arrighi and Drangel (1986) contend, the income of a country represents its command over global economic resources. Since labor is an important economic resource, it is expected that the income of a country is closely associated with labor time in- and out-flows. This relationship is evident in Figure 2. I will examine this relationship formally through regression analysis.

The second seeks to test the hypothesis of "oligarchic wealth," which defines the struggle of countries to obtain core positions as a zero-sum game. Arrighi (1990) and Arrighi et al. (2003) borrow Harrod's (1958) concept of "oligarchic wealth" in contrast to "democratic wealth" to explain the impossibility that all states in the capitalist world system simultaneously achieve economic advance or attain the status of core states.

> Democratic wealth is the kind of command over resources that, in principle, all can attain in direct relation to the intensity and efficiency of their efforts. Oligarchic wealth, in contrast, bears no relation to the intensity and efficiency of its recipients' efforts, and is never available to all because generalized attempts to attain it raise costs and reduce benefits for all actors involved. (Arrighi et al. 2003: 19)

There are two reasons for the zero-sum property of oligarchic wealth: first, we cannot all command services and products that embody the time and effort of more than one person of average efficiency; second, some resources are scarce in an absolute or relative sense or are subject to congestion or crowding through extensive use (Arrighi 1990). The wealth of core states is, in this sense, oligarchic wealth that cannot be generalized to all states, since it is based on appropriation of surplus from the rest of world. Therefore, the struggle of a country to improve its position in the capitalist world-economy (i.e., to attain oligarchic wealth or capture a larger share of surplus produced within commodity chains) tends to reduce the chance of upward mobility, or even squeeze the wealth (or income), of other countries. In essence, not every country can occupy the throne at the center of a network! I refer to this fallacy of composition as the "oligarchic wealth" hypothesis.

Arrighi (1990) and Arrighi et al. (2003) do not test this hypothesis but rather use the concept to explain the failure of Third World countries to converge to core states through industrialization. It might be difficult to test this hypothesis directly. However, the network of international labor time flows corresponds to the first reason for oligarchic wealth: that a state increases its command over foreign labor relative to its exported labor necessarily means that some other states have to reduce their imported labor relative to their exported labor. It is true that capital intensity, labor skills and other factors are encoded in the international labor time flows, and critically determine the economic performance (e.g., income per capita). Those factors not only affect the amount of product per labor hour, but also influence the capability of a country to capture surplus produced within commodity chains. The crucial point here is that the capability of a country to capture surplus is also influenced by other countries' efforts to improve their world-system positions. Therefore, the "oligarchic wealth" hypothesis predicts that the relationship between the income of a country and the labor time flows remains statistically significant even if we control for capital intensity, labor skills, and other standard variables.

It is worth noting that the possibility of "oligarchic wealth" has also been recognized by leading trade theorists. For example, in modelling Vernon's (1966) product cycle theory, Krugman (1979) postulates an innovating North country and a non-innovating South country, and investigates the different effects of innovations and technology transfer on the world distribution of income. He demonstrates that "higher Northern per capita income depends on the quasi rents from the Northern monopoly of new products, so that North must continually innovate not only to maintain its relative position but even to maintain its real income in absolute terms" (1979: 253). Otherwise, technology transfer from North to South—in other words, the process in which the South country struggles to capture a larger share of surplus—would dissipate the Northern quasi rents and decrease its real income.

Regression Analysis

Dependent variable. *GDP per capita, PPP (base 10 logged).* I use GDP per capita (PPP) to measure the income of each country. Arrighi and Drangel (1986) use GNP per capita to measure income. However, in order to capture the notion that a state encloses *within its jurisdiction* a mix of core and peripheral activities, I decide to use GDP per capita, which is measured in the purchasing power parity to represent command over resources.

Independent variables are as follows:

World-system Position (v – u), derived from the network of international labor time flows. The combination of in-coreness and out-coreness is a two-dimensional representation of a country's position in the network. To ensure simplicity, I shall use the difference between in-coreness and out-coreness ($v - u$) as a proxy for a country's position relative to the world average.

