ABSTRACT

DRISCOLL, ADAM ROURKE. A Cross-National Analysis of Agricultural Dependency and its Impacts on Environmental Degradation. (Under the direction of Edward L. Kick.)

This dissertation examines the relationships between nations' positions within the global food and agriculture system and the environmental degradation associated with their agricultural activities. Using a cross-national analysis, each nation's position in the world-system, the degree to which they are developed, and the degree to which their economy is predicated upon the production of agricultural products for global markets is operationalized. These political-economic factors are then examined to test the influence of three different forms of environmental degradation that are all linked to agricultural production (Biodiversity loss, nitrous oxide emissions from agriculture, and methane emissions from agriculture). These three different analyses will constitute the three separate empirical chapters. Taken as a whole, this dissertation examines broad patterns of international power relations, linked processes of development and agricultural dependence, and the environmental degradation that results from these processes. This work represents a contribution to both environmental sociology as well as our broader understanding of the social dynamics that structure and lead to environmental degradation. Specifically, by connecting agricultural dependency with environmental degradation, it provides a systematic exploration of how the global food and agriculture system is structured in a way that concentrates environmentally degrading agricultural processes into developing nations.

A Cross-National Analysis of Agricultural Dependency and its Impacts on Environmental Degradation

by
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DEDICATION

To my parents, friends, and family, who continue to love and support me throughout all of life and academia’s many highs and lows.

BIOGRAPHY

Adam Rourke Driscoll was born on May 11, 1978, in Baltimore, MD. He was raised in the suburbs of Philadelphia and rural Central Pennsylvania. He attended West Perry High School and graduated with honors in 1996 while running track and cross-country and participating in way too many school activities. He went on to attend Drexel University on a joint academic/athletic scholarship and graduated in 2001 with a Bachelor of Science degree in Biological Sciences. After graduation, he taught for the department for two and a half years before deciding to leave academia. He went on to work for a year as an organic farmer for Village Acres Farm in Mifflintown, PA and then spent a summer biking across Southern Germany while working on various farms. After those adventures, Adam returned to academia, enrolling in East Carolina University's graduate program in Sociology. There, he formed a strong friendship with Bob Edwards who encouraged Adam to pursue his PhD. After a long application and decision process, Adam decided to enroll in North Carolina State University's PhD program. At NC State, Adam was lucky to work with such outstanding scholars and mentors as Ed Kick, Brett Clark, and Maxine Atkinson. He also managed to teach far more classes than any graduate student should, both in the classroom and online. In the fall of 2014, Adam will join the Department of Sociology and Archaeology at the University of Wisconsin, La Crosse as an assistant professor. He is looking forward to what the next phase of life has to offer.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE- INTRODUCTION AND LITERATURE REVIEW

Introduction

As David Cruzten (2002) describes with his term Anthropocene, we are living in an era in which human beings are increasingly responsible for changes in the physical world. Since approximately 1780-1820, transformations in human activity that are largely associated with the Industrial Revolution have radically increased humanity's potential to disrupt the planet's capacity for supporting human life (Steffen, Crutzen, and McNeill 2007; Vitousek 1994). Agricultural production is one of the primary realms in which these transformations have occurred. Consequently, agriculture is a key source of pollution, climate change, and degradation of natural resources (Tilman 1999). As research within environmental sociology has repeatedly demonstrated, the social organization of human activities, across all scales, is a key factor in determining their environmental impacts. Agricultural activities are no exception, and the uneven structure of the global food and agriculture system shapes the environmental consequences of agricultural production in important ways. This dissertation seeks to better understand that connection by empirically examining the complex relationships between the power structure of the world-system, development, the global division of agricultural labor, and the environmental degradation that is created by agricultural production.

While technological and organizational developments in agriculture (primarily associated with the Green Revolution) have yielded both economic and nutritional benefits to humankind, they have disrupted the global ecosystem in dangerous and not-fully understood ways (Kiers et al. 2008). Modern agriculture has contributed to humans transforming land and the oceans to meet their needs, altering or disrupting global biochemical cycles (e.g. the carbon, water, and nitrogen cycles), and exponentially increasing the rates of species extinction (Vitousek et al. 1997). These various forms of degradation all constitute an erosion of the ecological balance that, up to this point, has maintained human civilization on this planet. If current trends continue, we may soon see rising sea-levels and abrupt shifts in forests and agriculturally suitable land areas due to anthropomorphic climate change (IPCC 2007). We are already seeing species become extinct at global mass-extinction rates, a development that threatens the stability and resilience of ecosystems (Barnosky et al. 2011). We are also experiencing increased disruptions in the nitrogen and phosphorus cycles at the planetary scale, a trend that directly threatens aquatic ecosystems with nutrient-loading and creates the potential for a large-scale ocean anoxic event, an occurrence that has been linked to previous mass extinctions of marine life (Rockstrom et al. 2009b). Combined with similar developments, these changes would severely challenge the stability and viability of contemporary human societies as well as the ability of our planet to continue to support human life and wellbeing. In many ways, the current ecological crisis is the most important challenge facing humankind. How we chose to address it will have vast repercussions for future generations, as well as the planet itself.

As agricultural production constitutes one of the central mechanisms through which human societies interact with their physical environment to meet their material needs (Ponting 1991), it is also a key nexus for environmental degradation (Cox and Atkins 1979). In the modern era, useful food and fiber are produced in a wide diversity of systems, ranging from large-scale, highly mechanized methods that depend on large inputs of fuel and synthetic chemicals to shifting cultivation and pastoralism which is largely reliant upon human and animal power. Different forms of agriculture differ widely in the nature and scale of their environmental impacts. The clearance of land for permanent systems of crop cultivation and pasturage can completely replace previous habitats and ecosystems. Expanding agricultural production, whether for consumption or trade, is one of the leading causes of biodiversity loss (Czech, Krausman, and Devers 2000). Agriculture is also one of the leading sources of non-carbon dioxide greenhouse gases, such as methane and nitrous oxide (Ham et al. 2000).

The global food system is becoming increasingly dominated by corporate, industrialized production (Weis 2007). These more industrialized forms of agriculture rely upon fossil fuel consumption, whether used to power tractors and other agricultural machinery or as chemical precursors to fertilizers. The reliance upon fossil fuels has led to modern agriculture being described as a way of “turning oil into food” (Clark and York 2008, 2005; Foster and Magdoff 2000). This leads to both increased depletion of dwindling fossil fuel reserves and increased emissions of carbon dioxide, one of the primary contributors to global climate change (IPCC 2007). Agricultural production is one of the leading contributors to deforestation (Rudel 2005). It also has the potential to completely disrupt global nutrient cycling, as the manufacture of fertilizer for food production and the cultivation of leguminous crops is the leading source of disturbance in the global nitrogen and phosphorous cycles (Rockstrom et al. 2009a). Agriculture can also heavily degrade soil structure and fertility, contributing to soil erosion, salination, compaction, and nutrient loss

(Cox and Atkins 1979). Finally, agriculture is likely the leading source of water pollution (Moss 2008; Steinfeld et al. 2006). Run-off from fields, pasturelands, and confined animal feeding operations can contaminate nearby water bodies with silt and organic nutrients, leading to eutrophication and increased turbidity. These changes can completely disrupt aquatic ecosystems, leading to phenomena such as the "dead zone" at the mouth of the Mississippi River in The Gulf of Mexico (Downing et al. 1999). Taken collectively, these various forms of environmental disruption demonstrate how critical of a role agriculture plays in the current ecological crisis.

Agricultural systems and their impact on the environment cannot be fully understood when studied in isolation. In the modern era of increased trade liberalization, formerly independent national agricultural systems have been increasingly integrated into an interdependent global food regime (Friedmann and McMichael 1989; Clapp 2012). The food regime is a competitive system, structured by power differentials among the various stakeholders (McMichael 1994). Furthermore, the global food system is embedded in the broader world-system, a continuous network of power and dependency relationships that possesses sets of nested hierarchies (Chase-Dunn 1998, Wallerstein 1974). One of the key features of both the world-system and the global food regime is an international division of labor in which some individuals or regions are responsible for growing the food and fiber products that sustain others. This division of labor has vast repercussions for the nature of agricultural production at all scales, as both what is being produced and the manner in which is it being produced is now increasingly influenced by global concerns instead of local ones. The autonomy of individual agricultural producers declines as "the economic forces developed under a capitalist world-system shape [the] integration of agricultural producers into the world economy" (Longo and York 2008:85). These global concerns reflect existing geopolitical power relations, typically favoring the interests of those in developed nations over those in less-developed nations. Therefore, the nature of agricultural production and its environmental impacts need to be understood from a global, political-economic perspective, as agriculture production and trade are heavily influenced by the global power structure of the world-system.

As world-system and dependency approaches to the study of environmental degradation have demonstrated, the global division of labor can both directly drive environmental degradation (Bunker 1984, Grimes 1999, Grimes and Kentor 2003) as well as structure what regions, nations, and peoples most directly experience environmental degradation and its negative consequences (Frey 1998, Pellow 2007). While lacking an explicit central theory, work within this perspective proceeds from the central premise that "global modes of production and accumulation are intimately linked to environmental degradation" (Jorgenson and Kick 2003:196). In general, wealthy nations are able to use poor nations as both supply depots for natural resources and repositories for wastes. In this way, rich nations protect their own living space by shifting the environmental degradation associated with both resource extraction and waste disposal onto the poor nations.

A relatively underdeveloped area within world-systems and dependency approaches to environmental problems is the study of the environmental consequences of the global food system. Following the logic of world-systems and dependency theory, the environmental degradation associated with agriculture is shaped by the global organization of agriculture and food systems. The world-economy and the legacy of unequal power relations that underlie it are strong determinants of both what is grown and how it is grown. In turn, what is grown and the way in which it is produced will largely drive the form and amount of environmentally degradation that is caused by agricultural production. At the cross-national level, these relationships will take the form of some nations occupying positions in the global division of labor where their economies are structured around the production of basic agricultural products for the global market, while other nations possess stronger, more articulated and diversified economies. Individuals and firms within the nations with the more developed economies are able to forgo or displace agricultural activities that lead to environmental degradation. Those within the nations that are dependent upon export agriculture as their economic base need to engage in such agricultural activities, often under the direction or control of agro-transnational corporations housed in the developed nations, to access foreign capital and promote economic growth. Consequently, a disproportionate amount of the environmental degradation created by agricultural activities that support the global economy will be localized within less-developed, less-powerful nations.

This dissertation will examine the relationships between nations' positions within the global food system and the environmental degradation associated with their agricultural activities. Using a cross-national analysis, I will operationalize each nation's position in the world-system, the degree to which they are developed, and the degree to which their economy is predicated upon the production of agricultural products for global markets. I will then examine how those political-economic factors influence three different forms of environmental degradation that have all been linked to agricultural production (Biodiversity loss, nitrous oxide emissions from agriculture, and methane emissions from agriculture). These three different analyses will constitute my three separate empirical chapters. Taken as a whole, this dissertation will examine broad patterns of international power relations, linked processes of development and agricultural dependence, and the environmental degradation that results from these processes.

This work represents a contribution to both environmental sociology as well as our broader understanding of the social dynamics that lead to environmental degradation. As a subfield, environmental sociology has consisted of the application of sociological theory and methods to issues of geo-physical limitations and environmental degradation (Gramling and Freudenburg 1996; Pellow and Brehm 2013).[1] Work within this field has addressed a broad range of topics including, but not limited to: examinations of public awareness of and concern over environmental issues (McCright and Dunlap 2011); the generation and management of environmental risk (Perrow 1999; Beck 1992); studies of environmental justice (Bullard 1994; Mohai, Pellow, and Roberts 2009); and explorations of the political-economic dynamics that generate environmental degradation (Foster 1999a; O'Connor 1998; Schnaiberg 1980; York, Rosa, and Dietz 2003). This dissertation falls within the latter category, as it examines global-level political-economic processes (largely the global division of labor) and the ways in which they can contribute to environmental degradation. Specifically, by connecting agricultural dependency with environmental degradation, it

[1] The term environmental sociology was originally coined as the name of a subfield of sociology which included physical variables and viewed humans as part of the larger ecosystem (Catton and Dunlap 1978; Dunlap and Catton 1979). However, reviews of the work that falls under the environmental sociology umbrella continually demonstrate that the subfield is concerned with the broad study of environmental problems,

provides a systematic exploration of how the global food and agriculture system is structured in a way that concentrates environmentally degrading agricultural processes into developing nations. While some studies have examined aspects of this relationship (see: Jorgenson 2007a, 2007b; Jorgenson and Kuykendall 2008; Longo and York 2008), more work is needed to fully understand the complex dynamics that link global food production with global environmental degradation. This dissertation represents a contribution to that understanding and therefore a contribution to environmental sociology.

Additionally, there is a substantial body of work outside of sociology that is equally concerned with the environmental impacts of agricultural production (Moss 2008; Steinfeld et al. 2006; Tilman et al. 2001). Scholars from a wide range of disciplines, including agronomy, soil science, ecology, history, and environmental science have all explored the issue of how modern agricultural production degrades the physical environment. Studies within this area consist of models projecting future impacts (Pelletier and Tyedmers 2010), review pieces that examine the pathways through which agriculture negatively impacts ecological systems (Moss 2008), and risk assessment models that predict environmental responses to changes in agriculture (Butler, Vickery, and Norris 2007; Benton 2007). Most of the work within this area takes a neo-Malthusian approach, focusing upon growth in population and affluence and the corresponding increases in agricultural production (e.g. Tilman 1999). This literature often downplays, or outright ignores, how the structure of the global food system and the inequalities built into that structure can both drive environmental degradation and shape who bears its consequences. This dissertation will add to this body of

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including their social origins, their social construction, knowledge and opinions about them, and their relative knowledge by highlighting various ways in which our global agricultural system involves relationships of power and dependency. The factors that shape agriculturally related environmental degradation are not limited to population and income, but also contain a political-economic, organizational component that this research will help illuminate. As much of the work in this area is intended to inform the decisions of policy makers in order to create a more sustainable global agricultural system, an awareness of these structural elements is vital for effective policy formation.

Literature Review

This dissertation is primarily informed by two bodies of literature: 1) world-systems and dependency approaches to environmental issues, and 2) food regime analysis. This literature review will examine both bodies of work, highlighting their contributions to this dissertation while also pointing out gaps in the literature that this dissertation addresses. I begin this review by briefly outlining my starting assumptions about the nature of human/environment interactions and about drawing from multiple theoretical perspectives. I then review world-systems and dependency approaches to environmental issues, focusing upon work within this area that has explored the environmental consequences of the global food system. I discuss the strengths of this approach while also highlighting areas of inquiry that remain in need of development. Following that, I review the food regime analysis body of literature and discuss how it informs this dissertation. In particular, I highlight the insights I draw from that literature while describing how it has relatively not been applied to

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distribution (Buttel 1987; Foster 1999b; Goldman and Schurman 2000; Pellow and Brehm 2013).

environmental issues. I conclude this literature review with a synthesis of these arguments and a description of my theoretical framework.

Prolegomenon

Every scientific work proceeds from certain underlying ideas that influence both the questions asked and the answers arrived at. Therefore, it is important at the beginning of this dissertation to clarify my *a priori* assumptions as well as contrasting viewpoints and arguments that may exist. Here, I explain: 1) my integrative approach toward the use of multiple literatures, and 2) my views about the fundamental nature of human attempts to manage and manipulate ecological systems. In terms of my integrative approach, this dissertation will utilize a synthetic method that draws insight from different theoretical perspectives, rather than a competitive one that attempts to demonstrate the superiority of one theoretical orientation over another. In essence, a theory is a general explanatory principle that provides a logical link between cause and effect (Popper 1966). Therefore, the more valid theories are the ones that most accurately reflect the mechanisms and interactions that operate in and govern the physical and social realms (Collins 1989). The accuracy of theories is assessed through empirically testing the validity of the predictions that can be derived from them; exposing those predictions to potential falsification (Popper [1963] 2000). Whereas theories are statements of causality, the predictions (hypotheses) are statements of observation. If X is theorized as causing Y, than we should be able to observe the hypothesis that every time X increases, Y increases as well. If this is not observed, the theory is rejected (Babbie 2013). Through this process, scientists can select between theories that describe the world with a reasonable accuracy and theories that do not. It is also possible to identify and modify aspects of theories that are less valid and therefore hone the overall theory. Therefore, science is a progression of constantly rejecting, reformulating, and refining theories in response to attempts to empirically disprove them. In this way we "invent more and more powerful searchlights" that more clearly illuminate the real world (Popper 1966:361).

However, this linear accumulation of knowledge is an idealized version of science that ignores both the subjective external relations (the political-economic circumstances of the time that guide scientific questions and answers) (Hessen [1931] 2009) and the personal motivations of the actual practitioners of science. The generation of scientific knowledge occurs within an institutional system that rewards distinction and recognition over the selfless pursuit of knowledge (Merton 1973). This incentive structure can lead to a form of "gladiator science" (Driscoll and Kick 2013:4) or a "theory-bashing" approach (Lofland 1993) in which competing theorizations (or their derived hypotheses) are tested in an exclusionary fashion, with one being validated at the expense of others. In the "ideal-type" form of this approach (Weber 1949), individual scientists possess professional allegiance to one theory or another; an allegiance that is decoupled from the theory's scientific merit. This can lead them to present "strawperson" versions of alternative perspectives which are easily discredited and dismissed.

An alternative to gladiator science can be found in an integrative approach that draws insights from the common ground between different theories, using their complementary strengths to create a theoretical framework with broad explanatory powers. This framework and hypotheses drawn from it can then be subjected to empirical tests and potential falsification in the Popperian tradition. As renown scholars throughout history have argued (Bacon 2001; Epicurius 1994; Lucretius 1995; Merton 1973; Popper 1966), the goal of science is to develop our understanding of the world we inhabit in order to better guide our actions. A synthetic approach allows for a more nuanced articulation of the relationships that exist among human societies, their agricultural systems, and their physical environment. A greater understanding of those relationships will allow for a more accurate explanation of the social dynamics that contribute to agriculturally driven environmental degradation. Therefore, in this dissertation I construct a synthetic theoretical framework from the shared premises of multiple literatures and derive testable hypotheses from that framework. These hypotheses are constructed in a way that tests the validity of my theoretical framework, rather than testing competing explanations from different lines of thought.

