Preceding and governing measurements: an Emmanuelian conceptualization of ecological unequal exchange

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Introduction

In a world where the ecological walls literally are closing in on us, the recent combination of world-system analysis and ecological economics provides a novel way to address one of the most pressing contradictions of global capitalism: the uneven distribution of natural resources and environmental burdens. As two scholarly strands sharing several conceptual overlaps, the biophysical lens of ecological economics can shed new light on existing ideas, themes and questions within the world-system school, as well as formulating new ones.

The hallmark of this disciplinary combination is undoubtedly the various ecological interpretations of unequal exchange. Typically depicted as monetarily non- or under-compensated net transfers of biophysical resources, occurring beneath the reciprocal nature of economic exchange, a cadre of scholars have spent the last two decades specifying, theorizing, and operationalizing the concept of ecological unequal exchange. Undoubtedly, the approach makes perfect analytical sense: contradicting the equalization effect of market exchange as assumed in mainstream theories of international trade, the global distribution of resources and environmental risk seems to constantly favor the few haves over the many have-nots.

Indeed offering new insight into the biophysical dimension of the modern world-system, there are nevertheless shortcomings with existing conceptualizations of ecological unequal exchange. First, although explicitly concerned with exchange, few studies look at actual exchange occurring on the world market. Rather, the formal operationalizations of this concept seem more focused on national indicators of resource usage and environmental burdens, thus assuming that these reflect international exchanges that, additionally, are assumed to be of an ecologically unequal kind. Secondly, contrary to how the original concept was described, the ecological variety typically signifies the actual phenomena of net resource transfers per se, rather than representing a hypothesis of the mechanism causing this phenomena. As such, existing analyses are somewhat detached from the highly relevant theoretical foundations found in this heterodox development tradition. Related to this, thirdly: despite claims of building on the original formulation, *l'echange inegal biophysique* has very scant – if any – ties to how Arghiri Emmanuel specified unequal exchange in terms of factor cost differentials.

Inspired by global commodity chain studies and their findings on factor mobility and segmented production, this paper proposes an alternative Emmanuelian conceptualization of ecological unequal exchange. Similar to the original formulation, it is a theory about factor cost differentials, but instead of looking at labor and how wages differ between nations, the proposed theory looks at the third, oft-forgotten Ricardian production factor of “land”/resources. Building on Jorgenson's structural theory, the hypothesis is that such factor cost differentials are related to positionality in the world-system, but rather than operationalizing such structural properties using Jorgenson's index, which I argue to be unreliable in this context, network methods for role-analysis and blockmodeling are used to determine structural positionality.

Analyzing trade flow data between 1990-2010 for three commodities – coal, crude oil, and liquefied natural gas – selected to represent the "land" production factor, combined with a more comprehensive role-analysis of the world economy of 1999-2001, this paper exemplifies how this novel conceptualization of ecological unequal exchange can be operationalized and measured. The results from this analysis and a general evaluation of ecological unequal exchange as factor-cost differentials concludes this paper.

Ecological economics: taking world-system analysis beyond the social sciences

Extending the postwar neo-Marxist and dependency traditions into the *longue durée* of the French Annales school of history, the world-system perspective offers a unique way to describe, analyze, and theorize about social change and global dynamics, past and present. Surpassing the ontogenetic assumptions of the "whole nation biases" as found in related disciplines (e.g. Snyder and Kick 1979:1097; Wellhofer 1988:282ff), world-system analysis deems the only feasible unit of analysis in the modern world to be the world-system itself, where individuals, cities, nations and regions in various ways are tied together into a co-dependent and co-evolutionary whole.

Despite a label that reflects its research area, it has been argued that world-system analysis is not primarily concerned with analyzing such singular historical world-systems; rather, it is more of a post-autistic academic protest movement:

> World-systems analysis is not a theory about the social world, or about part of it. It is a protest against the ways in which social scientific inquiry was structured for all of us at its inception in the middle of the nineteenth century. (Wallerstein 1987:309)

And indeed, the existing, and ongoing, partitioning of our knowledge about ourselves into distinct disciplines – anthropology, economics, political science, history etc – does obstruct our ability to ask questions about the social world that overlap these artificial domains, and it is this refusal to view the social, the economic and the political as separate spheres of human existence that allows for social inquiry that surpasses the ontogenetic assumptions of each discipline.

But what about inquiries that, by their very nature, need to stretch beyond the *geisteswissenschaften*, into the natural sciences?

The world-system perspective has increasingly been combined with the strand of thinking known as ecological economics (e.g. Martinez-Alier 1987; Costanza et al 1997). Whereas mainstream economics begins with social entities – individuals, households, firms, institutions etc – and an assumed type of rationality among such agents, ecological economics typically starts off with the biophysical system which the economic system is seen as embedded in. Rather than describing economic processes and flows in terms of socially constructed value schemes, ecological economics describes economic systems using the terminology of the underlying "base system" - such as flows of energy and materials, emission of hazardous chemicals, appropriated bioproductive hectares, and the like. This difference also separates ecological economics from environmental economics: whereas environmental economics "deal with the application of concepts of economics to the study of nature" (Martinez-Alier 1987:x), such as reflected in its assignment of monetary values to biophysical resources and services[1], ecological economics represents "the ecological approach to the study of human society and economy." (ibid.; see also Borgström Hansson 2003).

World-system analysis and ecological economics have conceptual overlaps that make their combination particularly seamless. First, both schools are interested in the totality of systems, viewing such as something more than the sum of their parts. Instead of looking at individual sub-entities or conceptual levels in Hobbesian isolation, both schools place greater emphasis on the structures that tie these parts into a grander whole. Through this, secondly, both schools recognize the finiteness of planetary systems, implying a greater emphasis on the distribution of resources and risks instead of modeling component parts as something detached from the evolution of others.

The usefulness of this scholarly combination is its provisioning of a biophysical dimension to the study of one of the most pressing and conflict-laden contradictions of global capitalism, i.e. the unequal sharing of planetary bounties and environmental burdens. Bridging the social and the material, this "new historical materialism" (Bunker and Ciccantell 1999:107) provides world-system analysis with the tools needed to situate studies of the contemporary world-economy into the grander biophysical system of which it undeniably has found itself to be a part of.

Contemporary interpretations of ecological unequal exchange

The hallmark of this scholarly combination is the ecological approach to unequal exchange. Although interpreted in various ways – e.g. externalization of carbon dioxide emissions (Roberts and Parks 2007; Muradian et al 2002), distribution of organic water pollution (Shandra et al 2009), transfers and appropriation of genetic resources (Fowler et al 2001) etc. – ecological unequal exchange is typically used to signify monetarily non- or under-compensated net transfers of biophysical resources (Bunker 1984, 1985; Hornborg 1998, 2001, 2003, 2006, 2009; Röpke 2001; Martinez-Alier 2004; Jorgenson 2006, 2009, 2011, 2012; Rice 2007a, 2007b, 2008; Jorgenson and Clark 2009; Jorgenson et al 2009; Hermele 2012). This "net transfer" interpretation of ecological unequal exchange stipulates that even though the equality of a market exchange is defined by the mere occurrence of the exchange itself, the trading of goods of equal exchange value could very well imply an unequal exchange with regards to their biophysical properties, the resources that went into their production, or the environmental impact of their production and distribution. This is the underlying idea behind the works of Bunker, Hornborg, and Jorgenson, but variations in their respective analytical approaches and conceptual operationalizations motivate a closer look at these three scholars.

The idea on under-compensated net resource transfers is not a novel idea[2], but the origin

1 A vivid example of the discrepancy between monetary and biophysical evaluations of economic phenomena is given by Herman Daly when reflecting on William Nordhaus' statement that global warming would only have an insignificant effect on the U.S economy as agriculture only constitute a few percent of total value added. Daly thus concludes, ironically, that "[e]vidently it is the value added to seeds, soil, sunlight, and rainfall by labor and capital that keeps us alive, not the seeds, soil, and sunlight themselves." (Daly 1996:63ff)

2 In his impressive thesis on the history of unequal exchange concepts, John Brolin (2006) finds a precursor to ecological unequal exchange in the mercantilist mind of Richard Cantillon, who combined labor values and income levels with the biophysical unit of appropriated hectares: "When a State exchanges a small product of Land for a larger in Foreign Trade, it seems to have the advantage; and if current money is more abundant there than abroad it will always exchange a smaller product of land for a greater. When a State exchanges its Labour for the produce of foreign land it seems to have the advantage, since its inhabitants are fed at the Foreigner's expense." (Cantillon 1931 [1755]:255, from

of the modern-day interpretation of ecological unequal exchange is typically attributed to Stephen Bunker (1984;1985; see Martinez-Alier 1987:238; Rice 2007a:1371; Hornborg 2009:249). Proposing a functional distinction between extractive and productive economies, Bunker argued that "the unbalanced flows of energy and matter from extractive peripheries to the productive core provide better measures of unequal exchange in a world economic system than do flows of commodities measured in labor or prices" (Bunker 1984:1018), as "[t]he fundamental values in lumber, in minerals, oil, fish, and so forth, are predominantly in the good itself rather than in the labor incorporated in it" (ibid.:1054). Without ruling out other possible manifestations of unequal exchange (Bunker 1985:122), Bunker argued that a continued excessive concern with labor values, wages and profits sterilizes the development discourse by restricting it within its purely social domains.

Hornborg has spent the last two decades refining his ideas on ecological unequal exchange (e.g. Hornborg 1992; 1998; 2001; 2003; 2006; 2009). Although the biophysical metrics used by Hornborg have evolved during this time – from exergy/negentropy (Hornborg 1992; 1998; 2001), to ecological footprints, space, and time (2003; 2006; 2009) – a number of themes permeate all his studies. First, critical of how technology, economy and ecology are treated as separate fields of inquiry, Hornborg argues that an integrated perspective is necessary to understand the world-system and its societal distribution of planetary bounties and risks. A second recurrent theme is his critique towards "machine fetishism" where industrial technology, in liaison with neoclassical ideology, facilitates the unequal exchange of productive potential, labor time and bioproductive space. Inspired by Georgescu-Roegen (1971) and Gudeman (1986), Hornborg takes a very thermodynamic perspective[3] on international exchange, placing more emphasis on thermodynamically defined properties and less[4] so on the social valuations that underpins such exchanges. Still, preferring to keep the two realities analytically separated, Hornborg focuses on the intersection between social-economic valuations and objective material properties: as demonstrated in his study on 19th century English exports of manufactured textiles and imports of wool and cotton (Hornborg 2006), it is the exchange ratio of such vertically traded commodities that, he argues, will reveal ecological unequal exchange.

