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Chapter 4

INTERNATIONAL TRADE IN FUEL COMMODITIES: A NETWORK APPROACH

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Much as the contemporary understanding of world trade is often based on simple models where two countries engage in trade, so is world trade in fuel commodities typically conceived as consisting of either net-importing or net-exporting countries. However, by paying attention to the structure of world trade, represented by actually occurring trade flows between the actors in such networks, it becomes evident that the structures of such networks are far more complex than intuitively understood. In this chapter, role-analytical tools from social network analysis are applied to bilateral fuel commodity trade flows between 85 countries. Using a novel heuristic for identifying ties between role-equivalent sets of actors, this chapter maps the structure of fuel commodity trade by looking at both the value of such trade flows as well as the non-monetary energy dimension of such flows. Comparing these structural maps with a typological Galtung-style core-periphery structure shows significant similarities, although at a resolution that reveals the existence of 6-8 different roles, expanding the simple, intuitive distinction between net-importers and net-exporters.

INTRODUCTION

Three months after two airliners crashed into the World Trade Center in New York, Michael Klare wrote the introduction to *Resource Wars* (2002), correctly predicting that "Washington will take other steps to bolster its position in the Gulf, including the initiation of a new drive to oust Saddam Hussein." (ibid.:xi). In line with the theme of Klare's book, the reason behind such a positional bolstering in the Gulf is the scramble for control over natural resources scattered across the globe, a scramble which constitutes, as the book's subtitle says, "the new landscape of global conflict".

Whether Klare turns out to be correct or not in the long run is perhaps too early to say. However, the "non-negotiability" of certain lifestyles that imply the consumption of large volumes of natural resources, especially energy, is not merely a proviso from George Bush Sr. when signing the Convention on Climate Change, but an active ingredient in national policy guidelines across the world. In the writings of the PNAC think-tank, one of the suggested policies for securing continued US prosperity is concerned with keeping markets open and non-monopolistic, with force if necessary, analogously to domestic anti-trust legislation within USA:

> A concerted national trade and security policy to prevent monopolistic collusion by foreign energy producers, especially in crude oil--and thus to restore more U.S. energy independence. Since collusion is not tolerated in any domestic industry, why must we tolerate collusion abroad against a vital U.S. interest, especially by oil-producing countries whose political existence depends to a large extent on U.S. military power? (Lehrman 2003:29)

While the PNAC writings did not officially represent the government doctrine of George Bush Jr., a recent speech by Jaqcues Chirac on a visit to the strategic air and maritime base in Landivisiau, Bretagne, hints at a similar shift in military doctrine, from the defense of national territories to a defense of 'vital interests', including natural resources outside the national jurisdiction:

> Our world is constantly changing and searching for new political, economic, demographic and military equilibria. It is characterized by the swift emergence of new poles of power. It is confronted with the appearance of new sources of imbalance, in particular *the sharing of raw materials, the distribution of natural resources*, and changing demographic equilibria. […] [S]afeguarding our *strategic supplies* or the defence of allied countries are, among others, interests

> that must be protected. […] The credible threat of their [nuclear weapons] utilization permanently hangs over those leaders who harbour hostile intentions against us. It is essential for making them see reason and for making them aware of the inordinate cost their actions would entail for themselves and their States. Furthermore, it goes without saying that we always reserve the right to resort to a final warning to mark our determination to safeguard *our vital interests* (Chirac 2006, my italics)[1].

Among the different types of natural resources demanded by human societies, fossil fuels clearly stand out in importance. As the major part of our various transportation systems, and through this our whole economy, is dependent on these resources, and because of their scattered spatial availability, we find very peculiar patterns of trade flows in these commodities. With increasing demand from growing economies, notably China, in combination with growing political tension between regions of extraction vis-à-vis consumption, these trade patterns are most likely to change, unless the contemporary fuel-dependent nations of today, notably USA, interpret such changes as "collusional" and decide to act accordingly.

The aim of this chapter is fairly straightforward: to identify the different roles played by different nations in the network of fuel commodity trade, and to map the exchange structure between these different sets of roles. Although I suppose that most of the readers of this chapter have an intuitive grasp of the countries that are large importers and exporters respectively, the network-analytical tools applied in this chapter allow for role identification at a higher resolution. Instead of a trivial categorization of net exporters and importers of fuel commodities, the role-identification tools applied in this chapter identify 6-8 different role-sets, subsequently mapping the relationships between these different role-sets. Furthermore, the structure of fuel commodity trade is analyzed both from a monetary as well as an energetic perspective, yielding their respective maps of the world's fuel commodity exchange structure.

This chapter analyzes bilateral trade among 85 countries for the period 1995-1999, looking at the four most significant fuel commodities: coal (non-agglomerated), crude oil, motor gasoline, and gas oils. This chapter provides a snapshot of the contemporary structure of fuel trade flows, as transfers of both economic value and energy contents, identifying the different roles played by each country.

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[1] Speech available at http://abolition2000europe.org/index.php?op=ViewArticle&articleId=134&blogId=1

The first section of this chapter will address the monetary side of these resource flows, this section being divided into three steps. After a statistical overview of the used dataset, 85 countries are selected for study based on their coverage of world fuel trade. Followed by a presentation of the notion of regular equivalence, this procedure is applied to the values of traded fuel commodities, thus identifying the different roles played by each country in the exchange structure. Although the identification of these role-sets indeed reflects how we intuitively perceive the distinction between countries that are importers and exporters of fuel commodities, a total of 8 different role-sets are identified in the procedure. We will then proceed with identifying relations between these sets of national economies, applying a novel network-analytical heuristic well suited for networks where the total in- and outflows between actors (countries) differ substantially. Through this, we arrive at a structural map of international trade of these four fuel commodities as measured in their economic exchange values.

The second section of this chapter addresses the physical dimensions of fuel commodity flows. By calculating the energy content of the four different fuel types, an aggregated flow matrix is generated that depicts energy transfers among the selected 85 countries. A role-set identification is then conducted based on this energy flow matrix, followed by an examination of the relations between and within each of these sets, similarly to what was previously done with regards to the exchange-values of these commodity flows. The chapter is rounded off with a concluding discussion of its role-analytical findings.

