



Appraising Sociological Approaches to Ecologically Unequal Exchange Theoretical Considerations and Quantitative Consequences

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Abstract

Ecologically unequal exchange has enjoyed several decades of rich theoretical and empirical scholarship. Quantitative assessments of the theory in sociology typically sample lower income nations to see whether more trading to high income nations contributes to environmental problems in the former. In this paper, we explore ecologically unequal exchange theory, as well as related traditions, to draw attention to how these theories develop relational understandings of global advantage and disadvantage in socioecological terms. Thus, we argue that relational methods, like social network analysis, among other approaches, better align with the underlying theoretical framework in the research area. More specifically, ecologically unequal exchange's emphasis on "extractive peripheries" calls for those geographic zones to be the primary site of analysis as opposed to bifurcating nations based on income. We specifically propose social network tools and methods, such as position/role analyses, because they can directly analyze trade data to construct categories of nations, such as extractive export sites. Generally, we argue that these methods better approximate the underlying theory, while acknowledging the utility of the longstanding approach, calling for methodological diversification in general and embracing relational methods in particular.

Keywords: Ecologically Unequal Exchange; International Political Economy; Research Methods



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Sociological work on ecologically unequal exchange (EUE; also known as unequal ecological exchange) has enjoyed several decades of rich theoretical and empirical scholarship. Especially considering climate change and ongoing environmental crises, the global scope of the theory yields valuable insight into cross-national environmental problems, particularly as they relate to sustainable development. In this article, we outline the theoretical and quantitative development of the research area, appraise the strengths and limitations of conventional means for operationalizing the theory in quantitative research, and suggest ways to align methods more closely with theory.

Stephen Bunker's (1984, 1985) seminal work on serial underdevelopment in the Brazilian Amazon incorporated ecological features into earlier conceptualizations of unequal exchange (Emmanuel 1972), showing how the construction of built infrastructures to support rubber and timber extraction constricted domestic developmental pathways. Generally, the theory holds that extractive export zones are linked to productive and consumptive zones via trade, producing unequal flows of raw materials and environmental inequities. Recent theoretical interventions draw attention to properly measuring EUE as an exploitative relationship where the economic exchange of money provides an illusory notion of equivalence while there is asymmetry in ecological terms (Hornborg 1998, 2009, 2020). Indeed, the theory situates extractive export economies within an international context and connects the local to the global (Gellert 2019). Consequently, it is not only appropriate to appreciate EUE as a robust, structural theory of global environmental inequities (Givens, Huang, and Jorgenson 2019), but also as a relational¹ theory of exploitation and advantage in a global context.

Quantitative research on EUE has produced a rich understanding of how poor countries disproportionately exporting to relatively richer nations contribute to environmental problems in the former. Jorgenson's (2006) foundational work uses a novel measure, weighted export flows, to measure the extent to which lower income countries export to high income nations and assesses whether there exists an association between these flows and deforestation in lower income countries. A bevy of research uses this general framework to understand how weighted export flows or percentage of exports to high income nations contributes to environmental degradation in lower income nations (e.g., Jorgenson, Austin, and Dick 2009; Shandra et al. 2009; Shandra, Leckband, and London 2009; Jorgenson 2012; Noble 2017). While relational (trade flows from exporters to importers) and attributional data (national affluence levels) are used to construct weighted export flows (Jorgenson 2006), the bifurcation and/or sampling of data by national income status in analyses may not effectively locate the geographic zones where the relevant extractive economic activity occurs.

Meanwhile, social network analysis has commonly been employed to assess the structure of the global economy (e.g., Mahutga 2006), yet has only begun to be incorporated in studies on

¹ Throughout this paper, we use "relational" in the sense of social network theory: that actors should be understood in relation to other actors and not in isolation. Extractive export hubs are in a relationship with importing nations and can only be meaningfully understood through this relationship. Of course, this also implies connections between local extraction sites and the global market and inequities (e.g., Gellert 2019).

EUE. Social network analysis “is based on an assumption of the importance of relationships among interacting units” and holds that “actors and their actions are viewed as interdependent rather than independent, autonomous units” (Wasserman and Faust 1994: 4). While some research has been conducted using social networks in this research area (Prell and Sun 2015; Sommer 2020), surprisingly little has used position/role analysis despite its prevalence in investigations of the global economy (see Nemeth and Smith 1985; Mahutga 2006; Mahutga and Smith 2011). In general, position/role analyses address “how patterns of relations characterize roles within networks” (Light and Moody 2020: 20). In the context of international trade in general and world-systems in particular, position/role analysis can assess and describe “the unity and structure of a hierarchical, differentiated world economic system” (Smith and White 1992: 858). Given that EUE is similarly concerned with the structure of the global economy and its implications for environmental inequalities (Rice 2007), we encourage more use of social networks and position/role analysis in this research area because they can more closely attend to these relations of economic activity by locating the specific geographic sites at which they occur.

