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Towards a Structural Analysis of the Second Contradiction of Capitalism

DISSERTATION

submitted in partial satisfaction of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

in Sociology

by

Danielle J. Vesia

Dissertation Committee:
Professor David A. Smith, Chair
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2018

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DEDICATION

To my father, without whose Netflix password this dissertation might have been completed a *little* sooner. I love you, Dad!

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ABSTRACT OF THE DISSERTATION

Towards a Structural Analysis of the Second Contradiction of Capitalism

By

Danielle J. Vesia

Doctor of Philosophy in Sociology

University of California, Irvine, 2018

Professor David A. Smith, Chair

This research models the structure of the global trade network of environmentally destructive industries, namely the trade of natural resources over time. In doing so, it illuminates the social relations embedded within the global distribution of environmental degradation. Chapter 2 presents a comprehensive review of the relevant literature on the relationship between the environment and economic conditions, and builds a theoretical framework for a structural analysis of the second contradiction of capitalism. Chapter 3 presents a network analysis for the structure of the trade of natural resources, showing where the trade of natural resources is centered in the global economy for the years 1970 through 2015. The findings present a structure in which nations traditionally thought of as "core" in the world-system maintain their core status in this structure predicated on the trade of natural resources. Chapter 4 measures the effect of structural conditions in the trade of natural resources on different measures of environmental degradation. The findings show that non-core nations experience worse environmental degradation on measures that are not directly tied to extraction, but do not experience worse environmental degradation on measures that are directly tied to extraction. Chapter 5 explores the relationship between structural changes in the trade of natural resources and economic growth. The findings show that non-core nations experience higher economic growth than core nations, raising the question of whether

environmentally degrading extraction is to blame, or if the analysis is capturing embedded political economic relationships in the global economy.

Chapter 1

Introduction

The trade-off between economic growth and environmental degradation is well established in the literature. It is not controversial to suggest that economic development has externalized environmental costs - even the most optimistic sociological theories of development acknowledge that the process of development is fraught with environmental harms. This position that economic growth externalizes environmental costs has become so mainstream that even the 2018 Nobel Prize in Economics was awarded to economists who study the impacts of economy on environment, and the ways in which economic growth fuels environmental degradation (Elliot, 2018).

In popular media, these debates regarding the trade-offs between economics and the environment often emerge. Beginning with Malthus' warnings about a crisis point beyond which population demands will outstrip food production, to discussions of the limits to growth cropping out of the Club of Rome report, to discussions about energy dependence amidst warnings about a crisis of peak oil, these discussions often devolve into the foretelling of the demise of civilization as we know it (Malthus, 1888; Meadows et al., 1972).

In spite of these alarmist public debates, the idea that environmental degradation affects economic growth has been further explored in sociological circles, at least at a level of production (O'Connor, 1991). These theories do not go so far as to suggest that degradation will trigger the demise of capitalist society, but do suggest that degradation can trigger crises in capitalism. Some other theorists suggest that these crises are averted by the spatio-temporal opportunities inherent within a system of economic globalization, which is why these environmental crises are not felt at a global or structural economic level (Bunker and Ciccantell, 2005; Harvey, 2004; Foster et al, 2011).

This dissertation seeks to adopt a structural, world-systemic lens in order to explore whether there is evidence for an impacts of environmental degradation on economic growth. As the theory suggests, threats posed by environmental degradation are often mitigated through the restructuring of global trade relations. As such, in order to understand the effects of degradation at the global level, it is imperative to first study the relations of trade that exist between nations, and show how those relations may change in response to degradation. The following analysis will accomplish this by constructing trade networks for the flows of natural resources between countries, and examining how these relations evolve over time. Next it will examine the extent to which environmental degradation within nations is attributable to these structural relations. Finally, it will measure how these structural relations are associated with differing patterns of economic growth over time. In doing so, I hope to show whether there is evidence for the effects of environmental degradation on economic growth at the structural level.

In order to adapt the second contradiction of capitalism at a structural level, the primary research question of this dissertation asks whether nations with higher environmental degradation experience slower economic growth. Implications of this study

are to test for evidence of diminished economic growth amid a context of environmental degradation and to better understand how the structural relations within the global economy absorb these threats.

There is reason to believe that environmental degradation is not distributed evenly within the world-system, but rather is distributed in alignment with the social relations embedded within structures of trade. Furthermore, the economic consequences associated with environmental degradation are also likely to be mediated according to these relations. Finally, structural mobility might be indicative of the spatio-temporal fix, in which environmentally degrading practices are globalized in response to local threats.

This research, therefore, models the structure of the global trade network of environmentally destructive industries, namely the trade of natural resources over time. In doing so, I illuminate the social relations embedded within the global distribution of environmental degradation. Next, this dissertation measures the effects of structural features within the trade of natural resources on both environmental degradation and economic growth.

Chapter 2 presents a comprehensive review of the relevant literature on the relationship between the environment and economic conditions, and builds a theoretical framework for a structural analysis of the second contradiction of capitalism.

Chapter 3 presents a network analysis for the structure of the trade of natural resources, showing where the trade of natural resources is centered in the global economy for the years 1970 through 2015. The findings present a structure in which nations traditionally thought of as "core" in the world-system maintain their core status in this structure predicated on the trade of natural resources.

Chapter 4 measures the effect of structural conditions in the trade of natural resources on different measures of environmental degradation. The findings show that non-core nations experience worse environmental degradation on measures that are not directly tied to extraction, but do not experience worse environmental degradation on measures that are directly tied to extraction.

Chapter 5 explores the relationship between structural changes in the trade of natural resources and economic growth. The findings show that non-core nations experience higher economic growth than core nations, raising the question of whether environmentally degrading extraction is to blame, or if the analysis is capturing embedded political economic relationships in the global economy.

Chapter 2

Review of the Literature

2.1 Introduction

This dissertation is an empirical application of some of the prevailing theories in the field of environmental sociology. The following section will describe the historical and current state of the field, and will summarize the existing empirical work by scholars. Additionally, this chapter will investigate the theoretical links between the field of environmental sociology and structural theories of economic development. This chapter will conclude by tying it all together, highlighting how the analysis in this dissertation contributes to this robust body of literature.

2.2 Environmental Sociology

One major focus in the field of environmental sociology is the relationship between the environment and political economic processes. The environment is recognized as a source of both wealth and material inputs to productive processes in the form of natural

resources as well as a cause of hazardous conditions to both humans and social structures alike when considered through processes like pollution and the over-exploitation of resources. This precarious balance is generally acknowledged throughout the various strains of theory, but debate persists regarding how social structures like the economy and the state stand to influence this balance.

2.2.1 Ecological Modernization

One of the early theories in environmental sociology is the theory of ecological modernization. Ecological modernization theory developed out of environmental scholarship in western and northern Europe, and is very much tied to modernization theories of development (Spaargaren and Mol, 1992; Pellow and Nyseth Brehm, 2013). This theory proposes the existence of an ecological Kuznets curve, in which a nation's level of development has a parabolic correlation to its level of environmental degradation (Jorgenson, 2016).

In the 1970s and 80s, the predominant debate in environmental sociology centered on the destructive role of capitalism on the environment. Ecological modernization theory emerged in the early 1980s in response to this discussion as a fundamentally optimistic perspective on the potential of the capitalist system to confront environmental problems emanating from that very system. Early ecological modernization explored the potential for technological advancements that accompany capitalist activities to counteract the negative environmental consequences of economic development. The theory developed into an expanded discussion of the role of the state, markets, and other social institutions in confronting environmental problems.

The theory suggests that though development is associated with environmental harms, further development will reduce these problems. As development reaches a certain level,

a more affluent consumer populace will demand sustainable goods. Through deregulated, "free" market forces, capitalist production will innovate in an "eco-friendly" direction.

This research points to an environmental Kuznets curve, in which least developed countries experience minimal environmental problems as the role of capitalist production in these countries is negligible, industrializing nations experience significant environmental harms as they experience the growing pains associated with development, but the most developed nations again have lower environmental problems. Modernization, then, is viewed as the best and only way to address the ecological crisis.

This theory ultimately falls victim to same fallacies as similarly prescriptive developmental theories, that is, in treating national development as independent of a broader social context, it fails to recognize that the so-called "modernizing" path is not an option for the world's least developed countries. Empirical evidence for this theory is strong for nations in the global north in the modern era. However, it fails to consider that a major precipitating cause for the decline in environmental degradation amongst these nations is the export of environmentally degrading industries to the global south. The problems with this theory arise from its failure to take into account the international dynamics of both the market and the environment. Though there may be empirical evidence to support this ecological Kuznets curve in the European nations from which the theory originated, the theory fails to consider that the environmental harms associated with the level of development of those nations has not been eliminated but merely displaced

This theory continues to resurface, experiencing several re-imaginations in recent years.

2.2.2 Treadmill of Production

Similar to ecological modernization, the treadmill of production theory suggests an important role of processes of modernization or development in determining environmental outcomes (Gould et al., 2004; Jorgenson, 2016). However, in offering a broader examination of the entire structural context of capitalist production, the treadmill of production theory argues that economic growth has an overall negative impact on environmental degradation, and that modernization through technological advancements actually poses a paradoxically higher threat to the environment.

Contrary to the optimism of ecological modernization theory, the treadmill of production theory suggests that development leads to environmental degradation. The treadmill of production theory developed by Alan Schnaiberg and his colleagues (2004) contends that the emphasis on innovation and market based reforms to the ecological crisis only brings up the issue of the Jevons paradox, which states that gains made by sustainable innovations only result in more production and consumption, thereby offsetting any ecological benefits.

In some ways, the theory is one of economic change that bears on environmental impacts. The incorporation of efficient technologies into production processes changes the fundamental relations of production. Whereas in previous models of production, surplus capital is extracted from production by increasing the efficiency of production per worker, the incorporation of labor saving technologies eliminates this avenue for accumulation as the more technologically driven modes of production represent sunk costs for firms. In order to continue to increase the return on investment, there must be an increased production output, requiring more and more material inputs and resources. Thus, capitalist society with its demands for continued growth is stuck on this treadmill of ever-increasing demands on the environment.

The root of the ecological crisis according to this treadmill theory, then, is the imperative for economic growth inherent within the capitalist system. The only way to reverse this tendency towards environmental destruction is through the restructuring of the fundamental political and economic structures of the capitalist system. Any idea of "green" capitalism proposed by ecological modernizationists is blind to the growth imperative of capitalism and its associated ecological impacts.

2.2.3 Ecological Unequal Exchange

The theory of ecological unequal exchange emerged as an analysis of the mechanisms through which the outcomes identified in ecological modernization and the treadmill of production are obtained. This is a structural application of these other theories. Research in this field examines the global structures through which environmental hazard is distributed in the world economic system, thereby recognizing that environmental degradation is a processes that is embedded in a global economic system. The premise in much of this research is that a nation's structural position in the world-economy as determined either through its relative level of development or its relation to other nations will lead to particular levels of environmental risk and degradation, with an overall pattern of core, or highly developed, nations pushing the environmental burden of their consumption onto peripheral and semi-peripheral, or less developed nations (Jorgenson, 2003; Jorgnson, 2006; Jorgenson, 2016).

This theory is supported by substantial empirical work. Nations with high levels of economic dependency on the world-system and greater levels of debt experience deforestation more so than do nations with lower levels (Shandra et al., 2008), suggesting that nations in structurally vulnerable positions in the world-system experience more environmental degradation. Level of development and structural position in the world-

economy are found to be correlated with levels of deforestation, finding that deforestation is most severe in semi-peripheral regions, but that even within less developed nations, development is negatively associated with deforestation (Ehrhardt-Martinez, 1998; Burns et al., 2003; Jorgenson, 2006; Rudel, 1989). Unequal exchange, wherein the export of resources flows vertically from peripheral to core nations, is found to act to exacerbate environmental degradation in the peripheral exporting nations (Jorgenson, 2006; Bunker, 1984). All the while, unequal exchange limits consumption of environmental goods in the least developed nations (Rice, 2007).

Echoing these findings, trade is known to be an important predictor in studies of deforestation among environmental scientists. Studies have repeatedly pointed to distal market demand and international trade as among the largest drivers of deforestation and other land use changes (Lambin et al. 2001; Lambin and Geist, 2006; Meyfroidt et al., 2013). Not surprisingly, these studies suggest that global demand is driving localized environmental degradation, and therefore point to the need to examine the full global causes and effects when studying deforestation.

2.2.4 The Second Contradiction of Capitalism

Whereas the previous three theories attempt to explain the impact of economic processes on environmental conditions, the second contradiction of capitalism proposes a reverse causality, namely suggesting there is an impact of environmental degradation on economic processes.

Capitalism, according to Karl Marx, is a mode of production in crisis (Marx, 2011). This crisis arises from a fundamental contradiction endemic to the system itself, which is the tendency towards crises of overproduction. According to his analysis, this contradiction of capitalism is one between the owners of the means of production, and the

forces of production. In its endeavor to maximize profits for the owners of the means of production, downward pressure is exerted on wages, such that workers ultimately will no longer be able to afford the products they themselves are creating. This is the first contradiction of capitalism.

Sociologist James O'Connor (1991) identified a second contradiction of capitalism, which is an exogenous threat to the system of production. The second contradiction of capitalism describes the tendency of capitalism to undermine the conditions of its own reproduction. O'Connor pointed to the tendency of capitalism to require ever-increasing inputs of finite natural resources, its ever-increasing release of harmful pollutants into the environment, and its strain imposed on the health of workers as examples of the ways in which capitalist expansion might run up against natural limits. The failure of the system to account for these externalized costs leads to a crisis of underproduction.

Similar to the treadmill of production, this theory occurs at the level of production. Much like the theory of unequal exchange did for the treadmill of production, this dissertation seeks to scale the theory of the second contradiction up to global production therefore showing that economic development is a process that is embedded in a global ecosystem.

2.2.5 The Metabolic Rift

Environmental sociology has come close to a structural theory of environmental crisis by singling out trade relations in mediating the effects of environmental degradation. According to this theory, historically, capitalism as a system has avoided environmental limitations to the continued growth required by productive capitalism by geographic expansion, the so called "spatio-temporal fix"(Bunker and Ciccantell, 2005; Harvey,

2004; Foster et al, 2011). Various scholars suggest that these spatial expansions are spurred by unequal power dynamics that create patters of ecological imperialism, accumulation by dispossession, and exploitation.

On the other hand, the global expansion of resource extraction creates a global metabolic rift, whereby more powerful nations experiencing declining environmental conditions are guilty of "environmental overdraft" by redirecting natural resources into their own production and thereby ecosystems, and failing to replenish the ecosystems from which the resources originated. The theory of the metabolic rift comes out of Marx's own writing on soil erosion, and suggests that as consumption becomes further removed from production, nature loses its ability to metabolize the waste associated with consumption. For example, as agricultural products are exported from their place of production, the nutrients in the land are no longer replenished in a way that maintains the fertility of the soil.

2.3 World-Systems Analysis of Economic Development

In addition to examining theories in the field of environmental sociology, the work in this dissertation draws upon theories of economic development, particularly a world-systems analysis of development. Implicit in much of the above discussion is the existence of a world-economy as a singular unit of analysis. The following sections will review the literature in this field in order to provide requisite theoretical context.