STATISTICAL DESCRIPTION OF THE DATASET USED

Based on a total of 100 countries, representing more than 95 percent of total world GDP and about 85 percent of total world population, total trade value is divided into the 10 main SITC categories as depicted in Figure 1 below. In relation to capital goods (SITC 7), representing more than 40 percent of the value of total trade, the total value of fuel commodities (SITC 3) trade could seem somewhat irrelevant to the world economy, representing a meager 6.4 percent. However, if we choose to determine the importance of different commodities based on their economic values, we commit the same fallacy as Nordhaus did when he argued that global warming would only have an insignificant effect on the U.S. economy as agriculture only represented about 3 percent of GDP (Daly 1996:63).

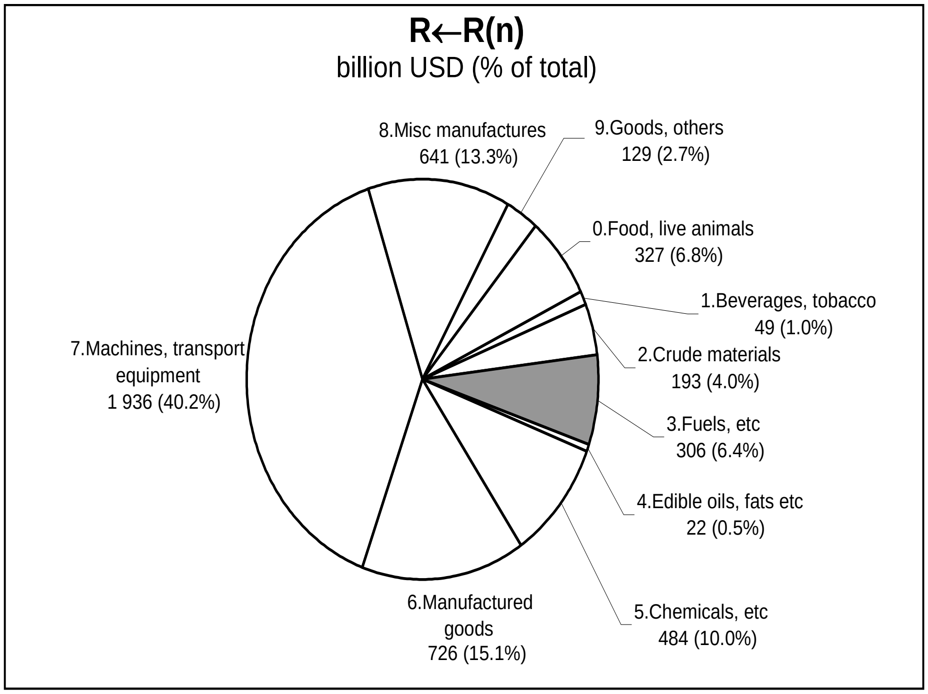

Figure 1. Value and share of total imports among different 1-digit SITC categories for 100 countries. (Data: Comtrade/PC-TAS 1995-1999).

One way of understanding the importance of SITC category 3 for the world economy is to look at political history. After the Yalta conference in 1945, President Roosevelt met with King Abdel-Aziz ibn Saud, allegedly to agree on unlimited access to Saudi oil fields in exchange for the preservation of the Saud dynasty (Klare 2001), and the continued international interest and intervention in the region has no equivalent with regards to other geographic regions rich in strategic natural resources. Although the total value of world imports of cars (SITC 7812) for the whole period 1995-1999 exceeds the corresponding value of crude oil (SITC 3330), valued at 1.2 and 1.0 trillion USD respectively, there has been no similar international interventions in Japan, Trollhättan, or Bavaria in order to safeguard access to the supply of automobiles. The price of fuel commodities is not related to its importance as reflected in geo-political strategies.

Table 1. The set of 85 countries analyzed in this chapter

USA	USA	POL	Poland	LTU	Lithuania
SAU	Saudi Arabia	THA	Thailand	HRV	Croatia
JPN	Japan	ARG	Argentina	EST	Estonia
NOR	Norway	ZAF	South Africa	PAN	Panama
DEU	Germany	DNK	Denmark	TUN	Tunisia
NLD	Netherlands	EGY	Egypt	SVN	Slovenia
GBR	Great Britain	FIN	Finland	BGD	Bangladesh
CAN	Canada	TUR	Turkey	GTM	Guatemala
RUS	Russian Fed.	CHE	Switzerland**	SEN	Senegal
KOR	South Korea	HKG	Hong Kong	PRY	Paraguay
FRA	France	PHL	Philippines	URY	Uruguay
VEN	Venezuela	PRT	Portugal	CYP	Cyprus
NGA	Nigeria	AUT	Austria	YUG	Yugoslavia
SGP	Singapore	CZE	Czech Rep.	GHA	Ghana
AUS	Australia	ECU	Ecuador	NIC	Nicaragua
MEX	Mexico	CHL	Chile	CRI	Costa Rica
KWT	Kuwait	PAK	Pakistan	SLV	El Salvador
BEL	Belgium*	GRC	Greece	AZE	Azerbaijan
IDN	Indonesia	ROM	Romania	SDN	Sudan
ITA	Italy	SVK	Slovakia	KEN	Kenya
CHN	China	BRN	Brunei	NER	Niger
ESP	Spain	HUN	Hungary	ISL	Iceland
DZA	Algeria	NZL	New Zealand	MDA	Moldova Rep.
BRA	Brazil	PER	Peru	BOL	Bolivia
OMN	Oman	IRL	Ireland	MUS	Mauritius
IND	India	BLR	Belarus	LKA	Sri Lanka
MYS	Malaysia	TTO	Trinidad-Tobago	ZWE	Zimbabwe
SWE	Sweden	LVA	Latvia	MDG	Madagascar
COL	Colombia				

* Includes Luxembourg.
** Includes Liechtenstein.

Another way to conceptualize the importance of fuel commodities is to look at traded volumes. While the total tonnage of cars during the period 1995-1999 is set at approximately 120 billion (metric) tons for the set of 100 countries, the corresponding total tonnage of crude oil was almost 70 times as high: approximately 8,200 billion tons of crude oil was transported across the national borders of these 100 countries in the period 1995-1999, a figure not including Iran, the fourth largest exporter of crude oil.[2]

In the analysis that follows, Comtrade import data are used to calculate annual average trade flows in the period 1995-1999. As some countries lack reported imports for one or more of these years, average annual trade flows for the period as a whole are calculated and used throughout this chapter. Each record in the database contains data on the value and quantity of each of these years. While only a few countries report fuel commodity imports in other quantities than metric tonnes, there are countries that completely lack data on traded quantities. In order to reflect the relation between value and quantity as well as possible, reported trade flow records that lack data on quantities are excluded from the analysis that follows.