Regarding the nature of human attempts to manipulate ecological systems, much of the work in this dissertation proceeds from the understanding that naturally evolved ecosystems exist in a state of dynamic equilibrium (Daly 1996; Georgescu-Roegen 1971). This state imparts a relative stability (which includes a large amount of short-term fluctuations and long-term adaptations) and capacity for self-reproduction (Botkin 1990). Therefore, human attempts to manipulate and "improve" natural ecological systems will tend to threaten that evolved stability and reduce ecosystems capacity for self-renewal. This assumption is most succinctly stated with Barry Commoner's (1971) third law of ecology, which states that "nature knows best."[2] This law asserts that "any major man-made change in

[2] In some ways, Commoner's (1971) "Laws of Ecology" are inter-related and over-lap in the principles they describe. The fact that "everything is connected to everything else" (the cyclic balance of ecosystems), "everything must go somewhere" (energy and matter may be converted, but neither can be created or

a natural system is likely to be *detrimental* to that system" (Commoner 1971:41). The basis of this pessimism lies in the long-term, iterative nature of evolution. Through the evolutionary process, a near-infinite number of different possibilities and combinations of organisms and the physical world have been produced. Only the combinations and arrangements able to survive all disruptions and threats have been preserved. Therefore, the structure, composition, and organization of a natural ecosystem have already been heavily "screened" for any possible improvements or weaknesses (Darwin [1859] 1999). Consequentially, any change in that system is likely to be worse than the present arrangement in terms of the system's ability to maintain itself. This stance should be understood as not arguing that technological innovation, development, and the manipulation of nature have not yielded amazing benefits for humanity, but instead clarifying that those benefits have all come with ecological costs.

Other foundational ecologists have taken similar stances to that of Commoner, arguing that human attempts to "fix" or improve upon natural systems will most likely result in some form of environmental degradation (Carson 1962, Leopold 1966). The basis of this viewpoint is the understanding that much of western science (and how it is used to inform our interactions with the physical world) is based upon reductionist approaches toward knowledge (understanding systems on the basis of their parts). While a powerful intellectual tool, reductionist understandings tend to create problems when applied to holistic systems. In particular, reductionist approaches are not particularly well-suited to understanding

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destroyed), and "there is no such thing as a free lunch" (anything extracted from the environment must be replaced) all also describe how any human interference with natural systems is likely to result in the disruption of a pre-existing balance.

interactions, cumulative effects, and emergent properties (Carson 1962). When complex systems are broken down into their constituent components (either analytically or physically), the individual parts can be clearly seen, manipulated, and understood. However, when component parts are studied in isolation, it is more difficult to understand how they interact in the complex system, particularly when the system contains properties that are not found in any of the individual components. Therefore, efforts to alter a complex system that are based on a reductionist understanding of the component parts run high risks of encountering unforeseen (and negative) consequences.

One example of the problems arising when one applies reductionist logic to a holistic system can be found in the U.S. government's program to eradicate indigenous sagebrush in the high western plains and replace it with grasses more suitable to cattle grazing. The elimination of the sagebrush wreaked havoc upon the region's ecosystem, stripping the land of moisture and wiping out a number of dependent species. Furthermore, the annual rainfall was insufficient to support the desired sod-forming grass. These results demonstrate a gross error of logic in human attempt to "improve" naturally evolved systems. "It was by no accident, but rather the result of long ages of experimentation by nature, that the great plains of the West became the land of the sage" (Carson 1962:65). A similar demonstration of this principle can be found in Aldo Leopold's (1966:139-141) description of how the elimination of wolves from mountainous regions lead to the denuding of all ground-level vegetation and eventual starvation among the deer herds that were the intended beneficiaries of the wolf-eradication programs. These examples demonstrate the flaw in applying reductionist logic to evolved systems. "Ecosystems are governed by stubborn, largely unalterable natural forces" and human attempts to manipulate and control natural systems fly in the face of millions of years of natural experimentation through evolutionary processes (Commoner 1992:79).

While the idea that nature knows best is at the core of much of ecology and environmental studies, it must be acknowledged that many other disciplines and scientists proceed from a different fundamental understanding of the relationship between humanity and nature, which can be described as human domination. This viewpoint proceeds from the assumption that natural ecosystems may be improved upon in terms of their anthropocentric utility through human ingenuity and technology.[3] In essence, human-designed systems will better serve human needs through the application of rational logic. Support for this viewpoint may be drawn from (among many other examples) evidence of increased agricultural yields that are made possible through the application of reductionist scientific principles to agricultural systems (Tauger 2010).

In summation, this dissertation will be working from the assumptions that 1) an integrative approach to using multiple bodies of literature is more constructive than a competitive one that seeks to validate one theory or hypothesis over another, and 2) that human attempts to manipulate evolved ecosystems which are based on reductionist understandings are overwhelmingly likely to do harm to those ecosystems. I next review world-systems and dependency approaches to the environment and the food regime analysis bodies of literature.

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[3] The distinction between the "nature knows best" and "human domination" perspectives in some ways parallels Dunlap and Catton's (1979) contrasting between the "human exemptionalism" and "new environmental" paradigms. However, their arguments focus upon the relevance of the physical, environmental factors to sociological investigation, rather than underlying assumptions about the incompatibility of reductionist logic with evolved ecosystems.

World-systems and Dependency Approaches to Environmental Degradation

World-systems and dependency theories are two closely related political-economy perspectives within the development literature. Broadly conceptualized out of critiques of modernization theory, these two literatures share a focus on how the relationships between developed and developing worlds (typically examined at the national level in dependency theory and at the global level in world-systems theory) can contribute to uneven development and resultant global inequality. Processes of capital accumulation occurring within a global division of labor and a hierarchy of nation-states extract surplus value from actors within developing nations and consolidate it among actors within developed nations (Amin 1974, 1976; Baran 1957; Frank 1967, 1975; Prebish 1949; Wallerstein 1974). The flow of surplus value provides nations in positions of higher power within the world-system with the capital and resources to develop, innovate, and modernize more rapidly than those occupying positions of lower power. As a theoretical approach, it has been critiqued as anthropocentric; focusing primarily upon political-economic social history as the driver of long term global transformations at the expense of ecological factors (Chew 1997). However, a body of work has emerged that applies world-systems and dependency theories' insights to the understanding of contemporary environmental issues (Jorgenson and Kick 2003).

The application of world-systems and dependency theories to the study of environmental issues is a broad category that encompasses a wide range of works that are not defined by a distinct theory or method. The common thread that unites these studies is the idea that global processes of capital accumulation drive environmental degradation. Furthermore, this approach examines how the power structure of the world-system and the international division of labor allows actors within core nations to displace environmentally destructive industries and materials onto actors within weaker developing nations while appropriating a disproportionate share of the world's natural resources (Bunker and Ciccantell 2005; Roberts and Grimes 1999). Additionally, studies within this area explore how the uneven development that characterizes the world-system leaves the populations of peripheral nations particularly vulnerable to environmental hazards (e.g. contaminated water supplies, airborne pollutants, occupational exposure to toxic materials) due to their limited education, resources, and institutions (Frey 1998).

While research on the environment within world-systems and dependency frameworks does not identify one central mechanism that explains the origins of environmental degradation or its transfer from developed to developing regions, a central idea within the school of thought is that the political-economic mechanisms that generate environmental degradation differ greatly among the different zones of the world-system. Within Wallerstein's (1974) conception of the world-system, there are three distinct structural tiers in the global hierarchy of nations; the core nations at the top, peripheral nations at the bottom, and semi-peripheral nations in between. Nations within these separate tiers differ greatly in their degree of modernization and development. Additionally, they tend to wield an amount of international power and occupy positions within the global division of labor that correspond to their position within the hierarchy. Consequently, economic activities vary greatly between the different tiers and the environmental degradation that results from those activities varies accordingly (Roberts and Grimes 1999).

Researchers within this school of thought have demonstrated that different rates of environmental destruction (such as deforestation) occur among the various zones of the world-system. These different rates support the argument that different causal mechanisms are at work within the different tiers (Burns et al. 1994; Kick et al. 1996). These different mechanisms are the result of differing states of development and different relations to the global economy. Additionally, the relationships between nation-states are highly dependent upon those nation-states' position within the world-system and those relationships can greatly influence the amounts and types of environmental degradation that occurs. By way of example, the dependence of less-developed nations on foreign investment is heavily associated with environmental degradation as developed nations use economic investment to shift environmental externalities onto the less-developed nations. Some have argued that this relationship stems from transnational capital seeking out "pollution havens," or nations with lower environmental standards (Grimes and Kentor 2003; Jorgenson, Dick, and Mahutga 2007). Others have countered that this trend originates from trans-national corporations' routine profit seeking activities (e.g. seeking nations with lower wages) which tend to result in investing in nations with lower environmental standards (Jorgenson 2010; Manderson and Kneller 2012). While encompassing a wide range of topics and theories, these various approaches utilized in world-systems and dependency studies of environmental issues are united by their shared treatment of environmental degradation as a result of global processes of capital accumulation.

It must be pointed out that while these (and other) literatures frequently theorize and discuss environmental degradation as a single, homogenous outcome, quite often this is not the case. There are a great number of different forms of environmental degradation, each of which possesses a wide range of unique aspects including physical properties, scale, causal mechanisms, peoples impacted, and ways in which the physical world is altered. While macro social processes such as global capital accumulation can be accurately described as "degrading the environment," that description is an aggregation of a constellation of smaller, more nuanced processes and relationships, some of which counter and off-set one another. Referring to environmental degradation as a whole is a useful convenience, but it is done with the implicit understanding that the term denotes a large, complex composite of heterogeneous processes and outcomes.

Within world-systems and dependency studies of environmental issues, there have been some studies that explore the links between the structure of the global food system and environmental degradation. This line of exploration largely examines how transformations in the structure of the global agricultural system lead to nations adopting domestic agricultural systems that are damaging to the environment. Much of the work within this area proceeds broadly from the Marxian critique of the global division of labor, in which "a new and international division of labor, a division suited to the requirements of the chief centres of industry, springs up, and converts one part of the globe into a chief agricultural field of production, for supplying the other part which remains a chiefly industrial field" (Marx [1876] 1976:579-580). As described by the food regime literature (see below), this international division of labor has both intensified and been radically reorganized since the time of Marx's writings. Therefore, national-level agricultural activities in the modern era are "embedded in the highly stratified and unevenly distributed global agricultural system" (Jorgenson 2007b:30).

While examining issues pertaining to national agricultural systems' relationship to the global food systems, I use the term "agricultural dependency" to denote the degree to which a nation's economy is constituted around the production of agricultural products for global markets. Nations with a high degree of agricultural dependence are those that occupy a position in the global division of labor producing relatively unprocessed agricultural products, primarily for external consumption. Agricultural producers in nations with a high degree of agricultural dependency are integrated into the capitalist world-economy at a position of marked disadvantage in terms of power and autonomy (Longo and York 2008). The idea of agricultural dependency draws heavily from dependency theory's concepts of disarticulation and cash-crop economies. Disarticulation is a term that describes an economic structural distortion that is characterized by weak or non-existent integration among unevenly developed economic sectors (Amin 1974; Baran 1957; de Janvry and Garramon 1977). Disarticulated economies suffer from "extraversion" (the domination of an economy by an external market orientation), where the export sector is more highly developed and uses more modern technology and capital intensive practices than the domestic sectors (Amin 1976). However, this developed sector of the economy is poorly linked to other sectors due to its reliance upon foreign capital, thus growth and investment in the export sector does not facilitate growth in other sectors (Breedlove and Armer 1997; de Janvry 1981). The economies of agriculturally dependent nations suffer from a high degree of disarticulation, as their agricultural sector is well-developed but heavily influenced by foreign interests, dependent upon export markets, and poorly linked with other sectors of the economy.

Closely related to the idea of disarticulation, the concept of cash-crop economies describes national economies that are structured around (and dependent upon) the production of basic agricultural commodities (e.g. coffee, copra, cotton, sesame, peanuts, and sugar) for Western markets. Cash-crop economies have their origins in the colonial system, under which the best farming lands in European colonies were appropriated for plantations. These plantations were devoted toward commercial agriculture that supplied European consumers and industries with tropical exports and raw materials (Amin 1974). The emphasis on cash-crop production was maintained after the dissolution of the colonial system by the development project, as developing nations were encouraged (or outright forced) to invest in cash crops as a means of generating income to finance their development (McMichael 2004). An important consequence of emphasizing cash crops was that their expansion came at the expense of domestic food production, leading to a perverse reliance of agricultural nations upon staple food imports from industrial nations (Maxwell and Fernando 1989; Weis 2007). Nations that are agriculturally dependent are highly reliant upon cash crops as a substantial portion of their economy.

In summation, the term agricultural dependency describes the degree to which a nations’ economy is reliant upon the production of agricultural commodities for sale on global markets. Farmers and farming firms in agriculturally dependent nations are pressured (via both direct control and economic incentives) by external agents (largely transnational agro-corporations and international development institutions) to focus upon high-value, export products for trade on the world-market. The resultant economic systems are built around cash crops and marked by high degrees of disarticulation and external control. This external control influences producers in nations that are agriculturally dependent to adopt specific production methods, often at the expense of traditional practices (Jorgenson and Kuykendall 2008). Nations with a high degree of agricultural dependence possess the following traits: 1) agriculture constitutes a large portion of that nation's economic activity and workforce; 2) agricultural production is focused upon high-value export products, rather than staples for domestic consumption; and 3) agricultural production is heavily influenced by foreign interests.

Of particular interest in this dissertation is the question of how agricultural dependency leads to or exacerbates environmental degradation. It is well established in the dependency and world-systems literatures that global processes of capital accumulation drive a great deal of environmental degradation (Jorgenson and Kick 2003). Similar dynamics operate within the global food system, where the pursuit of profit at the transnational level often causes nations that are more agriculturally dependent to adopt agricultural practices that are relatively environmentally destructive. In general, foreign ownership has been linked to increased environmental degradation as decision makers are less likely to weigh environmentally sustainability against profitability when the environment being considered is not their own (Jorgenson 2007c; Jorgenson et al. 2007). Additionally, foreign investors and transnational corporations are more likely to make investments in nations with lower environmental standards and policies (Clapp 1998, Frey 2003). Therefore, these firms are more likely to invest in agricultural systems that will not be held to costly environmental standards. The technology financed by foreign investment is also more likely to be outdated and ecologically inefficient as well as highly automated and energy-consumptive (Grimes and Kentor 2003). Finally, the indirect influence of external interests (e.g. global market demand, competing commodities, etc.) can also lead to more environmentally degrading agriculture as those economic forces pressure agriculturally dependent nations to grow products that are more damaging to the local environment. For example, if Western consumers prefer bananas of a uniform length and color that can only be reached through the heavy application of artificial fertilizers, than agriculturally dependent nations will bear the environmental consequence of that fertilizer run-off.

Agricultural dependency (while not described using that term) has been operationalized in a number of different ways in empirical studies that examine its impacts upon environmental degradation. Andrew Jorgenson (2007a, 2007b; Jorgenson and Kuykendall 2008) has focused upon the amount of foreign direct investment in the primary sector. Building his “ecostructural theory of foreign investment” he argues that environmental degradation in LDCs is partially driven by export flows and foreign investment. This argument (and operationalization) extends from a wide range of studies in macrocomparative research that have treated foreign capital penetration as one of the primary forms of international dependence (e.g. Bornschier and Chase-Dunn 1985, Dixon and Boswell 1996, Grimes and Kentor 2003). However, the effects of foreign capital penetration may differ across the distinct sectors of the host economy. Therefore there is a need to separately assess the impacts of FDI in those sectors on environmental outcomes (Jorgenson 2006). This operationalization of agricultural dependency most directly captures its third trait, direct control by foreign interests. While FDI in agriculture would be the best indicator of the extent to which transnational corporations are dominating the agricultural systems of host countries, data limitations restrict Jorgenson's work to FDI in the primary sector. [4] Others have examined agricultural dependency as the degree to which a nation's economy is constituted upon agricultural exports, measuring the value of agricultural exports as a proportion of gross domestic production (Longo and York 2008). This measure best captures the second trait of agricultural dependency, the focus upon high-value export products. Collectively, these works have focused on the degree of foreign control and the external orientation of a nation's agricultural production.

The condition that I describe as agricultural dependency has been linked to a number of forms of environmental degradation. As mentioned above, agriculture is a large contributor to much of our anthropomorphic greenhouse gasses (Ham et al. 2000; IPCC 2007). Foreign investment in the primary sector has been shown to directly contribute to carbon dioxide emissions from agriculture (Jorgenson 2007b) as well as overall nitrous oxide emissions (Dick and Jorgenson 2010). Other studies tested the connection between agricultural dependence and methane emissions but failed to find support for such a link (Jorgenson 2006). Interestingly, despite the argument that agriculture is one of the main contributors to methane and nitrous oxide emissions, no prior work has specifically examined emissions of either type that originate solely from agricultural activities. Given the tremendous differences in the social and economic dynamics at work within the different

[4] Preliminary analyses in this dissertation examined each and found that while there are some anomalous nations (Primarily oil-producing nations), FDI in the primary sector and FDI in agriculture do correlate at a statistically significant level.

economic sectors and industries, there is substantial reason to examine emissions generated from these industries and sectors separately, rather than in aggregation (Jorgenson 2006, 2007b).

Conditions of agricultural dependency have also been linked to increased use of both synthetic pesticides and artificial fertilizers (Jorgenson 2007a; Longo and York 2008). Transnational agro-industrial firms operating in less-developed countries utilize higher intensities of pesticides and fertilizers than they do in developed nations (Jorgenson and Kuykendall 2008). Accompanying the introduction of chemical-intensive production methods into less-developed nations' agricultural systems is a general movement away from traditional and environmentally sustainable farming practices such as crop rotation and the recycling of organic matter (Altieri 2000). To hasten short-term returns to investment, foreign interests replace these systems with the high-intensity use of pesticides and synthetic fertilizers in large-scale, mono-crop production (Jorgenson 2007a). Heavy use of artificial fertilizers leads to nutrient run-off and accumulation in both groundwater and local surface-water systems. High levels of nutrients, particularly nitrates, in drinking water are associated with a number of cancers and methemoglobinemia (blue-baby syndrome) in children (Altieri 2000). Additionally, elevated nutrient levels in aquatic ecosystems (eutrophication) can lead to the excessive growth of plants, algae, and plankton. This state destabilizes the ecosystem through the creation of algal blooms and subsequent oxygen depletion of the water (Tilman 1999). Eutrophication can also disrupt ecosystems by fostering the excessive growth of toxic organisms, such as *Pfisteria piscicida* (Burkholder and Glasgow 2001, Burkholder et al. 1992). The heavy use of fertilizers can also lead to increased greenhouse gas emissions both directly (through nitrous oxide emissions from ammonium and nitrogenous fertilizers) and indirectly (through carbon dioxide emissions from the use of energy-intensive tractors and other machinery needed for their transport and application) (Jorgenson and Kuykendall 2008).