2.3.1 The International Division of Labor, the New International Division of Labor, and Resource Peripheries

World-systems analysis is a relational perspective, describing unequal power and economic relationships resulting from trade and exchange. World-systems analysis describes a tripartite global economic system. According to this perspective, globalization as a process is a function of the modern world-system, which is characterized by a world economy with an internal exchange of basic and essential goods in pursuit of endless accumulation. Thus, the quest for accumulation through exchange is the mechanism that drives globalization through the expansion of the world-system. The theory of capitalism as an exchange relation allows for analyses of global capitalism that extends centuries (Wallerstein, 2004; Robinson, 2004; Wallerstein, 2011).

Though raw material extraction is generally acknowledged to be a feature of underdevelopment, there is considered debate in the literature regarding defining the bounds of so-called resource peripheries. World-systems analysis lends itself to a simple definition.World-systems analysis is a relational perspective, describing unequal power and economic relationships resulting from trade and exchange in a tripartite global economic system. One of the defining structural features of the modern world-system is the international division of labor between core and peripheral territories in which raw materials and hyper-exploited labor are provided by peripheral nations. In identifying an international division of labor between core and peripheral regions, the distinction between the two is the predominant mode of production located therein. Core processes are industrialized, peripheral processes are not. Thus, extractive economies are peripheral by definition, as they provide inputs of raw materials to the industrialized core.

However, further analysis of a new international division of labor has produced a more nuanced approach to understanding resource peripheries. Technological advancements in the transportation sector and disparate regulatory environments of both wage labor and production conditions sent heavy industry from core regions to semi-peripheral and peripheral regions, turning the traditional theories of the international division of labor on its head. In the new international division of labor, Wallerstein suggests it is not the mode of production that determines the bounds between core and peripheral regions, but rather the degree of profitability that is derived from the economic activities. Core regions derive relatively high degrees of profit, whereas peripheral regions derive relatively low profits. Thus, core regions may contain extractive processes, but are likely to be more profitable than similar processes in peripheral regions. This discrepancy is likely due to investments in technological advancements that industrialize these modes of extraction - core activities are capital intensive.

In his analysis of the underdevelopment of the Amazon, Stephen Bunker (1984) argued that extreme resource peripheries can be identified by the degree of dependence on the export of natural materials, the low amount of capital and labor embodied in the total value of the exports, and by their limited capacity to build "productive" infrastructure, thus reinforcing their dependence on raw materials. In developing a general model for extractive economies, Bunker pointed to the differing dynamics between productive and extractive economies including the scale of economic activities, the few local economic linkages within these economies that create conditions of extreme labor control, dependence on industrial countries for investment in transportation infrastructure, and the role of the state in governing extraction of resources.

This discussion suggests that identifying resource peripheries requires more than determining where raw materials are sourced. The social, political, and economic conditions of extractive regions must be considered when categorizing nations.

2.4 Tying it all together: building a theoretical model of a structural analysis of the second contradiction

The goal of this research is to build off these theories and existing research to adapt a structural analysis of the second contradiction of capitalism. As this environmental sociology literature shows, there is an established link between economic development and environmental conditions. Research coming out of ecological modernization theory and the treadmill of production theory both agree that the process of economic development results in externalized environmental costs, as measured through increased environmental degradation. Research adhering to the theory of unequal ecological exchange shows that trade mediates the environmental impact of economic growth as nations in structural positions of power incur ecological debts from developing nations, and have disproportionately large ecological footprints when these debts are taken into account.

The research in this dissertation is influenced by this body of work, but diverges in two major ways. First, this dissertation seeks to take the first empirical steps towards reversing the causal arrow in the discussion of the relationship between economic development and environmental growth. The second contradiction of capitalism suggests that continued environmental degradation undermines the ability of economic activity to continue to grow and expand. At the structural level, this begs the question of whether environmental degradation impedes a nation's capacity for economic growth. Second, this research draws upon methods of analysis of the structural features of the global economy. By modeling the relationships between nations in the global trade of natural resources, this research acknowledges that both economic exchange as well as

environmental conditions are features of a global system that needs to be accounted for.

This discussion identifies several feature that must be considered in the creation of a structural theory of the second contradiction of capitalism. First, the role of trade is a crucial element because not only has trade has been theorized to mediate the global economic effects of environmental degradation but as world-systems analysis suggests, social relations are embedded within structures of trade that determine political and economic outcomes. There is reason to believe, therefore, that environmental degradation is not distributed evenly within the world-system, but rather are distributed in alignment with the social relations embedded within structures of trade. Furthermore, the economic consequences associated with environmental degradation are also likely to be mediated according to these relations. Finally, structural mobility might be indicative of the spatio-temporal fix, in which environmentally degrading practices are globalized in response to local threats.

As this discussion shows, the second contradiction of capitalism predicts a feedback loop of environmental degradation of material inputs that affects future production. At the level of production, this theory can be depicted as a circuit of degradation. Material inputs (I) fuel production (P), which through processes of degradation diminishes the conditions necessary to maintain inputs, resulting in fewer inputs (I') and therefore diminished productive capacity (P'):

$$I - P - I' - P'$$

To scale this model to the level of the structural global economy, this discussion shows that the intervening effect of trade must be considered. At the structural level, trade relations allow the process to by-pass the phase of diminished inputs by identifying new sources of material inputs (I_t):

$$I - P - I_t - P$$

This research will examine how structural conditions t relate to national levels of inputs (I) and production (P). It will start by modeling the structure of the global trade network of environmentally destructive industries, namely the trade of natural resources over time. In doing so, it will illuminate the social relations embedded with-ing the global distribution of environmental degradation. Next, this dissertation will measure the effects of structural features within the trade of natural resources on both environmental degradation and economic growth.

Chapter 3

Examining the Structure of the Natural Resources Trade Network

3.1 Introduction

The following analysis models the global structure of the trade of natural resources over time. In doing so, the analysis proposes a global structure of natural resources flows based on conceptions of "extractiveness," and shows how this structure evolves over time. By modeling the changing structure of the global natural resource trade, the following discussion provides an opportunity to evaluate the structural theories of resource extraction to better understand how degradation is allocated in the global economy. It lays the empirical foundation for subsequent chapters that will measure the extent to which the structural evolution presented here is associated with the degradation of environmental conditions in exporting nations within the trade structure, and measure the economic effects for nations in various structural positions in the evolution of the structure.

This analysis is motivated by theories of the effects of environmental degradation on both the capitalist mode of production and structural relations in global trade. Historically, capitalism as a system has avoided environmental limitations to the continued growth required by productive capitalism by geographic expansion, the so called "spatio-temporal fix" (Bunker and Ciccantell, 2005; Harvey, 2004; Foster et al, 2011). Various scholars suggest that these spatial expansions are spurred by unequal power dynamics that create patterns of ecological imperialism, accumulation by dispossession, and exploitation, culminating in unequal exchange relations. Through geopolitical processes of unequal exchange, debt and structural dependence, and (under)development, this spatial fix to the dilemma of environmental degradation follows existing exploitative/dependent relations within the world-system (e.g. see Burns et al., 2003; Jorgenson, 2006; Shandra et al., 2008).

The global expansion of resource extraction creates a global metabolic rift, whereby more powerful nations experiencing declining environmental conditions are guilty of "environmental overdraft" by redirecting natural resources into their own production and ecosystems, and failing to replenish the ecosystems from which the resources originated, thus exacerbating deterioration of environmental conditions. The theory of the metabolic rift comes out of Marx's own writing on soil erosion, and suggests that as consumption becomes further removed from production, nature loses its ability to metabolize the waste associated with consumption. For example, as agricultural products are exported from their place of production, the nutrients in the land are no longer replenished in a way that maintains the fertility of the soil. Marx described this rift between town and country, in which urbanized, densely populated areas strip the agriculturally productive rural areas of their nutrients. In a world-systemic perspective, this discussion is important for two reasons: its emphasis on the role of trade in hastening the depletion of natural resources, and the distinction between town and country which can be extrapolated out to conform to conceptions of core areas and

resource peripheries. In other words, patterns of trade and the structural relations within trade networks are important considerations in the analysis of the global effects of environmental degradation.

3.2 Background: Defining resource peripheries

Though raw material extraction is generally acknowledged to be a feature of underdevelopment, there is considered debate in the literature regarding how to define the bounds of so-called resource peripheries (Chase-Dunn, 1998). World-systems analysis provides a simple definition. It is a relational perspective, describing unequal power and economic relationships resulting from trade and exchange in a tripartite global economic system. One of the defining structural features of the modern world-system is the international division of labor between core and peripheral territories in which raw materials and hyper-exploited labor are provided by peripheral nations. In identifying an international division of labor between core and peripheral regions, the distinction between the two is the predominant mode of production located therein. Core processes are industrialized, peripheral processes are not. Thus, extractive economies are peripheral by definition, as they provide inputs of raw materials to the industrialized core.

However, further analysis has produced a more nuanced approach to understanding resource peripheries. Wallerstein (2005) suggests it is not the mode of production that determines the bounds between core and peripheral regions, but rather the degree of profitability that is derived from the economic activities. Core regions derive relatively high degrees of profit, whereas peripheral regions derive relatively low profits. Thus, core regions may contain extractive processes, but are likely to be more profitable than similar processes in peripheral regions. This discrepancy is likely due to investments in

technological advancements that industrialize these modes of extraction - core activities are capital intensive.

In his analysis of the underdevelopment of the Amazon, Stephen Bunker (1984) argued that extreme resource peripheries can be identified by the degree of dependence on the export of natural materials, the low amount of capital and labor embodied in the total value of the exports, and by their limited capacity to build "productive" infrastructure, thus reinforcing their dependence on raw materials. In developing a general model for extractive economies, Bunker pointed to the differing dynamics between productive and extractive economies in scaling, the few local economic linkages within these economies that create conditions of extreme labor control, dependence on industrial countries for investment in transportation infrastructure, and the role of the state in governing extraction of resources.

This discussion suggests that identifying resource peripheries requires more than determining where raw materials are sourced. The social, political, and economic conditions of extractive regions must be considered when categorizing nations.

This chapter will conduct a network analysis of trade relations based on natural resource commodities to model the structure of extractive exchange and identify the features of nations that are most central in this exchange of natural resources. Previous studies have used similar methodology to the one used here to model the structure of the overall global economy, but these studies focus on a wider array of commodities than just raw materials (Mahutga and Smith, 2011). Some scholars take a more narrow approach and focus on singular commodities, as in the case of Bunker and Cicantell's analysis of aluminum extraction (2005). Other studies seek to model the structure of environmentally unequal exchange, but in doing so ignore the processes of raw material extraction in more developed nations (e.g. Jorgensen, 2006). This analysis is unique in that it take a holistic approach to studying the structure of the natural

resource economy only, looking at the commodities that are considered to be natural resources, but looking over the structure of the trade network within the context of the overarching world-system. It is an updated structural look compared to Mahutga and Smith, looking at a larger set of nations and including a more recent time period. The contribution of this analysis is to better understand the structural relations between extractive economies and level of development, and lays the groundwork for subsequent analyses that will empirically apply the theory of the second contradiction of capitalism to the global economy.

3.3 Methods and Data

The analysis in this dissertation depends upon the construction and analysis of trade network data. This chapter adopts a holistic approach by examining the overall network structure of nations clustering within groups based on network features, and differentiates these clusters by showing their differences across several key economic measures.

The first step in this analysis was the construction of the trade networks. In particular, this analysis is focusing on the trade of natural resources. The decision was made to focus on the trade of natural resources for several reasons. Natural resources are extractive industries, and there are several environmental consequences directly associated with their production. In modeling the structure of the trade of natural resources, it is possibly to identify nations that occupy more extractive positions within the global trade structure.

The definition of natural resources used here is an adaptation from the World Trade Organization's preferred classification of natural resources, narrowly defined (World

Trade Report, 2010). In this dissertation, the definition of natural resources includes commodities from two broad categories of primary products from the first revision of the Standard International Trade Characterization: forestry, and fuels and mining products. The full list of these commodities considered to be natural resources is included in table 3.1. To calculate the total volume of natural resources traded, the volumes for each commodity were summed in accordance with the WTO's guidance. The data informing this analysis comes from the United Nations Commodity Trade Statistics (Comtrade) Database. This was done for the years 1970 through 2015, at 5 year increments.

Table 3.1: SITC Revision 1 Natural Resource Commodities

	SITC1	Commodity
1	24	Wood, lumber and cork
2	25	Pulp and paper
3	27	Crude fertilizers and crude minerals
4	28	Metalliferous ores and metal scrap
5	3	Mineral fuels, lubricants and related materials
6	68	Non ferrous metals

For each year of the analysis, data on reported bilateral imports as well as exports were reported for the 138 nations in this sample. This means that for each exporting nation i that trades with importing nation j, the volume of trade for each commodity reported by both i and j is reported in US dollars. Discrepancies may exist between reported exports and imports for a variety of reasons, though imports are thought to be more reliable accountings of trade as given the collection of import taxes (Mahutga, 2013). For the purposes of this analysis, trade matrices were constructed using the maximum of the two values. The values were then dichotomized to 1 or 0 to indicate the presence or absence of a trade tie. A cutoff point of 100,000 USD was established as the minimum value for a tie to be established. The result of this process is a 138 by

138 matrix for each year of the analysis which shows whether ties exist between each of the 19,044 possible directional pairs of nations.

To capture a more holistic view of the changing structure of the trade of natural resources over time, I clustered nations into groups using a clustering algorithm. Given the relative stability of structural features over time, this analysis was done only for the years 1975, 1995, and 2015. I used the matrices constructed based on the natural resource data to partition nations into clusters of nations based on their structural equivalence for each reported year in order to examine how nations' groupings in these clusters changes over time and to assess changes in the composition of the structure of the global trade of natural resources. To calculate the structural equivalence, I created a matrix of distances between nations i and j using the hamming distance. Hamming distance is calculated by summing the differences between the connections between nation k and nation i, and nation k and nation j. The hamming distance dij will equal 0 if nations i and j are perfectly structurally equivalent.

$$d_{ij} = \sum_{k=1}^{g} (\mid x_{ik} - x_{jk} \mid + \mid x_{ki} - x_{kj} \mid)$$

Though previous research has examined regular equivalence, this dissertation uses structural equivalence in its network analysis. Whereas structural equivalence is based on how similarly nations interact with each other nation, regular equivalence adopts a more lenient measure of similarity by scoring nations according to how they interact with other nations that occupy a similar role.

I then plotted each nation in multidimensional space using dissimilarity measure based on the structural equivalence measures using a principal coordinates analysis. This analysis assigns coordinates in multidimensional space to each nation so that the distances between the points are equal to the measures of dissimilarity. Nations more

structurally equivalent will be closer together in this multidimensional space, and nations farther apart are less structurally equivalent. Finally, using these coordinates, I clustered nations into three clusters using a k-means clustering algorithm. K-means clustering assigns nations into clusters in such a way that the variance within each cluster is minimized. I opted for three clusters to follow theoretical precedent of a tripartite world-system, but also verified that three is an empirically sound number of clusters using a scree plot.

3.4 Results

The full results of the clustering analysis for each of the 138 nations and each of the three years in this analysis are reported in Appendix A. Table 3.2 shows the clustering of nations for nations that are consistent in each year of the analysis. In other words, this table reports nations that are not mobile within the structure of the trade of natural resources. The labels "core,", "semi-periphery," and "periphery" here refer to the structural position within the trade of natural resources, not within the world-system more generally. In that sense, the use of these labels throughout this analysis is particular to this analysis and diverges from the typical usage of these phrases in world-systems analysis. Nations that are consistently clustered into the core group include many nations from Western Europe as well as the United States. Nations consistently grouped into the semi-peripheral group includes a broader set of nations including some from Europe and North Africa. The nations consistently clustered into the peripheral group include nations from all across the globe, including the Caribbean, Asia, and Africa. This is also the largest set of nations.