This paper assesses quantitative sociological research on EUE, while suggesting pathways for future work that expands methodological approaches that more closely align with the underlying theoretical framework. Primarily, this paper contends that the research design pioneered by Jorgenson (2006) and used extensively in subsequent research, while very fruitful, has limitations. We discuss how this methodological approach neglects the relationality of EUE, occludes significant attention to relationships between human labor and the environment, and thus does not fully incorporate the “social character” of EUE. Our suggestions largely follow three lines. First, more consideration of the implications of related theoretical work and historical/qualitative case studies would benefit quantitative research. Second, the use of social network analysis in general, and approaches that emphasize position/role analysis in particular, provide more consistency with theoretical emphases on “extractive peripheries.” And finally, drawing from related research traditions in other environmental social science fields can expand our methodological toolkit and, by extension, bring the social back into EUE.

Ecologically Unequal Exchange: Theoretical and Quantitative Work

Theoretical Work on EUE

Unequal exchange theories conceptualize development and underdevelopment as the result of asymmetrical flows of value across nations through international trade. Originally, this process was conceived as an asymmetrical flow of “embodied labor” in that wage differentials across nations foster unequal exchanges of value in a relational process that inheres the accumulation of wealth and underdevelopment simultaneously (Emmanuel 1972). Bunker (1984: 1018, 1985) argues that processes of unequal exchange should be considered in ecological terms: “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.” To support the economic demands of the world-system,

infrastructures were built to carry out the extraction and export of timber products in the Amazon Basin, thus constraining Brazil's future developmental pathways, since local political elites and the long-term impacts of land use inhibit the formation of new industries (Bunker 1985). In this way, extraction of resources *for international markets* comprises EUE, as transboundary transfers of natural resources are dependent on the existence of stable extractive export hubs.

Yet, there exists some theoretical disagreement as to how to properly measure an EUE relationship. More specifically, there is a question of whether and how Marxian notions of value are appropriate in this context. For instance, Foster and Holleman (2014) borrow Howard Odum's (1995) concept of "emergy" as a pathway to incorporate use-values. Put simply, emergy (embodied energy) accounts for all inputs into the production of a commodity, including human labor time. Exchanges of emergy thus represent exchanges of use-values across nations and may be used as the method for measuring EUE (Foster and Holleman 2014). Conversely, Hornborg (1998, 2009, 2014, 2015) argues EUE is more properly measured as an asymmetrical flow of biophysical resources, since attempts to evaluate the worth of nature in economic terms entails a confusion of logical types, given entropy cannot be recouped by monetary value (cf. Georgescu-Roegen 2013). By extension, Hornborg's (2015) argument implies that linking unequal exchange to an undercompensation of values, for instance via the ecological debt notion (e.g., Roberts and Parks 2009), is inappropriate, as any conception of value is socially situated and is reflective of a semiotic process that should not be conflated with physical processes. In this vein, Dorninger and their associates (2021) and Hickel along with their colleagues (2022) recently measured the unequal transfers of biophysical resources (raw materials, energy, land, and labor) embodied in commodities traded between developed and underdeveloped nations in non-monetary units.

Despite theoretical disagreements about how to properly conceptualize and measure EUE, the underlying empirical implication is that there exists an exploitative relationship between extractive and productive sectors of the global economy such that extractive dependence and serial underdevelopment are accompanied by the accumulation of wealth and technological advances (Gellert 2019; Hornborg 2019). Indeed, these theorists share the central postulate that processes of extraction, production, consumption, and disposal are shaped by positionality in the global economy.

Quantitative Sociological Work on EUE

A large body of quantitative research in sociology attends to EUE. As noted, Jorgenson (2006) originally developed a way to assess the theory through "weighted export flows" (Jorgenson and Rice 2005), a measure used to evaluate the extent to which nations trade to wealthy countries. Jorgenson (2006) found that lower income countries with more weighted export flows (i.e., that tend to trade more to richer nations) experience more deforestation. Consequently, the general research design of sampling lower income nations and using some measure of degree of exports to wealthy nations (e.g., weighted exports flows, percentage of commodity trade share to high income nations) became prominent.

Later quantitative research on EUE builds on these studies by specifying trade measurements with a variety of dependent variables (e.g., ecological footprint, forest loss, emissions, etc.), and limiting trade to specific countries. Rice (2007) employs a global sample to show that the proportion of total exports to high income nations decreases ecological footprint for low income and lower middle income nations, but not for upper middle or high income nations. In this way, high income nations inequitably use the environmental space of lower income countries. Jorgenson (2009) shows increased weighted export flows decrease the ecological footprint per capita for lower income nations. Meanwhile, export intensity decreases ecological footprints, showing that countries reliant on exports face decreased resource consumption (Jorgenson and Burns 2007). The relationship between weighted export flows and ecological footprint per capita intensifies over time, indicating that trade relationships have become increasingly unequal in terms of suppressing natural resource consumption in lower income nations (Jorgenson and Clark 2009). Quantitative research consistently demonstrates that various measures of trade flows to high income nations are associated with suppressed resource consumption in lower income nations.