Synthetic pesticides have been proven to be harmful to both human beings and other organisms found in natural ecosystems (Carson 1962; Harrison 2011). In some cases, transnational corporations will use certain pesticides in less-developed nations that have been banned in the corporation's home nation due to their environmentally harmful nature (Frey 1995). Synthetic pesticides are particularly problematic due to two reasons. First, being artificially designed, there is no corresponding natural system that breaks them down, which causes them to persist in the environment far longer than any evolved compounds or substances. Second, due to the fact that most synthetic pesticides build up in fat tissues and are not excreted from animals' bodies, these pesticides are subject to phenomenon known as "biomagnification," where they build up in intensity as they travel up food chains. This process leads to these pesticides accumulating to their most dense levels in top predators such as wolves, birds of prey, and human beings (Reece et al. 2011). In terms of their direct effects, exposure to pesticides has been linked to both toxic poisonings and various forms of cancer in humans (Harrison 2011; World Health Organization 1990). Pesticides can also have a severe impact on other organisms in the environment. Similar to fertilizers, pesticides find their way off of fields where they are used through drift, water runoff, and soil erosion. Once in ecosystems, pesticides can prove fatally toxic to wild birds and mammals, as well as numerous small organisms (Rathore and Nollet 2012). By systematically poisoning other species, pesticides contribute substantially to biodiversity loss and other forms of ecosystem disruption (Carson 1962; Riffel et al. 2009). In summation, agricultural dependency has the potential to increase the output of greenhouse gases and the use of both synthetic pesticides and artificial fertilizers. As these factors substantially contribute to the environmental crisis, agricultural dependency needs to be understood more fully.

Food Regime Analysis

Food regime analysis is a distinct body of literature that some classify as falling under the sociology of food and agriculture (Bonnano 2009). This analytical tool was originally conceptualized by Harriet Friedmann (1987) and further developed with Philip McMichael (Friedmann 2005, Friedmann and McMichael 1989, McMichael 2005). This approach argues that the organization of food and agricultural can be understood as evolving through relatively stable and alternative unstable periods of capital accumulation defined by particular relations of geopolitical power, ownership, modes of production, and consumption as well as specific patterns of circulation of food in the world economy. As a form of analysis that argues that the nature of global food systems are driven by "global constellations of power and property" (Friedmann 2005:228), food regime analysis can be seen as the application of world-systems analysis to the study of agriculture and food (Bonanno 2009). Its primary contribution to our understanding of how societies feed themselves and organize agricultural production is its structural (rather than historical) approach to the study of food and agriculture. It views regional and national food sectors as component parts embedded in a global division of labor. It also views changes within those individual sectors as constituent parts of broader processes of change reflective of inherent contradictions and tensions within the capital accumulation process (McMichael 2009).

There is relative consensus among food regime scholars about the existence of two distinct food regimes and debate exists over the possibility of a third food regime. The first food regime (approximately 1870-1930)[5] was a creation of the colonial system and characterized by European nations importing tropical products from tropical colonies along with grains and livestock from ex-colony settler nations (Friedmann and McMichael 1989). It is important to note that the differences between the tropical colonies and the settler ex-colonies extended far beyond the types of agricultural products being produced. In general, the tropical colonies were colonies of occupation, with economies based on mono-culture plantations and marked by high degrees of disarticulation. In contrast, the settler ex-colonies were models of twentieth-century development with highly articulated agricultural and industrial sectors (McMichael 2009). The imports in food staples from the ex-colonies displaced agriculture in Europe, leading to mass de-peasantization and corresponding increases in both the number of urban, industrial workers and in the emigration of settlers to the colonies (Friedmann 1987). In this way, the first food regime supported and maintained the colonial division of labor, with Europe producing most of the world's manufactured goods.

The second food regime (approximately 1950-1970) was organized around U.S. hegemony in food production and involved developing nations being forced to shift from

[5] While food regime scholars tend to argue for a fixed timeframe for each respective food regime, their periodization is somewhat problematic. Depending on the tensions and dynamics being examined, one can

self-sufficiency to import dependency. This food regime was marked by intensive agricultural production in the developed world and extensive production in the developing world (Friedmann 1987). Green Revolution technology, agro-industrialization, and state-subsides led to food surpluses in the developed world (particularly the United States) and corresponding massive food exports (primarily in the form of food aid) which displaced traditional foods in developing nations (Friedmann and McMichael 1989). Additionally, the United States' privileged position as a "dominant exporter" allowed it to restructure international trade in its favor, forcing ex-colonies from self-sufficiency to import dependency (McMichael 2009). This transnational restructuring of the global food system disrupted the internal coherence of national farm sectors in developing nations. The second food regime went into crisis in the mid-1970s when U.S. surpluses shifted from the developing world to the USSR. The developing nations were left in a tenuous position of having an underdeveloped agricultural sector that was reliant upon U.S. surplus grain to feed their populations and massive amounts of debt from their reliance upon imports (Friedmann 1987).

While food regime scholars generally agree that the second food regime came to an end in the early 1970s, considerable debate exists as to the nature of the global food system since. Scholars are divided on the issue of whether we are currently experiencing a third "corporate food regime" (Burch and Lawrence 2005, 2009; McMichael 2005) or experiencing a period of contestation that will lead to an emerging "corporate-environmental food regime" (Friedmann 2005, 2009). The collapse of the second food regime was followed

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argue for the validity of alternative timeframes. However, this critique does not imply that food regime analysis by the dissolution of U.S. food aid and a corresponding food crisis that primarily impacted developing nations. Additionally, the recovery of European production and power, combined with the rise of second rank exporters such as Argentina, Canada, and Australia, led to a shift in the global food system away from U.S. hegemony and toward a multi-lateral system (McMichael 2009).

The shift toward multi-lateralism was accompanied by an increase in the power of global agri-food corporations that are profiting from the reorganization of the global food system. The rise of these corporations in power gave them considerable influence toward promoting a neoliberal regulation framework, often through structural adjustment loans from the World Bank and International Monetary Fund (McMichael 2004).[6] A byproduct of this unevenly imposed neoliberal framework is the preservation of farm subsidies for the Northern farmers (a trend that maintains low grain prices), while Southern states are forced to reduce agricultural protections, subjecting their farmers to competition with cheap Northern staples (McMichael 2009). The unfolding third food regime is also characterized by a deepening reliance upon advanced biotechnology and genetically modified organisms (Pechlaner and Otero 2008). Regardless of whether we are in a period of contestation or we are in a new, distinct third food regime, certain features of the current global food system are generally agreed upon. The current global food system is multilateral, it is led by global agri-food corporations, and it is governed by a neoliberal mode of regulation.

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is not a useful literature for framing and organizing studies of the global food and agriculture system.

[6] While more recent (post-2000) events may constitute a deviation from this trend of increasing liberalization and the beginning of a potential new era, they have yet to be definitively classified or placed in a historical context.

Food regimes are characterized by more than just the structure of international food trade. An important aspect of each food regime is the nature and distribution of the diets that people are consuming during that period. The current global food system is marked by what Tony Weis (2013) terms an intensive “meatification” of diets. This term describes how modern diets have been radically re-structured around the consumption of animal products. Meat consumption in the average global diet has nearly doubled since 1950 and continues to rise (Steinfeld et al. 2006). This aggregate trend obscures huge disparities that exist between nations in both current meat consumption and rates of increasing meat consumption. Meat consumption is greatest in developed nations, but is rising much faster in developing nations (FAO 2012). This trend has important implications for the environment as diets heavy in animal products result in a much higher ecological footprint (Baroni et al. 2007; Goodland 1997; Marlow et al. 2009). This is largely due to the law of ecological efficiency, which states that approximately only 10% of net production at one trophic level is transferred to the next (Reese et al. 2011). For agriculture, this means that consuming an animal only gives one access to 10% of the energy and nutrition in that animals diet. Put another way, you could support ten humans on the amount of grain and water required to produce enough meat to support only one human.

One of the biggest contributions of the food regime literature and concept is how well it clarifies the structure of the global food system. However, this work is largely historical and descriptive; there has been little comprehensive empirical analysis of that structure or its various consequences. More relevant to this dissertation, there has been little scholarship that applies food regime analysis to issues of environmental degradation. Despite the strong relevance that the organization of the global food system has for the environmental impacts of agricultural production worldwide, the only substantial work done within food regime analysis that directly relates to the physical environment has been attempts to incorporate Marx's concept of the "metabolic rift" (as articulated by Foster [1999, 2000]) as a political-ecological perspective (McMichael 2009). These attempts to integrate food regime analysis with the metabolic rift perspective have conceptually examined how the global divisions of agricultural labor that characterize the different food regimes contribute to a separation of food production from its natural, ecological base. These transformations lead to a reduction in nutrient recycling, disruptions in normal water and soil cycling, the replacement of local, organic inputs with synthetic, industrial products, and the substitution of bioengineered seeds and genetic materials for local, traditional varieties of crop plants (Campbell 2009; McMichael 2010).[7] While these works have generally described some of the ecological contradictions inherent within industrial agriculture, they have not examined that connection empirically.

Food regime analysis will provide this dissertation with a theoretical orientation as to the organization of the modern global food system and the historical basis of those relationships. While I do not directly analyze either the transition from one food regime to another or the nature of regulation characterizing the current food regime, I use this

[7] It is worth noting the degree to which the ecological transformations described by the application of the metabolic rift perspective to food regime analysis mirror the concept of "appropriationism" from the sociology of food and agriculture. This term captures the stepwise process of replacing discrete natural elements of the agricultural production process with industrial activities and inputs (Goodman, Sorj, and Wilkinson 1987). Scholars within this area argue that in order to maximize profits, industrial capitals attempt to reduce dynamics and fluctuations outside of human control, therefore limiting and reducing the influence of nature in agricultural production.

framework as a conceptual tool to “identify significant relationships and contradictions in capitalist processes across time and space” (McMichael 2009:163). More specifically, food regime analysis provides a structural, rather than historical, interpretation of the global food system. It describes and helps explain the polar nature of the global division of agricultural labor, in which Northern farmers produce labor-extensive grain crops and Southern farmers produce high-value, labor-intensive products such as meat, fruits, and vegetables (McMichael 2009). It also helps explain the interdependent nature of the global food system and how subsidized surpluses from developed nations make up the overwhelming majority of agro-trade, yet the majority of the farming population can be found in food-dependent, developing nations (Clapp 2012; Weis 2007). As this dissertation is an exploration of the environmental consequences of the global food system, it is crucial to have a clear framework in which to understand the nature and workings of that system. In addition to illuminating the structure of the modern global food system, food regime analysis also provides a historical context for that system. It helps explain why some nations occupy the positions that they currently do in the global division of agricultural labor. Through the approach’s understanding of alternating periods of contestation and stable relations of capital accumulation, it is possible to trace the current global food system back to its roots in the legacy of the colonial system. This historical context is crucial for both understanding the current system and for discussing potential alternatives as well as the policies and actions that might make such alternatives possible.

Synthesis and Summation

This dissertation will be drawing from world-system and dependency approaches to environmental degradation as well as the food regime analysis literature. Used synthetically, these two schools of thought provide an excellent theoretical framework for understanding and interpreting the environmental impacts of agricultural dependency. The capitalist world-system possesses a single, global division of labor that exists within a framework of competitive nation-states. Part of that global division of labor is the food and agricultural system. That food and agricultural system has progressed through alternating periods of contestation and stability, with the structure of each subsequent period being shaped by the relationships of the prior. This historical progression has led to a current food and agriculture system that is highly polarized in nature. On one hand, developed nations produce subsidized meat and grain surpluses through industrial means as only a small part of their economy. On the other hand, developing nations focus their economies upon the production of cash crops for export. This external focus involves a great deal of external control and leaves developing nations dependent upon export agriculture as one of their primary economic activities. This state of agricultural dependence possesses negative economic, social, and environmental consequences. The negative environmental impacts stem from the agro-TNCs that control a great deal of the global food and agricultural system investing in nations with lower environmental standards as a consequence of their profit-seeking activities. Additionally, as most of those agro-TNCs are housed in developed nations, they do not possess any incentives to protect the environments of the developing nations they are investing in. Moreover, the agro-TNCs are more likely to utilize outdated and ecologically inefficient technology in developing nations. Consequentially, agricultural dependence leads to, among other forms of environmental degradation, increased greenhouse gas emissions and biodiversity loss. From this theoretical framework it is possible to draw concrete hypotheses regarding the relationships between the global power structure, development, agricultural dependency, and environmental degradation.

Research Questions with Related Hypotheses

- How does agricultural dependency influence environmental degradation? In line with the theorization presented above (See pgs. 20-24, 29-30), agricultural dependency is expected to cause increased levels of environmental degradation. Therefore:
    - H1: Higher degrees of agricultural dependency will be positively associated with greater amounts of environmental degradation, net of all other effects
        - H1a: Higher degrees of agricultural dependency will be positively associated with greater amounts of per capita nitrous oxide emissions from agriculture, net of all other effects
        - H1b: Higher degrees of agricultural dependency will be positively associated with greater amounts of per capita methane emissions from agriculture, net of all other effects
        - H1c: Higher degrees of agricultural dependency will be positively associated with greater amounts of biodiversity loss relative to the number of existing species, net of all other effects

- How does modernization influence environmental degradation? According to broad political economic arguments (See pgs. 15-16), while the modernization process tends to generate environmental degradation, that degradation is often displaced from more modern nations to less-modern nations. Therefore:
    - H2: Higher degrees of modernization will not demonstrate a significant association with environmental degradation, net of all other effects
        - H2a: Higher degrees of modernization will not be significantly associated with greater or lesser amounts of per capita nitrous oxide emissions from agriculture, net of all other effects
        - H2b: Higher degrees of modernization will not be significantly associated with greater or lesser amounts of per capita methane emissions from agriculture, net of all other effects
        - H2c: Higher degrees of modernization will not be significantly associated with greater or lesser amounts of biodiversity loss, net of all other effects
- How does modernization influence agricultural dependency? As theorized in this dissertation and in keeping with general world-systems and dependency arguments (See pgs. 17-19, 29-30) the modernization process is expected to reduce agricultural dependency. Therefore:
    - H3: Modernization will be negatively associated with agriculturally dependency, net of all other effects

- How does position in the world-system hierarchy influence agricultural dependency?

As theorized in this dissertation and in keeping with general world-systems and dependency arguments (See pgs. 17-19, 29-30) positions of power within the world-system should enable nations to avoid agricultural dependency. Therefore:

  - H4: Positions of higher power in the world-system hierarchy will be negatively associated with agricultural dependency, net of all other effects

- How does position in the world-system influence modernization? As many world-

system and dependency scholars argue, occupying a position of power in the world-system allows nations to modernize more rapidly than others (See pg. 14). Therefore:

  - H5: Positions of power within the world-system hierarchy will be positively associated with higher degrees of modernization, net of all other effects

Outline of Proceeding Chapters

Here, I briefly outline the contents of the rest of this dissertation, in order to provide the reader with a clear orientation as to the work as a whole.

Chapter Two: Methods

The second chapter of the dissertation clearly outlines my methodological strategy. I briefly review structural equation modeling (SEM), discussing its relative strengths and weaknesses and why it is a particularly suitable method for this study. In this review, I visit the debates as to whether or not SEM can be used to establish causality. I then describe the particular analytical strategy employed in the three analyses that constitute the empirical chapters of the dissertation and explain why it was used. I discuss the sample of nations included in the dissertation and the rationale behind their selection. I also outline all of the measures used in this study, describe their particular suitability, and report their origins. This chapter also includes a brief review of potential analytical techniques and strategies that may have contributed to this analysis but were not employed. In that review I explain the reasons those techniques were not used.

Chapter Three: Agricultural Dependency and Nitrous Oxide Emissions

The third chapter of the dissertation is the first of the three empirical chapters and examines how agricultural dependency impacts nitrous oxide emissions from agriculture. I discuss nitrous oxide emissions as a form of environmental degradation, outlining their sources and describing how they negatively impact the global ecosystems. I then review prior work that has examined the social drivers of anthropogenic nitrous oxide emissions. I also briefly discuss some of the unique methodological aspects of operationalizing nitrous oxide emissions from agriculture and exploring their origins. I then present my findings and discuss them. I find that nations that a nation’s degree of modernization has a direct positive effect on nitrous oxide emissions from agriculture, but an indirect negative effect on those emissions through agricultural dependency. Based on these findings I argue that agricultural dependency leads nations to adopt forms of agriculture that generate elevated levels of nitrous oxide emissions. I also argue that more modern nations experience increase levels of nitrous oxide emissions from agriculture due to the meat-intensive nature of their domestic agricultural systems. I follow this with a brief discussion of alternative models and variables that were tested but yielded null findings. I finish this chapter with a discussion of my findings, their potential implications, and my conclusions.

Chapter Four: Agricultural Dependency and Methane Emissions

The fourth chapter of the dissertation examines how agricultural dependency impacts methane emissions from agriculture. I discuss methane emissions as a form of environmental degradation and outline how they negatively impacts both human beings and natural ecosystems. I then review prior work that has examined methane emissions and outline the causal mechanisms described in that work. I also briefly discuss some of the unique methodological aspects of operationalizing methane emissions from agriculture and exploring their origins. I then present my findings and discuss them. I find that world-system position has a positive direct effect on methane emissions from agriculture. I also find that modernization has an indirect, negative effect on methane emissions from agriculture by having a negative direct effect on agricultural dependency which has a positive impact on the emissions. Based on these findings I argue that agricultural dependency leads nations to adopt forms of agriculture that generate elevated levels of methane emissions. Additionally, I find that net of the effects of agricultural dependency, nations higher in the world-system have higher levels of methane emissions due to how they dispose of their animal wastes. I follow this with a brief discussion of alternative models and variables that were tested but yielded null findings. I finish this chapter with a discussion of my findings, their potential implications, and my conclusions.