Table 3.2: Consistent Clusters Membership

	Consistent.Core	Consistent.Semi.Periphery	Consistent.Periphery	Consistent.Periphery..Cont.d.
1	Belgium	Algeria	Afghanistan	Guyana
2	Canada	Argentina	Albania	Haiti
3	France	Bahrain	Andorra	Honduras
4	Germany	Bulgaria	Bahamas	Jamaica
5	Italy	Chile	Barbados	Lao People's Dem. Rep.
6	Japan	Denmark	Bermuda	Liberia
7	Netherlands	Finland	Bolivia (Plurinational State of)	China, Macao SAR
8	Spain	Ghana	Belize	Madagascar
9	Sweden	Hungary	Solomon Isds	Malawi
10	Switzerland	Iran	Brunei Darussalam	Maldives
11	United Kingdom	Ireland	Burundi	Mali
12	USA	Israel	Central African Rep.	Mauritania
13		Ivory Coast	Chad	Mauritius
14		Kuwait	Congo	Nepal
15		Lebanon	Cuba	Vanuatu
16		Morocco	Benin	Nicaragua
17		New Zealand	Dominica	Niger
18		Nigeria	El Salvador	Papua New Guinea
19		Pakistan	Equatorial Guinea	Guinea-Bissau
20		Peru	Ethiopia	Rwanda
21		Philippines	Faeroe Isds	Saint Kitts and Nevis
22		Romania	Fiji	Sierra Leone
23		Tunisia	Djibouti	Somalia
24		Venezuela	Gabon	Suriname
25			Gambia	Togo
26			Gibraltar	Uganda
27			Guatemala	Samoa
28			Guinea	

Looking at the trade networks over time, clear patterns emerge. Figure 3.1 shows the overall density of the trade network of natural resources over time. Density is a measure of the proportion of existing ties relative to the total amount of possible ties. It is clear from this figure that trade of natural resources in intensifying among the 138 nations in the sample. More specifically, this shows that nations are trading with more partners over time. Indeed, the volume of trade has also increased substantially between 1970 and 2015. Without accounting for inflation or changes in commodity pricing, the total value of natural resources traded within this network jumped from 58 billion USD in 1970 to more than 2 trillion USD in 2015.

When examining the correlation between logged gross domestic product and the number of export ties a nation has, independent of clustering, an interesting pattern emerges. Figure 3.2 shows the positive, linear correlation between these two variables. This correlation suggests that higher income nations have more export ties, and lower income nations have fewer export ties. This suggests that the most extractive set of nations is comprised of the wealthiest nations.

Partitioning the data into clusters also yields important patterns, both in terms of the characteristics of each cluster as well as in the trade of natural resources. Figures 3.3, 3.4, and 3.5 depict each nation plotted in multidimensional space according to dissimilarity measures derived from the structural equivalence of the nations. They also show the clustering of nations based on the k-means clustering analysis.

Table 3.3 shows number of nations in each cluster for each time period. Over time, there are fewer nations in the periphery, and more in the core. In fact, core membership more than double between 1975 and 1995. The semi-periphery experiences a less clear pattern: it experiences a decline in membership between 1975 and 1995, but regains members between 1995 and 2015. Looking at the actual memberships detailed in Appendix A, no nations jump directly from the periphery to core at any time point,

Figure 3.1: Trade Network Density over Time

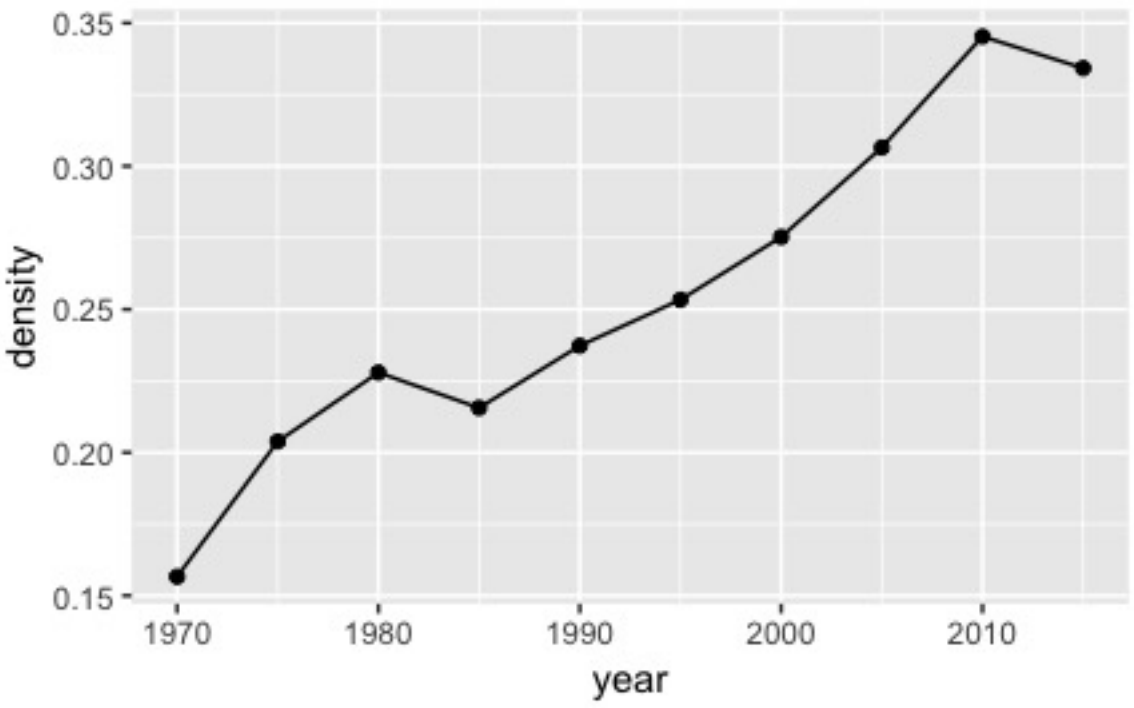


Figure 3.2: Export partners and Logged GDP

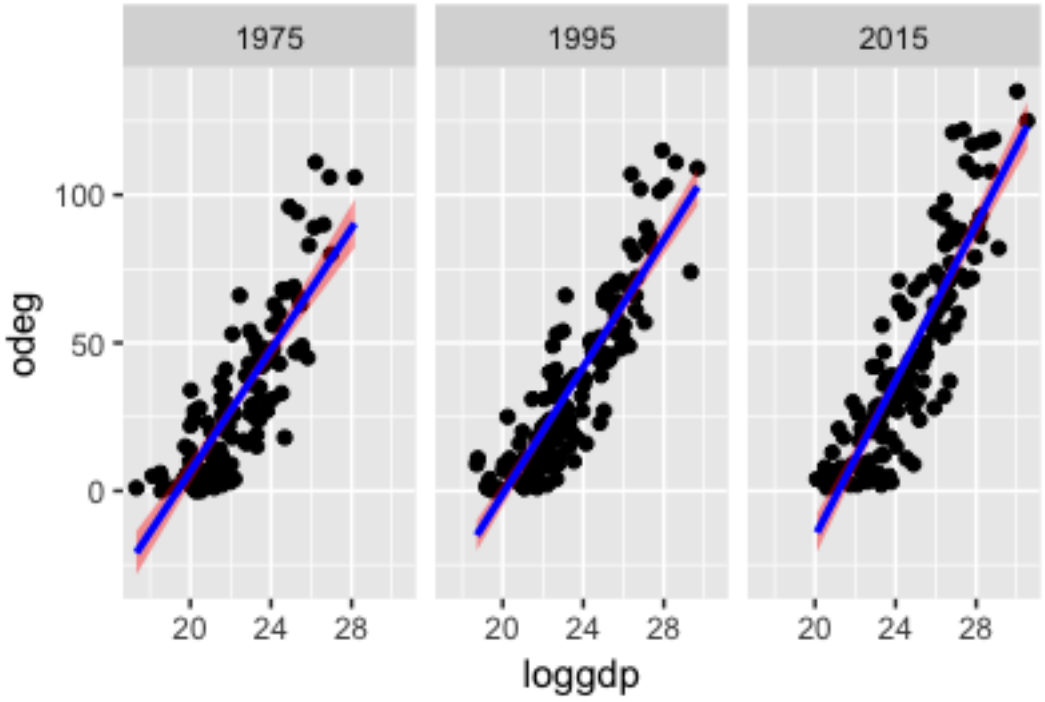


Figure 3.3: Clustering: 1975

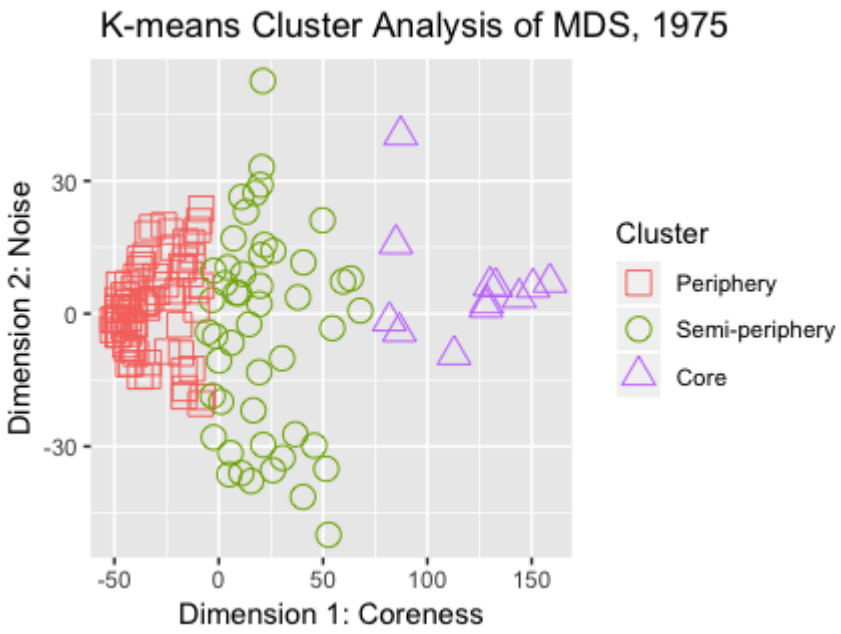


Figure 3.4: Clustering: 1995

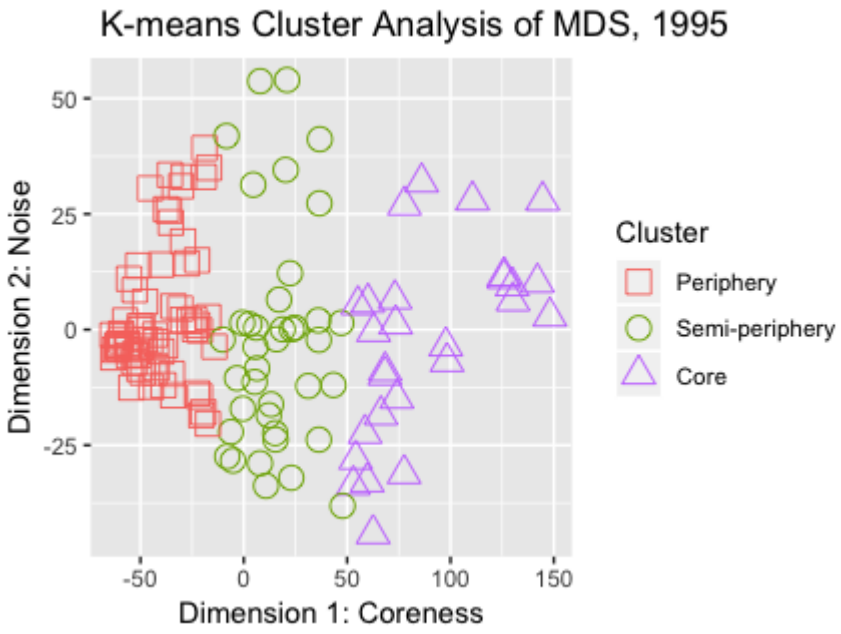
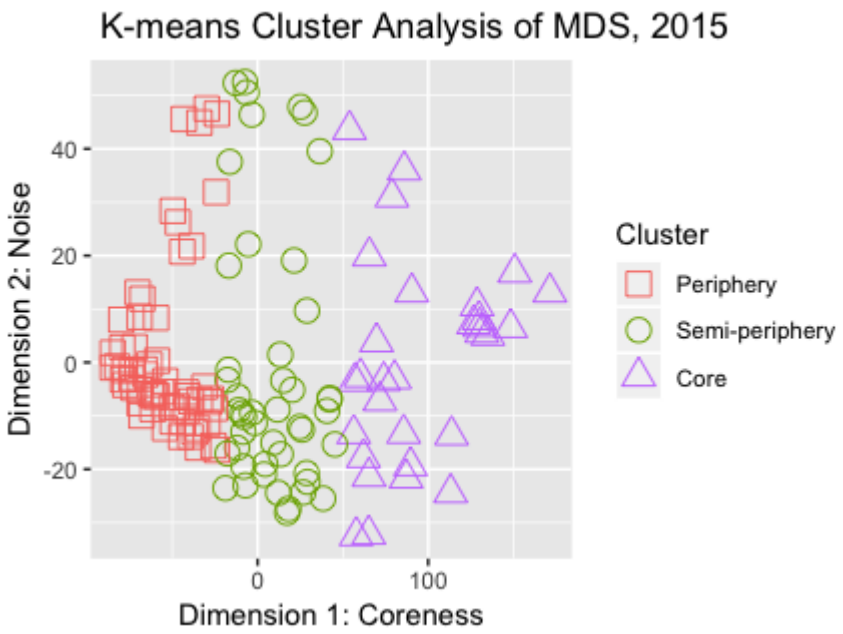


Figure 3.5: Clustering: 2015



so these changing membership patterns actually represent shifts into and out of the semi-periphery.

Figures 3.6, 3.7, 3.8, and 3.9 show some bivariate analyses related clusters over time that allow us to better understand the clusters. First, figure 3.6 shows differences across groups in GDP per capita over time. It is evident from this figure that across time, core groups have significantly higher GDP per capita than either the semi-periphery and the periphery - a key insight that helps to identify these as core nations. However, there are not significant differences between the periphery and semi-periphery, and none of the groups experience significant changes over time within the clusters. A second factor that helps identify the clusters is the clusters' dependence on exports of natural resources. Figure 3.7 shows the confidence intervals for the mean ratio of exports to GDP. Again, we can see that in general, exports account for a lower proportion of GDP for core nations across time, and again, we see no significant differences between the periphery and semi-periphery. However, one important insight from this analysis is that based on the size of the confidence intervals, core nations have much less variability in

Table 3.3: Cluster Size by Year

	Cluster	Year	N
1	Periphery	1975	77
2	Periphery	1995	72
3	Periphery	2015	61
4	Semi-periphery	1975	49
5	Semi-periphery	1995	39
6	Semi-periphery	2015	47
7	Core	1975	12
8	Core	1995	27
9	Core	2015	30

dependence than do peripheral nations, particularly when comparing 1975. However, the confidence interval for peripheral nations does narrow after 1975.