Some studies on EUE incorporate world polity theory to illuminate factors mitigating environmental harm and specify independent variables adhering more closely to EUE emphases on extraction. Shandra, Shor, and London (2009) find that while total exports contribute to organic water pollution for developing countries, inter-governmental organization memberships and environmental treaty ratification reduce organic water pollution. Shandra and their colleagues (2009) show that increased primary sector flows to high income nations intensify biodiversity loss in terms of threatened mammal populations in lower income nations, while INGO memberships decrease the number of threatened mammal species. Shandra, Leckband, and London (2009) show that lower income nations with increased forestry exports to high income nations face higher levels of deforestation, while INGO memberships decrease deforestation. Jorgenson and Colleagues (2009) show that increased primary sector flows to high income nations increase deforestation and decrease agricultural natural resource consumption. Noble (2017) demonstrates that specialization in cocoa production is linked to deforestation in lower income nations. Methodological refinement of variables has allowed for more specific case studies of EUE, and inclusion of world polity variables expand our understanding of the implications of globalization on environmental outcomes.

EUE has also been applied to CO₂ emissions, showing uneven trade relationships contribute to climate change. Jorgenson (2012) finds increased exports to high income nations increases emissions for lower income nations, and increasingly so over time. Huang (2018) limits the sample to lower income exports to the United States. Increased exports to the United States are associated with more emissions for all years from 2000 to 2010 except 2008, where the effect was negative. Thus, the Great Recession mitigated unequal exchange relationships, suggesting that economic downturns in high income nations may ease the effects of uneven trade relations. In short, unequal exchange dynamics appear to contribute to emissions, although the economic circumstances of more powerful countries may affect their intensity.

Given the *high/lower income dichotomy* imposed by the research highlighted above, early work in EUE largely ignored the role of middle income (or, semi-peripheral) nations in uneven trade relationships. In response, recent quantitative research has specified trades to nations undergoing rapid industrialization to see whether such nations contribute to environmental degradation in other lower income nations. For example, Shandra, Restivo, and Sommer (2020) find that agricultural exports to China increase forest loss in other lower income nations, showing rapidly industrializing nations also partially externalize their environmental harms to other nations. Similarly, Shandra, Restivo, and Sommer (2019) find that increased forestry exports to China increase forest loss for other lower income nations. Sommer, Restivo, and Shandra (2020) show that heightened palm oil exports to India fuel forest cover reductions in other lower income nations. Expansion of mining exports to China also increases forest loss in lower income nations (Sommer, Restivo, and Shandra 2021). Consistent with the expectations of world-systems analysis (Wallerstein 2004), these studies show that semi-peripheral nations exploit peripheral nations in the pursuit of development.

The quantitative research outlined above has generated deep and nuanced understandings of EUE. Consistent support has found that trading more to high income nations increases environmental problems and suppresses resource consumption in lower income nations. Rapidly industrializing nations with large economies, such as China and India, also shift environmental costs onto other lower income nations. While this approach has been a fruitful path for analyses of EUE, the bifurcation of samples by national income levels may not be the closest approximation to EUE theory, as extractive export hubs in specific commodity flows may not align with income status. Thus, further methodological diversification is necessary to better align methods with theory and to create expanded ground for productive and innovative research. Next, we further explore EUE and related traditions and the implications these bodies of work have for quantitative assessments of EUE. Then, we review the literature on social network analysis and position/role analysis in global trade, detailing how this parallel line of research can yield insights for work on EUE, a research tradition which is also concerned with national positionality in commodity flows. Third, we investigate approaches to global environmental inequality across disciplines to outline how sociological research might better align methods with theory. We conclude by summarizing our argument while providing a roadmap for future research on EUE.

Ecological Imperialism, Colonialism, and Historical Treatments of EUE

While Bunker's (1984, 1985) seminal work is the common point of departure for empirical analyses of EUE, there exists a wealth of theoretical and historical research discussing the uneven environmental implications of international trade (Frey, Gellert, and Dahms 2018). By contextualizing empirical research within this broader tradition, we can enhance quantitative research on EUE. For example, dependency theory could be very useful in this regard, as shown by Samir Amin's (1976, 1977) notion of unequal *development* and his analyses of imperialism, which contain a sophisticated ecological component. Amin elaborated on and criticized

Emmanuel's notion of unequal economic exchange (phenomenon) by placing it as a component of a wider process of unequal development (essence). Amin posited that certain areas of our planet are plundered for the benefit of others, and unequal exchange reproduces the conditions of unequal access to natural wealth. This, he said, was at the basis of many environmental issues such as the depletion of raw materials. Likewise, Amin (1977: 71) argued that the profitability of the Green Revolution in tropical Africa was "obtained at the cost of soil exhaustion, deforestation, desert encroachment, and the lateralization eventually revealed by drought." Moreover, Amin wrote that capitalism relies on pre-capitalist forms of appropriation still extant in the periphery to avoid paying for preserving the land. Thus, the "[s]ystematic destruction of soils is a major factor of long-term impoverishment for the dependent countries" (Amin, quoted in Foster and Holleman 2014: 208).