Chapter Five: Agricultural Dependency and Biodiversity Loss

The fifth chapter of the dissertation examines how agricultural dependency impacts biodiversity loss. I discuss biodiversity loss as a form of environmental degradation and outline how it negatively impacts both human beings and natural ecosystems. I then review prior work that has examined biodiversity loss and outline the causal mechanisms described in that work. I also briefly discuss some of the unique methodological aspects of operationalizing biodiversity loss and exploring its roots. I then present my findings and discuss them. I find that agricultural dependency is not strongly related to biodiversity loss and that instead, biodiversity loss is primarily driven by human ecology factors. Biodiversity loss tends to be greater in large nations with large populations that are located closer to the equator. I follow this with a brief discussion of alternative models and variables that were tested but yielded null findings. I finish this chapter with a discussion of my findings, their potential implications, and my conclusions.

Chapter Six: Conclusions and Implications

This final chapter provides a summary and analysis of the dissertation as a whole and discusses the implications of this work. I review the central arguments and findings and interpret the meaning of those overall findings. Following that, I highlight the contributions this study makes to both environmental sociology and our broader understanding of the relationships between the structure of the global food system and environmental degradation. I then discuss the shortcomings and limitations of this work as well as future directions for this research agenda. I conclude the dissertation with a broad description of the implications of this work for a more environmentally sustainable global food and agriculture system.

CHAPTER TWO- METHODOLOGIES

Introduction

In this chapter I describe the research method I employ in this dissertation, my sample and measures, and my general analytic strategy. I start with a discussion of the relative strengths and weaknesses of structural equation modeling (SEM) and its particular suitability for this study. Following that, I describe the general analytic strategy that I employ in this dissertation. I then review some of the debate that exists over which goodness-of-fit measures should be employed and describe the rationale behind the measures I use. Next, I describe what nations are included in my sample and the measures used in my analyses. I conclude this chapter with a brief discussion of some of the analytical techniques and strategies that may have contributed to this analysis but were not employed. In that discussion, I explain what those techniques may have offered and the reasons they were not used.

Structural Equation Modeling

SEM is a statistical modeling technique that is based on the general linear model (the underlying basis of all regression techniques) (Bollen 1989). While its use has grown more popular in the social sciences only recently, as Ross Matsueda (2012) describes, it has its origins in the causal modeling work of Wright (1921), Blalock (1964), and Duncan (1959; 1975). The technique can be described as a combination of factor analysis and path analysis (Hox and Bechger 2001). The factor analysis aspect of SEM is its ability to model latent variables that represent theoretical constructs that do not lend themselves well to direct measurement. These unobserved variables are measured by different other indicators of the underlying concept that can be observed (Garson 2012). The path analysis aspect of SEM is its ability to simultaneously model variables as both causes and effects. A structural equation model implies a structure for the covariances between *all* of the observed variables. This path diagram is merely an isomorphic representation of a linear equations system (even ones describing non-linear relationships) (Byrne 2010). However, while still based on correlation, the technique has the advantage of allowing for the analysis of overall models, rather than individual coefficients in isolation (Garson 2012). By testing the implied covariance structures against the existing covariance matrix, it is possible to determine how well the proposed path diagram fits the data and therefore how well the theoretical structure is empirically supported (Bollen 1989).

This technique has a number of advantages relative to OLS (and its various derivatives) that make it particularly suitable for analyzing the questions I engage in this dissertation. In addition to its abilities to model latent variables, examine both direct and indirect effects, and assess overall model fit, SEM provides favorable treatment of measurement error and allows for interpretation in the face of multicollinearity, which has been described as "the bane of cross-national research" (Firebaugh 1983:263). Multicollinearity (a linear dependence between separate independent variables regardless of their relationship with the dependent variable) is a pervasive problem in cross-national analysis where a number of national indicators (e.g., GDPpc, literacy rates, industrialization, life expectancy) overlap greatly (Babones 2014). This can lead to a “partialing,” where the overlapping variables split the available variance within the independent variable. While high multicollinearity may still decrease the reliability of SEM estimates when unaccounted for, SEM provides two ways to address this problem. First, the use of latent variables allows for the inclusion of highly multicollinear indicators as the latent variable captures the shared variance among their indicators and directly models its effects. Second, SEM allows a research to explicitly model the correlation among independent variables as direct interactions or covariance relationships among indicators and/or their error terms (Garson 2012). In summation, SEM is the most appropriate technique for this dissertation because it allows me to treat some central factors (e.g. modernization) as latent variables, it allows me to specify a theoretical model that treats some of my variables as both causes and effects, and it is robust against the multicollinearity issues that are present in much of cross-national literature.

A point of contention regarding the use of SEM as a method is the degree to which it actually establishes causality—"the Holy Grail of the social sciences" (Babones 2014:133). This aspect of SEM research is "on the one hand, of pivotal methodological importance and, on the other hand, confusing, enigmatic, and controversial" (Pearl 2012:68). The "founding fathers" of SEM (Wright (1921), Blalock (1964), and Duncan (1959; 1975) considered it a tool that would allow conclusions about causality to be drawn from theoretical assumptions and observational data. An important and often underplayed part of that stance is the reliance upon strong theoretical grounding. The models specified should be derived from theory-driven causal hypotheses. However, some researchers moved away from the theoretical grounding and started to claim that they were empirically establishing causality from data alone (Hope 1980). On the other side of the debate, some cite the problems associated with drawing causal inferences from observational (as opposed to experimental) data and argue that SEM contributes nothing to our understanding of causality (Cliff 1983; Freedman 1987). I share a moderate stance with many researchers which allows that “there is of course nothing in structural equation modeling that magically transforms correlational data into causal conclusions” (Hox and Bechger 2001:15). As with any other statistical analysis, the causal logic represented by a SEM model may be corroborated by the data but the fact remains that a different, untested model might fit the data better. However, while SEM does not *prove* causation, it does yield results that can be usefully interpreted as causal effects (Pearl 2012). When compelling theoretical logic is combined with valid measures that are properly time ordered, one can make the argument that the existence of causal relationships is being supported.

Analytical Strategy

Overall, I utilize an *alternative models approach* to SEM, which consists of testing two or more causal models to evaluate which one fits the data best (Garson 2012). Many researchers using SEM focus on refining a single model that best supports their argument. However, this strategy fails to yield a firm basis for making claims about the relative support for that argument verses any others, as no others have been tested. As described above, other untested models may actually fit the data better and provide stronger support for alternative arguments and theoretical frameworks. Using the alternative models approach, it is possible to make strong statements about the relative merits of one model verse another, as both are being tested. If a researcher sets up two models that accurately represent competing theories or arguments, the researcher can make firm claims about which model is more empirically grounded, or which theory is better supported by the data. In this way, the alternative models approach allows a researcher to make stronger claims as the "explicit comparison of competing models carries more conviction than testing (and failing to reject) just one model" (Hox and Bechger 2001:15).

While my overall strategy revolves around comparing different models, I also incorporate elements of the *model development approach*, in which one constructs a model, tests it, and then modifying it based on changes suggested by SEM modification indexes (Garson 2012). While the models that I compare are based on either existing literature or my theoretical framework, all of them have been altered to some degree in order to better fit the data. Such an approach carries the risk of developing models that lack external validity (only fit the exact data being used), therefore I only make changes in the models that carry some form of theoretical justification and do not allow the data to overly inform my theory.

My general strategy in each empirical chapter is to first specify my measurement model, in which any latent variables (e.g. modernization) are tested alone to confirm the underlying factor structure (Acock 2013). I then specify a political-economy model, which incorporates the general political-economic causes for the specific form of environmental degradation that I am testing. The political-economy model for each chapter is derived from existing literature on the causes of the form of environmental degradation which that chapter focuses on. In many ways, it represents the existing arguments as to the origins of that form of degradation. Following that, I specify my agricultural dependency models, which include indicators of that concept. The core of my analysis is the comparison between the political-economic models and the agricultural dependency models. As I demonstrate that models including measurements of agricultural dependency provide a better fit to the data than political-economic models that lack such indicators, I provide support for the argument that agricultural dependency is an important pathway through which powerful, developed nations displace environmental degradation onto less-powerful, less-developed nations.

While this dissertation is not a longitudinal analysis, I follow a common practice among quantitative macro-comparative research (see Jorgenson 2006; McKinney 2012; and Shandra et al. 2009 for examples) and specify my model in time-ordered fashion, with all of my independent variables predating my dependent variables by approximately 10 years. This design allows time for the effects of the independent variables on the dependent variable to occur. While the static, cross-sectional design of this project does not allow for true analysis of change, this time-lagged specification does allow a researcher to make stronger statements about inferred causality than one in which all data came from the same time point (Babones 2014).

Assessing Goodness of Fit

One of SEM's strengths is its ability to directly test how well the relationships specified by the causal model accurately reflect the patterns of variance and correlation within the actual data. In short, fit measures test how well the model being tested matches the relationships being empirically observed within the sample. This ability to assess the fit of the model as a whole is one of the distinct advantages that SEM possesses over more traditional estimation techniques, such as OLS. Within the alternative methods approach, model fit measures are the basis for evaluating whether one model fits the data better than another (Garson 2012). However, statisticians have sought and developed new and improved fit indices since SEM was first introduced and considerable debate exists as to which fit indices best reflect the degree to which the model accurately represents the data (Hooper, Coughlan, and Mullen 2008). While a complete review of this debate is beyond the scope of this dissertation, in the following section I briefly describe the fit measures I use to assess the models in this dissertation and justify their selection.

The base test for model fit is the model chi-square, which assesses the magnitude of discrepancy between the covariance relationships specified in the model and the covariance matrix in the sample. Essentially, the model chi-square tests how well the relationships specified in the model reproduce actual bivariate covariances (or their absence) in the data (Acock 2013). As the chi-square test is a test of whether the model covariance structure differs from the sample covariance matrix to a significant degree, a strong model fit is indicated by an insignificant chi-square. An insignificant result indicates that the relationships specified in your model do not significantly differ from the relationships that exist in the data. A significant chi-square (typically below 0.05) indicates that the researcher’s model does not adequately fit the data (Bollen 1989). A large disadvantage of the chi-square test is its sensitivity to sample size. As with other tests of statistical significance, large enough samples lead to almost all relationships being significant. In the case of SEM, very large samples will lead to false-negatives, or rejecting models that may fit the data well. With smaller samples, the chi-square lacks the power to discriminate between good fitting models and poor fitting models (Garson 2012). In general, while it is convention to report the chi-square and it represents an important first criteria for rejecting a poorly fitted model, one needs to rely upon other fit measures to obtain a more refined sense of how well the model fits the data.

An indicator that is growing in popularity among SEM researchers is the root mean square error of approximation (RMSEA) (Schreiber et al. 2006). The RMSEA examines the amount of error in a model relative to the number of degrees of freedom. In this way, the RMSEA rewards parsimony in a model and penalizes unnecessary complexity (Byrne 2010). The RMSEA is also relatively less affected by sample size, although very small sample sizes can lead to an overestimate of the goodness of fit (Bollen 1989). RMSEA scores range from zero to positive infinity, with a value of zero indicating exact model fit and larger scores reflecting poorer model fit. The generally accepted cutoff points for RMSEA scores are below 0.08 (indicating an adequate fit) and below 0.05 (indicating a close fit). However, researchers have demonstrated that there is little empirical support for the use of any universal cutoff values for RMSEA and that the choice of cutoff values depends on model specification, degrees of freedom, and sample size (Chen et al. 2008). Another indicator of general model fit is the standardized root mean square residual (SRMR). This measure is the average of all the differences between each hypothesized correlation in the model and the actual correlation between the two variables in the sample (Hox and Bechger 2001). Similar to the RMSEA, SRMR values below 0.08 are deemed as acceptable fit, while values less than 0.05 indicate a well-fitted model (Hooper et al. 2008).

Another widely used measure of model fit is the comparative fit index (CFI), which compares the predicted model's fit (relative to the observed covariance matrix) against that of a null model in which there is no relationship between any of the variables (Acock 2013). The reported number is an indication of the degree to which the predicted model's fit to the observed covariance matrix is an improvement over that of the null model. While a cut-off point of greater than 0.90 was initially accepted as indicating good model fit, 0.95 is becoming the more widely used cut-off point today. This indicator is particularly useful in cross-national research as it performs well even with relatively small sample sizes (Byrne 2010).

While not indicators of absolute fit, informational criteria indices are excellent tools for comparing non-nested or non-hierarchical models that use the same variables and data (Bollen 1989). While the scale of these measures is not fixed and therefore there are no set cut-off points, a relatively lower score indicates a better fit. These measures are not used to evaluate single models, but provide very useful information when comparing models. The best known informational criteria measure is the Akaike's information criterion (AIC). The AIC is a goodness-of-fit measure that examines the model chi-square, but adjusts to reward more parsimonious models (Garson 2012). Given that I am using the alternative methods approach which is based upon comparing between models, the AIC should provide valuable information. However, it is worth noting that the reliability of the AIC becomes questionable with sample sizes below 200 (Hooper et al. 2008).

A general problem with indicators of model fit is that they tend to reward models that approach saturation due to more of the observed covariance matrix being represented in the model (Byrne 2010). In simpler terms, model fit tends to increase as you specify more relationships, all other things being equal. This occurs simply because you are specifically modeling more of the cells in the matrixes being compared (as opposed to implicitly constraining them at zero by not specifying a relationship). To help guard against this problem, it is recommended that researchers comparing between models use some of the parsimony of fit indices, which use the parsimony ratio (the degrees of freedom in the researcher's model divided by the degrees of freedom in a null model) to penalize models for complexity (Bollen 1989). Parsimony measures such as the parsimony comparative fit index (PCFI) lack strict cut-of points, but when comparing between nested models, a lower score indicates a more parsimonious fit. While less useful when assessing general model fit, the PCFI provides useful information when selecting between acceptable models.

While debates still continues about the relative merits of the various indicators of fit, it is generally agreed that one should use multiple indicators of model fit to avoid inaccurate assumptions (Hox and Bechger 2001). Used together, a collection of different fit indices can provide a clear picture of how well your models fits the actual data and give you clear criteria with which to assess competing models. For each of my models, I follow convention and report the chi-square and RMSEA as general indicators of model fit. I supplement those two standard indicators with the SMRM as it provides and indicator of model fit that is not based on the chi-square. I also report the CFI given my relatively low sample sizes and that indicator's relative robustness in the face of small samples. Finally, given the reliance of my arguments upon the comparison of different models, I report both the AIC and the PCFI as these two measures are both sensitive to model parsimony and useful in determining which models represent a better fit to the data than others.

Sample

My samples will consist of the entire population of nations for which the necessary data are available. A number of global scholars prefer to perform separate analyses on developed and less-developed nations (e.g. Grimes and Kentor 2003; Kentor and Boswell

2003; Jorgenson and Kuykendall 2008; Shandra et al. 2009). The reasoning behind such an approach is that macro-level conditions and social processes are radically different between the developed and less-developed worlds. Therefore, including all nations in one sample can lead to inaccurate findings where multiple (and sometimes offsetting) processes and relationships are missed due to aggregation error. However, other researchers stress the theoretical and empirical importance of including all nations into one's analysis and attempting to explicitly model the difference between developed and less-developed nations (e.g. Chase-Dunn 1998; Kick et al. 1996; Jorgenson and Clark 2012; McKinney et al. 2009). The arguments behind this strategy are that the differences and relationships between developed and less-developed nations are an important part of the global system and analyses that exclude either group obscures those important differences. Following this logic, I include all nations for which data are available on my dependent variables in each of my analyses.

Singapore and Hong Kong were dropped from the sample due to their small size (in terms of both population and land area) and their exceptional nature as a sovereign city-state and a special administrative region of China (respectively). The Democratic People's Republic of Korea was dropped from the sample due to missing data for a number of important predictor variables. The Marshall Islands were dropped from the sample due to their small size and missing data for a number of important predictor variables.

Given that I am conducting my analyses on a population of data, rather than a random sample, it is necessary to clarify my use of statistical significance testing. My data consists of the entire population of cases for which data is available. Therefore, there is no larger population to make inferential claims about (Babones 2014). However, it is both expected and meaningful to provide indications of statistical significance in cross-national research for two reasons. First, it is the convention within the social sciences to provide such indications, particularly when cross-national research is being read by a general audience (See Chase-Dunn 1975; Kentor and Boswell 2003; Jorgenson and Clark 2012; Snyder and Kick 1979; and York et al. 2003 for examples). Second, tests of statistical significance give the probability that the true relationship between the independent variable and dependent variable is actually zero, when the observed relationship is not. That probability may be influenced by either omitted variables or by measurement error, neither of which pertain to sampling. The significance of the relationship is an indication of the strength of the association between the two variables and the distribution of error. Therefore, tests of significance provide valuable information about the confidence in the observed relationship. "The argument that statistical significance is meaningless in analyses based on populations is just as wrong for sample survey research as it is for quantitative macro-comparative research" (Babones 2014:113). However, it should be made clear that as my data are an enumeration of all available cases, the actual significance level for all findings is 0.000, not the computed level, which assumes the data are a random sample of size n.

In order to preserve the largest number of nations for which data are available (which maximizes the generalizability of the study), I used a form of multiple imputation to replace missing data for some of my variables.[8] Multiple imputation is a process in which multiple

[8] While no data were imputed for any of the endogenous outcome variables in these analyses, in structural equation modeling, all variables that are not exogenous (including endogenous mediator variables) are dependent variables. Some argue that imputing values for dependent variables is questionable as it reduces the variance contained in said dependent variable. However, other scholars (Alison 2001; Little and Rubin 2002) argue that imputed values for dependent variables is necessary to obtain unbiased coefficients.

copies of the original sample are constructed. In each copy, missing data are replaced with a set of plausible values (often derived through regression imputation). The specified analysis is then performed on each of the samples and the results of the multiple analyses are pooled (IBM 2011). As pooled SEM analyses cannot be evaluated for goodness-of-fit statistics (StataCorp 2013a), I could not use standard multiple imputation. Instead, I used SPSS to create 20 copies of my data set with missing data for *GDP per capita 2000*, *Energy Use per capita 2005*, and *Agriculture as a percentage of GDP 2000* being imputed. I then used the mean case value across the 20 imputations to replace the missing data points. Please see Appendix A for a list of imputed data points.