Capital intensity (base 10 logged). Capital intensity is measured as the ratio of capital stock to employment. Chase-Dunn (1998) argues that it is the defining indicator of core/peripheral activities.

Schooling years (25+). It is the average years of schooling in the population aged 25 years and older. This variable is a proxy for skill levels. Chase-Dunn (1998) argues that core activities employ relatively skilled, relatively highly paid labor. This variable is also a standard human capital indicator in accounting for economic growth (Barro 2013).

Trade openness. It is measured as the sum of import and export as a percentage of GDP. Open trade may exploit a country's comparative advantage and induce technology diffusion. In addition, trade facilitates the exchange of labor. Hence it is necessary to include trade openness as a control variable to avoid estimation bias. Mahutga and Smith (2011) control for this variable when using their measure of the world-system position to explain economic growth.

Trade Deficit. It is measured as the difference between import and export as a percentage of GDP. An increasing trade deficit may imply a worsening economic performance but lead to an improvement of the position on the labor time network. Hence it is necessary to control for this variable to avoid estimation bias.

Employment to population ratio, age 15 or older (base 10 logged). This variable accounts for the labor market conditions and reflect the fluctuations in aggregate demand (Leon 1981). It is also expected that for two countries with the same labor productivity, the country with a higher employment to population ratio has a higher GDP per capita.

Urban population, as a percentage of total population. This indicator reflects a country's economic structure. Many developing countries have a dual-economy structure. Lewis (1954) argues that as surplus labor from the subsistence sector (e.g., the agricultural sector) is absorbed into the capitalist sector, economic growth will ensue. In history, urbanization and industrialization were in essence synonymous (Todaro and Smith 2015: 357).

Descriptive statistics and data sources are provided by Table A1 and A2 respectively in the appendix.

Estimators. To test the hypothesis that the income of a country represents its command over global labor time, a cross-sectional OLS regression for any year will suffice. To support the "oligarchic wealth" hypothesis, we must expect that the climb on the network of international labor time flows (which necessarily means that the network positions of some other countries fall) will lead to an increase in income, net of the effects of capital intensity, labor skills, and other factors that may affect the amount of products produced by one labor hour. Hence, the fixed effects estimator is appropriate. Additionally, following the insights of the "oligarchic wealth" hypothesis, I run the fixed-effects two-stage least squares estimator (FE2SLS) to check robustness and avoid potential endogeneity problems. Specifically, a country's world-system position ($v - u$) is instrumented by the labor-time-inflow-weighted averages of *log Capital Intensity* and *Schooling Years* of all other countries.[8] The intuition is straightforward. *Ceteris paribus*, a country's world-system position ($v - u$) will deteriorate and thus have a lower income when other countries enhance their relative capabilities to claim surplus through accumulating physical capital and improving labor skills.

Regression Results

Table 5 reports the regression results. Model 1 is a cross-sectional OLS regression of log GDP per capita on the world-system position measure ($v - u$) for a single year 2005. The significant and positive coefficient of ($v - u$) and the large R^2 (0.824) suggest that the per capita income of a country does represent its command over global labor time.[9] Model 2 adds other independent variables that may influence the level of income. The coefficient of the world-system position

[8] Suppose $(v - u)_{it}$ represents the world-system position of country i in year t, then the instruments for it are $\sum_{j\neq i}\frac{L_{ji}^{1995}}{\sum_{j\neq i}L_{ji}^{1995}}log\ Capital\ Intensity_{jt}$ and $\sum_{j\neq i}\frac{L_{ji}^{1995}}{\sum_{j\neq i}L_{ji}^{1995}}Schooling\ Years_{jt}$, where L_{ji}^{1995} is the labor time flow from country j to country i in 1995. Therefore, the weights reflect the different structure of labor time inflows of each country, and the weights are time-invariant, which minimizes the possibility that the weights are endogenous.