Figure 3.8 shows the mean number of export partners for the trade of natural resources in each cluster over time. Here, the clearest patterns emerge. Core nations have the most number of export partners. Semi-peripheral nations have significantly fewer export partners, and peripheral nations have significantly fewer than both groups.

Comparing the relatively higher dependence on exports for peripheral nations with the low number of export partners across time, this suggests that for some nations in the periphery, classical dependency relations may have been in effect for these nations. This may explain why there appears to be more volatility in these trends for peripheral nations.

Finally, figure 3.9 shows the average value of the total exports of natural resources over time for each cluster. This figure shows that while each cluster experiences increases in the average value of natural resource exports over time, important comparisons can also be made across clusters within any given time point. In addition to being the most embedded cluster in the trade of natural resources, the cluster of nations constituting the core are on average more extractive than other clusters at each time point.

Figure 3.6: GDP per Capita by Cluster

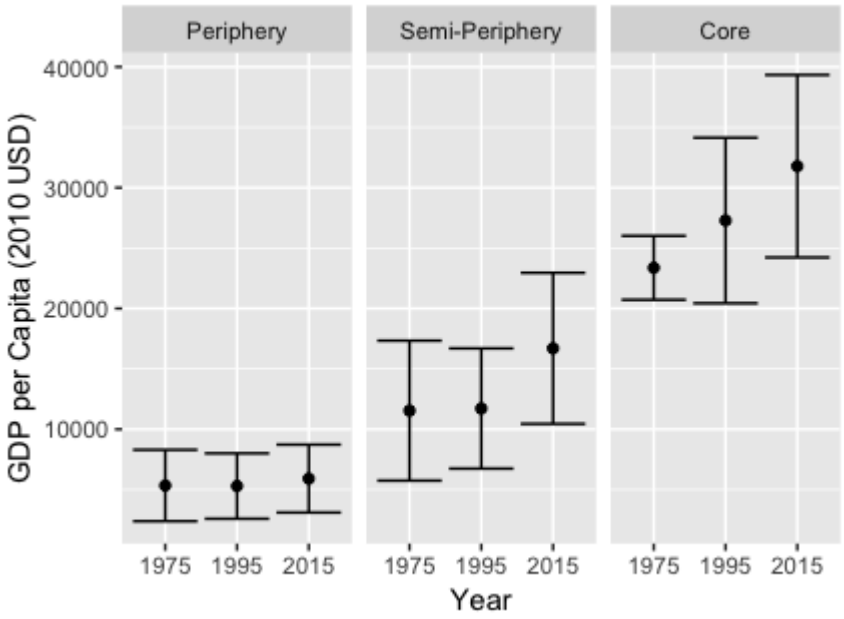


Figure 3.7: Exports of Natural Resources as a Proportion of GDP by Cluster

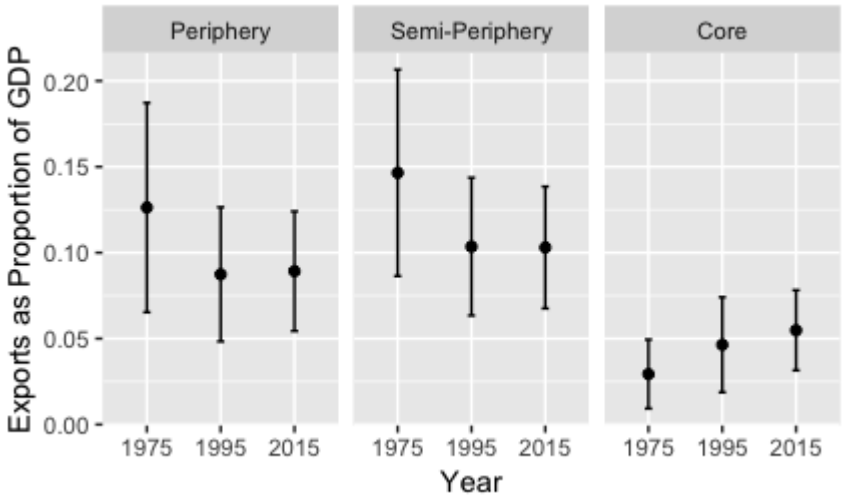


Figure 3.8: Number of Export Partners by Cluster

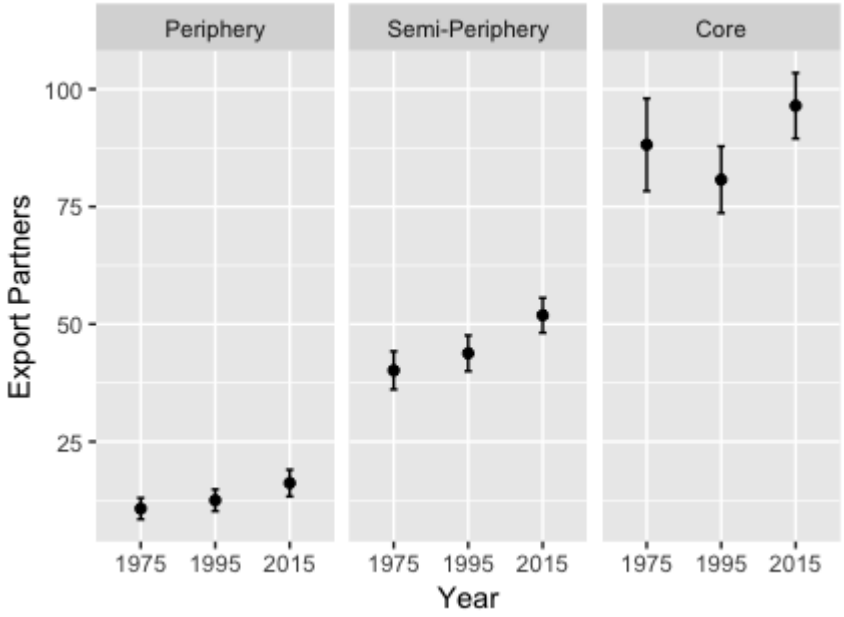
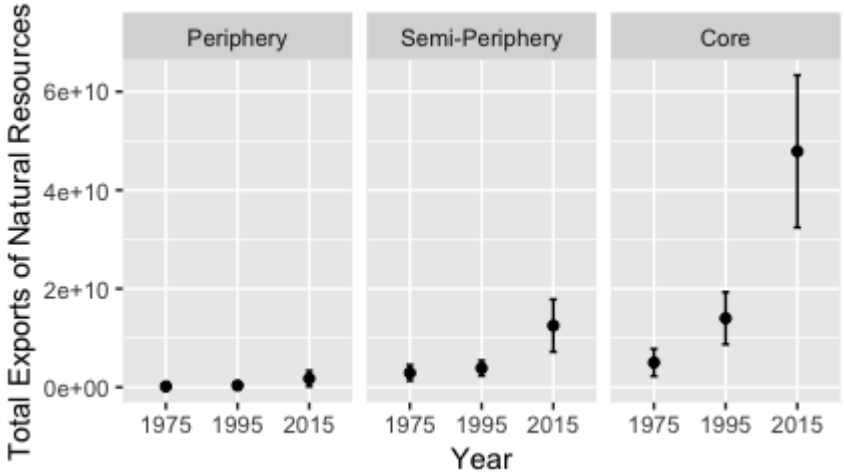


Figure 3.9: Average Export Value by Cluster



The next step in the network analysis is to examine how the blocks relate to each other in the overall trade of natural resources. Tables 3.4, 3.5, 3.6 show density matrices for the clusters for the years 1975, 1995, and 2015. In each table, the densities, or the proportion of existing ties relative to the total number of possible ties between the groups are reported in parentheses. Exporting clusters are reported in the rows, and importing relations are reported in the columns. Each relation is assigned a value of 1 or 0, depending on whether the density of the relation in question is higher than the density of the overall network.

In 1975 and 1995, the overall structure shows a classic center-periphery relationship. What I have labeled the "core" nations are at the center of this, meaning that in these years they export to and import from every other cluster more than we would otherwise expect. Peripheral nations, on the other hand, primarily only trade with the core. Meanwhile, semi-peripheral nations trade among themselves and with the core.

In 2015, this structural relationship shifts. In this year, the pattern that emerges is more centralized in the core. Peripheral nations no longer trade as much with nations in the core, and semi-peripheral relations only export to nations in the core, but no longer to each other. The core still exports to the semi-periphery.

Table 3.4: Density Matrix 1975

	Periphery	Semi-Periphery	Core
Periphery	0 (0.025)	0 (0.082)	1 (0.400)
Semi-Periphery	0 (0.103)	1 (0.442)	1 (0.917)
Core	1 (0.409)	1 (0.932)	1 (1.000)

Considering these patterns in which nations' structural position shifts over time, and export activity becomes increasingly concentrated in the core, a useful metric to examine is a measure of structural mobility, that is, how nations' structural position changes over time. This measure is adopted from the mobility measure used by Mahutga and

Table 3.5: Density Matrix 1995

	Periphery	Semi-Periphery	Core
Periphery	0 (0.028)	0 (0.071)	1 (0.289)
Semi-Periphery	0 (0.097)	1 (0.386)	1 (0.821)
Core	1 (0.318)	1)0.823)	1 (0.990)

Table 3.6: Density Matrix 2015

	Periphery	Semi-Periphery	Core
Periphery	0 (0.025)	0 (0.061)	0 (0.251)
Semi-Periphery	0 (0.074)	0 (0.267)	1 (0.687)
Core	0 (0.276)	1 (0.677)	1 (0.975)

Smith in their 2011 paper, and is calculated twice: mobility between 1975 and 1995, and between 1995 and 2015. Using nations' coordinates in multidimensional space, distance from a nation's position along the first dimension to the overall mean position of the core nations is calculated at each time point. Mobility u_{ik} is calculated as the difference in distance to the core a time t and distance to the core at time $t+1$ as a total proportion of the distance at time t. In other words, it is a the total distance towards or away from the center of the core a nation moves as a proportion of the total distance it would have had to move to reach the center of the core.

$$u_{ik} = \frac{(d_{it} - d_{i(t+!)})}{d_{it}}$$

where:

$$d_{it} = \overline{x}_{ct} - x_{it}$$

These measurements are summarized in table 3.7. This analysis shows that on average, peripheral nations are less mobile across the two time periods. Between 1975 and 1995,

both groups are, on average, upwardly mobile, but between 1995 and 2015, both groups are, on average, downwardly mobile. In other words, between 1975 and 1995, nations in the periphery and semi-periphery move closer to the core in terms of their structural equivalence. Between 1995 and 2015, though, during the same time period that trade of natural resources is becoming concentrated in the core, nations in the semi-periphery and periphery are moving further away from the core nations in terms of their structural equivalence.

Table 3.7: Average Mobility by Cluster

Cluster	1975-1995	1995-2015
Periphery	0.17	-0.074
Semi-Periphery	0.418	-0.04

3.5 Discussion

This analysis reveals three concurrent trends in the structure of the natural resource economy over time. First, there is a massive increase in the volume of natural resources traded among these 138 nations between the years 1975 and 2015, both in terms of overall value of exported natural resources and in terms of intensification of trade activity as measured through network density.

Second, between 1975 and 1995, there is an expansion of the categorization of nations that are considered to be core in the global trade on natural resources. Not only are these core nations the most active in the export of natural resources, they are also the wealthiest nations when looking at GDP per capita, and the least dependent on the export of natural resources when looking at exports as a proportion of GDP. This finding runs counter to classical world-systems theories that suggest dependency relations create a resource periphery in which less developed nations export raw materials to

the core through relations of unequal exchange. Rather, the findings from this analysis show evidence of a new international division of labor, at least within the trade of natural resources.

Finally, accompanying this expansion of both trade and the set of nations considered "core", we see a consolidation of trade activities among the expanded set of nations in the core category. This overall pattern is suggestive of a stratification over time in this structure of trade of natural resources. However, instead of a structure with a clear resource periphery, this analysis shows a concentration of export activity in the core.

The structural relations presented here reveal several different factors that may affect the relationship between environmental degradation and economic development, which will be analyzed in the subsequent chapters. If, as Wallerstein suggests, that extractiveness in core nations is characterized by capital intensity, there is reason to believe that the effect of environmental degradation on continued extraction may be less severe in these cases. Similarly, it is possible that the relationship between these factors will vary according to the dependence of each nation on its export of natural resources as Bunker suggests. This analysis also raises the possibility that the network analysis presented here is capturing a more general trend in the broader global economy: that the clustering memberships identified here generally align with most other similar world-systemic analysis, it is possible that the relations captured here are simply that the core nations have many more trading partners generally, and the periphery many fewer. Further analysis will attempt to tease out this distinction.

Additionally, it is worth exploring the role of environmental degradation in accounting for the structural shift that occurs after 1995 in which the trade of natural resources becomes centralized in the core. This structure that largely relies on high income nations to supply natural resources may be well suited to addressing environmental crises such that there is no impact on economic conditions. That is, these core nations

represent the wealthiest nations and those least dependent on natural resource exports, and therefore may be able to absorb any economic consequences brought about by declining environmental conditions.

Finally, it is worth exploring the role of environmental degradation in driving the centralization of exporting natural resources towards the core nations. It is possible that mobility in the structure of the trade of natural resources is tied to environmental degradation.

3.6 Conclusion

The analysis presented in this chapter sought to examine structural features in the trade network of natural resources over time to better understand how social and economic conditions relate to the distribution of natural resource exports in the global economy. It proposed that social relations of power are embedded in structural trade relations between nations. The findings presented here do show that economic wealth is tied to extractiveness in the network of natural resources. However, the data shows that more central nations in extractive exchange are the wealthiest nations. Instead of identifying a clear resource periphery in which low-income nations provide the global economy with the bulk of natural resources, this analysis shows that the most developed nations are both the providers and consumers of natural resources, while upwardly mobile nations in the semi-periphery vie for a more prominent structural position in the trade network.

Chapter 4

The Effects of Structural Measures on Environmental Degradation

4.1 Introduction

The aim of this chapter is to measure the relationship between structural features in the trade network of natural resources and various measures of environmental degradation. Using the clusterings within the structure of the trade of natural resources identified in the previous chapter, I will measure the extent to which cluster membership in 1995 as well as structural mobility between 1995 and 2015 predict several measures of environmental degradation.

As the previous chapter showed, there was an intensification of trade of natural resources over time as the trade network of natural resources experienced increases in both density and volume. Furthermore, the network analysis showed that these patterns of intensification are correlated with economic output, suggesting that nations with higher levels of development have more export partners and thus are more central

to the network. This points to the possibility that exporting natural resources could be seen as a path towards development by nations. Alternatively, it could be the case that this structural analysis is capturing more general structural relations, i.e., the nations that have been identified as core in the trade of natural resources are central in all trade networks. The purpose of this chapter is to try to tease out these ideas by bringing into this analysis an environmental component.

4.2 Background

The pressure endogenous to the logic of capitalist production to continually extract wealth from production builds towards what has been called the second contradiction of capitalism, or the "absolute general law of environmental degradation." James O'Connor (1991) identifies the tendency of capitalism to undermine the conditions of its own reproduction. The identification of the second contradiction suggests that factors exogenous to the system of production can affect that very system. O'Connor pointed to the tendency of capitalism to require ever-increasing inputs of finite natural resources, its ever-increasing release of harmful pollutants into the environment, and its strain imposed on the health of workers as examples of the ways in which capitalist expansion might run up against natural limits. The failure of the system to account for these externalized costs leads to a crisis of underproduction. Other writings on this theory predict that the economic repercussions of this contradiction will become apparent as the capitalist system internalizes more of the environmental costs of production (Foster, 1992).