Of the 100 countries that reported their trade statistics in this period, the analysis in this chapter comprises the 85 countries as listed in Table 1 above. The missing countries are those having a gross value, i.e. the sum of the values of total imports and total exports of the four commodities in question, less than 50 million USD. Israel, although above this threshold, has been removed from the dataset as the source of all their imports of crude oil (valued at 1.3 bn USD) has been categorized as non-specified. Checking Israel's mirror statistics, i.e. reported exports to Israel from other countries, reveals that Norway, Russia, Mexico, Azerbaijan, and South Africa, in decreasing order of importance, are the main sources of crude oil for Israel, albeit still not accounting for all of the non-specified imports reported by Israel.

Although the above 85 countries do indeed cover the vast majority of the contemporary world, both with respect to traded quantities and the population and GDP represented by these countries, it has to be stressed that our analysis of trade structures is concerned with these countries only. Just as we excluded Israel for lacking reported data on the source of their crude oil imports, all reported imports from other countries than the 85 in Table 1 are excluded in our analysis. For instance, all of Jordan's imports of crude oil derive from Iraq as the sole source:

[2] As the quantity unit for crude oil in the Comtrade database usually is metric tonnes, the total sum is calculated by adding all import quantities for the 100 countries that reported their trade statistics to the PC-TAS 1995-1999 dataset. For cars, however, some countries report their trading volumes either in metric tonnes or in number of units (i.e. number of vehicles), and in several cases have no recorded data on imported quantities whatsoever. Thus, in order to calculate an estimate of total traded tonnage of cars, I first calculated the ratio between value and weight for statistical records where the quantities are measured in tonnage. Using this ratio, combined with the total value of imported cars for the period, I arrived at an estimation of total traded tonnage. This estimate thus assumes that the ratio between weight and value is fairly homogenous across the world, or that anomalies from this ratio are spread fairly evenly among countries that import cars.

valued at 340 million USD, Jordan does indeed pass the 50 million USD threshold above. However, as Iraq is not a reporting country itself, these imports are discarded, thus pushing Jordan below the stipulated threshold. It is thus important to stress that our analysis is exclusively concerned with the network of trade among the 85 countries above.

Among the different types of fuel commodities, ranging from coal, peat, natural gas, various liquid fossil fuels, etc., the commodities chosen for this study are the four highest ranking fuel commodities when it comes to total import value. Representing 74 and 77 percent of total SITC 3 value and weight respectively, the sectoral division of these four commodities are given in the pie-charts below (Figure 2). Crude oil dominates the picture, both in value and traded tonnage and, as we shall see, also in concrete energy transfers between the nations of the world.

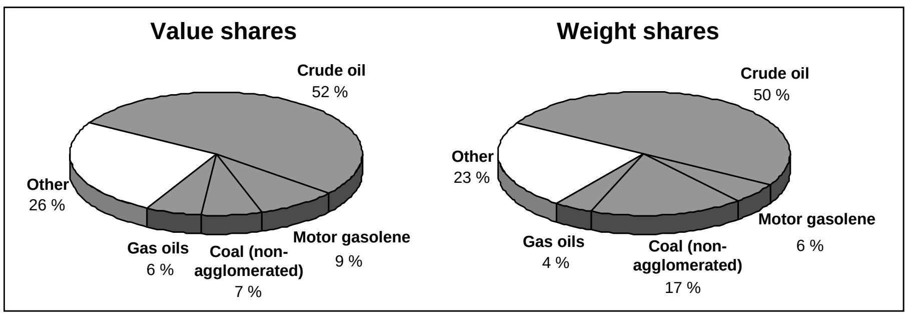

Figure 2. Weight and value shares of selected fuel commodities in relation to total weights and values. (Regarding coal: see note [3])

NETWORK ANALYSIS, STRUCTURAL ROLES, AND REGULAR EQUIVALENCE

Originating from the behavioral sciences, social network analysis is more suitably viewed as a set of tools than as a discipline . The best way to describe network analysis is to start with what it is not:

[3] SITC category 3212 consists of two 5-digit categories: Non-agglomerated bituminous coal (SITC 32121) and Other coal (SITC 32122). The value of total imports during the whole period 1995-1999 amounted to 79.6 bn USD for SITC 32121 and 17.5 bn USD for SITC 32122. For simplicity, we treat the whole SITC 3212 category as consisting of bituminous coal only, thus assuming an energy content as in bituminous coal for both these 5-digit subcategories.

> The network perspective differs in fundamental ways from standard social and behavioral science research and methods. Rather than focusing on attributes of autonomous individual units, the associations among these attributes, or the usefulness of one or more attributes for predicting the level of another attribute, the social network perspective views characteristics of the social units as arising out of structural or relational processes or focuses on properties of the relational systems themselves. […] Relational ties among actors are primary and attributes of actors are secondary. (Wasserman & Faust 1994:7-8)

Social network analysis is thus concerned with relations among social units in a system. What actually constitutes a social unit and a relation depends, of course, on what we are interested in: if we are to study social interactions among students in a class, each student would be an actor and the relation could either be through oral communication, email, telephone calls, or hanging out after school. If we were to study drug trafficking among different suburbs, the suburbs would comprise the actors and the flows of different drugs, syringes, and money could be the relations among the actors. In network-analytical approaches to international trade, nations and bilateral trade flows comprise the actors and relations that we should be interested in: in this study, the network is international trade in fuel commodities, the set of actors are given in Table 1 above, and the relations are aggregated trade flows for four fuel commodities, in their exchange values and energy contents respectively.

One of the major strengths of network analysis is its ability to identify different structural roles played by different actors in a network. For instance, if we were interested in the organization of a firm, we would naturally turn to its organizational chart and check the titles and, possibly, the paychecks of its employees in order to identify the different role-sets comprising workers and executives, and how these different roles relate to each other. Using the role-analytical tools available in network analysis, no such *a priori* organizational charts are needed: instead, the different types of roles, and the categorization of actors as belonging to these role-sets, are based solely on *relational* data, for instance how often each pair of employees talk to each other during the working day. While an organizational chart of a firm could be ideal, typological, or formal, network analysis is more focused on the *de facto* structural roles, allowing for the possibility that the janitor indeed could play a crucial role in the organization while a golf-loving executive could be very peripheral.