From the macrosociological tradtion, Andrew Jorgenson's writings on ecological unequal exchange are rich in empirical data and statistical methods. Contrasting how Hornborg envisions the combination of world-system analysis and ecological economics, Jorgenson treats the latter more as a supplement for understanding the effects of world-system dynamics. Seeing the biophysical dimension, such as ecological footprint indicators, a missing piece of the puzzle (Jorgenson 2003:376), the puzzle in which this piece fits is nevertheless the macro-sociological world-system perspective. In his articles, he argues that environmental outcomes, as reflected in national biophysical indicators on consumption, resource usage and environmental burdens, are a function of world-system structural positionality. Modeling the latter as the independent variable and national environmental indicators as dependent variables, as such underlining the above-

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Brolin 2006:28).

3 Another similarity with thermodynamics and the field of physics in general is perhaps Hornborg's strive towards a grand unifying theory that ties together technology, economy, economics-as-science, ecology and thermodynamics into a singular explanatory framework.

4 "We can completely disregard the subjective "utility" of the products, which is more or less arbitrary and ephemeral anyway – arbitrary because it is culturally defined (cf. Sahlins 1976), and ephemeral because it diminishes rapidly with use – and observe that if a finished product is priced higher than the resources required to produce it, this means that "production" (i.e. the dissipation of resources) will continuously be rewarded with even more resources to dissipate." (Hornborg 2001:45)

mentioned conceptual difference with Hornborg, Jorgenson proposes, and thoroughly test, a structural theory of ecological unequal exchange. Nevertheless, Jorgenson indeed depicts ecological unequal exchange as a net transfer of biophysical resources taking place through the assumed 'vertical trade' between low- and high-income countries, where the former exchange their primary products for manufactures, but the implicit assumption in Jorgenson's work is thus that such unequal exchange is accurately reflected in the biophysical national indices selected for analysis.

The different environmental indices used by Jorgenson ranges from per-capita ecological footprints (Jorgenson 2003, 2009; Jorgenson and Clark 2009), deforestation (Jorgenson 2006), both of these two (Jorgenson et al 2009), and carbon emissions (Jorgenson 2011). He also uses various ways to conceptualize structural positionality – from the composite Kentor-index of world-system positionality (Jorgenson 2003; see Kentor 2000), percentages of exports sent to higher income countries (Jorgenson 2011), to his own weighted export index:

$$D_i = \sum_{j=1}^{N} p_{ij} a_j$$

where D_i is the weighted export index for country *i*, p_{ij} is the proportion of exports from country *i* sent to country *j*, and a_j is the per-capita GDP of receiving country *j*. The p_{ij} variables, summing up to unity for all values of *j* for each country *i*, is based on total export flows in two articles (2006; Jorgenson and Clark 2009), whereas only primary goods exports are used in the latter (Jorgenson et al 2009) article.

Shortcomings with existing conceptualizations of ecological unequal exchange

From a neoclassical perspective, unequal economic exchange is an oxymoron: even though markets may be imperfect and rational actors might find themselves rollercoasting the demand curves, the actual exchange that occurs on a market defines the exchange value equality of the goods, services, money and credit changing hands. A barrel of oil contains a given amount of oil, but it is the spatiotemporal variations in supply, demand, and purchasing power that determines how much wheat this barrel of oil can be traded for. Even though a hectare of arable land is always a hectare of, hopefully, arable land, market exchange makes it possible, and likely very rational, to let the market transform one hectare of cash crop into two hectares of foodstuff – until saturated demand, changing preferences, and economies of scale (elsewhere) effectively could reduce that hectare to a fraction of its former capacity for sustenance. Intersecting the social and the material, ecological unequal exchange is uniquely situated to address such questions.

Whereas 'ecological unequal exchange' denoted the net flow phenomena per se, both Hornborg and Jorgenson provide theories on its underlying mechanisms. According to Hornborg, ecological unequal exchange is a scheme engineered by neoclassical ideology that upholds a cultural (mis)understanding of value: somehow, it is the neoclassical school of economics that has made people believe that they need, and thus value, a car, a CPU and a refrigerator more than the raw materials and energy that went into their production. Thus, prices per se, and mediums of exchange, act as ideological agents that makes market exchanges to appear as reciprocal (e.g. Hornborg 2009:240, 242ff).

As a contrast, Jorgenson's structural theory is more open for formal hypothesis testing. In addition, Jorgenson's concern with the structural properties of the international network of trade as reflected in his weighted export index is more in line with core issues of world-system and dependency studies, such as monopoly capitalism, asymmetric trade structures and the dominance effects of core-periphery hierarchical topologies (e.g. Galtung 1971; Frank 1966). However, although an interesting hypothesis, there are, I argue, a couple of shortcomings in its operationalization and, more generally, how ecological unequal exchange has been conceptualized so far.

First: although the concept explicitly refers to exchange, the studies by Jorgenson look at national environmental indicators that are assumed to reflect international trade flows that, it is further assumed, are of an ecological unequal kind. National indicators of consumption are also assumed *only* to reflect such net resource transfers among nations, excluding would-be endowments and domestic sink capacity. As Jorgenson look at the contemporary world-economy, for which detailed commodity trade data exists (values *and* quantities), less assumptions would go into a study of ecological unequal exchange that looks at actually occurring exchange. In Hornborg's study of the textile trade of England in the 1850s, Hornborg (2006) partly uses historical trade flow records when estimating the trade ratio between raw materials and manufactures. Aware of possible errors in such data, it is surprising that Hornborg has not yet attempted to verify his thesis using contemporary, readily available, trade flow data.

Second, Jorgenson's operationalization of world-system structural positionality is, I argue, somewhat flawed. Intended to capture a country's trade dependence[5], this index can be criticized on two accounts. First, although the proportions of exports to other countries (i.e. the p_{ij} variables) are calculated using relational data, their marginal-normalization *de facto* discards differences in significance of exports between countries[6]. Secondly, the multiplication of proportions with per-capita GDP of the receiving country (i.e. a_j) has a profound impact on results. Hypothetically, if all export vectors were perfectly balanced (i.e. where the shares of exports from each country is perfectly distributed across potential receivers), the rank order of the weighted export index and GDP per capita would be identical. As high-income countries mostly trade with each other, their weighted export index would thus be very high, irrespectively of its *p* vector.

Third, the existing conceptualizations of ecological unequal exchange have scant, if any, ties to how Arghiri Emmanuel defined unequal exchange as based on factor cost differentials. Emmanuel (1969; 1972) built his theory of unequal exchange on assumptions of free international trade and perfect competition, void of market irregularities, where the difference between labor and capital was the (partial) mobility of the latter. His model contained no monopoly capitalism (e.g. Baran 1957; Baran and Sweezy 1966) or asymmetrical trade in the dependency tradition (e.g. Frank 1966), nor was it technological rent, capital-intensity differentials[7], or product-specific properties or Singerish demand

5 Possible alternatives to the weighted export index (and the measure used in Jorgenson 2011) that captures a similar notion of structural positionality are the share-of-trade index employed by Gidengil (1978:56) and the relative acceptance index (Savage and Deutsch 1960; see also Dominguez 1971). Designed to capture partner concentration within core-periphery/hub-and-spoke structures, these indices are not only more established (and thus tested) than the weighted export index but they are also applicable identifying *both* core and periphery alike, i.e. not only a pre-determined set of low-income countries.

6 For instance, a country whose relatively insignificant exports goes to a singular high-income country would get a higher scoring than another country whose relative significant exports goes to another high-income country with a slightly lower GDP.

7 Emmanuel began his theoretical exposition by describing the exchange of products with unequal amounts of socially necessary labor time and based on different capital intensities, this being referred to by his tutor Bettelheim as unequal exchange in the broad sense. However, although many authors have referred to Emmanuel's *two* types of unequal exchange (e.g. Chase-Dunn 1989:231), the capital-intensity variety was not unequal exchange according to Emmanuel (1975b:80), but only a demonstrational device to distinguish and compare with the wage-differential situation of unequal exchange proper (Brolin

elasticities that caused unequal exchange. Rather, wage-differential between developed and developing countries was the exogenous independent variable that led to unequal exchange (Emmanuel 1975a:39; Brolin 2006:179, 215; see also Emmanuel 1972:126ff). Thus, although Hornborg, Jorgenson, and Rice dutifully refer to Emmanuel, placed alongside dependency and world-system scholars, claiming that their respective conceptualization builds on Emmanuel (e.g. Jorgenson et al 2009:264), they are not concerned with production factors and their cost differentials that characterized unequal exchange according to its founder. Even though Hornborg's 2006 study on the English textile trade is only a paragraph away from Emmanuel's factor-cost-oriented specification of unequal exchange, no such connection is made; instead, Hornborg proposes a continued mapping of “total” ecological unequal exchange, encompassing *all* traded commodities.

A simple empirical test that, I believe, proves the existence of ecological unequal exchange in the net transfer sense is the open-your-fridge test[8]. As global resources are channeled through the global market, the differences in the magnitude of one's consumption and, particularly, the geographic range from which resources are obtained are by themselves, I argue, adequate indicators for the existence of under-compensated net resource transfers. Describing such flows in minuscule quantitative detail could be worthwhile, but it does not necessarily help us understand its historical roots and underlying mechanisms. Also: as the social valuations that determine an economic exchange is disconnected from the biophysical properties of the goods and services changing hands – e.g., the decision to buy the *Plants vs. Zombies* smartphone game is based on perceived fun and purchasing power rather than its inherent productive potential (which I have found to be negative) or the resources that went into its production – we can safely assume that practically *all* exchanges are ecologically unequal as any linear relationship between metrics of social valuation and material properties would be nothing but coincidental.

Even though Jorgenson's structural theory is tied to the world-system tenets on relational structures, contemporary conceptualizations of ecological unequal exchange do not utilize existing theory, insights, and lines of thought to their fullest extent. Rather, the world-system tradition and the heterodox strands of social and economic development thinking is more of a compatible backdrop to the ecological-econometrics on fairly obvious net transfers of biophysical resources, rather than providing the historical ideas and conceptions that should precede and govern such measurements. In what follows, an alternative conceptualization of ecological unequal exchange will be proposed that, it is argued, is more in line with the original idea on unequal exchange as specified by Arghiri Emmanuel. Refining Jorgenson's structural theory through network-analytical methods, furthermore looking at actually occurring exchange rather than national indicators assumed to reflect such exchanges, the proposed conceptualization is nevertheless first and foremost a theory in the Emmanuelian mold, i.e. a theory about factor cost differentials.