[9] I also experiment with the OLS regression of $\log_{10}$(GDP per capita) on $\log_{10}$(total imported labor/total exported labor) for each year in 1995-2009. It turns out that my position measure ($v - u$) generates a higher R^2 than $\log_{10}$(total imported labor/total exported labor) for 13 out of the 15 years. It indicates that my position measure can better capture the structural pattern of the network than the aggregates. Moreover, it suggests that my position measure has minimized the confounding effect of an economy's size.

decreases from 5.990 in Model 1 to 3.621 in Model 2, but it is still statistically significant at the 0.1% level. Therefore, although the capital intensity, schooling years, and other variables that may affect the amount of product per labor hour absorb part of the effect of the world-system position, the position measure (*v* – *u*) still retains its explanatory power. It indicates that the world-system position captures some aspects of the capability of a country to claim surplus produced within commodity chains, which cannot be accounted for by the standard explanatory variables.

Table 5. Regressions of log GDP per capita (PPP) on select independent variables

	OLS for 2005		Fixed Effects Model		FE2SLS	
	1	2	3	4	5	6
World-system Position *(v – u)*	5.990***	3.621***	2.896***	2.748***	4.464**	4.132**
	(0.469)	(0.584)	(0.461)	(0.372)	(1.524)	(1.468)
log Capital Intensity		0.264**		0.509***	0.401**	0.422**
		(0.0830)		(0.110)	(0.137)	(0.131)
Schooling Years		0.0114*		0.0405**	0.0361*	0.0369*
		(0.00478)		(0.0129)	(0.0164)	(0.0154)
Trade Openness		0.000448*		0.000270	0.000345	0.000330
		(0.000187)		(0.000151)	(0.000246)	(0.000225)
Trade Deficit		-0.00731***		-0.00288**	-0.00466**	-0.00432**
		(0.00170)		(0.000938)	(0.00148)	(0.00141)
log Employment-Population Ratio		0.142		0.634***	0.583***	0.593***
		(0.172)		(0.134)	(0.156)	(0.149)
Urban Population		0.00125		-0.00274	-0.000216	-0.000704
		(0.000915)		(0.00205)	(0.00308)	(0.00300)
Year Effects	-	-	yes	yes	yes	yes
Constant	4.383***	2.479***	4.260***	0.270	-	-
	(0.0186)	(0.595)	(0.00579)	(0.726)		
Number of Observations	40	40	600	600	600	600
R^2	0.824	0.970	0.822	0.901	0.877	0.886
Kleibergen-Paap rk Wald F statistic	-	-	-	-	10.12	5.13
p-value Hansen J test	-	-	-	-	-	0.1123

Notes: Unstandardized coefficients are reported. Model 1 and Model 2 are the OLS regressions for the single year 2005, and the robust standard errors are reported in parentheses. Model 3 and Model 4 are the fixed effects regressions for 1995-2009, and the cluster-robust standard errors are reported in parentheses. Model 5 and Model 6 are the fixed-effects two-stage least squares regressions for 1995-2009, and the robust standard errors clustered by country with small-sample corrections are reported in parentheses. In Model 5, the excluded instrument for *(v – u)* is the weighted average of *log Capital Intensity* of all other countries. In Model 6, the excluded instruments for *(v – u)* are the weighted averages of *log Capital Intensity* and *Schooling Years* of all other countries. The weights are this country's labor time inflows from each of all other countries in 1995. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The fixed effects model allows us to assess how the improvement in the world-system position is related to GDP per capita. It eliminates the unobservable time-invariant characteristics of countries that may potentially cause estimation bias, such as the institutional and geographical factors. Model 3 and Model 4 also add the year effects to account for the influence of aggregate economic trends. The coefficient of the world-system position is 2.896 in Model 3, and it decreases only a bit to 2.748 when controlling for other variables in Model 4. Those results suggest that the improvement of the world-system position is positively associated with an increase in income, net of the effects of capital intensity, schooling years, trade conditions, labor market conditions, etc.