Leaving the business organization example behind, we note that Galtung's typological center-periphery structure (Galtung 1971:89) is suitable for explaining two common varieties of role-equivalence: *structural* vis-à-vis *regular* equivalence. Although depicted as a graph in Figure 3, the analysis of networks is often done using corresponding sociomatrices, i.e. data tables where the relations between each pair of actors are coded in matrix-form. In Galtung's example, the relations are binary – they either exist, or they don't – but relations may also be continuous, for instance to indicate the strength of the tie (or, if applicable, the volume of the flow) between each pair of actors.

If two actors are *structurally* equivalent, they have the same set of relations to *the same* actors. For Galtung's structure, this implies that the peripheral actors make up four separate role-sets: while P_{11} and P_{12} both have relations to the same actors (C_1 in this case), they are not part of the same role-set as P_{21} and P_{22} , since the latter two, constituting a role-set of their own, have identical relations to another core actor (C_2). Neither do the core actors form a structurally equivalent role-set, as they have ties to different peripheral actors, in addition to lacking ties to different core actors.

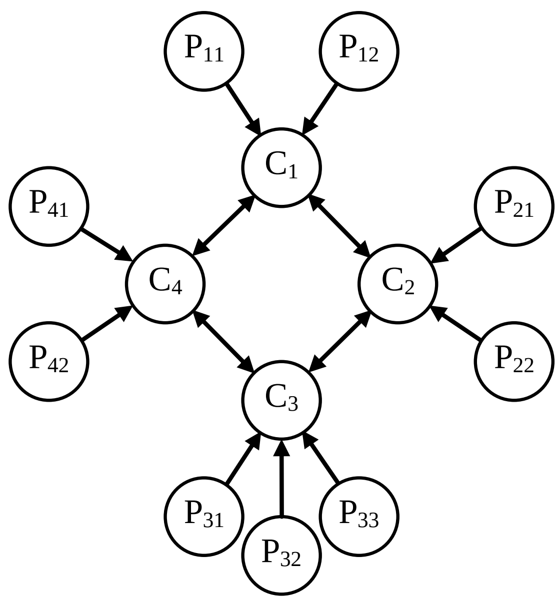

Figure 3. Galtung's 'Feudal center-periphery structure' (modified[4] from Galtung 1971:89).

Regular equivalence, on the contrary, represents a less strict definition of role equivalence. Instead of role-equivalent actors having similar relations to the *same*

[4] In Galtung's original figure, the relationships are non-directed. However, as the concept of regular equivalence only works for directed relations, these have been added for relations between peripheral nodes and core nodes.

actors, regular equivalence instead implies having similar relations to actors which in turn are part of the *same set* of regularly equivalent actors. As this means that there may be several sets of regularly equivalent actors in a network, the model that has the least number of sets is usually the most adequate . When applying the concept of regular equivalence to Galtung's typological structure above, two distinct role-sets emerge which follow the intuitive center-periphery division in the figure.

The REGE algorithm, introduced by White and Reitz (1983, White 1984), is aimed at providing a measure of regular equivalence between pairs of actors in a network. Using a directional sociomatrix as input, this iterative algorithm generates a new matrix containing a measure of the degree of role-equivalence between actors. Based on such equivalence matrices, there are a number of formal methods available to categorize the different actors into different subsets ('positions' in network terminology) of role-equivalent actors. Although we are free to choose the number of actor sets that the network should be split into, there are also a number of methods to establish the most suitable number of sets, which reduce the discrepancies from ideal would-be role-set classifications.[5]

Applying network-analytical concepts, especially the ideas of role-equivalence, to world-system analysis has become something of a cottage industry in recent decades. In Snyder and Kick's article from 1979, the structural equivalence of nations was calculated using relations of trade, conflict, treaty membership, and diplomatic ties, furthermore exploring the relationships between the different sets of role-equivalent nations, i.e world-systemic categories reflecting the trimodal division of core, semi-periphery, and periphery. This "first-cut" study was subsequently followed by others, studies focusing either explicitly on commodity flows (Breiger 1981, Nemeth & Smith 1985, Smith & White 1992, Krempel & Plümper 2003), trade flows in combination with other non-economic relational data (Kick 1987, 1995), monetary flows (Salisbury & Barnett 1999), and studies of international relations other than trade (Barnett 2001, Smith & Timberlake 2001).

From a world-system perspective, trade takes on a special theoretical importance as the flows of material resources can be seen as concrete manifestations of would-be situations of unequal exchange. The notion of unequal exchange in world-systems has thus been extended, or rather transposed, from a matter concerned with net profit transfers, organic compositions of capital, and factor cost differentials, into the realm of ecological economics. In the latter, the

[5] Based on the REGE output, we can test the Anova density (R-square) fit for different numbers of role-sets. This procedure is demonstrated in Luczkovich et al. (2003:310).

notion of unequal exchange is associated with net flows of 'resources' in a non-monetary sense, for instance as measured in unequal exchange of energy, ecological footprints, material mass, and other types of non-monetary units to quantify resources. As this chapter addresses the exchange structure and net flows of fuel commodities only, conclusions cannot be drawn regarding the possible existence of ecological unequal exchange in general. However, it will hopefully tell us something about international trade in these four commodities and the structure of the energy metabolism of the contemporary world-economy.