Towards an Emmanuelian interpretation of ecological unequal exchange: learning from global commodity chains

Introduced by Hopkins and Wallerstein (1982; Wallerstein and Hopkins 2000 [1986]), the global commodity chain (GCC) approach was conjured to address a particular historical

2006:180).

8 No fridge? Quae ergo per se demonstrandum!

question: whether a world-economy, characterized by fragmented production and an international division of labor, existed between the 16th and 18th century. The study of internationally segmented chains of commodity production and the local and global causes and effects of such – the origins, costs, and provisioning of inputs, organic compositions, regulations and institutions, social and environmental impacts, the local share (and distribution among factors) of total value-added etc – has crystallized into a distinct speciality (e.g. Gereffi 1994; Applebaum et al 1994; Heintz 2006; see particularly Bair 2005, 2009). Whether the Age of Reason had its GCCs or not, their contemporary counterparts are definitely more than hypothetical constructs – the Ford Escort I had in Sweden was apparently produced in 15 different countries, spanning three continents (Gereffi and Korzeniewicz 1994:1) – and the constant reconfigurations of chain segments reflect a rational search for cost minimization and profit maximization. The study of such chains poses a new, upgraded approach for understanding distributional aspects of the world-economy:

> If one thinks of the entire chain as having a total amount of surplus value that has been appropriated, what is the division of this surplus value among the boxes of the chain? This is the kind of issue that lay behind the debate on unequal exchange. (Hopkins et al 1994:49)

Indeed offering a new approach for studying unequal exchange (see Heintz 2003, 2006), this paper draws on two somewhat more rudimentary insights from the GCC school. The first insight is that the traditional perception of an industrial core and a non-industrial periphery is too simplistic:

> What the commodity chain construct makes evident is that the Colin Clark trinity of primary, secondary, and tertiary sectors is descriptive and not terrible helpful. Each box in the chain transforms something and is therefore 'industrial'. […] In any case, there is no long-term fixed priority for the 'secondary' sector as a motor of capitalist development. (Hopkins et al 1994:50)

Distorting previous assumptions on vertical trade, the contemporary logic of dislocation makes it somewhat straggling to ground debates on unequal exchange in particular commodity categories. If machines and industrial technology constitute the engines for core dominance and if the exports of manufactures characterize the beneficiary of ecological unequal exchange, can the relative (secondary sector) deindustrialization of the core fit into such a theory? Global commodity chains do not end ecological unequal exchange as we know it, but it does change the inbound parameters and assumptions – little has changed since 2006 and much have changed since the 1850's (cf. Hornborg 2006).

Secondly, global commodity chains tell us something about international factor mobility and the assumption of its immobility that permeates neoclassical trade theory – from Marshall (1930), (Heckscher-)Ohlin (1933), to Samuelson (1948). Similar to most assumptions of mainstream trade theory, the factor immobility postulate was inherited from the classicals:

> Experience..shows that the fancied or real insecurity of capital, which not under the immediate control of its owner, together with the natural disinclination which every man has to quit the country of his birth and connections, and intrust himself, with all his habits fixed, to a strange government and new laws, check the emigration of capital. (Ricardo 1996 [1817]:95)

Still, his magnum opus carries an english title due to the mobility of a production factor perceived as particularly immobile: Abraham and Abigail Ricardo, a dutch banking family originally from Portugal, were apparently okay with a strange government and new laws when, prior to David's birth, moving from Amsterdam to London. As a prerequisite for Ricardo's comparative cost advantages, John Stuart Mill chose to redefine international trade as trade between regions separated by factor immobility (Mill 1849:113; Condliffe 1950:187), a definition that implies that international trade of today is pretty much non-existent.

The existence of global commodity chains presumes international mobility of capital. Even though foreign guest workers constitute 94 percent of Qatar's economically active population and even though the swedish company Norrskensbär employs seasonal thai workers to pick lingonberries, the mobility of labor is not at par with the seemingly frictionless global movement of capital. And similar to the discourse in virtually all strands of development thinking, the focus on commodity chains and their segments is on these two production factors – capital and labor – and specifically how the mobility of the former combines with the overall immobile latter in different organic compositions of production at various locations, resulting in chains that, for instance, stretches three continents and 15 countries.

Through ecological economics, the world-system perspective can access the full triad of production factors: labor, capital, and land. Representing physical raw materials, this third Ricardian production factor is typically ignored in the classical Marxist discourse on wages and profits, as well as neoclassical Cobb-Douglas production functions. This exclusion is nevertheless often theoretically feasible: with capital and labor being partially substitutable with each other, the “land” factor is substitutable with neither. The extraction of such production factors typically follow a geographical pattern of natural endowments, but once commodified, they are injected into the same global commodity trade networks as any other commodity, eventually combined with labor and capital around the world. As demonstrated by its significant share of total global trade (see Figure 1), the (Alfred) Weberian logic of industrial location between resources and markets hardly seems like a determining factor in chain configurations. Similar to capital, possibly to an even greater degree, the third production factor made tangible through the biophysical lens of ecological economics traverses the network of international trade, feeding segments and chains with the material basis of production.

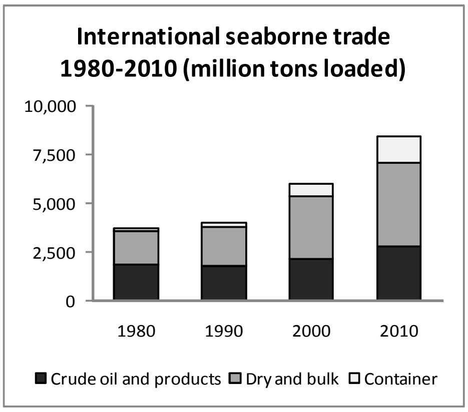

Figure 1: Trend in composition of global material flows (UNCTAD 2011:10)

Ecological unequal exchange as factor-cost differentials

Following Emmanuel, the variety of ecological unequal exchange proposed in this paper is concerned with factor cost differentials. Whereas Emmanuel examined national price-differentials for labor, i.e. wages, this paper looks at price-differentials between nations of the land production factor. Thus, Emmanuelian ecological unequal exchange is not concerned with measuring total net resource flows between countries; instead, focusing explicitly on commodities representing this particular production factor, it is perceived as would-be differences in import costs (and export revenues) per unit of biophysical resource.

Similar to Emmanuel's theory of unequal exchange, the hypothesis here is that factor cost differentials are related to the properties of a particular social structure. However, whereas Emmanuel theorized that wage-differentials between countries reflected national differences in the organization of labor, the hypothesis here is that cost differentials for "land" are related to structural positionality in the contemporary world-economy. Following Jorgenson, reflecting a characteristic tenet of the world-system and dependency traditions, the hypothesis is that those that are advantageously positionalized in global exchange networks typically are at the "receiving end" of ecological unequal exchange whereas those disadvantageously positionalized are relatively worse off.

In what follows, the proposed Emmanuelian conceptualization of ecological unequal exchange, including its structural theory, is tested using fossil fuel trade data for the period 1990-2010.

Testing the factor-cost version of ecological unequal exchange

To test the Emmanuelian variety of ecological unequal exchange, two datasets[9] are needed: an index that adequately captures the notion of structural positionality in world-system analysis, and national data on import costs (and export revenues) per exported unit of natural resource. The particular choice of commodities and the chosen method for establishing structural positionality are specific for this particular empirical analysis, i.e. without ruling out other possible datasets and methods for examining occurrences of Emmanuelian ecological unequal exchange.

Production factors of the third kind: fuel commodities

In this study, the commodities chosen for analysis are (non-agglomerated) coal (SITC 3212), crude oil (SITC 3330), and liquefied natural gas (SITC 3431), selected as good representatives of the "land" production factor and their respective importance in global trade. Data on bilateral commodity flows between 96 countries, measured in exchange value (USD) as well as physical mass (kilogram), were prepared[10] for three time periods: 1990-1992, 1999-2001, and 2008-2010.

With three time periods, three commodities, and two metrics for each flow (exchange value and mass quantities respectively), we have a total of 18 flow matrices. The original mass units were used in the factor cost analyses that look at respective commodity, i.e. with prices expressed as USD per kg, whereas the combined analyses converted these quantities into energy content, i.e. in terms of USD per (giga- or peta-)joule. In this paper, the analyses comprising total value and energy flows is for the 1999-2001 period, whereas the factor prices for the individual commodities cover the 1991-2009 period.

Structural positionality: network analysis and regular blockmodeling

Although "structural positionality" can be interpreted in different ways, the use of blockmodeling and role-analysis in world-system contexts have a relatively long and, seemingly successful, track record (e.g. Snyder and Kick 1979; Nemeth and Smith 1985; Smith and White 1992; Mahutga 2006). Using slightly different datasets and methods, obtaining different answers to slightly different questions, this sequence of studies traces a growing confidence in the "natural wedding" (Snyder and Kick 1979:1123) between world-

9 All data used in this paper is available on request: nordlundc@ceu.hu.

10 Extracting data from the Comtrade database for a total of nine years, three-year averages were calculated for each period. Bilateral data with missing quantity units were excluded from the dataset. Whereas excluded flows were insignificant for coal (<0.05 percent), 17.5 percent of the value of crude oil flows in 1992 had missing quantity units, thus only 1990 and 1991 were used to calculate mean annual trade in crude oil for the 1990-1992 period. Whereas the original data covered 118 countries, those with total imports below 1 million USD were excluded from the analysis, resulting in a set of 96 countries.

system analysis and blockmodeling (see also Breiger 1981:354; Nemeth and Smith 1985:521; Smith and White 1992:858). Contrary to country categorizations into core, semi-periphery and periphery based on country attributes (e.g. Kentor 2000), measures that “do not represent such positions any more than an individual's income or education measures his or her (discrete) class position” (Snyder and Kick 1979:1102), network-analytical studies engage with the structural tenets of the world-system school in a “referential context” (Nemeth and Smith 1985:522), where “the focus of the analysis is no longer on characteristics of individual countries, but on the relationships between countries” (ibid.).

Following this line of studies, this paper uses regular blockmodeling to determine structural positionality in the world-system. As a general network-analytical procedure, blockmodeling groups social entities (actors) into role-equivalent sets based on similarities in their interaction patterns[11]. Even though it is plausible that the structure of the world-economy changed, possibly considerable, between 1990 and 2010, this paper only establishes structural positionality for the 1999-2001 period alone.