The fixed effects model may still produce biased estimations due to the correlation between the world-system position and the time-variant factors in the error term. For example, if there is a general rise in work intensity in a country, then this country will, *ceteris paribus*, have a higher GDP per capita and probably a higher world-system position ($v-u$) because less labor hours are embodied in each unit of its product. In this situation, the resultant estimation bias for the coefficient of ($v-u$) in the fixed effects model would be upward. However, if a country tries to boost labor-intensive exports, it may *ceteris paribus* obtain a temporary rise in income and a lower ($v-u$), implying a downward estimation bias. Therefore, there might exist some endogeneity problems in the fixed effects model and the direction of the estimation bias is indeterminate.

The fixed-effects two-stage least squares estimator can potentially lessen the endogeneity concern. In Model 5, the instrument for $(v-u)_{it}$ is the labor-time-inflow-weighted average of *log Capital Intensity* of all other countries, i.e., $\sum_{j\neq i}\frac{L_{ji}^{1995}}{\sum_{j\neq i}L_{ji}^{1995}} log\ Capital\ Intensity_{jt}$. In Model 6, the instruments are the weighted averages of *log Capital Intensity* and *Schooling Years,* i.e., $\sum_{j\neq i}\frac{L_{ji}^{1995}}{\sum_{j\neq i}L_{ji}^{1995}} log\ Capital\ Intensity_{jt}$ and $\sum_{j\neq i}\frac{L_{ji}^{1995}}{\sum_{j\neq i}L_{ji}^{1995}} Schooling\ Years_{jt}$. The interpretation is clear-cut—the efforts of other countries to strengthen their capabilities of claiming surplus within commodity chains will influence this country's relative world-system position ($v-u$), and thus indirectly influence this country's income. The Kleibergen-Paap rk Wald F statistic in Model 5 is larger than 10, suggesting that the estimation doesn't have the weak-instruments problem (Andrews, Stock, and Sun 2019). The estimated coefficient of ($v-u$) in Model 5 is still statistically significant at the 1% level and has a larger magnitude than in Model 4. The Kleibergen-Paap rk Wald F statistic in Model 6 is only 5.13, and thus the estimation might suffer from the weak-instruments problem. It is caused by the fact that the weighted average of schooling years is not statistically associated with ($v-u$) in the first-stage regression, indicating that labor skills might be less important in determining the capability of claiming surplus than physical capital. Nonetheless, the estimation results of Model 5 and Model 6 are nearly identical.

Model 1 clearly validates the statement that the income of a country represents its command over global labor time. Models 2-6 conclude that the measure of the world-system position derived from the network of international labor time flows explains an essential part of a country's income that cannot be accounted for by the standard variables related to labor productivity. An interpretation of the results of Models 3-6 is that as a country strives to elevate its position in the world-economy by capturing more value with less labor within global commodity chains, it would have a higher per capita income, which is consistent with the upgrading literature (Brewer 2011). However, a world-system interpretation is that when a country's position falls as a result of the struggles of other countries to improve their positions in the world-economy, it would have difficulty in maintaining its income level, which is consistent with the oligarchic wealth hypothesis.

Conclusion

Has the core/periphery hierarchy of the capitalist world-economy changed in the current globalization era? The answer of this paper is no, at least for the period 1995-2009.

This paper speaks to the world-systems literature that empirically examines the core/periphery hierarchical structure of the world-economy. The critical review of the literature shows that there is a confusion between a country's position in relation to the inter-state system and a country's position in relation to the international division of labor. A close examination of the network selection (e.g., the trade networks) and the network analytical tools (e.g., the REGE algorithm) leads to the conclusion that the absolute size of an economy blurs the demarcation of core, semiperiphery and periphery in the past studies.