In this way, Amin (and others) not only developed an empirical analysis of EUE, but also cited historical case studies (i.e., the "Green Revolution" in tropical Africa) to incorporate discussions about the material practices underlying this asymmetry within and across nations. This is because Amin (1990) highlighted that there existed not only asymmetrical flows of material resources from the global South to the global North, but that ecological plunder (i.e., land grabbing) was underlying money flows. Amin also identified that soils in poorer regions were being systematically exhausted by global trade. Lastly, for Amin, the only substantive way for global South nations to escape the colonial-imperial trap imposed by the world's economic system was to delink completely from it via internal development and horizontal integration with similarly situated nations (Amin 1990).

World-systems theory, which was partly influenced by dependency theory, has also examined EUE historically. Wallerstein (2004) argued that a world-system comprises an international division of labor with global trade taking place to meet consumption needs. In other words, the world economy is linked such that extractive and productive processes largely happen in disparate regions, forming a relation between economic zones. World-systems theory presents three main zones of economic activity: the core, commonly historically imperial nations where sophisticated, high value production techniques take place; the periphery, where extractive economies and simpler manufacturing processes occur and is largely comprised of colonized nations; and the semi-periphery, where a mixture of these economic types take place. A central implication of world-systems analysis is that "peripheral countries, rather than developing along the same paths taken by core countries in earlier periods (the assumption of 'modernization' theories), are instead structurally constrained to experience developmental processes that reproduce their subordinate status" (Chase-Dunn and Grimes 1995: 389). In short, world-systems analysis develops a relational theory of global development, exploitation, and expropriation.

World-systems theory has engaged with ecological issues throughout the life course of the tradition. Wallerstein's (1974) foundational work addresses how differentiated economic modalities (e.g., agricultural, manufacturing) and exportation of these commodity types forms a hierarchical, tiered world economic structure. This involves a recognition of differential exposure to certain types of ecological degradation (e.g., soil depletion) corresponding to the heterogenous

allocation of productive activities across space (Moore 2003). World-systems analysis holds that relations of extraction, production, consumption, and disposal are geographically disparate through international trade relationships (Wallerstein 2004), drawing clear theoretical connections between world-systems and EUE, as both theorize relations between particular types of economic activity. Moore's (2010) treatment of the commodity frontier of Potosí, the main silver mining site of the Spanish empire in present-day Bolivia, in the sixteenth and seventeenth centuries, is an exemplary showcase of how EUE and world-systems are complementary:

On the mining frontier, this urban-imperial logic was carried to new heights. At once dominant and dominated, mining boomtowns ruled over the surrounding countryside, even as they subordinated to broader imperial and economic structures. They were the organizing centres, not only of underdevelopment in the economic sense, but of a profoundly unequal ecological exchange between American peripheries and European cores, enabling (and enabled by) a new, multi-layered and globalizing town-country antagonism. (Moore 2010: 42)

Emphasizing and deepening the ecological focus of world-systems connects the environmental experiences of local geographies to global processes. Ciccantell and Smith's (2009) work aimed at "lengthening" the scope of the global commodity chains approach through comparative methods to include extractive regimes in longer and larger time scales and economies. Gellert's (2010) piece on extractive regimes in Indonesia (1966–98) emphasizes the heterogeneity of the periphery and semi-periphery and the development of "extractive regimes." Connecting extractive regimes to larger geographical scales and forces provides a rich and nuanced ecological analysis linking the local to the global from a world-systems frame. Put concretely, world-systems analysis, its environmental insights, and its understanding of the global economic structure would benefit quantitative analyses of EUE, particularly the notion of semi-periphery (and how this status can change historically) and intra-categorical heterogeneity (see El Tinay 2024 for a recent quantitative investigation along these lines).

Another theoretical perspective that can enhance empirical research on EUE is Marx's theory of metabolic rift (Foster 1999, 2000). Metabolic rift theory has proved a powerful approach for analyzing concrete ecological degradation instances under capitalism related to agriculture and food systems, biogeochemical cycles, and aquatic ecosystems (Clark and York 2005; Mancus 2007; Longo, Clausen, and Clark 2015). In short, the metabolic rift is the systematic gleaning of soil/oceanic nutrients into cities, across geographic scales where they accumulate and are discarded, thus not replenishing the land/water. These rifts are provoked by the increasing rural-urban divide accompanying the historical development of capitalism following the Industrial Revolution and persist to this day (Magdoff and Williams 2017). Moreover, the rifts are not confined to the degradation of external nature but affect human metabolism as well in a process Foster and Clark (2020) call the "corporeal rift" (Loustaunau et al. 2021). The notion of the corporeal rift allows for an analysis of the undermining of human lives under oppressive living conditions linked to the broader ecological context in which it occurs.

Thus, contextualizing EUE within metabolic rift theory draws attention to the ways in which global capitalism not only produces disparate environmental conditions cross-nationally, but also shapes the nature of labor (i.e., of human metabolism) in extractive zones, something hitherto underexplored in EUE research. Metabolic rift theory has also offered empirical analyses on how to mitigate EUE, for instance through agroecology and sustainable agriculture (Foster and Holleman 2014; Betancourt 2020). These strategies are particularly relevant in the global South where biophysical resources are being siphoned from and where most small-scale farms exist embedded within a matrix holding most of the world's biodiversity (ecological wealth) and at least a third of global food production (Perfecto, Vandermeer, and Wright 2019; Ritchie 2021).