The multi-level data consists of commodity trade for six broad commodity categories[12], measured in exchange value, among the 96 countries in the fuel commodity data (see above). The assumption is thus that the structure of this particular layer of the world-economy reflects the overall structure of the world-system at large, a perhaps bold assumption[13] that nevertheless also is found elsewhere (Nemeth and Smith 1985; Smith and White 1992; Mahutga 2006). Using five iterations of the REGE algorithm[14] (White and Reitz 1983, 1985) in a simultaneous analysis of these six flow matrices, a subsequent single-link hierarchical clustering determined the various sets of role-equivalent sets at different cutpoints. To determine a suitable number of partitions, Anova density tests[15] were done for various partitions: the highest absolute R^2 value occurred at eight partitions, whereas the largest relative increases occurred when going from two to three, and from four to five partitions. As we are only looking at one aspect of the world-economy, we are not theoretically bound to the assumed trimodality of the world-system; to increase resolution, eight position partition was chosen[16]. This partition is given in Table X, including aggregate positional net value and energy flows for the selected commodities.

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11 Role-analysis and blockmodeling is a well-established approach within social network analysis – see e.g. Wasserman and Faust (1994) and Scott (2000).

12 Included commodities were Food, live animals (SITC 0), Mineral fuels, etc (SITC 3),Chemicals, related (SITC 5), Manufactured goods (SITC 6), Machinery etc (SITC 7), Misc. Manufactures (SITC 8). Together, the commodities in these six SITC divisions correspond to 92 percent of total trade in the 1999-2001 period.

13 Thus, we cannot, and should not, prove or disprove the theoretical trimodality of the contemporary world-system by this particular regular role-analysis.

14 Even though used previously in world-system contexts (Smith and White 1992; Mahutga 2006), the REGE algorithm is not the only way to partition a network according to regular equivalence: generalized blockmodeling could be used (Doreian et al 2005) or other algorithms (e.g. Reichardt and White 2007; Ziberna 2008). Despite its popularity, the REGE algorithm has been criticized for its point-scoring procedure and its ability to identify regular role-equivalence when it comes to valued datasets with great value spans (see Borgatti and Everett 1991, 1993). Due to the space limitations of this paper, the assumption made here is that the REGE-derived partitions reflect subsets of nations sharing similar structural positionality.

15 See Luczkovich et al (2003) for an example on how Anova density tests are used to identify suitable partitions.

16 In network-analytical terminology, a 'position' is a subset of actors that are considered role-equivalent and/or part of a blockmodel.

	Countries	Positional net flows (selected commodities) [mill USD]	[TJ; 10^{12} J]
A	Pakistan, Sri Lanka	1 324	588 849
B	Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Nicaragua, Panama, Peru, Trinidad and Tobago	-704	-191 407
C	Argentina, Belarus, Chile, Czech Rep., Denmark, Egypt, Finland, Greece, Hungary, India, Israel, Luxembourg, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, South Africa, Sweden, Tunisia, Turkey, Ukraine	-15 582	-4 993 119
D	Australia, Austria, Belgium, Brazil, Canada, China, Hong Kong, France, Germany, Indonesia, Ireland, Italy, Japan, Malaysia, Mexico, Netherlands, Philippines, Rep. of Korea, Singapore, Spain, Switzerland, Thailand, United Kingdom	103 911	30 689 393
E	Albania, Bolivia, Croatia, Cyprus, Estonia, Ghana, Iceland, Jordan, Kenya, Latvia, Lebanon, Lithuania, Madagascar, Malta, Mauritius, Paraguay, Senegal, Serbia and Montenegro, Macedonia TFYR, Uruguay	2 882	1 057 555
USA	USA	59 199	18 027 776
F	Algeria, Colombia, Iran, Iraq, Kuwait, Nigeria, Oman, Qatar, Saudi Arabia, United Arab Emirates, Venezuela	-151 086	-45 192 434
G	Mozambique, Nepal, Uganda, Tanzania, Zimbabwe	56	13 387

Table 1: The 8-positional partition of international trade 1999-2001 (with positional net flows of value and energy content)

USA has a very distinct structural position in this network, separating itself from the countries in position D and forming a singleton position at the 7-positional partition. Whereas most high-income European countries are found in position D, this position also contains the south-east Asian countries (including Japan) as well as Mexico and Canada, both deeply connected to USA. The Scandinavian countries are found in position C, which they share with the Central and East European countries, India, South Africa, and a few geographically dispersed countries in north Africa, Middle east, and southern Latin America. The northern Latin American countries, however, have their own position (B). Interestingly, position F is an exclusively fuel-exporting position: even though fuel commodities only constituted one (out of six) major commodity categories, these flows are apparently so distinct (and apparently substantial – see Figure 1) to yield their own role-similar position. Apart from position F and A, the other (non-singleton) positions contain a mix of net-importing and -exporting countries.

Complementing the blockmodel, a regular image graph was created[17] – see Figure 2. Mapping the functional anatomy of the network, the regular ties between and within each position were identified using a heuristic explicitly designed to handle datasets with huge value spans (Nordlund 2007), where the different shades reflect criteria-fulfillment for regular ties. Comparing with how a regular block image for Galtung's typological topology looks like[18], we are indeed looking at a core-periphery topological structure, especially as

17 The criteria-fulfillment percentage was calculated using formula 3 in Nordlund (2007:63). The 3-dimensional coordinates were established using a force-directed layout algorithm using the criteria-fulfillment percentages as relational data. As an inter-positional regular tie is directed in our blockmodel, the 8x8 data matrix used for this visualization was max-normalized: the criteria-fulfillment percentages given in this visualization thus corresponds to the maximum value of the two directional ties between each dyad. Visualized using Ceunet (cnslabs.ceu.hu).

18 A regular block image of Galtung's classical feudal interaction structure as a typological core-periphery structure (Galtung 1971:89) results in two role-equivalent positions – a core and a periphery – where the

USA and the countries in position D merge below at partitions below 7 positions.

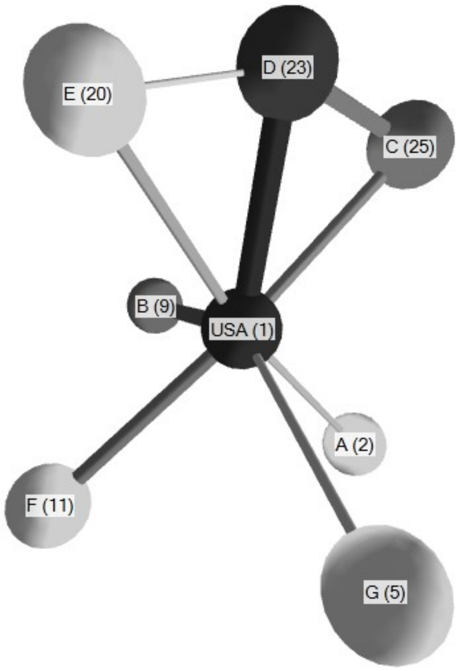

Figure 2: Regular image graph of world trade, 1999-2001

Ecological unequal exchange as monetarily under-compensated net energy flows

Converting the quantity flow matrices for each fuel commodity type into corresponding energy flow matrices, subsequently calculating aggregate matrices containing total value and energy flows, we can assess occurrences of ecological unequal exchange in the net transfer sense for these three commodities. The scatterplot in Figure 3 depicts national net flows of value and energy for the 1999-2001 period.

core has a regular self-tie, the periphery lacks such, and there is a regular tie between core and periphery.

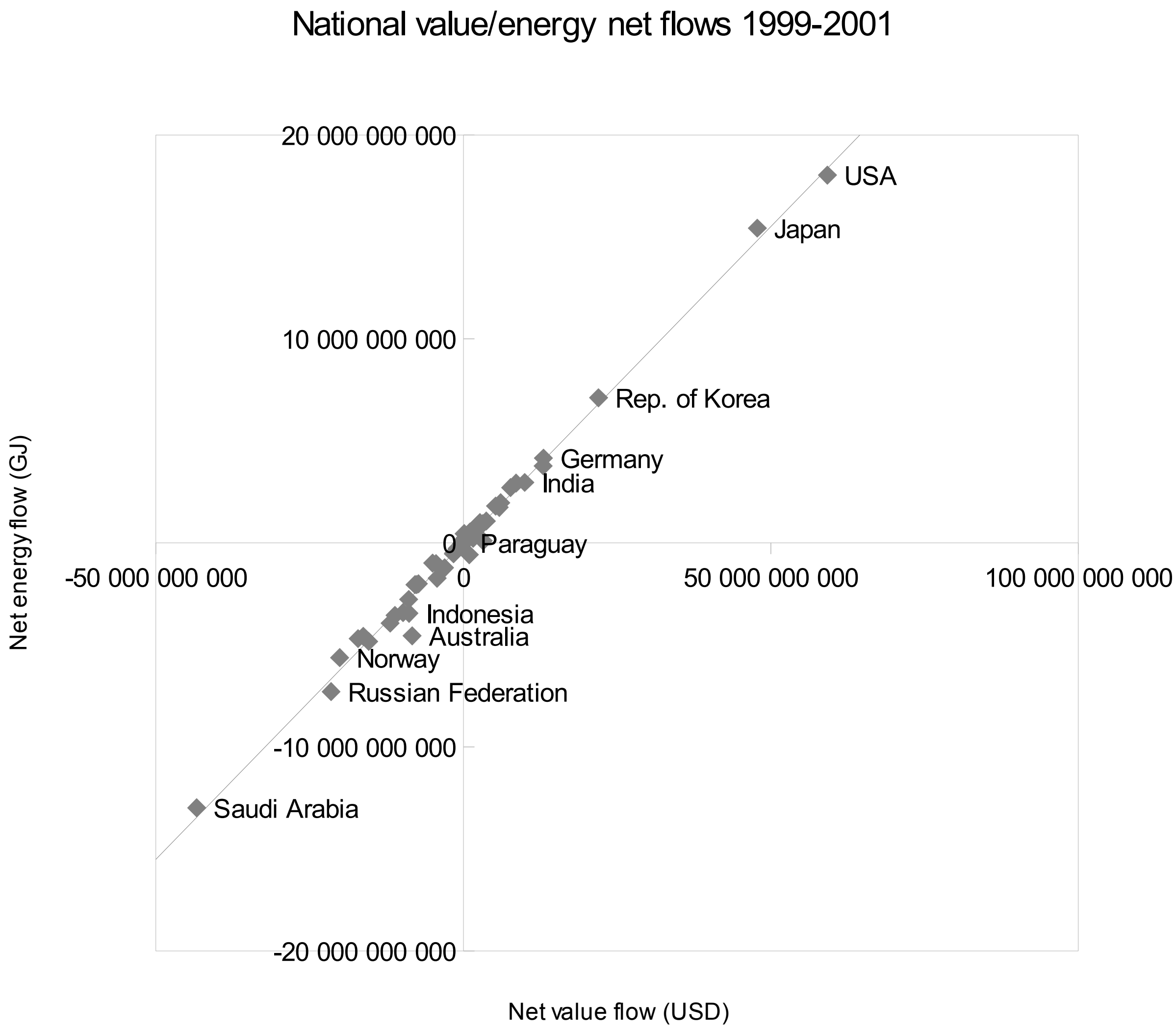

Figure 3: National net flows (energy and value), 1999-2001

Evidently, the trend is strongly linear: a net inflow (outflow) of energy implies a net import (export) of commodity value, and the ratio between energy and value appears to be relatively similar. Still, the scatterplot above obfuscates an exception: even though Guatemala had a (mean) annual net import of fuel commodities in the 1999-2001 period, valued at 47.5 million US dollars, its external trade in these three fuel commodities implied a net energy *outflow* of 2.9 petajoules. A closer inspection reveals that almost all of Guatemala's imports of fuel commodities came from Venezuela, carrying a relatively high price tag of 3.98 USD per gigajoule, whereas Guatemala's subsequent export of fuel commodities, overwhelmingly to the USA, only gave 2.33 USD in revenue per gigajoule. Even though the Venezuelan data could be unreliable[19], the low cost of US energy imports from Guatemala is nevertheless approximately a dollar cheaper than what it on average pays its energy suppliers.