Although network-analytical approaches to world trade can reveal the underlying structures of global resource transfers, it would be quite adventurous to aim at fully explaining the underlying mechanisms of exchange, equal as well as unequal, solely through such structures. However, network-analytical approaches to international trade structures nevertheless have several important tasks to address. First, the analysis of structures of exchange is relevant for understanding exchange relations, existing and would-be, among agents interacting in exchange with each other. As has been noted in the study of global commodity chains, monopoly situations and bargaining strengths in determining exchange ratios differ between production units in cores vis-à-vis peripheries, zonal categories that often are defined based on their position in a hierarchy, similar to the different interaction possibilities facing core and peripheral actors respectively in Galtung's typological structure (see Figure 3 above). Although mainstream economic theory often is based on a rudimentary setup of two actors, following the tradition of Ricardo, Mill, Marshall, Edgeworth, Heckscher-Ohlin, etc., or simply assuming that each trading partner is free to interact with each and every other trading partner, traces of something that could be called 'structural advantage', as a complement to comparative advantage, can be found in the so-called new economic geography in neo-classical economics (for instance Fujita & Mori 1996), in equilibrium theory (Nagurney 1998), and new trade theory (Krugman 1979). Furthermore, the different elasticities of demand for different products, for instance as manifested in the oft-quoted Prebisch-Singer theorem, can be conceptualized as a phenomenon based on structural advantage in a radial (star-like) network. It is thus not wrong to assume that structures of international exchange are not only shaped by historical particularities and the general development of the historical social system of today, but that the structures *in themselves* also affect the developmental trajectory of the world-system and the possible zonal transfers of national economies participating in global exchange.

Secondly, as has been done in the previous network-analytical studies mentioned above, network-analytical tools are well suited for identifying zonal boundaries of the contemporary world-system (Snyder & Kick 1979, Nemeth &

Smith 1985, Smith & White 1992). That is, instead of using internal attributes to categorize different national economies into core, semi-periphery, and periphery prior to analysis, as is often done in commodity chain analysis (Korzeniewicz & Martin 1992), structural role-analysis makes such a categorization based on *the relations* between the parts (i.e. national economies) making up the system (i.e. the world-system). A network approach thus seems to be in line with the 'sociological definition' of what world-system analysis is all about (Chase-Dunn & Hall 1997:4), i.e. inter-societal relations rather than internal properties (the latter of which indeed might reflect membership in different world-systemic zones but nevertheless are determined by nation-exogenous factors).

ROLE ANALYSIS OF FUEL COMMODITY TRADE: THE MONETARY DIMENSION

Summing the values of each bilateral flow between our set of 85 countries, we arrive at a total flow matrix containing the economic exchange values of our four fuel commodities. After running three iterations of the REGE algorithm on the value flow matrix, an Anova density analysis is conducted (see Luczkovich et al. 2003) to decide on the number of role-sets to split the network into, indicating that it is suitable to divide the 85 nations into eight distinct subsets (or positions, in network terminology). The contents of these eight positions, together with the gross flow and actor mean net flow for each subset, are given in Table 2 below.

Although critical voices have been raised regarding the REGE algorithm's capability for valued (continuous) data (Borgatti & Everett 1991), Table 2 indicates that the results of the algorithm seems to be in accordance with how we intuitively would perceive the different roles in world trade of each fuel commodity. The oil-exporting countries of the Middle East are members of the same role-set (F), together with the other major exporters of crude oil. Australia, whose exports of coal represent 35 percent of all coal exports, is also part of this group. Brunei, however, whose total export value is actually lower than Australia's, has been placed in another position (A), whose countries have a smaller per-nation value outflow of fuel commodities. Except for position (C), which contains a set of minor net exporters of fuel commodity value, the rest of the positions contain net importers of fuel commodities (measured in value), which seems to follow intuitive notions of 'developed' versus 'developing' countries, ranging from the high-income countries in position E, followed by D, B, G, and H in decreasing order of per-nation import volumes of fuel commodities.

Table 2. The value flow matrix split into eight separate positions containing actors which share similar regular-equivalent roles

Position	Countries	Gross positional degree (imports + exports) [kUSD]	Mean actor net flow (imports – exports) / nbrOfActors [kUSD]
A	Algeria, Argentina, Brunei, China, Ecuador, Egypt, Latvia, Malaysia, South Africa	26 250 154	-1 746 485
B	Guatemala, Panama, Peru, Trinidad-Tobago	2 164 119	151 492
C	Azerbaijan, Niger, Tunisia	586 684	-159 509
D	Austria, Belarus, Brazil, Chile, Croatia, Czech Rep., Denmark, Finland, Greece, Hong Kong, Hungary, India, Ireland, Italy, Lithuania, New Zealand, Pakistan, Phillipines, Poland, Portugal, Romania, Slovakia, Spain, Sweden, Switzerland, Thailand, Turkey	51 871 618	1 567 503
E	Belgium, France, Germany, Japan, South Korea, Singapore, USA	134 554 038	15 822 872
F	Australia, Canada, Colombia, Indonesia, Kuwait, Mexico, Netherlands, Nigeria, Norway, Oman, Russia, Saudi Arabia, UK, Venezuela	155 785 261	-10 005 514
G	Bangladesh, Bolivia, Costa Rica, Cyprus, Estonia, Ghana, Iceland, Kenya, Moldova Rep., Nicaragua, Paraguay, Senegal, Slovenia, Sri Lanka, Sudan, Uruguay, Yugoslavia	2 883 877	135 169
H	El Salvador, Madagascar, Mauritius, Zimbabwe	289 569	71 892

How do these sets of regularly equivalent actors, i.e. the positions in Table 2 above, relate to each other? In order to determine this, we first sort the original value flow matrix according to positional membership, i.e. creating a block model of the dataset, consequently looking at the submatrices containing the flow values from the actors in one position to the actors in another position. According to the formal definition, a regular tie from position X to Y exists if every actor in X has at least one significant tie to an actor in Y, and where each actor in Y has at least one significant tie from X. Although the notion of 'significant tie' is rudimentary when dealing with binary (or dichotomous, in network terminology) data, i.e. where a tie between two actors either exists or is non-existent, valued relations such as trade flows do pose a problem when identifying inter- and intra-positional relations. How do we establish what constitutes a 'significant' value flow when the economic and demographic strengths of the countries differ as much as they apparently do? To apply a system-wide cutoff-value in order to dichotomize all trade flows prior to analysis would be to ignore actor-based perspectives on what actually constitutes a significant flow. Although 90 percent of Bangladesh imports of crude oil come from Saudi Arabia, this trade flow only represents a meager 0.2 percent of total Saudi exports of crude oil: to apply a system-wide cutoff value would thus ignore such different notions of what actually constitutes a significant trade flow.