The second contradiction of capitalism predicts a feedback loop of environmental degradation of material inputs that affects future production. At the level of production, this theory can be depicted as a circuit of degradation. Material inputs (I) fuel produc-

tion (P), which through processes of degradation diminishes the conditions necessary to maintain inputs, resulting in fewer inputs (I') and therefore diminished productive capacity (P'):

$$I - P - I' - P'$$

To scale this model to the level of the structural global economy, this discussion shows that the intervening effect of trade must be considered. At the structural level, trade relations allow the process to by-pass the phase of diminished inputs by identifying new sources of material inputs (I_t):

$$I - P - I_t - P$$

Previous empirical research does suggest that there are correlations between economic conditions and environmental degradation, though these studies tend to be centered around questions of development and dependency. Nations with high levels of economic dependency on the world-system and greater levels of debt experience deforestation more so than do nations with lower levels (Shandra et al., 2008), suggesting that nations in structurally vulnerable positions in the world-system experience more environmental degradation. Level of development and structural position in the world-economy are found to be correlated with levels of deforestation, finding that deforestation is most severe in semi-peripheral regions, but that even within less developed nations, development is negatively associated with deforestation (Ehrhardt-Martinez, 1998; Burns et al., 2003; Jorgenson, 2006; Rudel, 1989). Unequal exchange, wherein the export of resources flows vertically from peripheral to core nations, is found to act to exacerbate environmental degradation in the peripheral exporting nations (Jorgenson, 2006; Bunker, 1984). All the while, unequal exchange limits consumption of environmental goods in the least developed nations (Rice, 2007).

The following analysis builds off both of these theoretical implications by measuring the extent to which environmental degradation is associated with social relations embedded within a nation's structural position in the world-system. Structural position, as described in the previous chapter, is a function of the relative trade relations between nations, and delineates core and peripheral areas in the trade network of natural resources. Furthermore, as discussed in the previous chapter, a nation's economic well-being as measured through it gross domestic product is correlated with the number of trade partners a nation has, which in turn is correlated with the structural position of a nation. Understanding how a nation's structural position in the trade network of natural resources is associated with environmental degradation, then, may offer insight into how the structural conditions of trade mediate the effects of degradation on the overall economic conditions of a nation.

4.3 Research Questions and Hypotheses

The purpose of the chapter is to ask how structural trade relations affect national levels of environmental degradation. The previous chapter shows a global trade structure in the trade of natural resources showing three clusters of nations, in which the most central, extractive nations are also the wealthiest nations and the least economically dependent on the trade of natural resources to sustain their economic growth. The analysis also showed patterns of mobility within the structure, as nations move into and out of the semi-peripheral cluster over time. Therefore, this chapter will also ask how structural mobility is correlated with environmental degradation. Accordingly, this chapter proposes two sets of hypotheses.

The second contradiction of capitalism tells us that the most extractive nations should experience more environmental degradation:

H_1a: The most central nations in extractive exchange will experience worse environmental degradation

However, previous empirical research in the field of environmental sociology tells us that semi-peripheral nations experience worse environmental degradation. Because the clustering in this analysis largely coincides with previous studied of structural development, we may expect similar patterns in this analysis:

H_1b: The semi-peripheral nations in extractive exchange will experience worse environmental degradation

Finally, previous research in environmental sociology also suggests that the process of development has consequences for environmental degradation:

H_2: Nations that are upwardly mobile in the structure of extractive exchange will experience worse environmental degradation

4.4 Data

4.4.1 Environmental degradation

This analysis measures the effects of structural position on four measures of environmental degradation: an environmental health related measure of exposure to air pollution, a measure of deforestation, and two measures of greenhouse gas emissions. All of this data was collected from the World Bank World Development Indicators.

- Deforestation: The measure for deforestation is calculated as the change in the proportion of forest area in square kilometers between 1995 and 2015. A positive score represents gains in forest cover, whereas a negative score represents

depletion of forest cover. This is a direct measure of environmental degradation associated with the extractive industries represented by the network analysis.

- Methane emissions: This is a measure of the average methane emissions of a nation between 1995 and 2015, expressed as the carbon dioxide equivalent using the global warming potential. Extraction of fossil fuels has been shown to be responsible for as much as 45 percent of methane emissions (Schwietzke et. al, 2016). This is a direct measure of an environmentally degrading byproduct associated with the extractive industries represented by the network analysis.

- Environmental health (PM2.5): This is a measure of the mean annual exposure of the population to levels of particulate matter in the air with a diameter of less than 2.5 micrometers, or 1 400th of a millimeter. Long-term exposure to PM2.5 has been tied to increased mortality risk, especially from cardiovascular causes. Short term exposure to high concentrations of PM2.5 has been tied to exacerbate lung and heart conditions. Sources of PM2.5 include emissions from vehicles, industrial emissions, and burning of non-smokeless fuels (UK Department for Environment, Food, and Rural Affairs). PM2.5 levels were pooled as the average mean annual exposure between 1995 and 2015.This is an indirect measure of environmental degradation associated with the extractive industries represented by the network analysis.

- Carbon dioxide emissions: This is a measure of the carbon dioxide emissions, measured as the ratio of kilograms of emissions to its gross domestic product. For each nation, this is averaged across the years 1995 to 2015.This is an indirect measure of environmental degradation associated with the extractive industries represented by the network analysis.

4.4.2 Structural position

Structural position is assigned according to the procedure described in the previous chapter. Nations are clustered into groups according to their structural equivalence. To calculate the structural equivalence, I created a matrix of distances between nations i and j using the hamming distance. Hamming distance d_{ij} is calculated by summing the differences between the connections between nation k and nation i, and nation k and nation j:

$$d_{ij} = \sum_{k=1}^{g} (\mid x_{ik} - x_{jk} \mid + \mid x_{ki} - x_{kj} \mid)$$

I then assigned each nation coordinates in multidimensional space based on a dissimilarity measure derived from their structural equivalence, and clustered nations into three groups using a k-means clustering algorithm. Though these three clusters are in line with other world-systems analyses of structural position, the use of the categories "core," "semi-periphery," and "periphery" in this research refers specifically to structural positions in the trade of natural resources. Core nations are also the most embedded in the trade network of natural resources but are least dependent upon the export of natural resources. This set of nations includes much of western Europe and the United States. Semi-peripheral are less embedded in the network than core nations and more dependent on the export of natural resources than core nations, and includes nations in Europe and North Africa. Peripheral nations are the least embedded in the network, and includes nations in the Caribbean and across Asia. The full list of membership in clusters for each time point is in Appendix A.

Dummy variables for cluster membership as measured in 1995 were created. Core nations are the category that was excluded from the analysis.

4.4.3 Mobility

The analysis includes a measure of structural mobility between the years 1995 and 2015. This is adopted from the mobility measure used by Mahutga and Smith in their 2011 paper. Using nations' coordinates in multidimensional space, distance from a nation's position along the first dimension to the mean position of the core nations is calculated at each time point. Mobility u_{ik} is calculated as the difference in distance to the core a time t and distance to the core at time $t+1$ as a total proportion of the distance at time t. This analysis excludes the extreme outliers.

$$u_{ik} = \frac{(d_{it} - d_{i(t+!)})}{d_{it}}$$

where:

$$d_{it} = \overline{x}_{ct} - x_{it}$$

4.4.4 Controls

Each of these measures was taken from the World Bank World Development Indicators.

- Debt: This is a measure of a nation's total central government's debt as a proportion of the nation's GDP. This is averaged for the years 1995 - 2015.
- Export Sums: This is the total value of exports of natural resources, averaged for the years 1995 - 2015.
- Forest Cover: This is a measure of the initial forest cover in 1995, measured in square kilometers.

- Trade openness: This is measured as the ratio of the sum each nation's total merchandise imports and exports to its gross domestic product. This measure should approximate a measure of how open to international trade a nation is. This is averaged for the years 1995 - 2015.

- Population density: This is measured as the total number of people per square kilometer of land area, averaged for the years 1995 - 2015.

- Gross Domestic Product (GDP): This is a measure of a nations GDP in 2010 US dollars, averaged for the years 1995 - 2015.

4.5 Method

Because reliable cross national environmental data is only available beginning in the 1990s, this analysis focuses on cluster membership in 1995 and 2015.The results show an ordinary least squares regression analysis in which pooled measures of environmental degradation are regressed on 1995 structural position in the trade networks of natural resources, structural mobility between 1995 and 2015, and other various controls. This model shows the effects of structural position and structural mobility on average measures of degradation across a twenty year time period. One benefit to doing this analysis in this way is that, given that cluster membership is measured at the initial 1995 level, it allows for more causal interpretations of the effects of structural position on degradation.

Table 4.1: Regression of Deforestation on Structural Measures

	Dependent variable:			
	Change in Forest Cover			
	(1)	(2)	(3)	(4)
Semi-periphery	−1.326	−3.026	−1.068	−1.134
	(3.663)	(4.654)	(3.888)	(3.848)
Periphery	−2.805	−3.753	−2.529	−2.291
	(3.962)	(4.998)	(4.233)	(4.256)
Mobility			−0.303	2.659
			(2.764)	(3.087)
Semi-periphery:Mobility				−14.821**
				(7.191)
Periphery:Mobility				−9.027
				(13.259)
Debt		0.015		
		(0.032)		
Export sums	−0.00004	−0.0001	−0.00004	−0.00002
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Forest cover 1995	2.543***	2.504***	2.535***	2.578***
	(0.139)	(0.153)	(0.143)	(0.144)
Trade Openness	−4.416	−1.237	−4.343	−4.321
	(3.187)	(3.611)	(3.268)	(3.235)
Population Density	0.002	0.001	0.002	0.002
	(0.002)	(0.002)	(0.002)	(0.002)
Child Mortality	−0.006	−0.013	−0.008	−0.007
	(0.025)	(0.038)	(0.026)	(0.026)
GDP	−0.000	0.000	−0.000	−0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Constant	5.106	3.708	4.878	4.257
	(4.010)	(5.338)	(4.253)	(4.220)
Observations	129	66	125	125
R^2	0.781	0.860	0.780	0.789
Adjusted R^2	0.767	0.837	0.763	0.768
Note:				*p<0.1; **p<0.05; ***p<0.01

4.6 Results

The results of the analyses are reported in tables 4.1, 4.2, 4.3, and 4.4. For each of the four measures of environmental degradation, the results of four models are presented.

The first set of models in table 4.1 examines the relationship between nations' structural position in the trade of natural resources and changes in forest cover. Across all four models, a significant predictor for changes in a nation's forest cover is the initial forest cover in the year 1995, controlling for all other variables. Across all models, more forest area is positively correlated with forest change, suggesting that nations with more forest area experience gains in forest cover. That non-core nations do not experience worse degradation on this measure is itself a substantively significant finding, as previous studies have overall shown that deforestation is most severe in semi-peripheral regions, and development has a generally negative correlation with deforestation (Ehrhardt-Martinez, 1998; Burns et al., 2003; Jorgenson, 2006; Rudel, 1989).

Looking at the full model, the interaction between mobility in the structure and semi-periphery is negative and statistically significant at the alpha = 0.05 level. This suggests that for nations in the semi-periphery, structural mobility between 1995 and 2015 has a negative effect on forest cover. In other words, this suggests that as semi-peripheral nations moved closer to the core, they experienced more forest loss, even after controlling for all other variables.

The results of the analyses looking at the effects of structural position on methane emissions are presented in table 4.2. The first model shows a significant, negative correlation between nations in the semi-periphery and methane emissions when compared to core nations, suggesting that nations in the semi-periphery have significantly lower methane emissions than core nations. The effect remains in second model that accounts for a nation's debt level. In this second model, peripheral nations also have a

Table 4.2: Regression of Methane Emissions on Structural Measures

	Dependent variable:			
	Methane Emissions (kt of CO2 Equivalent)			
	(1)	(2)	(3)	(4)
Semi-periphery	$-53,660.2$	$-65,021.0^{*}$	$3,545.2$	$2,859.5$
	$(35,311.2)$	$(33,974.6)$	$(14,230.1)$	$(14,146.5)$
Periphery	$-82,308.6^{**}$	$-88,325.5^{**}$	$-13,802.4$	$-15,772.5$
	$(38,611.6)$	$(36,849.7)$	$(15,662.1)$	$(15,815.1)$
Mobility			$-10,290.2$	$-20,320.1^{*}$
			$(10,185.2)$	$(11,540.8)$
Semi-periphery:Mobility				$49,527.4^{*}$
				$(26,473.3)$
Periphery:Mobility				$20,589.1$
				$(49,135.7)$
Debt		-193.1		
		(239.0)		
Export sums	0.1	1.1	0.8^{***}	0.7^{**}
	(0.7)	(0.8)	(0.3)	(0.3)
Trade Openness	$-34,294.4$	$-49,490.6^{*}$	$-24,791.6^{**}$	$-25,074.0^{**}$
	$(31,181.7)$	$(26,568.0)$	$(12,171.2)$	$(12,095.1)$
Population Density	0.2	2.3	1.8	3.0
	(20.0)	(15.7)	(7.9)	(7.9)
Child Mortality	341.3	639.0^{**}	164.4^{*}	173.8^{*}
	(226.5)	(257.6)	(88.6)	(88.2)
GDP	0.000^{***}	0.000^{***}	0.000^{***}	0.000^{***}
	(0.0)	(0.0)	(0.0)	(0.0)
Constant	$87,811.9^{**}$	$105,162.5^{***}$	$24,585.9$	$26,684.8^{*}$
	$(39,038.9)$	$(39,285.9)$	$(15,771.8)$	$(15,709.5)$
Observations	130	66	126	126
R^2	0.4	0.6	0.6	0.6
Adjusted R^2	0.3	0.5	0.6	0.6
Note:				*p<0.1; **p<0.05; ***p<0.01

significant, negative correlation with methane emissions at the alpha = 0.1 level. These effects disappear in the third model that accounts for structural mobility, but in this model the total value of exports of natural resources does show to be significantly and positively correlated with methane emissions. Finally, the fourth model that shows the interactions between structural position and mobility shows that upwardly mobile semi-peripheral nations have significantly higher methane emissions at the alpha = 0.01 level.

The results of the analyses looking at the effects of structural position on air quality are presented in table 4.3. The first model shows a significant and positive correlation between nations in the semi-periphery and exposure to particulate matter at the level of alpha = 0.01, and significant and positive effects for nations in the periphery at alpha = 0.1, controlling for all other variables. These findings suggest that nations in the semi-periphery and periphery have significantly higher levels of exposure to particulate matter than do nations in the core. However, looking at the effect sizes, these two groups do not have significantly different exposures than each other, a pattern that holds across all models.

In the second model that accounts for a nation's level of debt, the effect of being in the semi-periphery remains, however the effect of being in the periphery loses significance. Given the large amount of missing data, this analysis includes a much smaller sample size.