19 Although major anomalies were removed from the datasets, the export price data from Venezuela was consistently higher than the world average. However, as import data rather than export data was used in this analysis, the would-be error sources are theoretically to be found among importers rather than exporters such as Venezuela, thus making it difficult to motivate a removal of the Venezuelan export vectors in the flow matrices.

As we are only looking at three fuel commodities in this analysis, the observed proportionality between energy and value is not very surprising. As indicated by Hornborg (2006), a complete mapping of this net flow variety of ecological unequal exchange must by necessity cover virtually all commodities traded on the global market, and by including more commodities of different types, it is more feasible that we would find countries placed in the "unequal" quadrants as well. What the above trend line does show us, albeit slightly, is that there are indeed slight variations in the cost and revenues from energy trade. Russia, placed slightly below the trend line, earns less per exported joule than what Saudi Arabia and Norway, placed above the trend line, do. Similarly, USA gets less joule per dollar than what South Korea and Japan get.

Inter- and intra-positional energy flows and costs

Continuing with the total energy flow data for 1999-2001, Table 2 contains energy flows (in terajoules; 10^{12} J) within and between the 8 role-equivalent positions. By far the largest positional energy flow goes from the energy exporters in position F to the mostly high-income countries of position D. Corresponding to about a third of all energy flows in the dataset, these 27,3 exajoules are more than double the energy flow from position F to USA. However, the second largest value represents *intra*-positional within position D, i.e. energy flows between these 23 "developed" countries, thus by far outranking the cohesiveness of the other positions.

	A	B	C	D	E	USA	F	G
A			2 340	24 214				
B		186 621		155 304	1	497 419	45	
C	2 971	8 828	5 219 949	10 296 598	567 495	940 891	11 059	103
D	56 922	75 540	1 637 011	15 832 736	21 233	6 686 728	247 456	
E		23	82 675	110 673	3 523	3 964	1	69
USA		3 976	106 066	1 516 341	1 788		8 541	
F	555 511	372 995	5 005 571	27 306 821	663 601	11 535 487	9 674	19 554
G			1 254	4 240	842		2	101

Table 2: Inter- and intra-positional energy flows (Terajoule), 1999-2001

Expressed as petajoules (10^{15} J) and excluding positional flows below one petajoule, the topological features of inter- and intra-positional flows are highlighted better in Figure 4 below. The contrast between the significant cohesiveness of position D and the low intra-positional density of position F is per se an established definition of a core-periphery topology (Borgatti and Everett 1999), especially since the criteria of connectivity is fulfilled by the flow of 27 exojoules (10^{18} J) between F and D.

As already noted (Table 1), position C acts as an alternative net energy exporter in the system. Contrary to the main fuel-exporting position (F), position C is quite cohesive, having the second-largest intra-positional flow. However, even though C is an aggregate net energy exporter, only 7 of its 25 countries are energy net exporters – including Norway and Russia with net energy exports[20] at 5,6 and 7,3 exajoules respectively.

20 The net energy export figures for Norway and Russia includes exports to other countries within position C

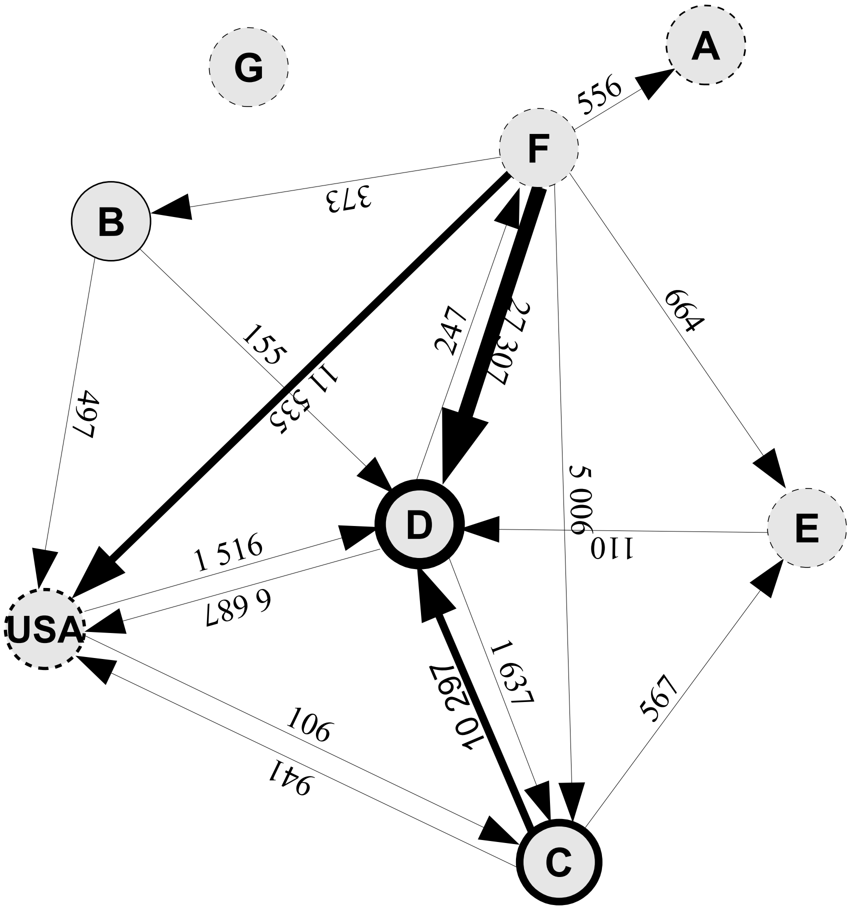

Figure 4: Inter- and intra-positional energy flows (Petajoule), 1999-2001

Providing position D with an alternative source for its energy needs, it is noteworthy that very little energy flows from position C to USA. Instead, it is position D that is the second largest source of US imports of energy: even though position D is the largest net energy importer in the structure, the 6,7 exajoules from D to USA is quite significant.

By dividing the individual items in the aggregate value flow matrix with its energy counterpart, we arrive at a new matrix containing cost-per-joule for each bilateral flow for the period 1999-2001. Mapping this price matrix on the blockmodel and its partition, we arrive at the cost-per-energy prices given in Figure 5 below. Several interesting observations can be made here, particularly with regards to position D. First, regarding imports from position F, it can be noted that position D pays less per joule than what USA pays (3.13 vs. 3.75 USD/GJ). Also, it can be noted that the energy flows from C to D is even cheaper[21], at 2.77 USD/GJ. But even if these energy costs are relatively low, the intra-positional energy cost within position D is significantly lower than what is the case for its extra-positional trade.

21 The even lower price tag of energy from C to USA is however made irrelevant due to the minor energy flow this price is attached to.