On the basis of theoretical and methodological considerations, I argue that the network of international labor time flows can reveal the core/periphery hierarchy in relation to the international division of labor. By deriving and analyzing the network of international labor time flows of forty economies for 1995-2009, I find that the core/periphery structure of the capitalist world-economy has in large part remained intact. Like prior studies, large wealthy countries are found to be in the core: the United States, Germany, the United Kingdom, France, Italy, etc. These are the countries that consume large chunks of foreign labor time. A notable difference is that China, India, Indonesia, and Brazil are placed in the periphery. These countries are often classified as core-contenders/upper-tier semiperipheral states (e.g., Mahutga and Smith 2011) or core states (e.g., Clark and Beckfield 2009). Without doubt, the studies that focus on multiple commodity trade networks have provided seminal insights on the international division of labor (e.g., Mahutga and Smith 2011; Prell et al. 2014). However, they likely have overstated the weight of core activities in the mix of core and peripheral activities for the populous countries such as China and India. After all, it is intuitively surprising that a country relying on cheap labor occupies the upper end of the international division of labor.

Through regression analysis, I confirm that the (per capita) income of a country is closely and positively associated with its command over global labor time. The analysis also lends credence to the oligarchic wealth hypothesis, since the positive association between a country's position in the hierarchy and its (per capita) income remains statistically significant, even if standard explanatory variables that might affect labor productivity are controlled for. It appears that the struggle of a country to improve its position in the capitalist world-economy (i.e., to attain oligarchic wealth or capture a larger share of surplus within commodity chains) tends to reduce the chance of upward mobility, or even squeeze the income, of other countries. In a word, these findings are consistent with Arrighi's theoretical insights (Arrighi and Drangel 1986; Arrighi 1990; Arrighi et al. 2003).

Although advanced countries stayed in the core, and poor but populous countries (notably, China, India, and Indonesia) stayed in the periphery through the period 1995-2009 as shown in Figure 3, there is an indication that the international labor time flows were becoming more symmetric for the period 2003-2009. It was driven by the fact that many of the Central and Eastern

European countries consolidated their semiperipheral position during that period, and that China and India kept alleviating their disadvantaged status within the peripheral zone.

Some questions naturally arise: what are the consequences if China and India with such large populations continued rising after 2009 and eventually get into the semiperiphery? If the oligarchic wealth hypothesis is true, will the notable rise of China deprive other peripheral and semiperipheral countries of upward mobility in the world-economy? Will the competitive pressures in the semiperiphery translate into interstate conflicts and inter-class conflicts? What does it imply for the stability of the capitalist world-economy? Will the logic of the capitalist world-economy be transformed so that we will have a more equal world-system? Those questions cannot be asked when China and India are already designated as core-contenders or core countries. It is also true that those questions cannot be addressed without extending the sample of countries and the period length of this study. Hopefully, this study lays down the theoretical and methodological foundation for extending the analysis when more data are available.

It must be acknowledged that the principal actors in this study are states, and thus the lack of explicit treatments of the intra-state regional hierarchy and more importantly, class relations, might invite criticism. As Ross and Trachte contend, the primary units of analysis for political economy should be the concrete experiences of classes and parts of classes (1990: 58). This study by no means denies the centrality of class in political economy. Instead, I see this study as complementary to the concrete class analysis at the national and international levels. Radical left writers have long recognized the constraints on class struggles imposed by the differentiated world-system position of each state, such as the issue of labor aristocracy in Lenin's (1999) famous discussion of imperialism, the revolutionary potential of semiperipheral areas (Chase-Dunn 1998: 339-342), and the resistance of the workers and peoples in the global South against imperialism (Foster 2019). The close scrutiny of international labor time flows opens the possibility of critically examining different social structures of capital accumulation and different forms of class antagonism, which are conditioned by or interact with world-system positions. The full and detailed investigation of these topics is reserved for future research.