Models 3 and 4 incorporate measures of structural mobility. In models three, mobility, semi-peripheral status, and peripheral status all are significantly and positively correlated with exposure to particulate matter. Again, this suggests nations in the semi-periphery and periphery have significantly higher levels of exposure to particu-

Table 4.3: Regression of Air Pollution on Structural Measures

	Dependent variable:			
	PM25 Mean Annual Exposure			
	(1)	(2)	(3)	(4)
Semi-periphery	18.429***	19.124**	22.839***	22.724***
	(6.316)	(7.487)	(6.158)	(6.000)
Periphery	11.642*	7.126	18.490***	15.728**
	(6.928)	(8.157)	(6.797)	(6.717)
Mobility			11.503**	7.042
			(4.409)	(4.894)
Semi-periphery:Mobility				29.203**
				(11.226)
Periphery:Mobility				−20.764
				(21.008)
Debt		0.010		
		(0.053)		
Export sums	0.001***	0.0003*	0.001***	0.001***
	(0.0001)	(0.0002)	(0.0001)	(0.0001)
Trade Openness	−6.234	−7.217	−5.917	−6.286
	(5.585)	(5.858)	(5.274)	(5.137)
Population Density	0.004	0.004	0.002	0.002
	(0.004)	(0.003)	(0.003)	(0.003)
Child Mortality	0.222***	0.149**	0.208***	0.213***
	(0.041)	(0.057)	(0.039)	(0.038)
GDP	−0.000*	−0.000	−0.000***	−0.000***
	(0.000)	(0.000)	(0.000)	(0.000)
Constant	7.717	12.758	2.367	3.406
	(6.987)	(8.657)	(6.829)	(6.665)
Observations	129	65	125	125
R^2	0.324	0.297	0.410	0.451
Adjusted R^2	0.285	0.197	0.370	0.403
Note:				*p<0.1; **p<0.05; ***p<0.01

late matter than do nations in the core, and also shows that nations that are upwardly mobile in the structure have higher exposure levels.

Finally, model 4 looks at the interaction between structure and mobility. Here, we see that the interaction effect between semi-periphery and mobility is positive and significant, showing that for upwardly mobile nations in the semi-periphery, there is an additional air quality penalty, as these nations have significantly higher exposure.

The final set of models in table 4.4 looks at the correlation between structural position and carbon dioxide emissions. Model 1 shows a significant and positive correlation between semi-peripheral nations and emissions, but not for peripheral nations. Model 2 which accounts for debt obligations, again with a much more limited sample, finds no significant results. Model 3 that includes a measure for structural mobility shows that both semi-peripheral and peripheral nations have significantly higher emissions than do core nation. Mobility is positively correlated with emissions, and is significant at alpha = 0.1. Finally, model 4 shows no significant correlation between the interaction terms and emissions.

4.7 Discussion

Results from these analyses reveal several important trends related to the effects of structural position in the trade of natural resources and environmental degradation. The first thing that stands out are the seemingly differing effects of structural position and mobility when looking at measures directly associated with extraction and those indirectly associated. When looking at deforestation and methane emissions, nations in the semi-periphery and periphery have either no significantly different effects than core nations, or have significantly lower measures of environmental degradation than core

Table 4.4: Regression of Carbon Dioxide Emissions on Structural Measures

	Dependent variable:			
	CO2 Emissions (KG per GDP)			
	(1)	(2)	(3)	(4)
Semi-periphery	0.244***	0.113	0.359***	0.358***
	(0.079)	(0.102)	(0.068)	(0.068)
Periphery	0.069	−0.088	0.213***	0.206***
	(0.087)	(0.111)	(0.075)	(0.076)
Mobility			0.096*	0.081
			(0.049)	(0.056)
Semi-periphery:Mobility				0.086
				(0.128)
Periphery:Mobility				−0.024
				(0.237)
Debt		−0.001		
		(0.001)		
Export sums	0.00000	0.00000	0.00000**	0.00000**
	(0.00000)	(0.00000)	(0.00000)	(0.00000)
Trade Openness	0.163**	0.101	0.185***	0.184***
	(0.070)	(0.080)	(0.058)	(0.058)
Population Density	−0.0001	−0.00003	−0.0001*	−0.0001*
	(0.00004)	(0.00005)	(0.00004)	(0.00004)
Child Mortality	−0.001	0.001	−0.001**	−0.001*
	(0.001)	(0.001)	(0.0004)	(0.0004)
GDP	0.000	−0.000	−0.000	−0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Constant	0.231***	0.408***	0.103	0.107
	(0.088)	(0.118)	(0.075)	(0.076)
Observations	130	66	126	126
R^2	0.184	0.201	0.337	0.339
Adjusted R^2	0.137	0.089	0.291	0.282
Note:				*p<0.1; **p<0.05; ***p<0.01

nations. However, in most models, semi-peripheral nations have significantly higher carbon dioxide emissions and exposure to particulate matter, the two indirect measures of environmental degradation, and in about half the models, peripheral nations also have higher levels of carbon dioxide emissions and particulate matter exposure. Looking at the effect sizes, though, there are not significant differences between semi-peripheral and peripheral nations in any of the measures of environmental degradation.

Taken as a whole, these results are seemingly contradictory. There is mixed evidence to support hypothesis 1a that the more central nations in extractive exchange have worse environmental outcomes. This finding support the theory of a second contradiction of capitalism, in that it shows that more extractive nations are experiencing worse environmental outcomes directly associated as a by-product of extraction, i.e. methane emissions. However, there is not evidence that more central nations have worse environmental outcomes on the one measure of the degradation of the conditions of production, i.e. deforestation. That being said, previous research suggests that deforestation is the most severe in the semi-periphery, so that there were not found to be significant differences between the core and semi-peripheral nations is notable (e.g. Burns et al., 2015).

Finding that semi-peripheral nations have significantly worse measures of indirect environmental degradation as it relates to extraction when compared to core nations is consistent with previous studies of global patterns of development, finding support for hypothesis 1b. These indirect measures of degradation are not only attributable to extraction but also heavy industry, for instance. As other research shows, as a result of technological advances and other forces in globalization, heavy industries moved from the core regions to the semi-periphery, so it is not all together unsurprising that these sets of nations have worse outcomes on these measures of air quality and carbon dioxide emissions (e.g. Jorgenson, 2016). In other words, this set of findings is indicative of

the complex development patterns that are embodied in the structural position in the global economy.

Another finding that stands out from this analysis is that upward mobility in the semi-periphery within the structure of the trade of natural resources experience higher levels of exposure to particulate matter, higher levels of methane emissions, as well as more deforestation, finding support for hypothesis 2. Indeed, on its own, mobility is correlated with higher emissions and particulate matter exposure. This paints a complex picture regarding the environmental consequences of development. These findings suggest that upwardly mobile nations in the semi-periphery get the worst of both worlds so to speak, in that they experience higher levels of direct measures of degradation, but also higher levels of the indirect degradation more commonly associated with industrial development.

Overall, though the findings in this chapter do present somewhat mixed findings for a second contradiction of capitalism theory in which the most extractive are expected to experience more environmental degradation, the findings predominately point to the complexity of the role of structural relations on resource extraction and environmental degradation. When examining the two measures of environmental degradation that are tied directly to extraction, i.e. deforestation and methane emissions, it is notable that core nations, the more central in extractive exchange, experience either no or significantly higher levels of degradation. On the one hand, considering that core nations are the most central in extractive exchange, it is notable that both peripheral and semi-peripheral nations have worse measures of general environmental degradation as measured through exposure to air pollution and carbon dioxide emissions.

These findings suggest that complex political economic relations are embedded within the structural analysis presented in the last chapter. Nations were clustered based on their patterns of relations of the trade of natural resources with other nations. That

the different clusters have inconsistent patterns of degradation depending on the type of degradation suggests that there may be additional political and economic factors that contribute to nations having particular trade relationships in the first place. The evidence in the chapter points to evidence for a new international division of labor theory, which suggests that technological advances in transportation capabilities and favorable regulatory environments allow heavy industrial processes to be increasingly located in more peripheral regions in the world-system.

4.8 Conclusion

Building off a network analysis of the global trade of natural resources, this chapter sought to understand how structural position in the trade of natural resources is associated with various measures of environmental degradation. The results of the analysis show that core nations experience no significantly different levels of deforestation than peripheral and semi-peripheral nations, but do experience significantly higher levels of methane emissions. These two measures can be directly associated with extractive industries. On the other hand, peripheral and semi-peripheral nations experience higher levels of degradation that are indirectly associated with extraction: carbon dioxide emissions and exposure to air pollution.

These findings provide limited evidence for a structural analysis of the second contradiction of capitalism. It was theorized that structural position in the global trade of natural resources would be a significant predictor in determining the distribution of environmental degradation across nations. Indeed, it has found that the most central nations in extractive exchange do have worse than expected direct environmental outcomes of extraction. Whereas we might have expected core nations to have less deforestation than semi-peripheral or peripheral nations based on previous research,

core nations don't have significantly different levels of deforestation. However, they do have higher levels of methane emissions, also an unexpected finding for nations that are typically considered central in all trading networks. This finding reaffirms the clustering of these nations, as it shows that the core nations

That upwardly mobile semi-peripheral nations are penalized for their mobility in that they experience worse environmental outcomes when measured both directly and indirectly is more consistent with what research coming out of theories of the new international division of labor may predict about the global distribution of natural resource extraction. These upwardly mobile nations that take on more central roles over time in the global trade of extractive natural resources are also experiencing worse environmental conditions as measured through outcomes tied to industrial production like carbon dioxide emissions and air pollution.

Chapter 5

The Effects of Structural Measures on Economic Growth, 1975-2015

5.1 Introduction

Previous chapters in this dissertation establish a network structure for the relationships between nations in the trade of natural resources, describe how the structure changes over time from a center-periphery structure to a more centralized structure, and measure the impacts of structural position on environmental degradation. This chapter will complete the structural analysis of the second contradiction of capitalism by measuring the effect of structural position in the trade of natural resources on economic growth.

Adequate regression models to explain variation in economic growth can be elusive. Economic growth is influenced by such a large number of factors, including demographics, technological innovation, policy changes, and market dynamics, that it is difficult to control for all of them.

Nevertheless, there is reasons to expect a correlation between network structure and economic growth in this context. The theory of the second contradiction of capitalism as adopted in this dissertation to the structural and global level predicts that nations with more environmental degradation should experience slower economic growth. As was shown in the previous chapter, there are correlations between environmental degradation and structural position over time. Nations with more deforestation are likely to be found in the declining periphery, while nations with worse air quality are likely to be found in the core and rising semi-periphery.

5.2 Background

Adherence to a structural theory of the second contradiction of capitalism would suggest that nations most central in the extractive exchange network might experience slower economic growth. This theory predicts that a crisis of underproduction will emerge as the social costs of production increase the cost of reproducing the conditions of production. At the structural level, this might be experienced as slowed economic growth. On the other hand, earlier research in this dissertation showed that the most extractive economies are also the least dependent on these exports, suggesting that structural position in the global structure of extractive exports may not be correlated with economic growth.

The second contradiction of capitalism predicts a feedback loop of environmental degradation of material inputs that affects future production. At the level of production, this theory can be depicted as a circuit of degradation. Material inputs (I) fuel production (P), which through processes of degradation diminishes the conditions necessary to maintain inputs, resulting in fewer inputs (I') and therefore diminished productive capacity (P'):

$$I - P - I' - P'$$

To scale this model to the level of the structural global economy, this discussion shows that the intervening effect of trade must be considered. At the structural level, trade relations allow the process to by-pass the phase of diminished inputs by identifying new sources of material inputs (I_t):

$$I - P - I_t - P$$

This chapter will measure the relationship between structural trade relations (t) and production (P). There is empirical precedent for a correlation between structural position in global trade networks and economic growth. A previous 2011 study by Matthew Mahutga and David A. Smith used a nearly identical method as presented in previous chapters in this dissertation to construct network measures based on five categories of commodities in order to measure how structural position in the world-economy more broadly is correlated with economic growth. Using a fixed-effects model similar to the one adopted in this chapter, the authors find that structural position in the world-economy is a significant indicator for predicting economic growth, showing that nations in the middle tiers of the global economy experience more growth than other positions, while overall finding bifurcating structure over time in which the upper tiers of the economy diverge from the lower tiers. With this theoretical and empirical background in mind, there is sufficient reason to believe that nations more central in extractive structural economy will experience slower economic growth.

5.3 Research Questions and Hypotheses

Previous chapters in this dissertation established a structural classification of nations according to their patterns of trade of natural resources, and showed how these structural relations are tied to different environmental outcomes. The central research question in this chapter asks how these structural relations in the trade of extractive materials affect a nation's rate of economic growth. The literature on the second contradiction of capitalism suggests that more extractive nations should experience slower economic growth, as the material inputs upon which growth depends are diminished through degradation. Similarly, previous research regarding the economic implications of structural relations suggests that semi-peripheral nations as well as upwardly mobile nations have higher economic growth than do core nations. Therefore, the two hypotheses being tested in this chapter are as follows:

H_1: Core nations will experience slower growth than semi-peripheral and peripheral nations.

H_2: Mobility in the structure of trade relations will be associated higher economic growth.

5.4 Data

5.4.1 Structural position

Structural position is assigned according to the procedure described in the previous chapter. Nations are clustered into groups according to their structural equivalence. To calculate the structural equivalence, I created a matrix of distances between nations

i and j using the hamming distance. Hamming distance d_{ij} is calculated by summing the differences between the connections between nation k and nation i, and nation k and nation j:

$$d_{ij} = \sum_{k=1}^{g}(\mid x_{ik} - x_{jk} \mid + \mid x_{ki} - x_{kj} \mid)$$

I then assigned each nation coordinates in multidimensional space based on a dissimilarity measure derived from their structural equivalence, and clustered nations into three groups using a k-means clustering algorithm. Though these three clusters are in line with other world-systems analyses of structural position, the use of the categories "core," "semi-periphery," and "periphery" in this research refers specifically to structural positions in the trade of natural resources. Core nations are also the most embedded in the trade network of natural resources but are least dependent upon the export of natural resources. This set of nations includes much of western Europe and the United States. Semi-peripheral are less embedded in the network than core nations and more dependent on the export of natural resources than core nations, and includes nations in Europe and North Africa. Peripheral nations are the least embedded in the network, and includes nations in the Caribbean and across Asia. The full list of membership in clusters for each time point is in Appendix A.

Dummy variables for cluster membership as measured in 1975 and 1995 were created. Core nations are the category that was excluded from the analysis.

5.4.2 Mobility

The analysis includes a measure of structural mobility between the years 1975 and 1995, and 1995 and 2015. This is adopted from the mobility measure used by Mahutga and Smith in their 2011 paper. Using nations' coordinates in multidimensional space,

distance from a nation's position along the first dimension to the mean position of the core nations is calculated at each time point. Mobility u_{ik} is calculated as the difference in distance to the core a time t and distance to the core at time t+1 as a total proportion of the distance at time t.

$$u_{ik} = \frac{(d_{it} - d_{i(t+!)})}{d_{it}}$$

where:

$$d_{it} = \overline{x}_{ct} - x_{it}$$

5.4.3 Economic growth

The dependent variable is a measure of economic growth per capita. It is calculating by taking the average annual change in GDP per capita over two time periods: 1975 - 1995, and 1995 - 2015.

5.4.4 Time Fixed Effects

Fixed effects were introduced in the model by creating a dummy variable for the observations occurring for the 1975-1995 period.

5.4.5 Regional Variation

The full model below also includes dummy variables for region in which a nation is located. In the models, the category for sub-Saharan Africa is excluded.

5.4.6 Controls

Each of these measures was taken from the World Bank World Development Indicators.