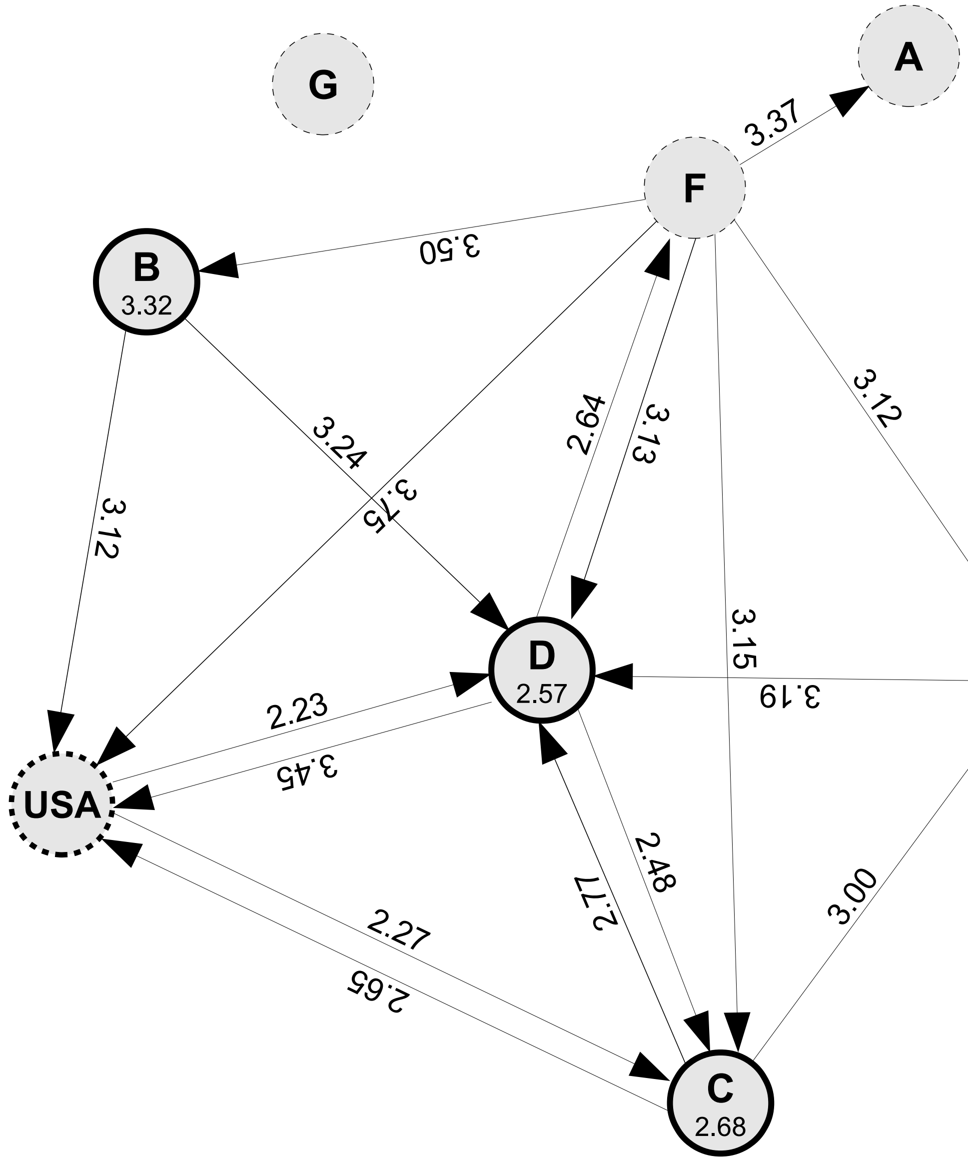

Figure 5: Inter- and intra-positional energy prices (USD/GJ), 1999-2001

Apart from paying relatively little for its energy inflows, position D is also the second largest source for USA. Although slightly cheaper than US imports from position F, position D earns 3.45 US dollars for each gigajoule flowing to USA. Thus, this data points to a peculiar situation for USA: highly dependent on a singular positional energy source (F), supplemented by imports *from* the largest net-importing position (D), and paying relatively much for each imported joule, these observations are indeed characteristic of dependency in the classical sense.

Price trends of individual commodities, 1991-2009

Although total energy flows are interesting from a purely thermodynamic perspective, it is doubtful whether different dollar-per-energy measurements are readily comparable with each other. The price of a particular fuel commodity does not only reflect their respective energy densities: even though an exchange between one ton of crude oil for 1.67 tonnes of coal might be thermodynamically equal, it is doubtful that trading partners would consider this an equal exchange. The missing component is of course utility: not only is coal 67 percent heavier than energy-equivalent crude oil, but solid coal is also less versatile than liquid oil. Few large-scale power plants run on crude oil and even less cars run on coal: just as with labor and capital, there are different kinds of “land”, and this empirical analysis is rounded off by looking at cost differentials for the three production factors individually.

Figure 6 below illustrates how positional prices of coal imports have increased over the period. Whereas prices were relatively similar in 1991, the positional price differentials had increased substantially by 2009. Of particular interest is the price of US imports: although increasing from 45 to 79 USD per ton over the period, this percentage increase is lower than the doubling, tripling, and, in the case of position F[22] – quadrupling of import costs from 1991 to 2009.

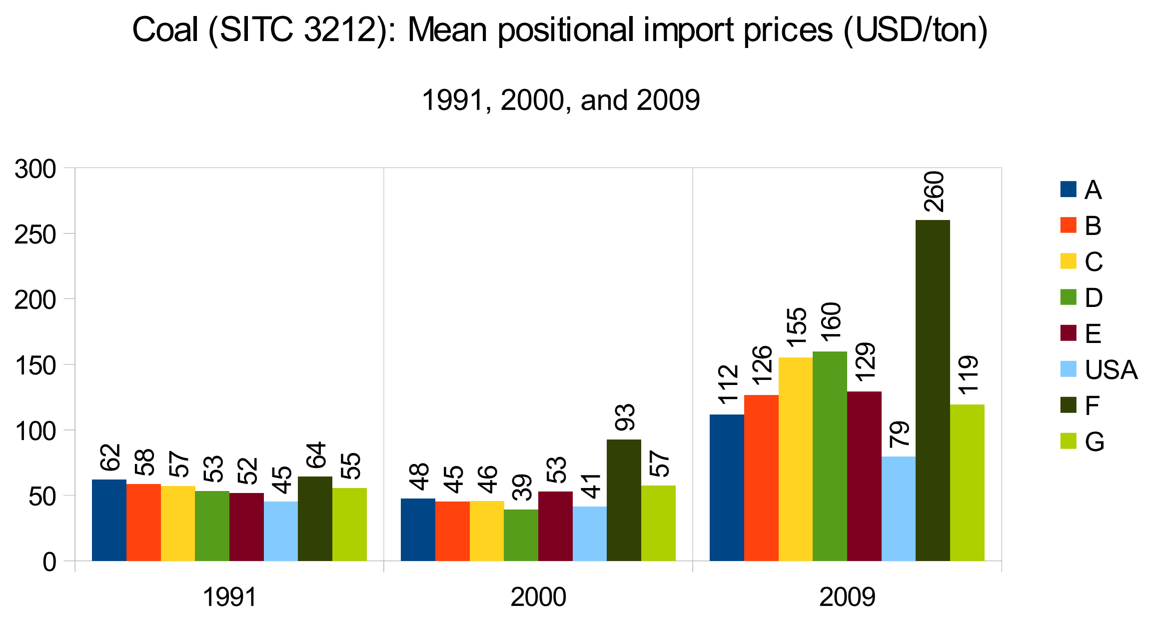

Figure 6: Coal: mean positional import prices (USD/ton), 1991-2009

Looking at positional mean export revenues (Figure 7), the revenue differentials are not as pronounced as in the case of imports. Position F actually obtains most revenue per exported tonne, albeit only 8 percent more than US revenues.

22 Although position F is a net exporter in coal, particularly due to Colombia being the fourth largest coal exporter, gross coal imports for position F rose from 837 million to 1.2 billion tonnes over the period studied.

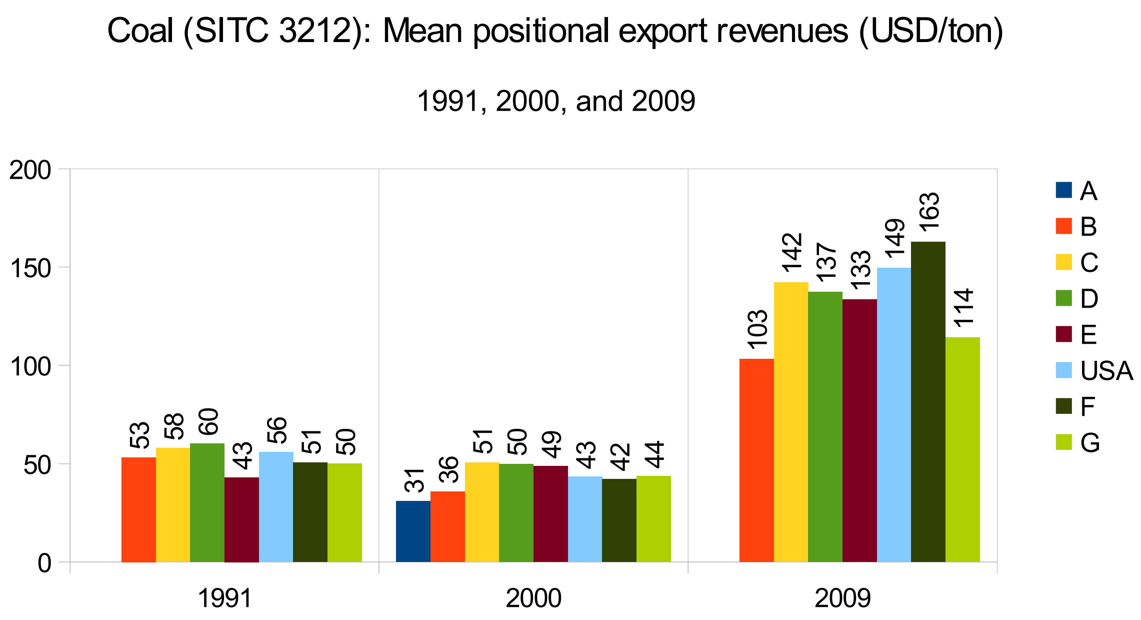

Figure 7: Coal: mean positional export revenues (USD/ton), 1991-2009

Combining these two diagrams, Figure 8 highlights the price-revenue differentials for each position. Whereas such differentials were relatively low in 1991, the negative throughput ratio for position F is noticeable over the period studied whereas USA seemingly earning 70 dollars for each tonne of coal imports that is matched to a corresponding exported tonne.

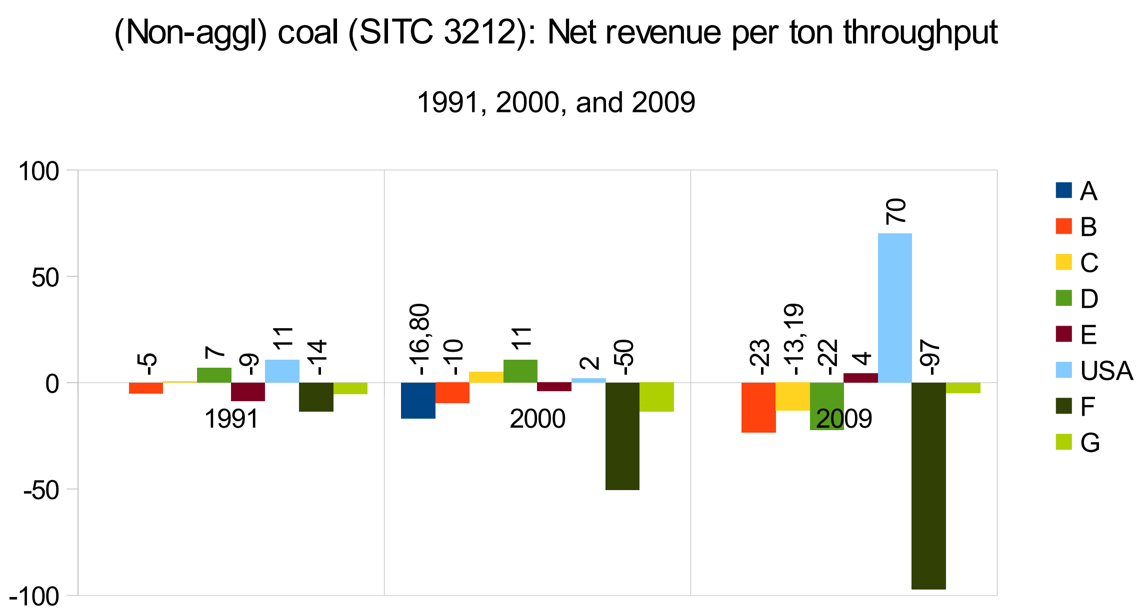

Figure 8: Coal: net revenue/loss per tonne throughput (USD/ton)

Corresponding diagrams on import costs, export revenues, and throughput for crude oil are found below. For position F, the cost (and thus the throughput ratio) should be interpreted with care: apart from its insignificant imports, the per-tonne import cost of 1,058 USD is only based on five data points. Significant, however, is the findings for position D: obtaining 788 USD per exported tonne, of most going to USA, position D “earns” 193 USD for each tonne of crude oil that passes through. As shown in these diagrams, such positional divergences are only observable for the 2009 data.