Lastly, Foster and Holleman (2014) argue both metabolic rift analysis and EUE have sought to address the ecological aspect of imperialism. They contend that, theoretically, a wider synthesis of EUE analysis with what they call ecological imperialism is needed. They argue that imperialism is seldom seen in terms of the expropriation (appropriation without equivalent) of the ecological wealth of lower income nations by affluent ones, and the destruction of their environments (Foster and Holleman 2014; Foster and Clark 2020). Instead, studies that emphasized the economic aspect of imperialism had prevailed (e.g., Lenin 1917). Thus, theoretically, ecological imperialism goes beyond unequal ecological *exchange*, in the sense that it posits that global trade under colonialism and imperialism is, in fact, pillage, without even the pretense of any goods being exchanged. A classic example of this, state Foster and Clark (2020), is the guano (bird dung) trade in the nineteenth century, whereby Britain—followed by continental Europe and the United States—depleted Peruvian guano deposits (1840–80) to fertilize their exhausted soils and maximize agricultural production and profitability.

In sum, both empirically and theoretically, EUE would benefit from a more robust analysis of imperial dynamics structuring cross-national ecological and economic inequities, allowing us to better understand why there are poorer and richer countries in the first place, how this situation has unfolded historically, and why this remains the case today. Moreover, these theories and analyses have resonated across the global South, providing the foundations for further research and grassroots organizing that seeks to tackle EUE. According to (Brolin 2006: 354), what is still lacking in theories of EUE is “historical flesh and concreteness,” and the use of economic-historical evidence on material transfers. Thus, Amin's (1976, 1977, 1990), Wallerstein's (1974, 2004), and Foster, Clark and Holleman's (Foster 1999, 2000; Foster and Holleman 2014; Foster and Clark 2020) theoretical contributions could be employed in addition to Bunker's to improve the theoretical-empirical apparatus of EUE through more historical detail and richer theoretical understanding of the power dynamics across nations.

Case studies commonly employ EUE and related theoretical traditions such as those discussed above to develop fuller socioecological understandings of global inequalities. R. Scott Frey (1994, 2015) uses EUE and world-systems analysis to address global flows of waste. Frey (2015) discusses labor practices involved in recycling and disassembling end-of-life vessels in South Asian yards producing localized environmental pollution and severe risks for workers, many of whom are migrant laborers, while core nations enjoy the increased commerce that ship building

and vessel ownership provides (Bunker and Ciccantell 2005). Using Marx's theory of metabolic rift (Foster 2000), the tragedy of the commodity (Longo et al. 2015), and EUE, Clark and fellow authors (2019) analyze the trajectory of labor exploitation in global seafood production, how capitalist economic relations interpenetrate human relationships with marine ecosystems to incentivize fisheries depletion to meet consumer demands, and how marine goods flow from the global South (e.g., Thailand) to the global North (e.g., the United States). The dual process of labor and ecological expropriation of the global South by the global North are thus exposed on global scale. Austin (2017) analyzes coffee production in Uganda through EUE, world-systems, and gender exploitation in global commodity chains (Dunaway 2014). Austin (2017) shows that while community members perceive expanded coffee production as economically beneficial, there exists a host of social, labor, and gender issues, including the labor-intensive nature of coffee production, the underpaid exploitation of male coffee laborers, and the unpaid expropriation of female laborers. These case studies, to review just a few, draw attention to the multidimensionality of global socioenvironmental inequities and the need to deploy several critical theories.

We contend that theoretical, historical, and case study analyses of EUE have much to offer; we are not the first to note that more analyses of this kind are needed (Givens et al. 2019). Perhaps less considered are the subsequent implications on quantitative research. Historical and case study analyses pay significant attention to labor issues embedded in unequal exchange relations. Quantitative analyses can better attend to labor conditions if analytical categories are constructed based on specific commodity flows, as the geographic extent of extraction and consumption are established. EUE and related traditions emphasize that the status of geographic zones representing the periphery, semi-periphery, or core in the global economy, or predominantly exporters or importers of specific commodity types, are meaningful contexts through which we can understand global socioenvironmental inequities. This departs from conventional operationalizations of the theory in quantitative work, which tends to focus on national income bifurcations and the extent to which lower income nations export to high income countries.

The International Structure of Nations, Networks, and EUE

Ultimately, EUE (and related traditions) theorizes global advantage and disadvantage as structured through asymmetric flows of resources between nations in international trade (Hornborg 2019). Explicit in this theorization is that development is *relational*. As articulated by Bunker (1984: 1056): "Self-bounded extractive economies may be able to maintain long-term ecological balance with their own environments; extraction for world markets may lead to progressive underdevelopment by disrupting this balance." In other words, the state of geographic zones as extractive export economies drives serial underdevelopment. At its core, EUE is concerned with the short- and long-term economic and ecological effects of spaces becoming and being extractive export hubs to meet global resource demands.