In a recent article (Nordlund 2007), I have developed a heuristic which takes an actor-based perspective on what constitutes significance in valued networks – for instance in networks of world trade. Through a two-step normalization procedure of the original block model, this heuristic defines 'significance' based on each actor's relative in- and outflows, based on total in- and outflows for the actor. Combined with different measures of criteria fulfillment for regular ties, the heuristic seems to be better at identifying relations between and within[6] positions containing regularly equivalent actors when the underlying data is continuous – such as our trade data.

[6] Whether actors are role-equivalent or not, i.e. fulfill the same type of role in a structure, does not automatically imply that role-equivalent actors form a cohesive subgroup of some kind, i.e. that they conduct significant trade with each other. Thus, positional self-ties must also be analyzed in a similar manner as ties between positions: within a position, if each actor has a significant outbound *and* inbound tie to any other actor in the position, a regular self-tie exists.

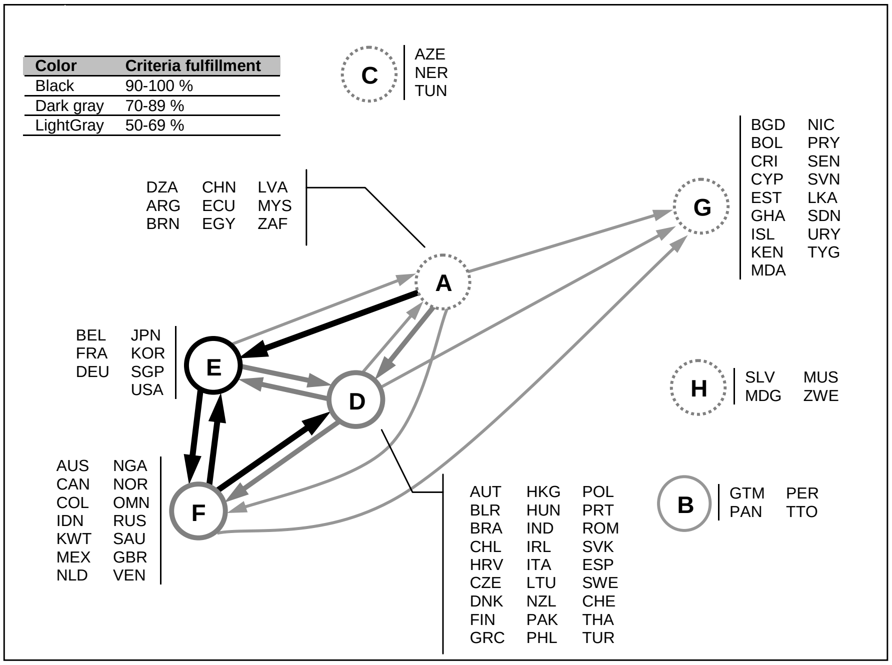

Figure 4. Ties within and between the eight regularly equivalent positions [applying criteria fulfillment formula 1 – see Nordlund (2007)]. (Coordinates established using Gower-style multidimensional scaling on the REGE coefficient matrix.)

Applying this heuristic to our trade value block model, we arrive at the structure in Figure 4 above, depicting the relations between different role-equivalent sets of actors. Using different graphical notation, the different shadings and widths of arrows and positions reflect to what degree a regular tie exists between and within positions. It can be noted that the fuel commodity exports from position F to positions E and D are indeed significant for all these positions. Furthermore, fuel commodity exports from the high-income position E to the fuel-exporting position F is equally significant for both these positions. The countries in E are however not only supplied by the major fossil fuel exporters in position F: there is also a regular tie from the lesser fossil fuel exporting countries in position A. In addition, the countries of position E do indeed form a fairly cohesive subgroup, trading these commodities with each other. The fuel commodity imports of the medium-to-lesser developed countries in position G are somewhat more spread out among different positions; although there is a regular tie from the F exporting countries, this tie is approximately as significant as the ties from D and A respectively. It can be observed that although positions C and

H have no regular ties in this figure, this proves that their trading profiles are not as clear-cut with respect to the other positions, rather than telling us that these countries are isolates. It is thus very important to remember that the arrows in Figure 4 are only indicative of the significance of trade flows as conceived by individual actors. Although these arrows indeed indicate that there are fuel commodities flowing along them, the arrows tell us very little, if anything, about the *absolute* value of such flows.

The absolute values of intra- and inter-positional flows are given in Table 3 below. The largest trade flows between positions, representing more than half of all trade flow values in our dataset, are the fuel commodities going from position F to E. These two positions dominate the picture quite profoundly: while almost four-fifths of all exports of fuel commodities come from the fossil-fuel-endowed actors in position F, three-fifths of all imports have the high-income countries in position E as destination.

An interesting pattern that can be observed both in the structural map (Figure 4) and in Table 3 below is the cohesiveness of the high-income countries of position E: with intra-positional flows at 4.8 billion USD, this represents 29 percent of all fuel commodity exports of the countries in this position. The self-tie of position D is even larger, where 46 percent of all its exports go to other countries within position D. These percentages notwithstanding, the applied heuristic in Figure 4 does indicate that position E is more cohesive than position D, with 93 and 80 percent criteria fulfillment, respectively, for regular self-ties.

Table 3. Fuel commodity trade flow values within and between the eight positions

	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**Out-degree**	**% of total**
A	204	246	1	7 306	10 382	2 498	419	132	21 188	9.9%
B	8	22	0	13	669	46	21	23	801	0.4%
C	0	0	0	245	259	26	2	0	533	0.2%
D	198	4	38	4 041	2 726	1 318	490	1	8 815	4.1%
E	1 803	122	10	5 755	4 837	3 904	281	21	16 734	7.8%
F	3 233	1 012	5	33 698	108 496	18 776	1 379	109	166 707	77.5%
G	24	0	0	80	124	63	6	2	299	0.1%
H	0	0	0	0	0	0	0	14	15	0.0%
Inde-gree	5 470	1 407	54	51 138	127 494	26 630	2 597	303		
% of total	2.5%	0.7%	0.0%	23.8%	59.3%	12.4%	1.2%	0.1%	Sum all flows:	**215 093**

All flow values in million USD. In and outdegrees exclude intra-positional flows.

If we were to apply the regular-tie heuristic on the Galtung typology (Figure 3), the self-tie criteria fulfillment percentage for the core position would be 100 percent, while the corresponding measure for the peripheral position would be zero: the occurrences of regular self-ties could thus, in combination with inter-positional ties, indicate the coreness of positions. With a self-tie criteria fulfillment percentage for position F at 86 percent, it is slightly lower than the self-tie of position E, the latter thus being more core-like in the exchange structure than the set of countries endowed with the resources in question.