- Export Sums: This is the total value of exports of natural resources, averaged for the years 1975 - 2015 and 1995 - 2015.
- Trade openness: This is measured as the ratio of the sum each nation's total merchandise imports and exports to its gross domestic product. This measure should approximate a measure of how open to international trade a nation is. This is averaged for the years1975 - 2015 and 1995 - 2015.
- Population density: This is measured as the total number of people per square kilometer of land area, averaged for the years 1975 - 2015 and 1995 - 2015.
- Initial Gross Domestic Product (GDP): This is a measure of a nations GDP in 2010 US dollars, measured in 1995 and 2015.

5.5 Method

The below effect of structural membership on economic growth is estimated using an ordinary least squares techniques, and includes fixed effects for regional affiliation. The reason for using region-level fixed effects is because at the national level, there is limited variation in structural position over time, meaning that these effects could not be included in a traditional fixed effects model. The model also includes a time specific fixed-effect by including a dummy variable for the time-period encompassing 1975-1995. The model uses panel corrected standard errors.

5.6 Results

The results of the regression analysis are reported in table 5.1. Models 1 and 2 show the effects of structural position in the extractive economy on economic growth, and models 3 and 4 include interaction terms with structural mobility. These models report the panel corrected standard errors.

Looking at models 1 and 2, both semi-peripheral status and peripheral status is significantly correlated with higher average levels GDP growth relative to nations in the core across the two time periods at at least the alpha = 0.1 level. Across both models, though, when examining the effect size, there are not significant difference when comparing peripheral and semi-peripheral nations. Model 2 shows that mobility is not significantly correlated with economic growth. However, after controlling for neoclassical predictors of economic growth, structural position retains significance.

Model 3 contains coefficients for the interactions between position and mobility. Here, we see that both interaction terms are positive and significant. This shows that upwardly mobile nations in the semi-periphery experience higher average economic growth than do mobile nations in the core, and when looking at the effect size, upwardly mobile nations in the periphery experience even higher rates of economic growth. When controlling for regional fixed effects in model 4, these patterns hold.

5.7 Discussion

Two important trends emerge from this analysis: the relationship between structural position and growth, and the relationship between mobility and growth. First, across the models, nations in the semi-periphery and periphery experience higher average

Table 5.1: Regression of Economic Growth on Structural Measures

	Dependent variable: Average GDP Growth			
	(1)	(2)	(3)	(4)
Semi-Periphery	1.068*	1.191***	0.567**	0.017
	(0.592)	(0.442)	(0.278)	(0.265)
Periphery	1.145***	1.411***	0.841***	0.391*
	(0.359)	(0.433)	(0.174)	(0.226)
Mobility		0.120	−0.143***	−0.202***
		(0.097)	(0.035)	(0.032)
Semi-periphery:Mobility			3.610***	3.488***
			(0.571)	(0.453)
Periphery:Mobility			7.185***	7.380***
			(0.395)	(0.578)
Time FE (1975-1995)	−0.977***	−0.903	−2.489***	−2.280***
	(0.357)	(0.599)	(0.650)	(0.655)
Europe and Central Asia				−1.613**
				(0.756)
Middle East and N. Africa				0.150
				(0.839)
Latin Am. and Caribbean				−1.456
				(0.945)
East Asia and Pacific				0.111
				(0.548)
North America				0.336
				(0.819)
South Asia				0.625
				(0.456)
Initial GDP		−0.00001***	−0.00001	−0.00002**
		(0.00000)	(0.00001)	(0.00001)
Population Density		0.001	0.001	0.0003
		(0.0005)	(0.0004)	(0.0004)
Child Mortality		−0.001	0.002	−0.005
		(0.010)	(0.009)	(0.010)
Trade Openness		−0.213	0.014	0.009
		(0.915)	(0.883)	(0.931)
Export sums		0.001***	−0.0004	−0.001
		(0.0001)	(0.001)	(0.001)
Constant	3.159***	2.972***	3.573**	5.044***
	(0.281)	(0.743)	(1.085)	(1.350)
Observations	222	222	222	222
R^2	0.051	0.073	0.175	0.242
Adjusted R^2	0.038	0.034	0.131	0.179
Note:				*p<0.1; **p<0.05; ***p<0.01

annual economic growth than nations in the core across the two time periods. This supports hypothesis one, and is in line with what was expected given the theory and empirical precedent. However, as in the previous chapter, it is difficult to discern from this analysis if the slower economic growth from the most central nations in the extractive exchange is attributable to either the the environmental pressures associated with extractive industries, or rather to other social relations embedded within the structure. It would be more sound to draw conclusions attributing the slower growth to degradation if the core nations were more dependent on exports of natural resources, but as chapter 3 showed, this is not the case. It is possible, even likely, that there may be additional political and economic factors that contribute to nations having particular structural relations resulting from the trade relationships in the first place.

The second important trend is the finding that the effect of structural mobility on growth is strongest in the periphery, but economic growth is also significantly higher for upwardly mobile semi-peripheral nations compared to core nations. This supports hypothesis 2.

Though upwardly mobile semi-peripheral nations were shown to experience worse environmental degradation across the board in the previous chapter, the findings from this analysis show that there seems to be economic benefit for these upwardly mobile nations in addition to the previously identified environmental harms. Taken together, these results seem to provide evidence for models of economic development that externalize environmental costs. Nations that are willing or able to externalize the environmental costs of development are rewarded with higher rates of economic growth.

These findings are consistent with other analyses of structural position on economic growth. This shows that while perhaps the findings here reaffirm that modeling structure using extractive industries is a valid model in that the findings are consistent with other structural analyses, once again, perhaps the economic effects found here are

attributable to other factors embedded within the structure - in other words that this analysis simply captured what we already know to be true. However, if this is the case it still supports a new international division of labor theory.

Finally, though the models in this chapter do control for factors like trade openness, population density, social capital, and initial GDP, the models only account for at most 24 percent of the total variation in economic growth. This suggests that while there are significant differences between the different clusters, the models are not sufficiently explaining why nations have different economic outcomes. Most likely, this is a function of the complexity of studying economic growth, which is susceptible to everything from political dynamics to market dynamics to the weather. Ultimately, these models show that a stronger analysis will encompass measures of environmental outcomes that are more directly tied to natural resource extraction.

5.8 Conclusion

This chapter sought to measure the relationship between structural position in the trade network of natural resources and rates of economic growth. Findings of a fixed-effects regression analysis suggests that there is indeed a statistically significant relationship between these two factors, showing that nations with more central positions in the exchange of extractive goods experience slower economic growth between 1975 and 2015. Both semi-peripheral and peripheral nations have significantly higher levels of economic growth, and the effect is even stronger for upwardly mobile nations in these groups.

Nevertheless, it is unclear from this analysis whether these trends are a resulting from environmental pressure in the form of degradation, or are manifestations of social

relations embedded within the trade structure. For instance, analysis from previous chapters in this dissertation shows that the semi-peripheral nations in particular have worse environmental outcomes, raising the question of whether economic growth in these groups is in fact a function of development arising out of the new international division of labor. Future research should look at more direct economic effects related to extractive industries instead of overall economic growth.

Chapter 6

Conclusion

This dissertation sought to build a structural model of the theory of the second contradiction of capitalism by showing how structural patterns across nations in trade of natural resources are correlated with environmental degradation and economic outcomes. It examined whether environmental degradation is distributed evenly within the world-system, or rather is distributed in alignment with the social relations embedded within structures of trade. It tested whether the economic consequences associated with environmental degradation are also likely to be mediated according to these structural relations. Finally, it examined if structural mobility might be indicative of the so-called spatio-temporal fix, in which environmentally degrading practices are globalized in response to local threats.

Chapter 2 provided an overview of the theories and previous empirical research examining the relationship between economic development, trade, and environmental degradation. It laid out a theoretical model for studying the second contradiction of capitalism from a structural position, one which was applied in the subsequent chapters.

Chapter 3 generated a structural model of the global trade of natural resources. Consistent with other world-systemic analyses of trade networks, it identified structural patterns in extractive industries to show that nations that are central to the trade of natural resources are also the among the wealthiest nations, and are least dependent upon the trade of natural resources.

Chapter 4 measured the effects of both structural position in the global trade of natural resources and mobility within the structure on various measures of environmental degradation. These results reveal two different patterns in the relationship between structure and degradation. On the measures of degradation directly tied to extractive industries, core nations that are most central in extractive exchange experience either worse, or no significantly different levels of degradation than semi-peripheral and peripheral nations. However, upwardly mobile semi-peripheral nations also experience worse degradation on these measures. Meanwhile, semi-peripheral and peripheral nations experience worse measures of general environmental degradation, i.e. exposure to air pollution and CO2 emissions. Furthermore, the analysis showed that upwardly mobile semi-peripheral nations in particular experience significantly worse environmental degradation across all measures - those directly and indirectly linked to extraction - providing empirical evidence for a new international division of labor theory in which environmentally harmful practices are relocated into semi-peripheral regions in the global economy as a model of economic development for these regions.

Finally, chapter 5 analyzed the impacts of both structural position in the global trade of natural resources and mobility within the structure on economic growth. The findings show that nations central in extractive exchange have lower average economic growth than peripheral and semi-peripheral nations. Additionally, upwardly mobile nations in both the periphery and semi-periphery have higher average economic growth. This could point to two possible explanations. It could be that the findings are in support

of a second contradiction of capitalism theory in that the most extractive nations experience slower growth as a result of the ecological consequences related to continued extraction. Alternatively, it could be the case that these findings are capturing other social processes embedded within the structure of the world-system. Further analysis should more directly measure the impacts of extraction and degradation on more direct measures of economic activity associated with extraction.

Taken as a whole, the findings in this dissertation reveal a few different trends. Between 1975 and 2015, extractive trade is becoming more dense, and this uptick in activity is increasingly concentrated in the set of core nations. Core nations, though, are least dependent on the export of these materials to maintain their GDP. Though these nations do experience significantly higher levels of methane emissions than the other groups and have no significant differences in measures of deforestation, these nations do not have significantly worse air pollution exposure or carbon dioxide emissions. Finally, these nations do have significantly slower economic growth than the other nations.

To revisit the structural model of the second contradiction of capitalism,

$$I - P - I_t - P$$

This dissertation was successful in modeling the structure of trade t, and showed the relationships between trade t and both material inputs I and production P.

However, based on this analysis, it is not possible to draw the direct conclusion that slower economic growth in the most central nations in the trade of extractive commodities is a result of the degradation of the environmental conditions upon which extraction is dependent, as the second contradiction would suggest. Instead, this analysis points to more complex political and economic relations embedded within the structure of trade relations that have a bearing on both the conditions leading to environmental

degradation as well as those leading to economic growth. This discussion is reminiscent of the identification of the new international division of labor, in which the forces of globalization allow for the movement of industrial processes out of the core regions, leading to potential economic benefit to developing nations.

This research represents the first step in applying concepts related to the second contradiction of capitalism to a structural level. Future research should explore these ideas more closely by examining more directly the economic effects of degradation and the role of environmental conditions in those trends. Instead of looking at national levels of economic growth, a future study could look at measures of revenue generated from extractive industries and better understand the role that environmental degradation plays in determining those economic outcomes.

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Appendix A

Membership in Clusters

Table A.1: Block Membership 1975 - 2015

1 = Periphery, 2 = Semi-periphery, 3 = Core

	Nation	1975	1995	2015
1	Afghanistan	1	1	1
2	Albania	1	1	1
3	Algeria	2	2	2
4	Andorra	1	1	1
5	Angola	1	1	2
6	Argentina	2	2	2
7	Australia	2	3	3
8	Austria	2	3	3
9	Bahamas	1	1	1
10	Bahrain	2	2	2
11	Barbados	1	1	1

Continued on next page

Table A.1 – continued from previous page

	Nation	1975	1995	2015
12	Belgium	3	3	3
13	Bermuda	1	1	1
14	Bolivia (Plurinational State of)	1	1	1
15	Brazil	2	3	3
16	Belize	1	1	1
17	Solomon Isds	1	1	1
18	Brunei Darussalam	1	1	1
19	Bulgaria	2	2	2
20	Myanmar	1	1	2
21	Burundi	1	1	1
22	Cameroon	1	2	2
23	Canada	3	3	3
24	Central African Rep.	1	1	1
25	Sri Lanka	1	1	2
26	Chad	1	1	1
27	Chile	2	2	2
28	China	2	3	3
29	Colombia	1	2	2
30	Congo	1	1	1
31	Dem. Rep. of the Congo	2	1	1
32	Costa Rica	1	1	2
33	Cuba	1	1	1
34	Cyprus	1	2	2
35	Benin	1	1	1

Continued on next page

Table A.1 – continued from previous page

	Nation	1975	1995	2015
36	Denmark	2	2	2
37	Dominica	1	1	1
38	Dominican Rep.	1	1	2
39	Ecuador	1	2	2
40	El Salvador	1	1	1
41	Equatorial Guinea	1	1	1
42	Ethiopia	1	1	1
43	Faeroe Isds	1	1	1
44	Fiji	1	1	1
45	Finland	2	2	2
46	France	3	3	3
47	Djibouti	1	1	1
48	Gabon	1	1	1
49	Gambia	1	1	1
50	Germany	3	3	3
51	Ghana	2	2	2
52	Gibraltar	1	1	1
53	Greece	2	3	3
54	Guatemala	1	1	1
55	Guinea	1	1	1
56	Guyana	1	1	1
57	Haiti	1	1	1
58	Honduras	1	1	1
59	China, Hong Kong SAR	2	3	3

Continued on next page

Table A.1 – continued from previous page

	Nation	1975	1995	2015
60	Hungary	2	2	2
61	Iceland	1	1	2
62	Indonesia	2	3	3
63	Iran	2	2	2
64	Iraq	2	1	1
65	Ireland	2	2	2
66	Israel	2	2	2
67	Italy	3	3	3
68	Ivory Coast	2	2	2
69	Jamaica	1	1	1
70	Japan	3	3	3
71	Jordan	1	2	2
72	Kenya	1	2	1
73	Rep. of Korea	2	3	3
74	Kuwait	2	2	2
75	Lao People's Dem. Rep.	1	1	1
76	Lebanon	2	2	2
77	Liberia	1	1	1
78	Libya	2	1	1
79	China, Macao SAR	1	1	1
80	Madagascar	1	1	1
81	Malawi	1	1	1
82	Malaysia	2	3	3
83	Maldives	1	1	1

Continued on next page

Table A.1 – continued from previous page

	Nation	1975	1995	2015
84	Mali	1	1	1
85	Malta	1	1	2
86	Mauritania	1	1	1
87	Mauritius	1	1	1
88	Mexico	2	2	3
89	Morocco	2	2	2
90	Mozambique	1	1	2
91	Oman	1	2	2
92	Nepal	1	1	1
93	Netherlands	3	3	3
94	Vanuatu	1	1	1
95	New Zealand	2	2	2
96	Nicaragua	1	1	1
97	Niger	1	1	1
98	Nigeria	2	2	2
99	Norway	2	3	2
100	Pakistan	2	2	2
101	Panama	1	1	2
102	Papua New Guinea	1	1	1
103	Paraguay	1	1	2
104	Peru	2	2	2
105	Philippines	2	2	2
106	Poland	2	2	3
107	Portugal	2	3	2