It is important to note that there is an inherent limitation in quantitative macro-comparative research (research that uses countries as cases and facts about countries as variables) (Babones 2014). Such an analytic strategy tends to reify the nation-state as a homogenous and central actor, when numerous processes and dynamics operate independent of national boundaries (Gereffi 1983; Robinson 2004; Sassen 2001; Sklair 2001). Additionally, a wide range of sub-national processes shape the global system in important ways that are not captured by national-level indicators.[9] However, in full recognition of these limits, the country remains the default unit of analysis for the overwhelming majority of quantitative macro-comparative research. National-level data are widely available, while systematic data on smaller units of analysis (individuals, organizations, classes, states, zones, etc.) for the entire globe are limited. Additionally, the nation-state remains an important political, economic, and cultural unit and is the only legitimate international actor for certain actions (Formal war, signing treaties, etc.). Therefore, national-level data can provide valuable information about global-level processes and there is ample precedent for its use in this dissertation (Babones 2014).

Independent Variables

World-System Position, 1999- This variable, developed by Kick et al. (2011) for the period 1995-1999, captures a nation's position within the global world-system. The measure updates the findings of Snyder and Kick (1979); calculating world-system position on the basis of connections among economic, military, cultural, and political networks. This measure identifies ten distinct blocks in the world-system. I have assigned each block a numeric rank with 10 being the cluster of the most powerful and influential nations and 1 being the cluster of the least.

Agriculture as a Percentage of Gross Domestic Product, 2000- This variable is one of the ways in which I operationalize agricultural dependency. It captures the extent to which a nation's economy is focused upon agricultural production. It is the value added (net output of a sector) of agricultural production (including forestry, hunting, and fishing, as well as the cultivation of crops and livestock production) as a proportion of the national GDP. These data were obtained from the World Bank's *World Development Indicators* (World Bank 2013).

Agricultural Exports as a Proportion of Gross Domestic Product, 2000- This variable is another one of the ways in which I operationalize agricultural dependency. It captures the

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[9] Among others, see Chase-Dunn 1980, Driscoll and Kick 2013, Dunaway 1996, Gellert 2010, Hall 1989, Hanna 1995, Leitner 2003 for examples of work that explores such sub-national dynamics.

extent to which a nation's economy is focused on the export of agricultural products. It was calculated by obtaining the total value of agricultural exports from the Food and Agriculture Organization of the United Nations (FAOSTAT 2013) and dividing it by the total GDP (World Bank 2013).

Agricultural Population, 2000- This variable is a third way in which I operationalize agricultural dependency. It measures the proportion of a nation's workforce employed in agriculture. It was calculated by dividing the total economically active population in agriculture (FAOSTAT 2013) by the total population (World Bank 2013). These numbers were double checked against the national percentage of the labor force employed in agriculture (CIA World Factbook 2014) and found to be comparable.

Modernization- One of the central variables throughout this analysis is modernization. This variable captures the degree to which a nation has developed from a "traditional society" (roughly characterized as a relatively poor society with a largely uneducated, rural population that works in the primary sector) to a modern, industrial society (roughly characterized as a wealthy, democratic society with an educated, largely urban population, that works in the secondary and tertiary sectors) (Lenski 2005). That progression includes changes in a nation's culture, economy, institutions, and technology (Inkeles 1969; Rostow 1990; Smelser 1964). As this is a multi-dimensional distinction, not easily captured by a single variable, it is treated in these analyses as a latent variable that is measured by several different indicators of the modernization process (See Kick and McKinney 2014 and McKinney 2014 for examples of a similar approach). These multiple measures of modernization would be highly multicollinear if included as separate predictors (Babones 2014). However, treating them as indicators of the one latent variable directly measures the variance that is shared among the indicators and uses that shared variance to predict other variables (Bollen 1989). The four indicators of modernization used throughout these studies are described next.

Gross Domestic Product Per Capita, 2000 (ln)- This variables measures a nation's relative level of economic development. These data were obtained from the World Bank's *World Development Indicators* and is measured in Purchasing Power Parity, using current U.S. dollars (World Bank 2013). I use the natural log of this variable to correct for skewness.

Urban Population, 2000- This variable measures the percentage of a nation's total population that is living in an urban area as defined by national statistical offices. These data were obtained from the World Bank's *World Development Indicators* (World Bank 2013).

Energy Use Per Capita, 2005(ln)- This variable refers to the total consumption of primary energy by a population. It is measured in equivalent kilograms of oil. These data were obtained from the World Bank's *World Development Indicators* (World Bank 2013). I used the measure from 2005 rather than 2000 as the data were more complete for that year and there was little change between the two years for nations that reported data for both years. I use the natural log of this variable to correct for skewness.

Life Expectancy at Birth, 2000- This variable is used as an indication of the relative health of a nation's population. It indicates the number of years a newborn infant can be expected to live if patterns of mortality remain constant throughout its life. These data were obtained from the World Bank's *World Development Indicators* (World Bank 2013).

Alternative Analyses

Multi-group Analysis

One analytic technique that I would have like to have used in my analyses was multi-group analysis. Through this technique, it is possible to compare how different sub-sets of a sample differ in how well they fit the model (Garson 2012). Performing multiple-group comparisons within SEM allows a researcher to test for differences in fit between the different groups, differences in the means, variances, and size of relationships between the different groups, and test for differences in specific parts of the model between the different groups (Acock 2013). Essentially, the researcher is constructing their model, seeing how well it fits the sample as a whole, then seeing how well the model fits individual sub-sets within the sample. This strategy offers a number of advantages over the interactive models commonly used in OLS regression and its numerous derivatives to explore differences among groups within a sample. This technique would be particularly useful in quantitative macro-comparative research as researchers attempt to examine how global processes and relationships differ among the different tiers of the world-system or between developed and less-developed nations.

I attempted to use multi-group analysis in my empirical chapters. Once I had constructed the models that depicted the relationships between world-systems position, modernization, agricultural dependency, I attempted to examine whether or not those relationships were the same for core nations verse peripheral, and for developed verse less-developed nations. Unfortunately, my attempts to do so were constrained by my small sample size. While I was able to get my models to converge for my entire sample, I was unable to get any of those models for the separate groups to converge. Within SEM, a failure to converge indicates that the software was unable to find an ideal solution for the model. This can be an indication of a mis-specified or under-identified model, or it can be due to poor starting values (StataCorp 2013b). In more general terms, it indicates that there is not a valid solution to the specified model for the sample. Given that some of the groups had an *n* of only 40 or so nations, this is not surprising. However, the technique has much to offer quantitative macro-comparative research and future analyses should attempt to incorporate it.

Agricultural Dependency as a Latent Variable

I also attempted to construct a latent variable for agricultural dependency that was indicated by: 1) Agriculture as a percentage of GDP, 2) Agricultural exports as a percentage of GDP, and 3) the relative percentage of the economically active population working in agriculture (see above for details of each variable). An exploratory factor analysis of the three variables revealed one underlying factor with a Cronbach's alpha of 0.68. This indicates an acceptable, if not excellent, internal consistency among the three variables (Hair et al. 1998). Conceptually, I saw modernization and agricultural dependency as two separate (although highly related in an inverse fashion) features of a nation. However, when examining my various measurement models, the indicators of modernization (GDP per capita, Urbanization, Energy Use per capita, and Life Expectancy) and the three indicators of agricultural dependency all loaded onto the same underlying factor (but in opposite directions). So empirically, I was unable to separate out these two distinct aspects as different latent variables.

FDI in Agriculture and the Primary Sector

An important component of how I am conceptualizing agricultural dependency in this dissertation is that it involves an element of foreign control over agricultural production, largely exercised by agro-TNCs. Other studies have attempted to measure this aspect of agricultural dependency as the amount of foreign direct investment in the primary sector (Jorgenson 2007a, 2007b; Jorgenson and Kuykendall 2008). This operationalization stems from the logic that the proportion of foreign direct investment to the local economy is a direct representation of external control (See Chapter One, pgs. 20-21 for more details). I attempted to replicate that measure in two ways, obtaining data on *Accumulated Stocks of Foreign Direct Investment in the Primary Sector as a Proportion of Gross Domestic Product, 2000-2002* and *Accumulated Stocks of Foreign Direct Investment in Agriculture as a Proportion of Gross Domestic Product, 2002-2007* (United Nations 2003; United Nations 2009). Both of these measures were obtained in total stocks and divided by national GDP in order to obtain a proportional indicator. While the second measure more directly captured foreign control in agriculture, it was also the more limited of the two in terms of availability (*n* of 93 for primary sector, *n* of 69 for agriculture). When these two measures are included in an exploratory factor analysis along with the other three measures of agricultural dependency, they reveal one underlying factor with a Cronbach's alpha of 0.76. This indicates a good, if not excellent, internal consistency among the three variables (Hair et al. 1998).

Unfortunately, despite the conceptual relevance of these indicators, their low *n* reduced the number of nations that could be included in my analysis while biasing my sample toward developed nations (for which more data on FDI was available). Due to this reason, these variables were not included in any of the analyses. However, while these direct measures of foreign control were not used in the analyses, the factor analysis supports that the measures that were used are highly related to these two measures that were excluded.

CHAPTER THREE- NITROUS OXIDE EMISSIONS

Introduction

This chapter explores the connection between agricultural dependency and nitrous oxide (N_2O) emissions from agriculture. Drawing from the theoretical framework outlined in chapter one, this chapter empirically tests the degree to which the division of labor in the global food and agriculture system leads to N_2O emissions from agriculture being produced disproportionately in agriculturally dependent nations. Agricultural activities are the leading source of anthropogenic N_2O emissions (Reay et al. 2012). As N_2O emissions are an important contributor to global climate change as well as the degradation of the ozone layer, understanding the social dynamics that shape their generation is critical to understanding the origins of both environmental issues. This chapter is a direct contribution to that knowledge as it improves our understanding of the socio-structural antecedents of N_2O emissions.

I start this chapter by describing the role N_2O plays in natural ecosystems and outlining its anthropogenic sources. I also describe how elevated levels of N_2O can negatively impact the global environment and the human societies that depend upon it. I then review existing research on the social drivers of increased N_2O emissions. Following that, I re-state my research questions and related hypotheses, as they specifically apply to N_2O emissions from agriculture. Next, I quickly describe the methodological features that are unique to this chapter. I follow that with a presentation of my findings and a discussion of what relationships and dynamics they represent. In that discussion I address the meaning of my findings, the shortcomings of this research, and avenues for future research. I then include a brief description of alternative models and variables that were tested but yielded null findings. I finish this chapter with a brief discussion of potential avenues for reducing N_2O emissions from agriculture that are implied by this work.

Nitrous Oxide Emissions as a Form of Environmental Degradation

Nitrous Oxide Emissions and the Environment

Nitrous oxide is a colorless gas formed by two nitrogen molecules bound to a single molecule of oxygen. Many know it as "laughing gas" due to its medical use as an anesthesia and it is also used as an oxidizer in rocketry and motor racing. Aside from these commercial uses, it is a natural component of our atmosphere and a vital link in the nitrogen cycle. Given that nitrogen is an essential component of all forms of protein, its availability is necessary to maintain life on our planet (Reese et al. 2011). Slightly over half of all atmospheric N_2O is of biogenic origins, being produced by bacteria that convert ammonium to nitrate and then use nitrate for respiration (EPA 2010). However, the concentration of N_2O in our atmosphere has been increasing for the last two centuries with the increases growing more rapid in the last 50 years (Kroeze and Mosier 2000). Overall, N_2O atmospheric levels have grown by 15-19 percent since the Industrial Revolution, with atmospheric concentration reaching 322.5 ppbv in 2009. The majority of this increase has been caused by human activities (Butterbach-Bahl et al. 2013; IPCC 2007). With N_2O being an important contributor to global climate change and the single most important substance that depletes stratospheric ozone, understanding the origins of its emissions is of the utmost of importance.

Globally speaking, approximately 40% of N2O emissions come from human activities (EPA 2010). The major anthropogenic sources of N_2O are agricultural activities and fossil fuel combustion, while biomass burning and industrial processes contribute lesser amounts (Ham et al. 2000). Of these, agriculture is the primary contributor, accounting for approximately three quarters of anthropogenic emissions (Reay et al. 2012). The three main agricultural sources of N_2O emissions are agricultural soils, animal production systems, and indirect emissions (Mosier et al. 1998). Agricultural soils (crop lands) generate N_2O as nitrogen inputs (animal manure, synthetic fertilizers, etc.) make nitrogen available to soil bacteria to convert to N_2O. The source, timing, rate, and placement of nitrogenous fertilizers all affect the amount of nitrogen released as N_2O (Snyder et al. 2009). Animal production systems generate N_2O emissions through animal wastes, which are rich in nitrogen (Davidson 2009). While this feature makes animal wastes valuable as a fertilizer for plant crops, it also makes them a large source of N_2O as the wastes break down. Finally, there are a number of indirect sources of N_2O in agriculture, including nitrogen run-off and leaching from fields and confined animal feeding operations. This run-off often finds its way into aquatic ecosystems, where indigenous organisms convert it into N_2O. Another indirect source of N_2O from agriculture involves nitrogen released from agricultural systems in the form of ammonia (NH_3), which later enters other ecosystems through atmospheric deposition and is converted to N_2O (Kroeze and Mosier 2000). Overall, modern agricultural systems are largely predicated upon high levels of nitrogen inputs, whether in feed for animal operations or as fertilizer for crop systems. Some of this nitrogen will inevitably be converted to N_2O by naturally occurring bacteria. Therefore, as agricultural systems expand and become more nitrogen intensive, they will continue to generate more N_2O emissions.

The other anthropogenic sources of N_2O emissions are fossil fuel combustion, biomass burning, and industrial processes. Prior to research in the 1990s, the combustion of fossil fuels was thought to be a major contributor to increases in atmospheric N_2O (Bowman 1992; Levy and Moxim 1989; Linak et al. 1990). While more recent research has shown its contribution to be secondary to that of modern agriculture, the burning of fossil fuels still accounts for approximately 5 percent of global N_2O emissions both directly through the release of nitrogen contained in the fuel being burned, and indirectly through the oxidation of atmospheric nitrogen (N_2) into N_2O. The internal combustion engines of motor vehicles are the leading source of N_2O emission from fossil fuels, while power plants are generally considered a relatively small source (Kroeze and Mosier 2000). Approximately 4 percent of global N_2O emissions come from the burning of biomass (e.g. wood for fuel, burning agricultural waste, and the clearing of vegetation from land). Finally, industrial processes contribute approximately 2 percent of global emissions of N_2O. While there are a number of industrial processes that create N_2O emissions, the production of nitric acid, adipic acid, and nylon are the leading sources (Kroeze and Mosier 2000).

The leading concern over increasing N_2O levels is their role as a major contributor to global climate change. Global climate change is the current rise in planetary temperatures, most of which can be attributed to human activities (IPCC 2007). This trend could cause "deleterious or potentially even disastrous consequences for humans" (Rockstrom et al. 2009a:472). These include rising sea levels, radical shifts in plant and animal ranges, a reduction in agriculturally-suitable land, longer, more intense heat waves, shifts in precipitation that can endanger rain-fed agriculture in certain regions, and other unforeseen consequences that stem from complex interactions between ecosystems and climate change (Motesharrei, Rivas, and Kalnay 2014; Vitousek 1994). Due to this host of concerns, global climate change has been described as the leading environmental issue of the twenty first century (Nagel, Dietz, and Broadbent 2010). N_2O emissions are currently a lesser contributor to global climate change relative to carbon dioxide, the leading anthropogenic cause of global warming. However, N_2O still plays an important role in global climate change due to several reasons. First, N_2O can persist for a relatively long time in the atmosphere. Estimates vary, but most give it an atmospheric lifetime (the average amount of time required for a molecule of the gas to breakdown and leave the atmosphere) of 100 to 120 years (Harvey 2000; EPA 2014). Therefore, increasing N_2O emissions will likely have a long-term impact on global climate change. Second, on a molecule for molecule basis N_2O has a much greater global warming potential than carbon dioxide. Again, estimates vary, but most have N_2O being the equivalent of between 200 to 310 times an equal amount of carbon dioxide (Butterbach-Bahl et al. 2013; EPA 2014). When these two factors are combined with the fact that global N_2O emissions are still increasing, understanding the social drivers of N_2O emissions becomes critically important to our efforts to understand and potentially slow global climate change (Kroeze and Mosier 2000).

In addition to their impacts on global climate change, N_2O emissions are also the largest anthropogenic ozone-depleting substance (Ravishankara, Daniel, and Portmann 2009). The ozone layer is an important region of our atmosphere that absorbs most of the sun's ultraviolet radiation. Elevated levels of ultraviolet radiation are harmful to all living things (including humans) and can lead to both cancer and harmful mutations (changes in genetic codes). Ozone depletion and the resultant hole in the ozone layer above Antarctica were one of the major environmental issues of the 20th century (Farman, Gardiner, and Shanklin 1985). While the Montreal Protocol has been highly successful in reducing the emissions of the historically dominant ozone-depleting substances (chlorine- and bromine-containing halocarbons), N_2O emissions are not regulated by that treaty. However, N_2O possesses the ability to catalytically break down ozone (Johnson 1971) and with its increasing anthropogenic levels and atmospheric longevity, it is currently the largest threat to the ozone layer and expected to remain so for the rest of the 21st century (Ravishankara et al. 2009).

In summation, nitrous oxide emissions are a dangerous pollutant that require attention if human societies intend to maintain (or improve) their current way of life. While nitrous oxide is an important component of the nitrogen cycle that sustains life on this planet, at elevated levels it can contribute substantially to global climate change and erode at the atmospheric ozone layer which is vital to life as we know it. Given that human activities (primarily agriculture-related ones) are driving an increase in global atmospheric N_2O levels, it is crucially important that we better understand the social dynamics driving and regulating those activities.