Yet, quantitative assessments of EUE rely upon national income classifications to bifurcate data. Situations can thus arise where states that are extractive peripheries (e.g., Saudi Arabia)

regarding specific commodities (e.g., oil) are not included because of the wealth generated (albeit unequally) from this extraction. Indeed, much scholarship is dedicated to rentier states and the “resource curse” resulting from dynamics germane to EUE (Ross 2015). These factors are occluded from current quantitative sociological investigations in the research area perhaps exactly because of the way in which data are typically bifurcated, pruning potential paths for new research through methodological choices. Moreover, the theory is not concerned with lower income nations per se, but with the ecological and developmental consequences of nations engaging in extractive activities to support world-system consumptive needs. Thus, it may make more empirical sense to determine which nations are positioned as meaningful exporters in commodity trades as opposed to *prima facie* presuming lower income nations compose that group. Put clearly, the use of national income categories does not capture the main stratifying mechanism of EUE: the relationship between extractive export economies and their importing counterparts. Categorizing nations by their position in commodity flows more closely aligns with the theoretical expectations of EUE pertaining to the limited geographical construction of economies and infrastructures to support the consumption of the world-system.

Fortunately, there exists a long tradition of research in sociology examining the role/position of countries in the global economy. This is largely accomplished using social network analysis of international trade data and using equivalence techniques developed to compute the social role actors play in networks (e.g., White and Reitz 1983). Scholars often use social network analysis to understand how power and inequality permeate the global economy in accordance with world-systems expectations.

Network research of the global economy examines trade relationships to determine the role/position of nations. Snyder and Kick (1979) investigate country-country relations through trade flows, military interventions, diplomatic exchanges, and conjoint treaty memberships to classify nations according to world-systems position. Countries are grouped together based on structural equivalence.² This procedure resulted in ten groups, yet many were deemed peripheral because “the structural relations...between them override the observed variations and warrant the ‘periphery’ designation” consistent with world-systems analysis (Snyder and Kick 1979: 1114). Later studies strictly use trade relationships to assess world-system position to correct for anomalies in Snyder and Kick’s (1979) approach. For example, Clark and Beckfield (2009) collect all trade data from 1980–1990 and use a central coreness procedure to classify countries into world-system positions. Comparing their results to Snyder and Kick (1979), Clark and Beckfield’s (2009) trade position more robustly predicts GDP per capita relative to the orthodox position scheme and was later updated (Clark 2012). Thus, international trade relationships are analytically powerful in determining national position in the world-system.

Network approaches have also been used to understand world-system position as the result of specific types of commodity flows between nations (unlike studies of aggregate trade data,

² Structural equivalence groups nodes (in this case, countries) based on whether they share the same tie structure with equivalent nodes.

highlighted above). National positionality in particular commodity flows may better reflect world-systems emphasis on relations between zones of economic activity. Nemeth and Smith (1985) collect trade data by commodity type and use structural equivalence and factor analysis to group commodities and countries. A global trade structure is illuminated whereby core nations export capital-intensive products to all other national groupings and food products flow to the core from all other groups. In other words, the core has productive industries while the periphery has extractive industries, “consistent with descriptions of the mechanisms of unequal exchange” (Nemeth and Smith 1985: 529). Smith and White (1992) extend this line of research by using regular equivalence to group countries according to relationships with other countries that occupy the same social role.³ Smith and White (1992) examine differences in commodity trade flows across world-system positions and whether there is temporal heterogeneity. Again, capital-intensive manufacturing exports were associated with the core, while agricultural exports were primarily sent from peripheral nations, while the trade core expanded through time.

Later research emphasizes changes in the world economic system. While the hierarchical structure of global trade persisted throughout the latter half of the twentieth century, Mahutga (2006) shows some less profitable industrial manufacturing was transported to semi-peripheral nations. Despite the persistence of global economic inequity, semi-peripheral countries are undergoing rapid industrialization, showing some convergence with core nations in their productive capacities while diverging from peripheral nations (Mahutga and Smith 2011).

Research at the intersection of the global economy, social network analysis, and world-systems has provided decades of insights into the functioning of global capitalism and the economic inequalities it generates. Examining the position or role a nation occupies in a given commodity trade constructs meaningful groups of nations more aligned with the relationality of EUE and its emphasis on extractive peripheries (Bunker 1985; Gellert 2010) over national income bifurcations.

It is important to note that some have already deployed social network analysis in analyses of EUE in several ways. First, trade relationships can be treated as a dependent variable to see how EUE relations are formed in the first place. Sommer (2020) predicts forestry export ties, finding rapidly industrializing nations are becoming more prominent in the structure of global forestry exports. Moreover, Sommer (2020) finds that economic development is negatively associated with forestry export ties, showing that more economically developed countries may avoid the consequences of exporting forestry products. Theis (2021) uses exponential random graph models to examine the structure of global e-waste trade, showing support for unequal exchange dynamics. Predicting trade ties shifts “the focus away from fiscal and unit flow measures to a relational network” (Sommer 2020: 315), and in the process illuminates the factors that organize unequal trade structures.