Even though position F pays a remarkably high price for its crude oil imports, these flows are very minor in an absolute sense.

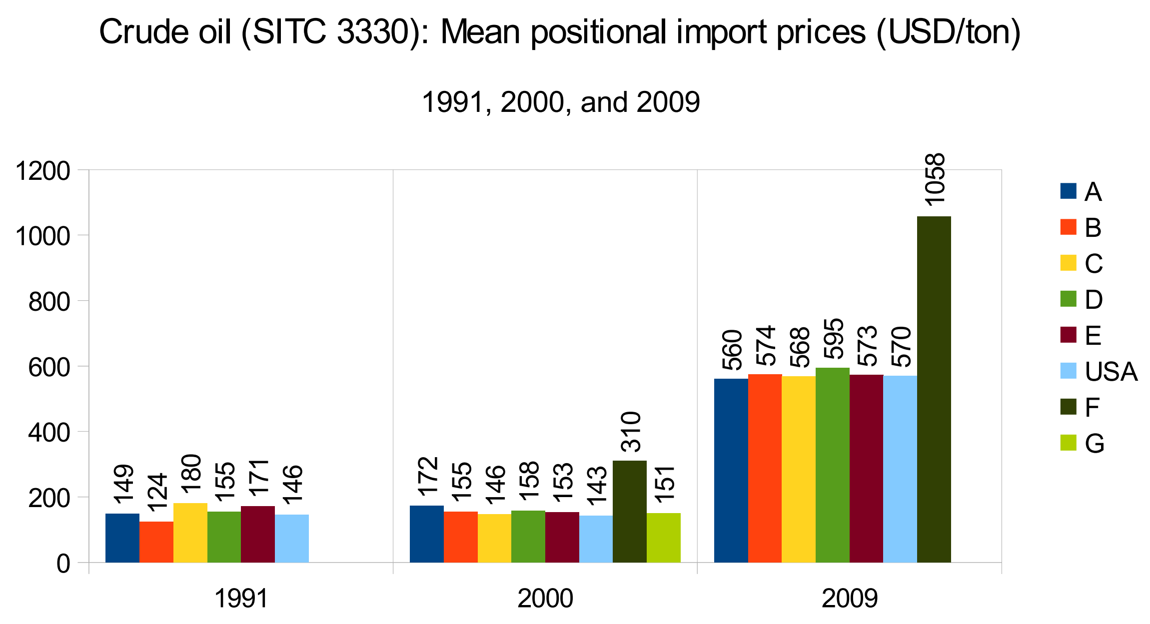

Figure 9: Crude oil: mean positional import prices (USD/ton), 1991-2009

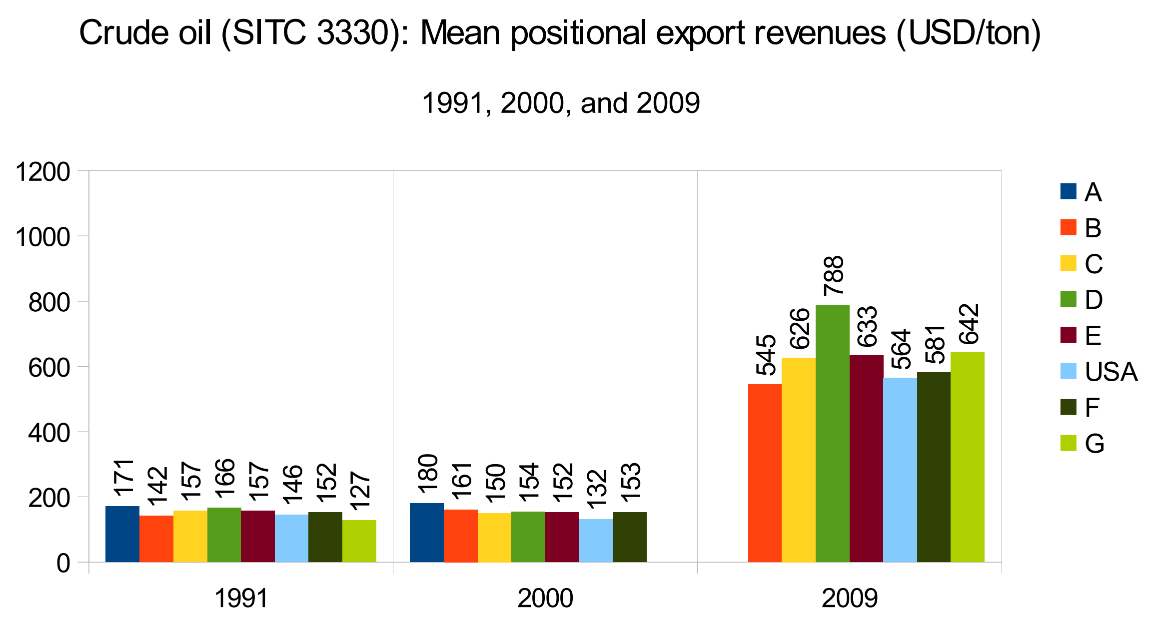

Figure 10: Crude oil: mean positional export revenues (USD/ton), 1991-2009

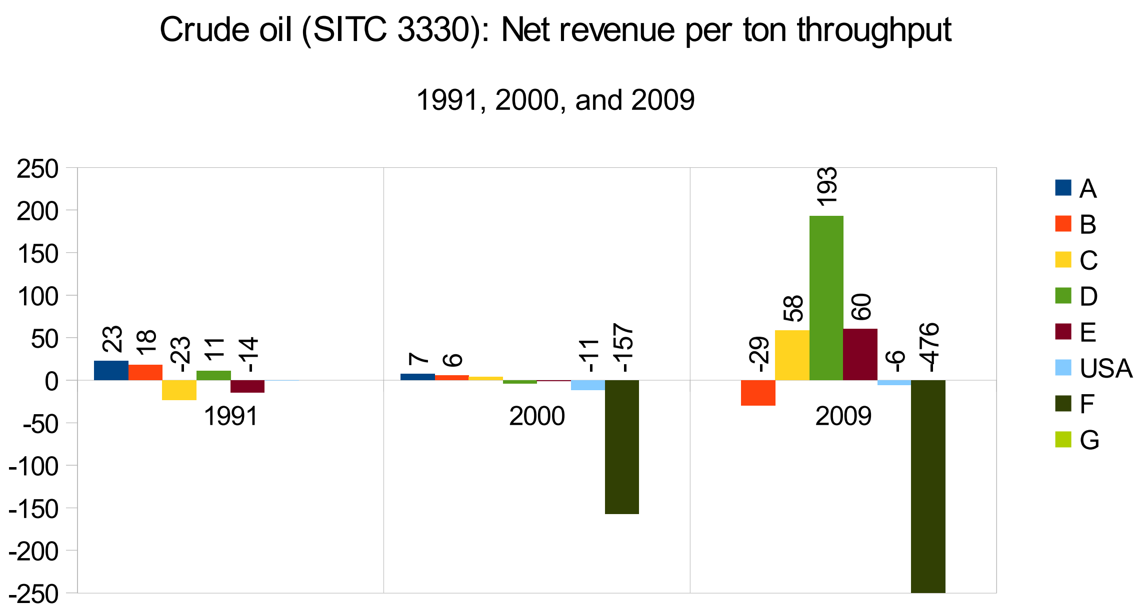

Figure 11: Crude oil: net revenue/loss per tonne throughput (USD/ton)

Compared to coal and crude oil, data availability for liquefied natural gas is quite sparse for the first two periods, as shown in the last three diagrams below. For 1991, adequate import and data only exists for position D, where latter years have slightly more data points. It is thus problematic to say anything general about the price trends over the whole period, but the data allow us to interpret 2009 imports and exports for position C and D, and most likely also USA[23]. The last diagram reveals that net-exporting position C has a significantly profitable throughput ratio: for every tonne of imported LNG that is matched by a corresponding tonne of exports, 349 US dollars are accumulated.

23 The number of import price datapoints (in brackets) for each position are B (4), C (47), D (107) and USA (9). Corresponding data coverage for exports are B(23), C(36), D(44), and USA (7).

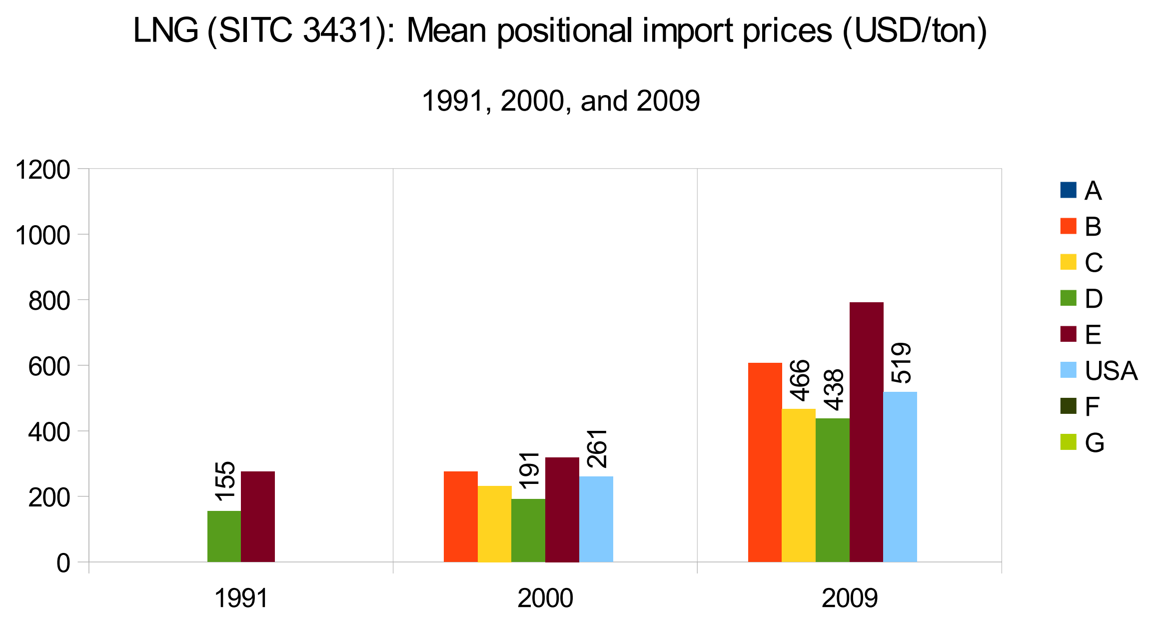

Figure 12: (Liquefied) natural gas: mean positional import prices (USD/ton), 1991-2009