The Social Drivers of Nitrous Oxide Emissions

While the proximate anthropogenic sources of N_2O emissions have been relatively well documented within the natural sciences (see above), these types of studies typically focus on establishing which human activities directly generate the emissions and estimating the relative weights of those contributions (*e.g.* Kroeze and Mosier 2000; Reay et al. 2012; Scheehle and Kruger 2006). Less attention has paid to the social dynamics and structures that drive and shape those activities. However, there is a substantial body of work within the social sciences that examines the ultimate origins of environmentally degrading behavior (*e.g.* Dove and Carpenter 2008; Grossman and Krueger 1995; Peet and Watts 1993; Robbins 2012). In particular, work within environmental sociology has (among other goals) attempted to illuminate the structure of relationships that shape and regulate the generation of environmental harms, including those political economic factors that operate at the global level (e.g. Ehrhardt-Martinez 1998; Frank, Hironaka, and Schofer 2000; Jorgenson and Clark 2012; York, Rosa, and Dietz 2003). However, to this author's knowledge, this body of work contains only one analysis of the social factors contributing to increased N_2O emissions.

The one exception to the dearth of research on the social causation of N_2O emissions is Dick and Jorgenson's (2010) study which examines the impacts of foreign investment dependence on N_2O emissions and finds a positive association. This study builds upon Jorgenson's ecostructural theory of investment dependence (Jorgenson, Dick, and Mahutga 2007) and follows Jorgenson's (2006) arguments that FDI in different economic sectors needs to be examined separately, as the relationships between foreign investment and environmental degradation are likely to differ greatly between the different economic sectors and aggregate measures of FDI often disguise large variations in the proportions of investment across the different sectors. Dick and Jorgenson's (2010) study finds that FDI in the primary sector positively predicts N_2O emissions, net of other controls, while FDI in the secondary sector has no significant relationship with N_2O emissions. The authors argue that this demonstrates how foreign control of particular industries can cause them to be more environmentally damaging.[10] The study also showed that total population and GDP per capita both positively predicted N_2O emissions, which supports general human ecology and political-economy arguments. As an important compliment to the natural science research that has helped establish both the environmental dangers of N_2O emissions and their specific origins, Dick and Jorgenson's work illuminates the social/structural context of the human activities that generate those emissions. Notably, the work highlights the role that power differentials in the world-economy plays in regulating the distribution of environmental degradation.

While an important contribution to our understanding of the social processes and relationships that give rise to N_2O emissions, Dick and Jorgenson's (2010) work is not without shortcomings. To begin with, due to data restrictions, the study only examines a sample of 44 nations while including up to seven variables in some of their models. This violates a number of OLS assumptions in addition to failing to qualify as a representative sample (Allison 1999).[11] While this limitation does not negate the contribution of the study, it does reduce the external validity of the findings and invites a more comprehensive analysis.

[10] For a more thorough explanation of this logic, see Chapter One, pages 16 and 20.
[11] This criticism is not unique to this particular study, as the majority of quantitative macro-comparative research violates a number of OLS assumptions, such as independence of cases (Babones 2014).

Additionally, while this study makes an important contribution to our understanding of the sectoral differences in the effects of FDI on environmental degradation, primary sector FDI is still a rather broad measure that represents very disparate components of an economy as unifed. By way of example, this measure would aggregate FDI in petroleum extraction together with FDI in agriculture; two economic activities with distinct causal mechanisms and very different ecological footprints. Finally, the study uses total N_2O emissions as its dependent variable, which includes emissions from a wide range of sources. As described above, the major anthropogenic sources of N_2O are agricultural activities, fossil fuel combustion, biomass burning and industrial processes. Each one of these contributors generates N_2O in a very different fashion and is likely to have a very different social/structural context. Therefore, it is important to study each source independently, to disentangle the different causal mechanisms of each one. Despite these methodological issues, the theorization and direction of their findings is suggestive and therefore helps shape the direction of the present work.

Aside from that one study, there has been no other research in the social sciences on the socio-structural drivers of N_2O emissions. While the mechanics of its emission are relatively well detailed, the social processes and relationships that lead to those generative activities are relatively unknown. In particular, despite agricultural activities being the leading source of anthropogenic N_2O emissions, there has been little to no examination of how the structure of our global food and agriculture system shapes those emissions. It stands to reason that if agricultural activities are accounting for the majority of anthropogenic N_2O emissions, than the form and nature of the global agricultural system will have a corresponding impact on those emissions. This chapter of the dissertation will address this lack of knowledge by examining the relationship between agricultural dependency and N_2O emissions that are specifically generated by agricultural activities. By examining those specific emissions independently, it is possible to avoid some of the aggregation issues that troubled prior research. The influence of agricultural dependency on N_2O emissions will be tested against the influence of accepted political economy factors. Pulling from the theoretical synthesis developed in Chapter One, this chapter will empirically test the degree to which the division of labor in the global food and agriculture system leads to forms of agriculture that produce N_2O emissions being practiced more frequently in agriculturally dependent nations. I outline my specific research questions and related hypotheses in the following section.

Research Questions with Related Hypotheses

- How does agricultural dependency influence the amount of N_2O emissions produced from agriculture? As theorized in chapter one, agricultural dependency is expected to cause elevated levels of per capita N_2O emissions from agriculture. Therefore:
    - H1: Higher degrees of agricultural dependency will be positively associated with higher levels of per capita N_2O emissions from agriculture, net of all other effects
- How does modernization influence levels of N_2O emissions from agriculture?

- H2: Higher degrees of modernization will not be significantly associated with greater or lesser amounts of per capita nitrous oxide emissions from agriculture, net of all other effects

- How does modernization influence agricultural dependency? As theorized in the first chapter, the modernization process is expected to reduce agricultural dependency. Therefore:
  - H3: Modernization will be negatively associated with agriculturally dependency, net of all other effects

- How does position in the world-system hierarchy influence agricultural dependency? As described in the first chapter, positions of power within the world-system should enable nations to avoid agricultural dependency. Therefore:
  - H4: Positions of higher power in the world-system hierarchy will be negatively associated with agricultural dependency, net of all other effects

- How does position in the world-system influence modernization? As described in the first chapter, occupying a position of power in the world-system allows nations to modernize more rapidly than others. Therefore:
  - H5: Positions of power within the world-system hierarchy will be positively associated with higher degrees of modernization, net of all other effects

Unique Methodological Features

While the general methodology strategy used in this dissertation was covered in Chapter Two (see above), in this section I will discuss the methodological features that are unique to the study of N_2O emissions from agriculture.

Sample

The sample for this study is limited to the 134 nations for which data on the dependent variable are available, minus three of the four nations that were dropped from the overall study (See Chapter 2, pg. 10). I provide a list of the 131 remaining nations included in this analysis in the Appendix.

Dependent Variable

Nitrous Oxide Emissions from Agriculture, Per Capita (ln), 2010. These data were obtained from the World Bank DataBank's World Development Indicators (World Bank 2013). They are reported in thousand metric tons of CO_2 equivalent, an indicator that describes the amount of N_2O in terms of the amount of CO_2 with an equal global warming potential. Importantly, this measure only reports N_2O emissions that arise from agricultural activities, which include fertilizer use (synthetic and animal manure), animal waste management, agricultural waste burning (nonenergy, on-site), and savannah burning. I divided these data by population to transform it into a per capita measure. I use the natural log (ln) of these data to correct for excessive skewness.

Independent Variables

The models in this chapter utilize independent variables described in Chapter 2 as predictors of *Nitrous Oxide Emissions from Agriculture* (see that chapter for more details). *Gross Domestic Product Per Capita, 2000 (ln)*; *Urban Population, 2000*; *Energy Use Per Capita, 2005(ln)*; and *Life Expectancy at Birth, 2000* are used as indicators of *Modernization*, which is treated as a latent variable (See Chapter Two, pgs. 14-15 for a more detailed explanation). *World-System Position, 1999* is used to measure a nation's structural position within the world-system hierarchy. *Agriculture as a Percentage of Gross Domestic Product, 2000* and *Agricultural Exports as a Proportion of Gross Domestic Product, 2000 (ln)* are alternatively used as measures of agricultural dependency.

Results

Table 1 reports key descriptive statistics and bivariate correlations for the sample as a whole. A cursory look at the bivariate correlations reveals that the modernization indicators (*Gross Domestic Product Per Capita, 2000 (ln)*; *Urban Population, 2000*; *Energy Use Per Capita, 2005(ln)*; and *Life Expectancy at Birth, 2000*) all correlate positively and significantly[12] with one another as well as with *World-System Position, 1999*. All four modernization indicators and *World-System Position, 1999* have a significant negative relationship with *Agriculture as a Percentage of Gross Domestic Product, 2000* and three of the modernization indicators have a significant negative relationship with *Agricultural Exports as a Proportion of Gross Domestic Product, 2000 (ln)*. This initially indicates that agricultural dependency is much higher in the less-developed and less-powerful nations. The positive, significant relationship between *Agriculture as a Percentage of GDP* and *Agricultural Exports* supports that these two measures are both capturing related aspects of agricultural dependency. Interestingly, the only variable that has a statistically significant bivariate relationship with the dependent variable is *Agricultural Exports*.

[Table 1 about here]

Before examining the full structural equation model, which examines the relationships specified by my theoretical framework, it is important to examine the measurement model to ensure that any latent variables are accurately capturing the intended underlying concepts. Figure 1 and Table 2 report the measurement model for *modernization*, a latent variable that represents the degree to which a nation is developed in terms of economics, technology, and standard of living.

[Figure 1 about here]

[Table 2 about here]

All four of the loadings are substantial and statistically significant at the p <0.001 level. Furthermore, as a whole, the model possesses strong goodness of fit statistics with a chi-square that is not significant and a SRMR well below 0.05. However, the RMSEA and CFI are both reporting "perfect" fit scores which is the result of the chi-square being less than the degrees of freedom. This indicates that the model is perfectly specified (Kolenikov 2012). Such findings are not uncommon in SEM analyses of cross-national data (see Kick, McKinney, and Thompson 2011 and McKinney 2014). Collectively, the model fit statistics support my specified latent variable being a good fit to the data.

With a confirmed indicator of modernization, I can now begin to examine the relationships among the variables and compare between models that represent alternative explanations for N_2O emissions from agriculture. Figure 2 and Table 3 report a political economy model, which is based upon existing literature on the social drivers of N_2O

[12] As described in Chapter 2 (pg. 11), significance levels are reported here largely to satisfy social science convention. However, as this is population data, all found relationships should be interpreted as existing in the population, not as the product of a sample drawn randomly from that population.

emissions (See page 8).[13] This model tests the general argument that nations that occupy higher positions in the world-system will be more developed and that development will lead to higher amounts of N_2O emissions from agriculture. This model includes two of the three factors that Dick and Jorgenson (2010) demonstrated to be significant predictors of N_2O emissions. GDP per capita is included as an indicator of modernization while population is incorporated as the denominator of the dependent variable. The model also represents (in a highly simplified form) the general political-economy argument that economic development tends to occur at the expense of the environment.[14] This model is testing the second and fifth hypotheses.

[Figure 2 about here]

[Table 3 about here]

The political economy model specifies world-system position as directly impacting modernization and having an indirect effect on N_2O emissions from agriculture through modernization. Modernization is specified as having a direct impact on N_2O emissions. The model as a whole has adequate goodness of fit statistics. The modernization latent variable continues to strongly load on all four of its indicators. Additionally, world-system position has the significant and positive impact on modernization that was expected, supporting the fifth hypotheses. Contrary to what is stated in most political-economy arguments, neither

[13] All four models in this chapter were also run weighting the cases by population. For each model, the same general results were obtained in terms of coefficients and statistical significance. However, models run with the weighted cases all reported significant chi-squares and RMSEA scores that denote extremely poor fit. The CFI and SRMR scores continued to indicate a good fit.

[14] This argument is frequently contrasted against ecological modernization, or decoupling approaches, which argue that economic development can occur without increased environmental degradation. See York, Rosa, Dietz (2003) as well as Jorgenson and Clark (2012) for broad comparative tests of the two general premises.

world-system position (indirectly) nor modernization (directly) has a significant impact on N_2O emissions from agriculture, which confirms the second hypothesis.

Figure 3 and Table 4 report the first agricultural dependency model, in which agricultural dependency (indicated by *Agriculture as a Percentage of Gross Domestic Product*, *2000*) is introduced as a mediating variable between modernization and N_2O emissions. This model represents the theoretical framework outlined in Chapter One. In essence, more powerful nations are more developed (H5) and consequently have a lower degree of agricultural dependency (H3). Nations with higher degrees of agricultural dependency have corresponding higher levels of per capita N_2O emissions from agriculture (H1). Like the political-economy model, this model also tests the impacts of modernization on N_2O emissions (H2).

[Figure 3 about here]

[Table 4 about here]

As with the political-economy model, world-system position has a significant and positive impact on modernization in the agricultural dependency model, supporting the fifth hypotheses. The indicator of agricultural dependency has a significant positive effect on N_2O emissions, which confirms the first hypothesis. Additionally, modernization has a significant, negative relationship with agricultural dependency, confirming the third hypothesis. Interestingly, where modernization did not have a significant impact on N_2O emissions in the political-economy model, in this model it has a significant, positive direct effect and a significant, negative indirect effect via agricultural dependency. In the political-economy model, these two distinct effects off-set one another, and only by including the measure of agricultural dependency is it possible to disaggregate the two.

The goodness of fit statistics for this model indicate that it is a questionable fit to the data. While the CFI and SRMR both show strong fit, the RMSEA is on the border between adequate and poor fit. Also, the chi-square is statistically significant to the $p < .05$ level, indicating that the covariance structure implied by my model is significantly different than the covariance matrix of the sample. Therefore, the findings in this model must be interpreted with some hesitation. While it demonstrates support for the first, third, fourth, and fifth hypotheses, it does not do so in a way that demonstrates that this model is superior to the political-economy model.

Figure 4 and Table 5 provide an alternative model of agricultural dependency, where I use *Agricultural Exports as a Proportion of Gross Domestic Product, 2000 (ln)* in place of *Agriculture as a Percentage of Gross Domestic Product, 2000* to represent agricultural dependency. I test this alternative indicator of agricultural dependency to boost the internal validity of the findings and argument. Obtaining the same general findings with a different measure of agricultural dependency lends weight to the argument that agricultural dependency is an important factor that contributes to N_2O emissions and helps ensure that this finding is not merely an artifact of the specific indicator used to measure agricultural dependency.

[Figure 4 about here]

[Table 5 about here]

Similar to the original agricultural dependency model, the alternative one yields approximately the same results with a similar questionable fit. Again, the indicator of agricultural dependency has a significant positive effect on N_2O emissions, which confirms the first hypothesis. The relationships between world-system position, modernization, and agricultural dependency are all the same as they were in the original agricultural dependency model. The one noteworthy difference is that in the alternative agricultural dependency model, modernization does not have a significant direct effect like it did in the original. However, the total effect of modernization on N_2O emissions is unchanged. In terms of fit, the alternative agricultural dependency model has strong CFI and SRMR scores and an adequate RMSEA score but the chi-square is statistically significant to the $p < .05$ level. Again, the findings in this model must be interpreted with some hesitation.

Figure 5 and Table 6 report the improved agricultural dependency model, in which I remove *Life Expectancy at Birth, 2000* as one of the indicators for the modernization latent variable. Given how well the four original indicators loaded together, removing the one should not substantially alter the meaning of the latent variable. Indeed, others have successfully modeled modernization using only GDP per capita and urbanization (*e.g.* Kick and McKinney 2014; Kick et al. 2011; McKinney, Kick, and Fulkerson 2010). It was discovered that removing life expectancy improved the model fit dramatically through a process of model development, wherein changes were made to the theoretical model to see what improved model fit.

[Figure 5 about here]

[Table 6 about here]

In terms of substantive findings, the improved agricultural dependency model replicates the results of the original. World-system position has a significant, positive direct effect on modernization and a significant, negative indirect effect on agricultural dependency. Modernization has a significant, negative direct effect on agricultural dependency. It also has the mutually offsetting direct and indirect effects on N_2O emissions from agriculture. Agricultural dependency has a direct positive effect on N_2O emissions. Where this model differs from the original agricultural dependency model is its excellent fit statistics. With a non-significant chi-square, a RMSEA below 0.05, a CFI above 0.95, and a SMRM below 0.05, this model has a much stronger fit to the data than any of the previous models, meaning it is more accurately reflecting the covariance relationships that exist in the sample.

One cause for concern is that this model has a lower PCFI than any of the previous models, other than the measurement model. While all of the models had relatively low PCFI scores, this indicates that my improved agricultural dependency model has a less parsimonious fit then the others and that its other fit statistics may be inflated due to a higher percentage of the possible parameters being specified. However, this result is driven by the removal of one of the variables which reduces the degrees of freedom in the independence model. Given that all of the existing parameters in the model besides the one between the latent and the indicator removed are being preserved, the resulting degrees of freedom drops accordingly. In essence, this model is not less-parsimonious because more relationships are being specified. It is less-parsimonious because there are less potential relationships that are not being specified. This does not seem to be a solid reason for dismissing the model's findings. Additionally, this model is simpler than the earlier ones in terms of the number of variables included, and following the principle of parsimony, all other things being equal, the simpler model should be the one selected (Bollen 1989).

Discussion

General Findings

This chapter of the dissertation examines how the division of labor in the global food and agriculture system impacts N_2O emissions from agriculture. The three models that include a measure of agricultural dependency all show it having a significant and positive relationship with N_2O emissions, confirming the first hypothesis and supporting the argument that N_2O emissions from agriculture are being driven by agricultural dependency. Additionally, while modernization shows no direct effect on N_2O emissions from agriculture when agricultural dependency is not included in a model, that apparent lack of an effect is actually two mutually offsetting effects that are revealed once a measure of agricultural dependency is introduced into the model. Modernization has a positive direct effect and a negative indirect effect on N_2O emissions from agriculture. The indirect effect stems from modernization being negatively related to agricultural dependency, which is positively related to N_2O emissions. While modernization's negative effect on agricultural dependency confirms the third hypothesis, the offsetting effects of modernization on N_2O emissions contradicts the second hypothesis. The other observed relationships (world-system position having a positive effect on modernization and a negative effect on agricultural dependency) confirm the fourth and fifth hypotheses, respectively.