³ Countries that export similar commodity types to similar alters are more regularly equivalent relative to countries that export dissimilar commodity types to dissimilar alters.

Second, network analysis and multi-regional input-output analysis can be used together to provide robust analyses of environmental degradation embodied in trade. For example, Prell and Sun (2015) use multi-regional input-output analysis to construct net carbon transfers, a ratio of carbon emissions embodied in imports (numerator) and in exports (denominator). A U-shaped relationship is found between GDP per capita and net carbon transfers, suggesting that mature economies partially externalize carbon-intensive industries to middle income nations, but not to low income ones. Moreover, network procedures are used to determine how central countries are to global trade in general and as exporters and importers. Prell and Sun (2015) find that countries that are more integrated in trade in general and as importers tend to increase carbon transfers. Thus, globalization may play a role in the weakening relationship between the economy and environment, taking a new approach to debates about ecological modernization and treadmill of production (Mol and Spaargaren 2000; York, Rosa, and Dietz 2003). In this way, embracing relational methods provides practical insights into longstanding debates in environmental sociology, as problems typically analyzed at the national level are put into global and relational contexts.

Third, network analysis and input-output analysis have been used to analyze the economic gains and environmental losses embodied in global trade. Prell and Colleagues (2014) examine how much value-added and sulfur dioxide emissions are embodied in trade relationships of U.S. consumption. Prell and their co-writers (2014) first conduct a positional analysis procedure to categorize countries in the global economy, and then show that core nations benefit most from international trade relationships while noncore nations tend to face environmental costs. This approach departs from conventional methods by considering the global extent of not only environmental costs (and gains) but also economic losses/benefits, attending to both the environmental and economic dimensions of unequal exchange dynamics.

Finally, network methods have been used to establish national positionality in specific commodity flows to see how it modifies the economy-emissions relationship. Vesia, Mahutga, and Buì (2023) place countries into positions using structural equivalence in the natural resource exchange network. While more economic development increases emissions across all countries, countries least integrated in the natural resource trade network experience intensified emissions. In other words, countries more dependent on resource extraction face more emissions because of their development, consistent with expectations from EUE and world-systems theory.

Identifying countries as occupying positions in trade networks opens up empirical questions to whether such categories modify the economic development-emissions relationship in general (Greiner and McGee 2018) or in natural resource exchanges specifically (Vesia et al. 2023) and could be extended to include a plethora of domestic factors relating to prominent questions and debates in macro-environmental sociological research. EUE theorizes geographic zones as occupying particular positions in the global economy in general and specific commodity trades in particular. Thus, treating the primary analytical category as occupying these positions widens the research area, as focus is shifted from “vertical flows” to how the context of countries being an extractive export economy shapes relationships between domestic factors (e.g., economic

development, extractive dependence) and forms of environmental degradation. These methodological approaches move away from treating trade as an independent variable to assess EUE, and towards beginning with determining the role countries play in trade networks and seeing how that context contributes to environmental problems.

Attending to Labor in EUE: Bringing the Social Back In

EUE and related traditions theorize co-constituted ecological and labor exploitation resulting from unequal exchange dynamics. The dominant use of weighted trade flows (and similar metrics) obscures this relationship, and may contribute to “reifying dependency, unequal exchange, or capitalism as causal agents” (Bunker, quoted in Gellert 2019: 114). While Foster (1999, 2000), Moore (2003), and much EUE scholarship focus on the dynamics of the capitalist system, key “ecological, demographic, organizational, and infrastructural dynamics in particular peripheries” (Gellert 2019: 115), and the role of the nation state are generally underexamined. Ultimately this points to the underemphasis of the exploitation of labor in favor of the dynamics of the exploitation of nature, though the historical and theoretical literature reviewed above build socioecological theory describing an inseparability and coproduction of these dynamics (e.g., the corporeal rift). Research in related social science traditions pays attention to these issues, largely through analyses of global value chains (GVC) and multi-regional input-output analysis, serving to reintegrate an analysis of labor, relationality, and co-constitutive socio-environmental relations in avoidance of reifying (E)UE as a causal agent.

Global commodity chains (GCCs) were initially integrated into world-systems analysis and EUE by way of Hopkins and Wallerstein (1977), who presented this analytical category in response to the difficulty of practically and empirically taking the world-system seriously as the key unit of analysis. Rather than centering analyses on the relationship between local and international trade and commodity production, Hopkins and Wallerstein (1977: 128) describe commodity chains as starting with a specific, “consumable item,” which researchers should then “...trace back the set of inputs that culminated in this item—the prior transformations, the raw materials, the transportation mechanisms, the labor input into each of the material processes, the food inputs into the labor.” GCCs have been reframed as GVCs to focus on the actions of large firms and point out that global commodity chains have been increasingly buyer and not supplier driven (Gereffi 1994). This control is employed in structuring value-added processes further down the commodity chain rather than in supplier nations or zones. Various empirical approaches to value chains underscore the relationality of trade relationships.