ROLE-ANALYSIS OF FUEL COMMODITY TRADE: THE ENERGY DIMENSION

While the four flow matrices containing the values of trade flows were extracted, flow matrices containing the physical quantities of these trade flows of fuel commodities were created. We thus have four flow matrices at our disposal, making it possible to analyze these flows from a physical, non-monetary perspective. Although we could analyze the traded quantities based on their weights, i.e. in essence conducting a material flow analysis of these commodities, I have instead chosen to transform these quantity flow matrices into energy flow matrices.

Table 4. Weight-energy conversion factors and aggregated flows in value, weight, energy

SITC	**Commodity**	**Energy content [GJ/ton]***	**Total value [kUSD]**	**Total weight [tonnes]**	**Total energy flows [PJ] (10^{15} J)**
3212	Oth.coal,not agglomerated	29	19 406 199	410 735 133	11 911
3330	Crude petroleum	44	152 935 261	1 216 423 528	53 523
3341	Motor gasolene, light oil	45	25 641 397	136 584 711	6 146
3343	Gas oils	48	17 804 771	108 937 419	5 229
		Sum:	**215 787 628**	**1 872 680 791**	**76 809**

Source: Oak Ridge National Laboratory (http://bioenergy.ornl.gov/papers/misc/energy_conv.html)

Table 5. The energy flow matrix split into six separate positions containing actors that share similar regular-equivalent roles

Position	Countries	Gross positional degree (imports + exports) [TJ] (10^{18} J)	Mean net flow per actor (imports – exports) / nbrOfActors [TJ] (10^{18} J)
A	Azerbaijan, Latvia, Niger, Tunisia	393 104	-89 859
B	Austria, Belarus, Brazil, Croatia, Cyprus, Czech Rep., Denmark, Finland, Ghana, Greece, Hong Kong, Hungary, India, Ireland, Italy, Lithuania, Pakistan, Philippines, Poland, Portugal, Romania, Slovakia, Spain, Sweden, Switzerland, Thailand, Turkey	18 149 459	569 104
C	Bolivia, El Salvador, Estonia, Iceland, Kenya, Madagascar, Mauritius, Moldova Rep., Nicaragua, Paraguay, Slovenia, Sri Lanka, Sudan, Uruguay	529 828	25 931
D	Belgium, France, Germany, Japan, South Korea, Singapore, USA	47 574 212	5 697 526
E	Algeria, Argentina, Australia, Brunei, Canada, China, Colombia, Ecuador, Egypt, Indonesia, Kuwait, Malaysia, Mexico, Netherlands, Nigeria, Norway, Oman, Russia, South Africa, Saudi Arabia, UK, Venezuela	61 548 920	-2 560 897
F	Bangladesh, Chile, Costa Rica, Guatemala, New Zealand, Panama, Peru, Senegal, Trinidad-Tobago,Yugoslavia, Zimbabwe	1 819 231	98 876

Table 4 provides conversion factors for the different fuel commodities, which are used to convert the traded quantities, measured in tonnes, to the energy content that these flows represent. Coal poses somewhat of a problem in our analysis as the energy content of coal varies depending on its geological point of origin and the type of coal. While the energy content of lignite coal is between 15 and 19 GJ/ton, anthracite and bituminous coal are usually in the range 27-30 GJ/ton, these variations depending on the point of extraction. Our coal category consists mainly of bituminous coal and although it would be possible to adjust coal export quantities depending on exporting country, I have instead chosen to use a global coal conversion factor of 29 GJ/ton.

Table 4 also gives total values, weights, and energy contents for each of the four fuel commodities in this study. Crude oil dominates all three accounting units, representing almost 70 percent of the 76.8 exajoules of the energy represented by these four commodities, while coal, being the cheapest energy source here, represents about 15 percent of total energy flows. Of course, different energy media have different usages – motor vehicles run on gasoline, not coal – but as all these energy commodities bring utility through their incineration, whatever technical form and for whatever purpose, the focus here is on the *de facto* energy transfers manifested in these trade flows.

Let us now repeat the procedure above, establishing the different role-sets for the energy flow matrix for the 85 countries in Table 1. Three iterations of the REGE algorithm on the energy flow matrix, followed by an Anova density check on the REGE coefficient matrix, indicates that 6 distinct role-sets are adequate to categorize each country according to their role-regular equivalence with respect to energy flows. The members of each position are given in Table 5 above.

A visualization of inter- and positional regular ties are to be found in Figure 5 above.

Figure 5 indicates that, in energy terms, the positions E and D do not only exchange significant energy flows with each other but also that flows among the actors in each of these positions are significant. Furthermore, energy flows from E to B are significant, while flows in the opposite direction are less significant. As Figure 5 only depicts regular ties where their definitional criteria is 50 percent or more, flows to and from positions A and C are missing: while their energy imports, mainly from position E, are very significant for A and C, these flows are quite insignificant export flows from the perspective of E, the latter making the criteria fulfillment share fall below 50 percent.[7]

[7] A probable objection towards this conclusion might be that the countries in positions C and A are small economies and fairly few. However, the heuristic applied here (Nordlund 2006) does take an actor-based perspective on what constitutes significance: what is relevant in this heuristic is not the