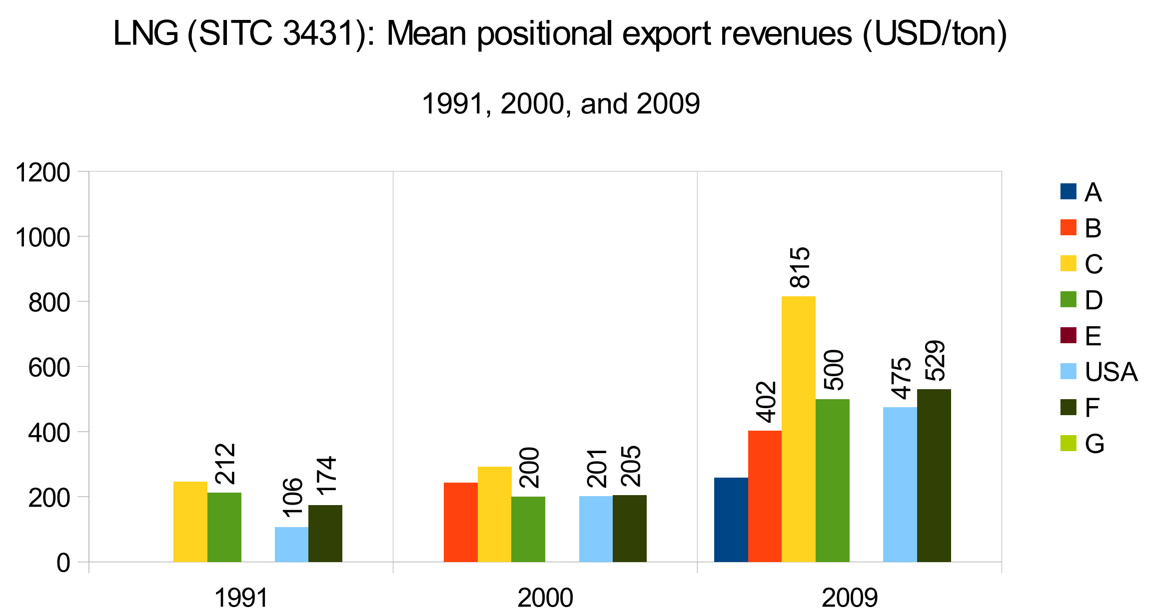

Figure 13: (Liquefied) natural gas: mean positional export revenues (USD/ton), 1991-2009

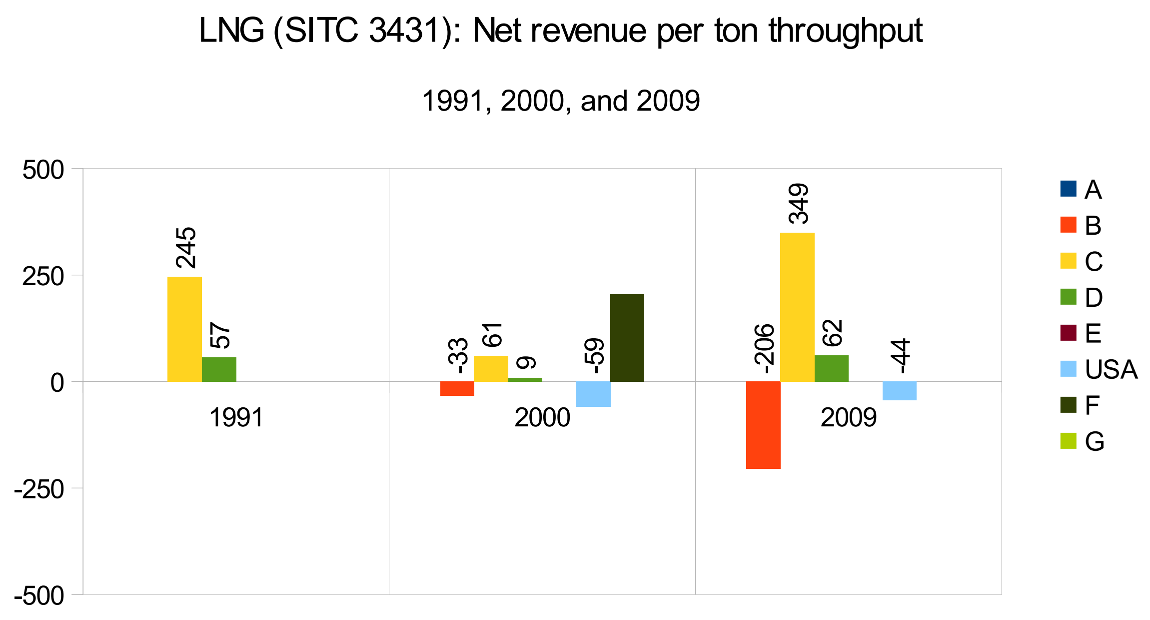

Figure 14: (Liquefied) natural gas: net revenue/loss per ton throughput (USD/ton)

To aggregate the three fuel commodities into a common biophysical unit is, of course, a rudimentary exercise: as the utility of these commodities is obtained through incineration, the energy content is a suitable unit for the biophysical accounting. Still, even for these very similar commodities, it is apparent that their value is not only in their energy content, but other physical properties as well. That is: ecological equal exchange is likely only equal in the thermodynamic sense.

When trying to aggregate a variety of different goods, finding a common biophysical unit could be difficult: how to convert lumber, fuel, rubber, metal ore, water and other production factors of the third Ricardian kind into a common unit that makes sense in an ecological, resource-oriented manner that can be used to conceptualize ecological unequal exchange, net-flow as well as Emmanuelian? Still, albeit imperative for measuring "total" ecological unequal exchange in the net-flow version, the strive towards converting different biophysical properties of goods and services into a common unit, such as ecological footprints, should be questioned. It is true that "[t]he alchemy of money, with its power of commensuration, lies in its ability to dissolve distrinctions between value schemes or measuring rods, and to create the fiction that a flattened, comparable world exists" (Gudeman 2001:15), but this does not imply that a similar simplification can be made with respect to the outer, biophysical system. Thus, even though the above analyses of the aggregate energy flow matrix tell us something thermodynamically, we are in effect mixing apples and oranges in a way that is not necessarily necessary.

As a snapshot of the 1999-2001 period, the mapping of energy flows and their prices onto the blockmodel does nevertheless give us some interesting insights. With significant internal trade and relatively low import costs from multiple sources, position D resemblances a core in the network-topological sense, and possibly also in a world-system sense. Even though USA joins the countries of position D at a lower partition cutoff level, its role is somewhat peculiar with a singular, relatively expensive, source for most of its energy imports, supplemented by expensive energy imports from position D. Another interesting phenomena is position C: as an alternative energy source to position F, it is more cohesive than position F, but earns slightly less per exported gigajoule than position F.

Thus, even though a net flow analysis depicts USA at the receiving end of ecological unequal exchange in the net flow sense, the Emmanuelian conceptualization of ecological unequal exchange, where the focus is on factor costs rather than net flows, points to a less advantageous situation for USA and a significantly better one for position D.

The analysis of individual fuel commodities reveal a more nuanced and high-resolution picture of Emmanuelian ecological unequal exchange. In the case of coal, a consistently low price tag on US imports over the period results in an advantageous throughput ratio. Position F suffers from a disadvantageous situation, where the cost of an imported tonne of coal overshadows the revenues from an exported tonne. For crude oil, position D emerges as a clear winner in factor cost differentials. Acting as a partial gateway between position F and USA, position D accumulates almost 200 dollars for each tonne of crude oil that passes through its positional borders. Position F is also interesting in this regard: even though holding a virtual global monopoly on crude oil, this does not translate into an exceptional high price tag on oil exports: the price tag of oil exports from D exceeds those from position F by approximately 200 dollars per tonne. Finally: although the samples for liquefied natural gas are too sparse for any broader conclusion, the 2008-2010 period has enough data for some interpretations. From this, it can be noted that position C a beneficiary of Emmanuelian ecological unequal exchange, earning significantly more per exported tonne than position D, E, F and USA.

Thus, the commodity-specific analysis indicates that position C, D and USA each have their own commodities that they are benefiting from – liquefied natural gas in the case of C, crude oil for position D, and coal in the case of USA .

Concluding remarks

Critical of existing conceptualizations of ecological unequal exchange, this paper proposed an alternative conceptualization that is, it is argued, more in line with the original formulation of Arghiri Emmanuel. Rather than mapping total net transfers of biophysical resources, the emphasis here is, similar to the original formulation of Emmanuel, on factor cost differentials among nations. Whereas Emmanuel looked at labor and wage differential, the herein proposed conceptualization of unequal exchange looks at the third Ricardian production factor, i.e. land/natural resources, and cost differentials of such. The suggested hypothesis, building on Jorgenson's structural theory of ecological unequal exchange, is that such factor cost differentials are related to structural positionality within the world-system.

To test the proposed conceptualization, three fuel commodity categories were chosen to represent the land production factor. Looking at bilateral trade data for 96 countries in the last three decades, factor cost differentials were compared with structural positionality determined through a blockmodel analysis for the 1999-2001 period. Aggregating the three commodities into total energy flows, as well as looking at individual commodities, the analyses yielded novel findings for both of these approaches.

Although the operationalization of structural positionality could be improved, and the choice of commodities as production factors could be different, it seems evident that the proposed Emmanuelian conceptualization of ecological unequal exchange yields interesting insights worthy of further study and interpretations. A possible extension would be to see whether factor cost differentials for various countries are reflected in secondary sector employment or any other similar indicator of production utilizing particular production factors.

However, despite its ties to the foundational ideas of unequal exchange, a conceptual orthodoxy might not necessarily serve us well. As underlined by Wallerstein (2000:153), concepts often depend on, and are best defined through, particular historical systems and timespace context, and it is indeed possible that the Emmanuelian conceptualization of ecological unequal exchange is not the best way for addressing the closing of the biophysical walls that surrounds us. Still, as a historically oriented field of study, we are almost obliged to connect past and present thoughts, something that I hope that this paper has managed to do.

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