Appendix 1. Included Countries and Their ISO Three-Letter Abbreviations

The included countries, ordered by their ISO three-letter abbreviations, are listed below:
AUS: Australia, AUT: Austria, BEL: Belgium, BGR: Bulgaria, BRA: Brazil, CAN: Canada, CHN: China, CYP: Cyprus, CZE: Czech Republic, DEU: Germany, DNK: Denmark, ESP: Spain, EST: Estonia, FIN: Finland, FRA: France, GBR: United Kingdom, GRC: Greece, HUN: Hungary, IDN: Indonesia, IND: India, IRL: Ireland, ITA: Italy, JPN: Japan, KOR: Korea, Republic of, LTU: Lithuania, LUX: Luxembourg, LVA: Latvia, MEX: Mexico, MLT: Malta, NLD: Netherlands, POL: Poland, PRT: Portugal, ROU: Romania, RUS: Russia, SVK: Slovak Republic, SVN: Slovenia, SWE: Sweden, TUR: Turkey, TWN: Taiwan, USA: United States.

Appendix 2. Descriptive Statistics and Data Sources

Table A1. Descriptive statistics of variables

	Mean	St. Deviation	Minimum	Maximum
Dependent Variable				
log GDP per capita (base 10)	4.358	.289	3.345	4.991
Independent Variables				
World-system position *(v – u)*	.002	.041	-.13	.064
log Capital Intensity (base 10)	5.335	.317	4.164	5.714
Schooling Years	10.061	2.202	3.513	13.364
Trade Openness (%)	84.843	52.81	15.636	343.562
Trade Deficit (%)	-.402	7.249	-33.271	20.682
log Employment-Population ratio (base 10)	1.735	.052	1.587	1.883
Urban Population (% of total population)	70.461	14.288	26.607	97.603

Notes: Number of countries = 40; Number of years = 15 (1995–2009); Number of observations = 600.

Table A2. Variable Measurement and Source

Variable	Measurement	Source
World-system Position derived from the network of international labor time flows	First, derive the network of international labor time flows. Then, find the in-coreness vector and out-coreness vector. Finally, use the difference between in-coreness and out-coreness as a proxy for the world-system position.	World Input-Output Database
GDP per capita, PPP	GDP per capita, PPP (constant 2011 international $), logged with the base 10 logarithm.	The data for all countries except Taiwan come from World Development Indicators Database. I obtain Taiwan's 2011 GDP per capita (PPP) from World Bank's international comparison program (ICP) 2011. Then I obtain Taiwan's annual growth rates of real GDP per capita using the data from the UNCTAD. Finally, I apply those growth rates to Taiwan's 2011 GDP per capita (PPP) to obtain its GDP per capita (PPP) for each year in 1995–2009.
Capital intensity	Capital stock/employment, logged with the base 10 logarithm. Capital stock at constant 2011 national prices (in mil. 2011US$); Employment: Number of persons engaged (in millions)	Penn World Table, version 9.1
Schooling years	Average years of schooling in the population aged 25 years	Penn World Table, Labor detail.
Trade Openness & Trade Deficit	(Import + Export)/GDP; (Import – Export)/GDP	World Development Indicators; Taiwan's data are from the UNCTAD.
Employment to population ratio	Employment to population ratio, 15+, total (%) (modeled ILO estimate)	World Development Indicators; Taiwan's data are from the ILO.
Urban population	Urban population as a percentage of total population.	World Development Indicators; Taiwan's data are from the UNCTAD.
Population	Total population	World Development Indicators; Taiwan's data are from the UNCTAD.

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Acknowledgements: I would like to thank Rudi von Arnim, Minqi Li, and anonymous reviewers for their valuable comments and suggestions. When studying in the economics Ph.D. program at the University of Utah, I received financial supports from the Economics Department, University of Utah and from the China Scholarship Council.

Disclosure Statement: Any conflicts of interest are reported in the acknowledgments section of the article's text. Otherwise, authors have indicated that they have no conflict of interests upon submission of the article to the journal.

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