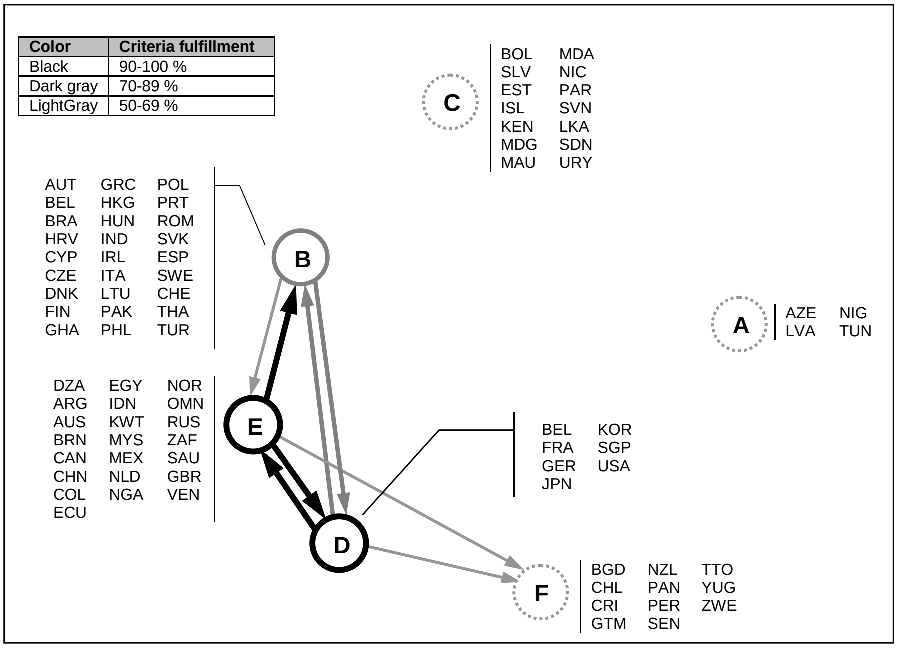

Figure 5. Ties within and between the six regularly equivalent positions.

Total intra- and inter-positional energy flows are to be found in Table 6 below. Similar to the value flows (Table 3 above), the majority (77 percent) of all energy outflows originate from the fossil-fuel-endowed countries (position E), while a similar majority (57 percent) of all energy inflows go to a small number of high-income countries (position D). Along the diagonal in Table 6, it can further be noted that energy flows from the countries in position B are most likely to end up in another country in this position. This, and the strong self-ties of the D and E positions, do indeed resemble a typological core, once again similar to Galtung's typology.

absolute flow volumes, but flows, inbound and outbound, as related to the total flows of each actor. If we instead looked at row-regular and column-regular ties respectively (see Doreian et al. 2005), instead of (fully) regular ties, this would reveal what constitutes significant in- and outflows respectively.

Table 6. Fuel commodity energy flows within and between the six positions

	A	**B**	**C**	**D**	**E**	**F**	**Out-degree**	**% of total**
A	0	145	1	121	110	0	376	0.5%
B	10	1 367	108	824	423	27	1 392	1.8%
C	0	21	7	34	26	2	83	0.1%
D	2	1 760	16	1 527	1 956	112	3 846	5.0%
E	5	14 824	308	42 494	8 507	1 314	58 944	77.1%
F	0	8	13	256	89	19	366	0.5%
Indegree	17	16 758	446	43 728	2 605	1 453		
% of total	0.0%	21.9%	0.6%	57.2%	3.4%	1.9%	Sum all flows:	**76 435**

All flow values in PetaJoules (10^{15}J). In and outdegrees exclude intra-positional flows.

As the members of position D in the energy flow structure are identical to the members of position E in the value flow structure, it is possible to compare the import-export profile of energy and values for these actors. While the import shares of energy and value for the position are fairly similar – 59.3 and 57.2 percent of total inflows of value and energy respectively – the export shares from this position differ somewhat. While the outflow of fuel commodities from these high-income countries represents 7.8 percent of total value outflows, the energy content of these exports represents only 5.0 percent of total energy outflows. In other words, the high-income countries pay 2.9 million USD for each petajoule imported, while receiving 4.4 million USD for each petajoule exported, in effect earning 1.44 USD for every gigajoule that passes through this position. “Profits” such as these, however, are most probably due to the different commodity compositions of imports and exports, i.e. different price-energy ratios for different types of fuel commodities, and not due to any collusions on behalf of these high-income countries.[8]

[8] Although not presented in this chapter, a study of energy/price ratios between imports and exports for each country revealed wide variations between different countries. With a mean energy price at 2.7 USD per GigaJoule, Azerbaijan tops the price list, paying more than 12 USD for each imported GigaJoule, contrasted by Zimbabwe, which only pays about 50 cents for each GigaJoule. Looking at exports, El Salvador receives 5.6 USD for each GigaJoule exported, while Poland only receives 1.5 USD per exported GigaJoule.

CONCLUSIONS

Using the network-analytical concept of regular equivalence, together with a heuristic for identifying structural relations between role-equivalent actors, this chapter has attempted to map the structure of the fuel commodity trade of the world. Although the trade data only covers 85 countries, excluding highly relevant countries such as Iran and Iraq, the resulting structural mappings nevertheless point to a number of findings.

First, by applying role-analytical methods from social network analysis, we can enhance the resolution of structural roles in the network of fuel commodity trade. While we might have an intuitive idea regarding countries which are either net-importers or net-exporters of fuel commodities, the analysis here reveals more kinds of role-types that stretches beyond a simple distinction between exporters and importers of fuel commodities.

Secondly, the results obtained here seem to indicate that role-equivalent 'developed' countries, although not being endowed with fossil fuel resources, do form cohesive groups as they trade fuel commodities with each other. This is in line with the results and hypotheses from studies of global commodity chains, and also reflect the different structural advantages of cores vis-à-vis peripheries as depicted in Galtung's typology. The nations that are members of a core-like position thus seem to interact with each other to a greater extent than nations sharing a peripheral position; this intra-core (high-income) trade thus reflects transactional freedom as is assumed in mainstream economic exchange theory. Nations that share a similar peripheral role in the exchange structure are less cohesive: with intra-positional trade in peripheral positions being less intensive, these nations, such as Bangladesh (see above), receive most of their energy from a very small number of fuel-endowed countries, or from higher-income countries acting as brokers. Exceptions (with regards to trade values) are Guatemala, Panama, Peru, and Trinidad-Tobago: these countries share a similar role, while actually fulfilling the criteria for a regular intra-positional tie above 50 percent.

Third, this chapter underlines the importance of looking at the non-monetary dimensions of economic exchange, here exemplified with the energy content of the major fuel commodities traded across the world. While there is an overall overlap between the monetary and non-monetary structural mappings of fuel commodity trade, we would commit a conceptual mistake if we equate these two perspectives with each other: it is the energy content of a fuel commodity, not its exchange value, that propels our cars, heats our homes, and turns the wheels of our industries.

Finally, while only looking at the energy/value ratio for the set of high-income countries, noting that these countries actually earn money in their role as energy brokers, this chapter indicates that further analysis of the energy/value nexus – a type of nature-culture interface – could bring further insights into the energy metabolism of the world.

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