More general approaches to GVC analysis have “ambiguous” findings with regards to environmental degradation and change, with a range of studies which find evidence for an environmental Kuznets curve as well as unequal distribution of pollution and rebound effects (Althouse et al. 2023). Some point out that GVC analysis attempts a difficult balance between meso-level firm-centered organizational analysis as mechanisms behind EUE while trying to not lose sight of the macro-historical (Bair and Werner 2011).

Empirical studies engaging with GVC span meso- and macro- quantitative approaches as well as historical and qualitative case studies. Macro, quantitative GVC approaches include direct interventions in common EUE empirical approaches relying on net-trade accounting, allowing for a disambiguation between displacement of environmental loads to less developed countries and less environmentally impactful exports from the core (i.e., less embodied resources in exports from the core due to efficiency gains) (Althouse et al. 2023). These approaches generally operationalize GVCs through various approaches of accounting of trade in goods at an intermediary point in value-added production (i.e., Ji et al. 2022).

The “tragedy of the commodity” framework also focuses on commodities to suggest the demands of commodity production and the commodification of nature intensify ecological extraction and production of wastes in pursuit of unending expansion of abstract exchange-value (Longo et al. 2015). Global labor value chain (GLVC) approaches complement the tragedy of the commodity framework by centering on labor relations, valuation, and exploitation. For example, Thailand’s relative position in the aquaculture GLVC and diminishing market share is a driver of conditions of severe labor exploitation and concomitant environmental degradation (Clark and Longo 2022).

Multi-regional input-output (MRIO) analysis also provides compelling pathways for understanding global environmental inequality. A large body of research uses MRIO models to analyze disparate environmental and economic impacts of international trade (Prell et al. 2014; Hubacek et al. 2017; Bolea, Duarte, and Sánchez-Chóliz 2020; Chen, Kang, and Han 2021; Dorninger et al. 2021; Chancel 2022; Hickel et al. 2022; Wang, Xiong, and Ma 2022). Well-established measures of environmental degradation, such as the ecological footprint, use MRIO to develop consumption-based measures of environmental harm, which are particularly useful for analyzing theories of global environmental change like EUE. This approach partially sidesteps market valuation of global trade flows in terms of price or monetary value in favor of direct material flows (i.e., land indirectly and directly required for production in hectares) while also accounting for trade in intermediary goods (Dorninger et al. 2021). In short, MRIO models provide sectoral, transactional accounting of international trade, enabling analyses of global inequities that capture the economic and environmental gains/losses from transboundary commodity flows.

In sum, we argue that methods and perspectives from related traditions in the social sciences, like MRIO and GVC (and their extensions), provide expanded grounds for analyses of EUE. Through these methods, attention is placed not only on environmental degradation in the global South, but also economic gains/losses globally and environmental benefits in the global North. Moreover, the emphasis on economic sectors allows for examining labor practices along the commodity chain and across space. In this way, methodological diversification brings the “social” back into EUE by drawing more attention to the clear and well-documented labor and economic gains/losses that accompany the important environmental consequences of an unequal world-system.

Conclusion

Quantitative research on EUE has enjoyed two decades of fruitful scholarship, developing structural understandings of global environmental inequities. From the approach developed by Jorgenson (2006) and subsequent derivations, a range of environmental issues and inequities have been unveiled, including water pollution (Shandra, Shor, and London 2009), biodiversity loss (Shandra et al. 2009), deforestation (Jorgenson 2006; Shandra, Leckband, and London 2009; Noble 2017; Shandra et al. 2019), and emissions (Jorgenson 2012; Huang 2018). Moreover, methodological refinements have been developed regarding specification of commodity flows (e.g., Jorgenson et al. 2009; Shandra et al. 2009; Noble 2017) and trading partners (Huang 2018; Shandra et al. 2019; Sommer et al. 2020). Recent work calls attention to the role of rapidly industrializing nations in the formation of global environmental inequalities (Shandra et al. 2019; Sommer et al. 2021). Yet, a common thread through this research lies in the conception of the research design: treating national income bifurcations as the central division through which unequal exchange relations take place across countries.

Recent work in macro-environmental sociology has brought methodological considerations to the fore (York and Light 2017; Thombs 2022; Thombs, Huang, and Fitzgerald 2022; Theis and York 2023). In this paper, we bring a more theoretical argument about methodological questions regarding how to assess EUE in that research designs employing national income bifurcations, while useful, could and should be complemented by research designs that locate extractive export hubs using social network analysis, incorporate measures of economic gains/losses, and more fully engage with the implications of EUE for the international division of labor. Given the contingent and contextual nature of EUE, it is important to locate the role nations play in specific commodity trades. GVC and MRIO approaches could incorporate ecological and economic gains/losses into our analyses of EUE, drawing attention not only to the generation of environmental problems in the global South, but also the economic and environmental benefits afforded to the global North. While quantitative analysts have already begun to expand the methodological range of EUE studies, our aim here is to organize these approaches and provide theoretical justifications for them, paving the way for future research on EUE that better aligns methods with theory.

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