Interpretation of Findings

The relationship of central interest to this chapter is the positive connection between agricultural dependency and N_2O emissions from agriculture. Broadly speaking, this finding supports the theoretical framework outlined in the first chapter. The two measures of agricultural dependency represent the position a nation occupies within the division of labor in the global food and agriculture system. Nations with a high degree of agricultural dependency are those that have focused their economies upon the production of cash crops for export, typically due to a lack of viable economic alternatives. The negative effects that both modernization (direct) and world-system position (indirect) have on agricultural dependency reinforces the fact that nations with a high degree of agricultural dependency tend to be less-developed and occupy positions of relatively lower power within the world system. These are the very nations that Marx ([1876] 1976) described as occupying the "farmer" position in the global division of labor. While they are not feeding the world (the majority of the world's food is being produced in the "agricultural factories" of the global North [Weis 2007]), the production of labor-intensive agricultural products (fruits, coffee, cacao, etc.) defines their position in the global economy.

While the two measures of agricultural dependency utilized in these models did not directly capture external control by the agro-TNCs, the position that they indicate in the global division of labor involves a great deal of control by foreign investors who provide the capital and marketing opportunities for these agricultural activities.[15] Those agro-TNCs have little incentive to protect the environment in these developing nations and every incentive to maximize profits by means that may prove detrimental to the environment (including using outdated and ecologically inefficient technology or farming strategies that have been outlawed in more-developed nations). Consequently, they encourage nitrogen-intensive agriculture, with large amounts of nitrogen being applied to fields and large amounts of animal waste being improperly disposed of. All of this leads to the increased production of N_2O emissions as the nitrogen in the fertilizers and wastes breaks down and is converted into N_2O, either in the field or in the surrounding ecosystems (Davidson 2009). In this way, agricultural dependency directly contributes to increase N_2O emissions from agriculture.

An unexpected finding that requires explanation is the positive direct relationship between modernization and N_2O emissions from agriculture. Once agricultural dependency is controlled for, it is the nations that are *more* modern that are producing higher levels of N_2O. Therefore, there is a second dynamic at work here, independent of the relationship between agricultural dependency and N_2O emissions. One explanation of this dynamic may lie in the composition of more modern nation's domestic agriculture system and the diets and lifestyle of those nations' populations. It is well established that the populations of more modern nations consume higher amounts of animal products on an individual basis (Weis 2013). The fifth of the world's population that live in developed nations consume, on average, four to eight times the amount of meat as those that live in the developing world (FAO 2012). Furthermore, it is well established that animal husbandry generates far more "per-calorie" N_2O emissions than plant crops. "Fertilizer use to support animal-production is likely to generate nearly twice as much N_2O as would its use for crops destined for direct human

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[15] See Chapter 2, pages 13 and 17-18 for a more in-depth discussion of the relationship between the different

consumption" (Davidson 2009:661-662). This is due to N_2O being produced at two stages in the production of animals (the application of fertilizer to the crops and the disposal of nitrogen-rich animal manure) and only one in the production of plant crops (the application of fertilizer to the crops). Therefore, the elevated meat consumption in more modern nations may account for the positive impact of modernization on N_2O emissions from agriculture.

This possibility raises great concerns as worldwide meat consumption is currently increasing and projected to continue doing so as affluence levels increase in the developing world. Per capita meat and dairy consumption in China alone has more than doubled over the past two decades (Nierenberg 2005). Even in sub-Saharan Africa, the world's poorest region, meat consumption is projected to double by 2020 (FAO 2012). If increased consumption of animal products is accounting for the link between modernization and N_2O emissions from agriculture and these trends in changing global diets hold true, than we can expect N_2O emissions to continue to rise in the future. It may be that the composition of future diets serves as a powerful determinant of future N_2O emissions (Reay et al. 2012).

Shortcomings

An important weakness of the findings of this chapter that must be discussed is the lack of convincing model fit. While my political economy and improved agricultural dependency models demonstrate strong model fit, my initial and alternative agricultural dependency models in general are poorer fits to the data. However, model fit statistics only evaluate one aspect of an SEM model and cannot provide a substantive evaluation of the suitability of a model on their own (Garson 2012). While the political economy model report

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indicators of agricultural dependency and the aspects of the concept that they each directly measure.

better fit statistics than the two agricultural dependency models, it also includes an insignificant relationship (between modernization and N_2O emissions from agriculture) that was later shown to contain two mutually offsetting significant effects. While the first two agricultural dependency models have less than robust fit statistics, they can both be considered improvements on the political economy model as all of their relationships are significant and they tease out the two distinct effects of modernization on the dependent variable. Finally, while my improved agricultural dependency model mostly has strong model fit statistics, it cannot be ignored that its parsimony comparative fit index is the lowest of all of the models, indicating that when the models are penalized for a lack of parsimony, it has a poor fit relative to the other models. However, the use of parsimony-adjusted fit scores is still debated among SEM scholars, with some choosing to be guided by the principle of parsimony, rather than directly adjusted fit statistics (Bollen 1989). Collectively, while the model fit scores are not as strong as one might wish, they are not so weak as to warrant the dismissal of my models as inaccurately reflecting the data in my sample. While is cannot be interpreted without reservation, there is adequate evidence here that supports my arguments.

Other shortcomings of this research include its lack of a true longitudinal design, a problem that is common in quantitative macro-comparative research (Babones 2014). While lagging my independent variables ten years behind my dependent variables allows for some measure of analyzing the effects of the independent variables over time, the use of panel regression or growth curve analyses would more directly measure change over time, an essential aspect of understanding causal relationships (Singer and Willet 2003). Another shortcoming of my research is also one common to most quantitative macro-comparative research, the treatment of nation-states as homogenous units. Many of the processes and dynamics explored in this chapter can differ throughout the different regions and peoples within nation-states. However, as there are no sub-national units of analysis (states, counties, provinces, etc.) that are consistent across all nations, a global analysis of such units is not possible (Babones 2014).

Future Research

A number of avenues for future research spring directly from the just-mentioned shortcomings. If sufficient panel data were obtained, it would be possible to use latent growth curve modeling to test the effects of a number of these predictors on the rate of growth of N_2O emissions from agriculture (Acock 2013). Analyzing the predictors of change would allow stronger causal inferences to be made (Babones 2014). Additionally, while data are not available to conduct a global analysis of sub-national units, it would be possible to supplement the findings contained here with a regional analysis of sub-national units, such as the European Union's production regions (Eurostat 2014). It is possible that such an analysis would be able to tease out processes and relationships that are being lost in the present analysis due to aggregation error. The current research would also be highly complemented by an in-depth case study of a particular nation or commodity. For example, a detailed examination of how coffee production in Colombia for external markets leads to increased N_2O emissions could provide a much richer understanding of the dynamics under examination in this chapter. While quantitative macro-comparative research possesses a high degree of external validity, it is relatively weaker in terms of internal validity. A well-developed case study could help establish the processes and relationships described here with much greater detail and precision. Finally, future research should attempt to better explain the positive connection between modernization and N_2O emissions from agriculture. While I have stated that the diet composition of more developed nations may account for that linkage, it would be possible to directly test that explanation using an indicator of per capita consumption of animal products. If such a measure were found to moderate the relationship between modernization and N_2O emissions, it would greatly substantiate the explanation offered here.

Alternative Measures and Variables Tested

In this section I briefly recount alternative models and variables that were tested but either yielded null findings or produced models that did not resolve or adequately fit the data. In some cases, knowing what did not work and why it did not can provide information that is useful in understanding the questions being explored. The purpose of this section is to both present that useful information as well as anticipate possible critiques and suggestions.

Initially, I used both a measure of total N_2O emissions from agriculture and a per capita measure. In the models where I used the total measure, I included population as an independent predictor. These models encountered substantial problems, likely due to the size effect of population as a variable (population size tends to heavily correlate with a number of other size measures (surface area, arable land, number of cars driven, etc.) and if those measure are not included in the model, than the population variable will absorb their effect) (Babones 2014). While population did significantly and positively predict the total amount of N_2O emissions from agriculture and had a significant, negative relationship with modernization (as a predictor or as a moderating variable), any models that included population as a predictor failed to have any other significant predictors of N_2O emissions from agriculture (including agricultural dependency) and yielded very poor model fit statistics. For these reasons, I chose to use the rate method and incorporate population as the denominator of my dependent variable.

I also attempted to use agricultural population (the percentage of a nation's economically active population that is employed in agriculture) as a third indicator of agricultural dependency. However, it did not have a significant effect on N_2O emissions from agriculture. I interpreted this as being due to the loose correlation between what sector or industry a nation's workforce is employed in and what sector or industry is accounting for the larger proportion of its economy. In a nation such as Equatorial Guinea, agriculture constitutes less than 5 percent of economic activity (most of the economy is driven by oil extraction). However, subsistence farming is the dominant form of livelihood and agricultural workers make up 25-30 percent of the population (CIA World Factbook 2014). Agricultural dependency is determined by a nation's economic activities and position in the global division of labor. The internal composition of its workforce is not an accurate representation of that concept.

In my initial models, I had also included the number of internet users (per 100 people) as an additional indicator of the modernization latent variable. While this variable loaded well onto the underlying factor, the models with the five-factor latent variable yielded worse fit statistics than the models with the four-factor latent. Additionally, I did not think that the number of internet users captured a vital aspect of modernization that wasn't well represented by the other four indicators. Therefore I did not include it. I also tested whether or not world-system position had a direct effect on either of my two indicators of agricultural dependency. It did not yield a significant direct effect on either of them. Therefore, the only way world-system position impacts agricultural dependency is indirectly through modernization.

Following a strategy common to quantitative macro-comparative research (see Babones 2014; Jorgenson and Clark 2012), I dropped the three nations with populations under 500,000 from my sample and re-ran all of my analyses. Doing so did not change any of the substantive findings and yielded slightly worse model fit statistics. However, the small drop off in fit did not change the interpretability of my findings. Due to this, I left those three nations in the sample.

I also tried to test some of the world-polity arguments that participation in the world environmental regime slows the rate or reduces the amount of environmental degradation (Frank, Hironaka, and Schofer 2000; Meyer et al. 1997; Schofer and Hironaka 2005). I did this by including a measure of state environmentalism (a ranking of how many environmental treaties a nation has signed and ratified) generated by Roberts, Parks, and Vásquez (2004). This variable failed to significantly impact N_2O emissions from agriculture, although it was positively predicted by modernization and world-system position. Additionally, including it in my model substantially lowered my model fit statistics.

Conclusions

The analyses in this chapter have found a distinct linkage between a nation's degree of agricultural dependency and its level of per capita N_2O emissions produced by agriculture. I argue that this linkage is best explained by the degree of external control over decisions about what to grow and how to grow it that agriculturally dependent nations experience. The structure of our global food and agriculture system is displacing environmental degradation onto less-powerful nations through agricultural dependency. Additionally, once agricultural dependence is controlled for, more modern nations experience higher levels of the same N_2O emissions. I argue that these emissions are best explained by the diet of those modern nations and the corresponding composition of their domestic agriculture system.

The findings of this chapter have important implications for how we, as individuals, societies, and a global community, can reduce the amount of N_2O emissions produced by agriculture and in doing so, help slow global climate change and protect the vital ozone layer. First, as agricultural dependency is helping drive N_2O emissions in agriculture, there is a need for some manner of restructuring of the global food system. In addition to helping address a number of other pressing issues (*i.e.* food insecurity, depeasantization, global inequality), such a redesign would help undo some of the social structures that are driving the increasing amount of N_2O being released into our atmosphere. While the exact steps and policy changes that would alter the existing system are beyond the scope of this dissertation, the need for such changes is clear. Second, the farming methods in both developed and developing nations need to be adjusted to reduce N_2O emissions. As the source, timing, rate, and placement of nitrogenous fertilizers all impact the end amount of nitrogen released as

N_2O, the use of fertilizing methods designed to reduce greenhouse gas emissions would help alleviate this problem tremendously (Snyder et al. 2009). Finally, as elevated levels of meat consumption are such an important contributor to N_2O emissions, reducing the amount of animal products consumed (or even slowing the rate at which their consumption is currently increasing) would also be an important step toward a more sustainable way of life. Given the greater ecological footprint of diets heavy in animal products, changes in policy and culture that may reduce the centrality of meat in both the Western and the global diet need to be explored (Davidson 2009; Goodland 1997; Reay et al. 2012).

Table 1- Descriptive statistics and bivariate correlations (*n* = 131)

Parameter	*Mean*	*S.D*	*Skew*	*Min.*	*Max.*		
1- Nitrous Oxide Emissions from Ag., 2010 (ln)	-8.187	0.891	-0.283	-11.563	-6.006		
2- GDP per capita, 2000 (ln)	8.746	1.271	-0.291	5.017	11.143		
3- Urban Population, 2000	58.391	21.424	-0.259	10.833	98.110		
4- Energy Use per capita, 2005 (ln)	7.276	1.069	0.147	5.057	9.916		
5- Life Expectancy at Birth, 2000	68.755	9.248	-1.100	41.783	81.076		
6- World System Position, 1999	5.397	2.470	0.138	1	10		
7- Agriculture as % GDP, 2000	13.155	12.102	1.287	0.355	57.239		
8- Agricultural Exports as % GDP, 2000 (ln)	0.570	1.414	-1.115	-4.619	3.135		
Correlations	*1*	*2*	*3*	*4*	*5*	*6*	*7*
1- Nitrous Oxide Emissions from Ag., 2010 (ln)	1.0000						
2- GDP per capita, 2000 (ln)	0.0301	1.0000					
3- Urban Population, 2000	0.0461	0.8007*	1.0000				
4- Energy Use per capita, 2005 (ln)	0.0023	0.8689*	0.7019*	1.0000			
5- Life Expectancy at Birth, 2000	0.0090	0.7522*	0.6527*	0.6459*	1.0000		
6- World System Position, 1999	0.1069	0.4235*	0.2544*	0.2886*	0.3982*	1.0000	
7- Agriculture as % GDP, 2000	0.0801	-0.8688*	-0.7297*	-0.6924*	-0.6046*	-0.3776*	1.0000
8- Agricultural Exports as % GDP, 2000 (ln)	0.4258*	-0.2600*	-0.2405*	-0.2285*	-0.1077	0.0501	0.3225*

***p* <.05, two-tailed**

Table 2- Structural equation model of modernization latent variable, measurement model

	Unstandardized Value	*Standardized Value*
Loadings		
Per Capita GDP (ln)	1.00 (fixed)	0.99***
Per Capita Energy Use (ln)	0.74***	0.88***
Percent Urban	13.72***	0.81***
Life Expectancy	5.56***	0.76***
Variances		
e. Per Capita GDP (ln)	0.03	0.02
e. Per Capita Energy Use (ln)	0.27	0.23
e. Percent Urban	158.17	0.35
e. Life Expectancy	36.02	0.42
Modernization	1.58	1.00 (fixed)

*****p* <.001, two-tailed**

Table 3- Structural equation model of nitrous oxide emissions from agriculture, political economy model

Outcome	*Direct Effects*	*Indirect Effects*	*Total Effects*	*Stnd. Error*
Measurement				
Modernization →				
Per Capita GDP (ln)	1.00 (fixed)	---	1.00 (fixed)	(constrained)
Energy Use pc (ln)	0.72***	---	0.72***	0.042
Percent Urban	14.25***	---	14.25***	1.130
Life Expectancy	5.82***	---	5.82***	0.524
Structural				
Modernization ←				
World-System Position	0.22***	---	0.22***	0.041
N_2O Emissions ←				
Modernization	0.03	---	0.03	0.064
World-System Position	---	0.01	0.01	0.014

Numbers in cells are unstandardized coefficients. Standard errors are reported for the total effects only.
***p* <.05, ***p* <.01, ****p* <.001, two-tailed.**

Table 4- Structural equation model of nitrous oxide emissions from agriculture, agricultural dependency model

Outcome	*Direct Effects*	*Indirect Effects*	*Total Effects*	*Stnd. Error*
Measurement				
Modernization →				
Per Capita GDP (ln)	1.00 (fixed)	---	1.00 (fixed)	(constrained)
Energy Use pc (ln)	0.67***	---	0.67***	0.041
Percent Urban	13.73***	---	13.73***	0.961
Life Expectancy	5.48***	---	5.48***	0.444
Structural				
Modernization ←				
World-System Position	0.22***	---	0.22***	0.041
GDP in Agriculture ←				
Modernization	-8.41***	---	-8.41***	0.452
World-System Position	---	-1.87***	-1.87***	0.351
N_2O Emissions ←				
Modernization	0.33*	-0.31***	0.03	0.127
GDP in Agriculture	0.04**	---	0.04**	0.013
World-System Position	---	0.01	0.01	0.014

Numbers in cells are unstandardized coefficients. Standard errors are reported for the total effects only.
***p* <.05, ***p* <.01, ****p* <.001, two-tailed.**

Table 5- Structural equation model of nitrous oxide emissions from agriculture, alternative agricultural dependency model

Outcome	*Direct Effects*	*Indirect Effects*	*Total Effects*	*Stnd. Error*
Measurement				
Modernization →				
Per Capita GDP (ln)	1.00 (fixed)	---	1.00 (fixed)	(constrained)
Per Capita Energy Use (ln)	0.72***	---	0.72***	0.042
Percent Urban	14.04***	---	14.04***	1.139
Life Expectancy	5.71***	---	5.71***	0.520
Structural				
Modernization ←				
World-System Position	0.22***	---	0.22***	0.041
GDP in Ag. Exports ←				
Modernization	-0.29**	---	-0.29**	0.098
World-System Position	---	-0.06**	-0.06**	0.024
N_2O Emissions ←				
Modernization	0.11	-0.09**	0.03	0.065
GDP in Ag. Exports	0.29***	---	0.29***	0.051
World-System Position	---	0.01	0.01	0.014

Numbers in cells are unstandardized coefficients. Standard errors are reported for the total effects only. *p <.05, **p <.01, ***p <.001, two-tailed.