Continued on next page

Table A.1 – continued from previous page

	Nation	1975	1995	2015
108	Guinea-Bissau	1	1	1
109	Qatar	1	2	2
110	Romania	2	2	2
111	Rwanda	1	1	1
112	Saint Kitts and Nevis	1	1	1
113	Saudi Arabia	2	3	3
114	Senegal	1	1	2
115	Sierra Leone	1	1	1
116	India	2	3	3
117	Singapore	2	3	3
118	Somalia	1	1	1
119	Zimbabwe	1	2	1
120	Spain	3	3	3
121	Suriname	1	1	1
122	Sweden	3	3	3
123	Switzerland	3	3	3
124	Syria	2	2	1
125	Thailand	2	2	3
126	Togo	1	1	1
127	United Arab Emirates	2	2	3
128	Tunisia	2	2	2
129	Turkey	2	3	3
130	Uganda	1	1	1
131	Egypt	2	2	3

Continued on next page

Table A.1 – continued from previous page

	Nation	1975	1995	2015
132	United Kingdom	3	3	3
133	United Rep. of Tanzania	1	1	2
134	USA	3	3	3
135	Uruguay	1	1	2
136	Venezuela	2	2	2
137	Samoa	1	1	1
138	Zambia	2	1	2

Appendix B

K-Means Clustering: Scree Plots

Figure B.1: Scree Plot: 1975

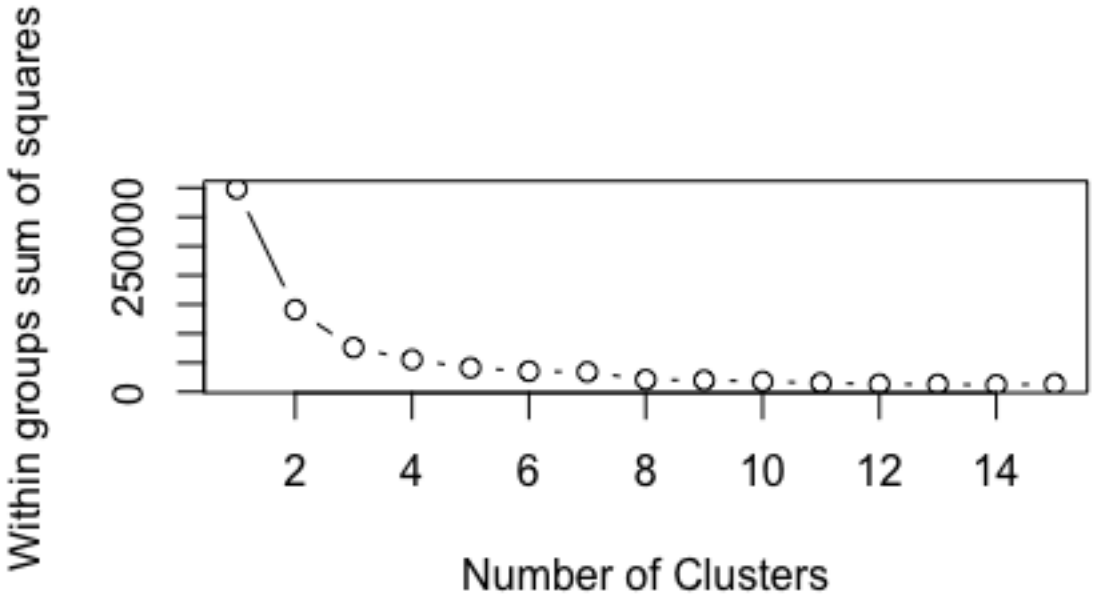


Figure B.2: Scree Plot: 1995

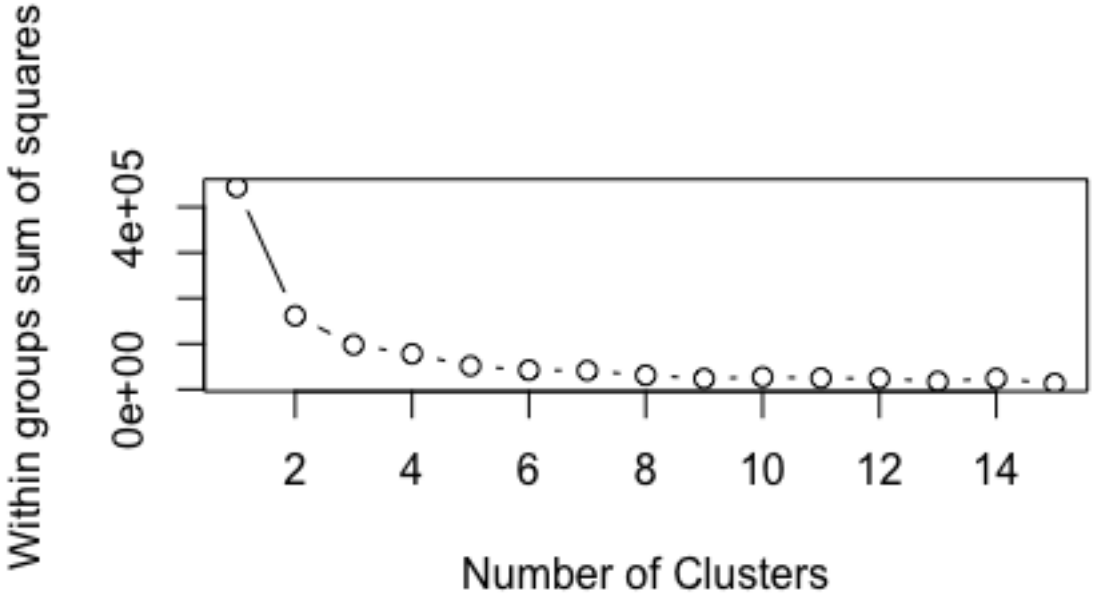
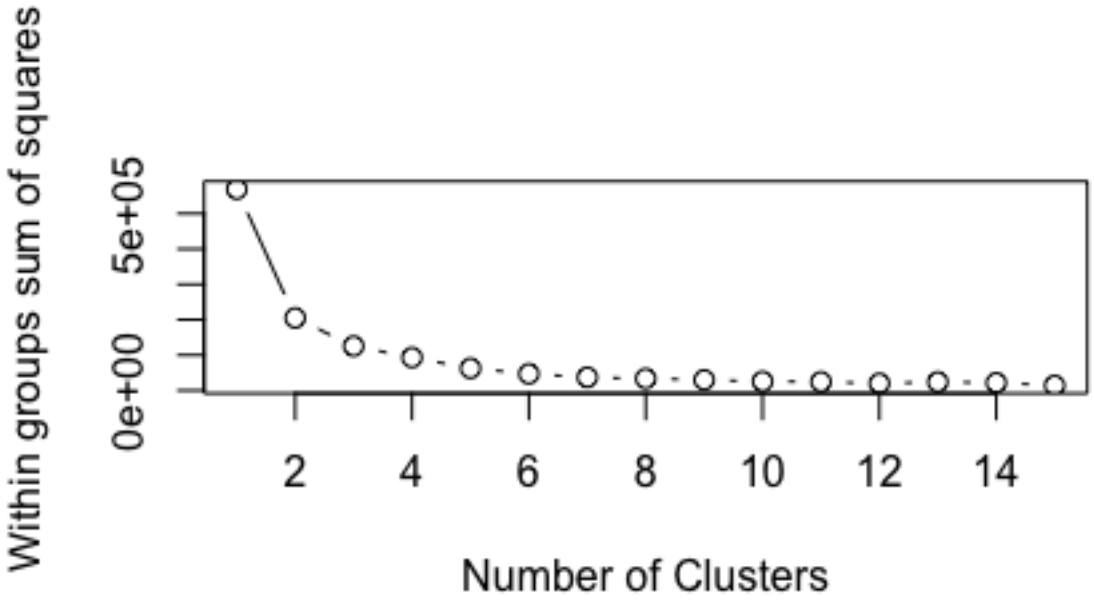


Figure B.3: Scree Plot: 2015



Appendix C

Correlation Matrix: Chapter 4

Table C.1: Chapter 4 Correlation Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1	-0.331	-0.477	-0.313	-0.323	-0.079	-0.150	0.515	0.240	0.523	-0.051	0.626	0.351
2	-0.331	1	-0.671	-0.076	0.362	-0.094	0.418	-0.045	-0.070	-0.137	0.152	0.020	-0.006
3	-0.477	-0.671	1	0.316	-0.083	0.149	-0.272	-0.362	-0.124	-0.284	-0.102	-0.510	-0.270
4	-0.313	-0.076	0.316	1	0.318	0.370	-0.042	-0.055	-0.155	-0.195	-0.376	-0.205	-0.129
5	-0.323	0.362	-0.083	0.318	1	0.100	0.473	-0.099	-0.009	-0.201	-0.046	-0.007	0.179
6	-0.079	-0.094	0.149	0.370	0.100	1	-0.208	-0.058	0.058	0.011	-0.052	-0.201	-0.067
7	-0.150	0.418	-0.272	-0.042	0.473	-0.208	1	0.029	-0.013	-0.084	0.152	0.061	0.183
8	0.515	-0.045	-0.362	-0.055	-0.099	-0.058	0.029	1	-0.095	0.738	-0.154	0.684	0.009
9	0.240	-0.070	-0.124	-0.155	-0.009	0.058	-0.013	-0.095	1	-0.033	0.034	0.088	0.232
10	0.523	-0.137	-0.284	-0.195	-0.201	0.011	-0.084	0.738	-0.033	1	-0.033	0.650	0.170
11	-0.051	0.152	-0.102	-0.376	-0.046	-0.052	0.152	-0.154	0.034	-0.033	1	-0.110	0.048
12	0.626	0.020	-0.510	-0.205	-0.007	-0.201	0.061	0.684	0.088	0.650	-0.110	1	0.171
13	0.351	-0.006	-0.270	-0.129	0.179	-0.067	0.183	0.009	0.232	0.170	0.048	0.171	1
14	-0.136	0.079	0.034	0.211	0.338	0.213	0.163	-0.120	0.062	-0.153	0.014	0.127	-0.005

Note: 1 = Core; 2 = Semi-periphery; 3 = Periphery; 4 = Child Mortality; 5 = PM2.5; 6 = Debt; 7 = CO2; 8 = Methane; 9 = Population density; 10 = GDP; 11 = Forest cover; 12 = Natural Resource Exports; 13 = Mobility; 14 = Natural Resource Exports as pct GDP

Appendix D

Correlation Matrix: Chapter 5

Table D.1: Chapter 5 Correlation Matix

	1	2	3	4	5	6	7	8	9	10
1	1	-0.163	0.018	0.079	0.039	-0.105	0.119	-0.011	-0.065	0.051
2	-0.163	1	0.104	0.008	0.129	-0.061	-0.052	0.279	-0.058	-0.041
3	0.018	0.104	1	-0.715	0.102	-0.114	-0.015	-0.136	-0.112	-0.068
4	0.079	0.008	-0.715	1	-0.037	-0.282	-0.092	0.394	-0.288	0.085
5	0.039	0.129	0.102	-0.037	1	-0.038	0.089	0.046	-0.095	-0.016
6	-0.105	-0.061	-0.114	-0.282	-0.038	1	-0.006	-0.219	0.988	-0.153
7	0.119	-0.052	-0.015	-0.092	0.089	-0.006	1	-0.154	-0.005	0.446
8	-0.011	0.279	-0.136	0.394	0.046	-0.219	-0.154	1	-0.218	-0.085
9	-0.065	-0.058	-0.112	-0.288	-0.095	0.988	-0.005	-0.218	1	-0.155
10	0.051	-0.041	-0.068	0.085	-0.016	-0.153	0.446	-0.085	-0.155	1
11	-0.029	-0.250	0.004	-0.424	-0.111	0.474	0.061	-0.279	0.480	0.012
12	-0.105	-0.061	-0.114	-0.282	-0.038	1	-0.006	-0.219	0.988	-0.153
13	-0.029	-0.250	0.004	-0.424	-0.111	0.474	0.061	-0.279	0.480	0.012
14	0.149	-0.018	0.038	-0.113	0.069	0.057	0.218	-0.198	0.080	0.130
15	-0.179	-0.029	0.066	-0.410	-0.085	0.136	-0.027	-0.378	0.117	-0.028
16	-0.137	0.044	-0.108	0.260	0.00004	-0.103	-0.082	-0.209	-0.106	-0.024
17	0.126	0.002	0.341	-0.231	0.025	-0.076	0.027	-0.135	-0.078	0.049
18	-0.051	0.016	-0.098	-0.134	-0.130	0.602	-0.036	-0.116	0.612	-0.076
19	0.116	0.001	-0.004	0.025	0.182	-0.035	0.062	0.069	-0.027	-0.098
20	0.038	-0.010	-0.204	0.391	-0.042	-0.171	-0.106	0.781	-0.175	-0.024

Table D.2: Chapter 5 Correlation Matrix (Continued)

	11	12	13	14	15	16	17	18	19	20
1	-0.029	-0.105	-0.029	0.149	-0.179	-0.137	0.126	-0.051	0.116	0.038
2	-0.250	-0.061	-0.250	-0.018	-0.029	0.044	0.002	0.016	0.001	-0.010
3	0.004	-0.114	0.004	0.038	0.066	-0.108	0.341	-0.098	-0.004	-0.204
4	-0.424	-0.282	-0.424	-0.113	-0.410	0.260	-0.231	-0.134	0.025	0.391
5	-0.111	-0.038	-0.111	0.069	-0.085	0.00004	0.025	-0.130	0.182	-0.042
6	0.474	1	0.474	0.057	0.136	-0.103	-0.076	0.602	-0.035	-0.171
7	0.061	-0.006	0.061	0.218	-0.027	-0.082	0.027	-0.036	0.062	-0.106
8	-0.279	-0.219	-0.279	-0.198	-0.378	-0.209	-0.135	-0.116	0.069	0.781
9	0.480	0.988	0.480	0.080	0.117	-0.106	-0.078	0.612	-0.027	-0.175
10	0.012	-0.153	0.012	0.130	-0.028	-0.024	0.049	-0.076	-0.098	-0.024
11	1	0.474	1	0.050	0.104	-0.135	0.173	0.420	-0.062	-0.225
12	0.474	1	0.474	0.057	0.136	-0.103	-0.076	0.602	-0.035	-0.171
13	1	0.474	1	0.050	0.104	-0.135	0.173	0.420	-0.062	-0.225
14	0.050	0.057	0.050	1	-0.186	-0.223	-0.150	-0.055	-0.083	-0.245
15	0.104	0.136	0.104	-0.186	1	-0.255	-0.172	-0.063	-0.095	-0.281
16	-0.135	-0.103	-0.135	-0.223	-0.255	1	-0.206	-0.075	-0.114	-0.337
17	0.173	-0.076	0.173	-0.150	-0.172	-0.206	1	-0.050	-0.076	-0.226
18	0.420	0.602	0.420	-0.055	-0.063	-0.075	-0.050	1	-0.028	-0.082
19	-0.062	-0.035	-0.062	-0.083	-0.095	-0.114	-0.076	-0.028	1	-0.125
20	-0.225	-0.171	-0.225	-0.245	-0.281	-0.337	-0.226	-0.082	-0.125	1

Note: 1 = GDP Growth; 2 = TimeFE 3 = Semi-periphery; 4 = Periphery; 5 = Mobility; 6 = Initial GDP; 7 = Population Density; 8 = Child Mortality; 9 = GDP; 10 = Trade Openness; 11 = Natural Resource Exports; 12 = Initial GDP in Millions; 13 = Natural Resource Exports in Millions; 14 = East Asia and Pacific; 15 = Europe and Central Asia; 16 = Latin America and Caribbean; 17 = Middle East and North Africa; 18 = North America; 19 = South America; 20 = Sub-Saharan Africa