Table 6- Structural equation model of nitrous oxide emissions from agriculture, improved agricultural dependency model

Outcome	*Direct Effects*	*Indirect Effects*	*Total Effects*	*Stnd. Error*
Measurement				
Modernization →				
Per Capita GDP (ln)	1.00 (fixed)	---	1.00 (fixed)	(constrained)
Per Capita Energy Use (ln)	0.66***	---	0.66***	0.042
Percent Urban	13.98***	---	13.98***	1.007
Structural				
Modernization ←				
World-System Position	0.22***	---	0.22***	0.040
GDP in Agriculture ←				
Modernization	-8.55***	---	-8.55***	0.514
World-System Position	---	-1.89***	-1.89***	0.353
N_2O Emissions ←				
Modernization	0.36*	-0.33***	0.03	0.141
GDP in Agriculture	0.04**	---	0.04**	0.015
World-System Position	---	0.01	0.01	0.014

Numbers in cells are unstandardized coefficients. Standard errors are reported for the total effects only.
***p <.05, **p <.01, ***p <.001, two-tailed.**

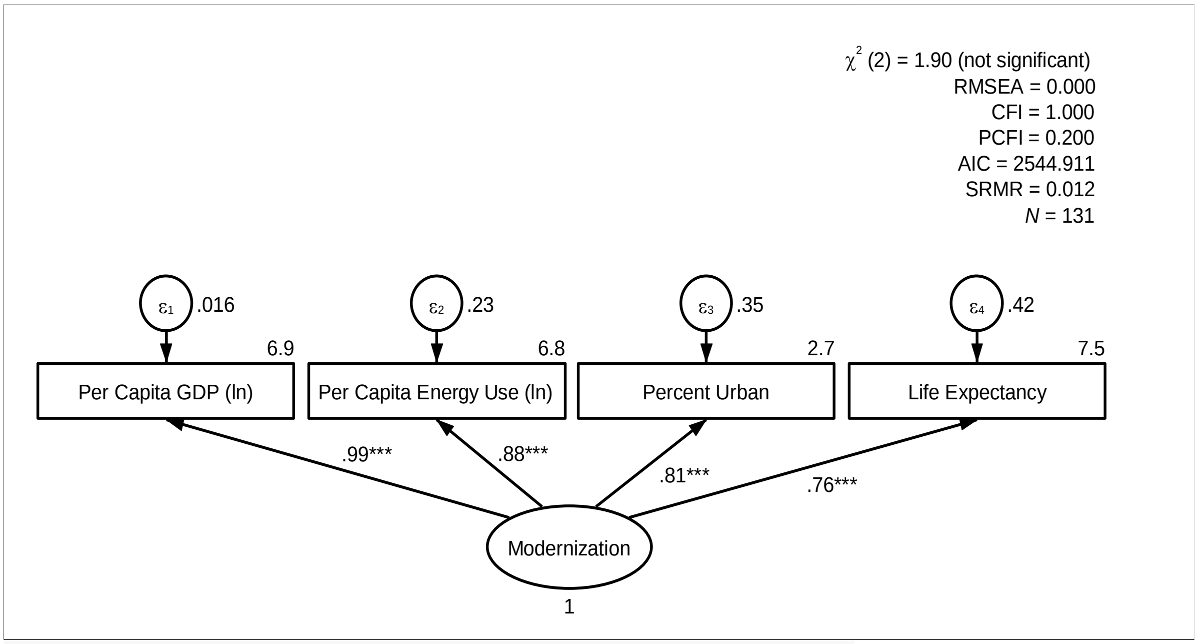

Figure 1- Structural equation model of modernization latent variable, measurement model. Path coefficients are standardized betas, ******p* <.001, two-tailed.

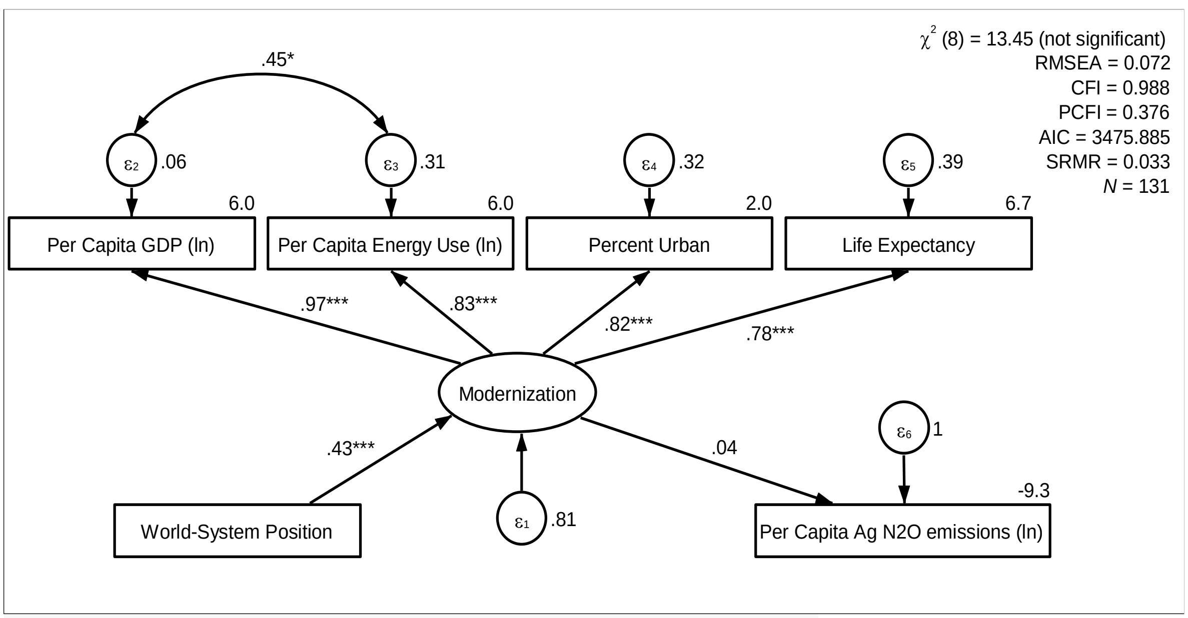

Figure 2- Structural equation model of nitrous oxide emissions from agriculture, political economy model. Path coefficients are standardized betas. **p* <.05, ***p* <.01, ****p* <.001, two-tailed.

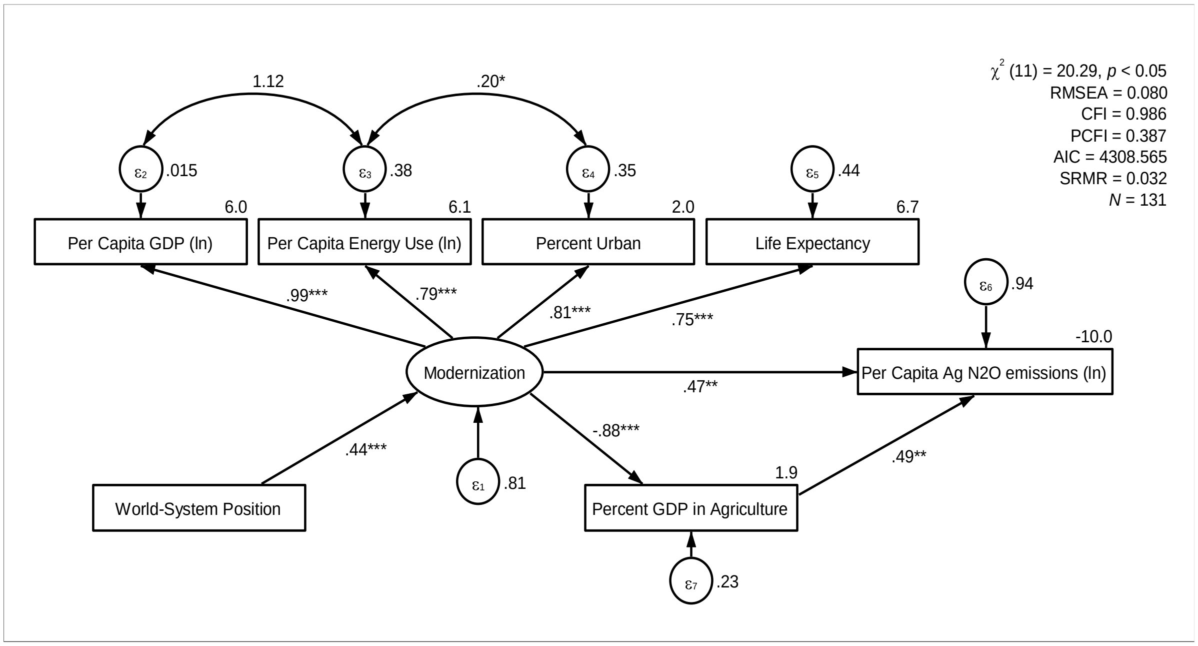

Figure 3- Structural equation model of nitrous oxide emissions from agriculture, agricultural dependency model. Path coefficients are standardized betas. *p <.05, **p <.01, ***p <.001, two-tailed.

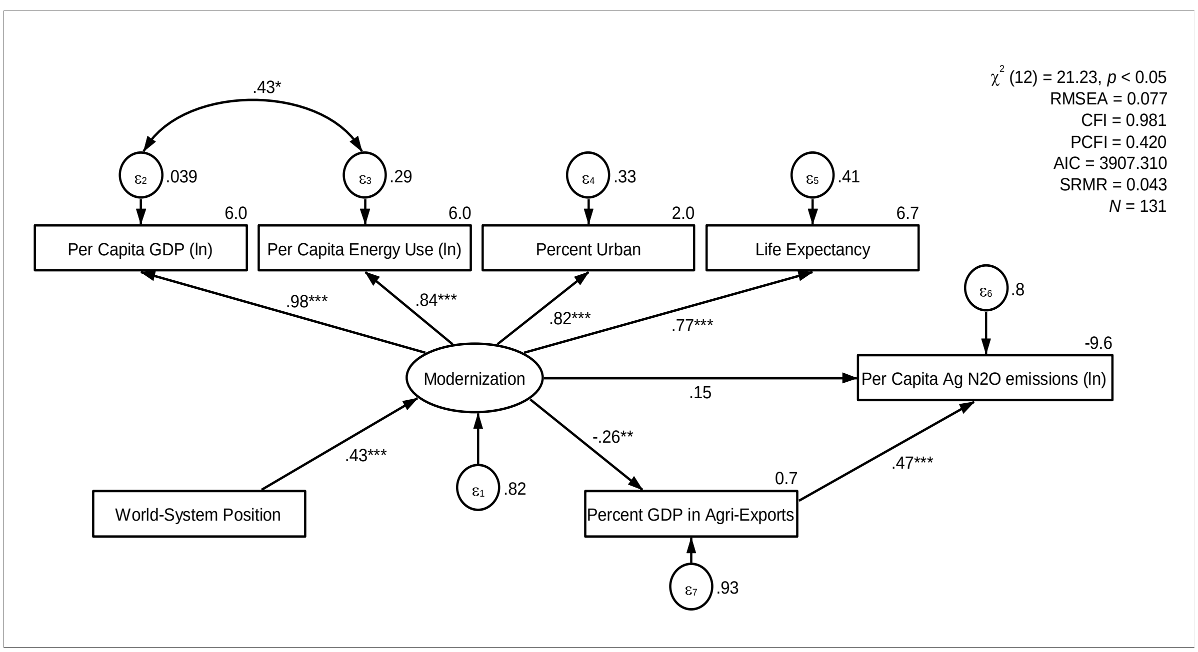

Figure 4- Structural equation model of nitrous oxide emissions from agriculture, alternative agricultural dependency model. Path coefficients are standardized betas. *p <.05, **p <.01, ***p <.001, two-tailed.

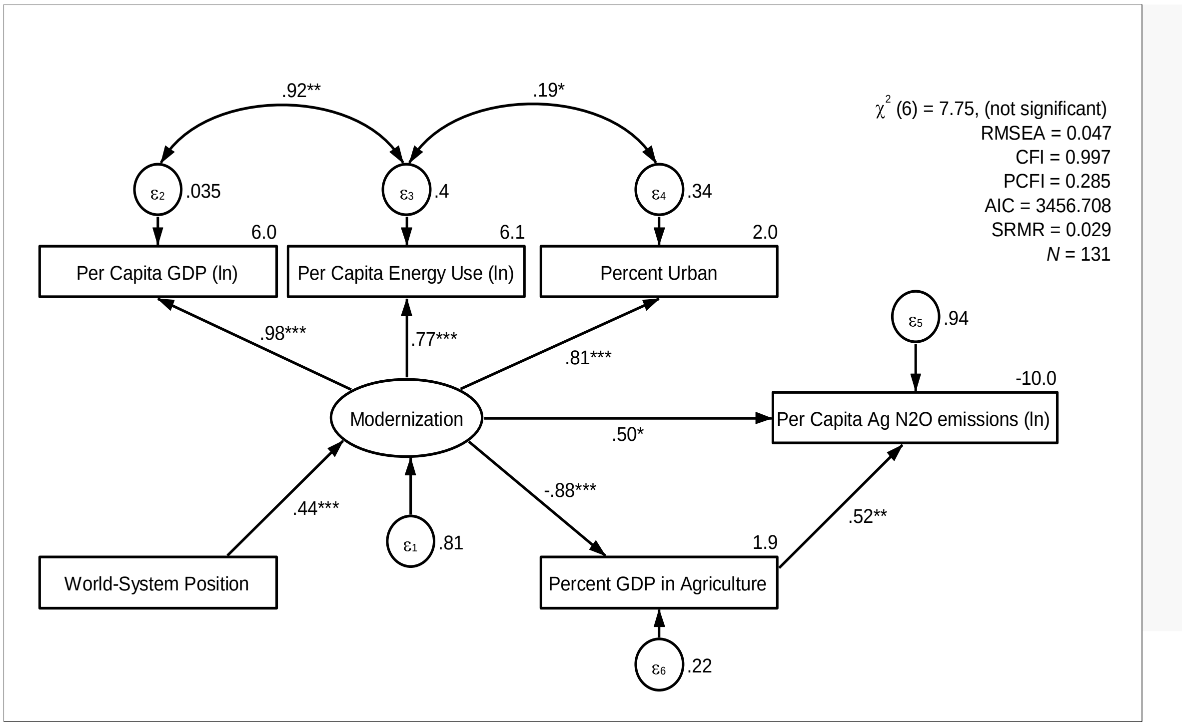

Figure 5- Structural equation model of nitrous oxide emissions from agriculture, improved agricultural dependency model. Path coefficients are standardized betas. ****p* **<.05, ******p*** **<.01, *******p*** **<.001, two-tailed.**

CHAPTER FOUR- METHANE EMISSIONS

Introduction

This chapter explores the connections between agricultural dependency and methane emissions from agriculture. Specifically, this chapter empirically tests the degree to which the division of labor in the global food and agriculture system leads to methane emissions from agriculture being produced disproportionately in agriculturally dependent nations. When considered collectively, agricultural activities are the leading source of anthropogenic methane emissions (Wuebbles and Hayhoe 2002). As methane is the second most important anthropogenic contributor to global climate change, it is imperative to better understand the social antecedents of its production. By examining the global dynamics that contribute to its production in agriculture, this chapter extends our knowledge of those social antecedents. It also broadly contributes to our understanding of the ways in which the structure and operation of the world-system can both cause and intensify environmental degradation.

I begin this chapter by describing methane and how it is produced. I review research on its various anthropogenic sources and some of the factors that may lead to greater or lesser amounts of these emissions. Following that, I describe how methane contributes to global climate change. I then review existing research on the social drivers of anthropogenic methane emissions. After the literature review, I re-state my research questions and related hypotheses as they specifically apply to methane emissions from agriculture. I follow that with a brief discussion of the unique methodological aspects of this chapter and then present my findings and interpret them. After that, I discuss the meaning of my findings, the shortcomings of this research, and avenues for future research. I then briefly describe some alternative models and variables that were tested but failed to yield any substantial findings. I conclude this chapter with a brief discussion of the implications of its findings and possible strategies for reducing methane emissions from agriculture in the future.

Methane Emissions as a Form of Environmental Degradation

Methane Emissions and the Environment

Methane (CH_4) is another colorless gas. It is the simplest of alkanes (molecules consisting of only carbon and hydrogen atoms sharing single bonds), consisting of a single carbon atom sharing bonds with four hydrogen atoms (Reese et al. 2011). Methane is the primary component of natural gas (making up over 90 percent), which has a number of commercial uses as a fuel source for heating, cooking, and electricity generation. As a fossil fuel, natural gas and the methane it contains can be found in underground reservoirs, often associated with other fossil fuels such as coal and petroleum. Methane can also be generated by microbes through methanogenesis, a form of anaerobic respiration (making energy without oxygen) that produces methane rather than carbon dioxide as its end product. These microbes inhabit low-oxygen soil and water environments (such as the flooded soils in wetlands or rice paddies) as well the digestive system of ruminants.[16] Globally, over 60 percent of methane emissions come from anthropogenic sources, which include the transport and use of fossil fuels, agriculture, organic waste disposal, and biomass burning (EPA 2014).

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[16] Ruminants are animals with two-stage stomachs. The first stage (the rumen) specializes in fermenting plant cellulose (fiber) into digestible nutrients. The fermentation process is primarily carried out by symbiotic

It is estimated that due to human activities, atmospheric concentrations of methane have more than doubled since the Industrial Revolution (Wuebbles and Hayhoe 2000). As methane is an important factor in global climate change, contributing approximately 20-30 percent of the anthropogenic climate forcing by greenhouse gases (IPCC 2007), understanding the social dynamics that drive its emission is crucial to our understanding of global climate change.

Methane emissions are second only to carbon dioxide in terms of anthropogenic contributors to global climate change (Frankenberg et al. 2005). As described in the previous chapter, global climate change is one of the most critical environmental issues human societies are currently facing (Rockstrom et al. 2009a). Methane has a relatively short atmospheric lifespan, lasting approximately 12 years to nitrous oxide's 114 or carbon dioxide's highly variable lifetime[17] (EPA 2014). However, over a 10-year period, a given amount of methane will trap 20 times the amount of heat as would an equal amount of carbon dioxide (IPCC 2007). Currently, methane is the third most abundant greenhouse gas in the atmosphere at 1750ppbv (parts per billion by volume), trailing only carbon dioxide and water vapor (Wuebbles and Hayhoe 2002). As the second most important anthropogenic greenhouse gas, methane emissions and their social antecedents are a vital piece of the global warming puzzle.

The main anthropogenic sources of methane are agriculture and the use of fossil fuels. Other anthropogenic sources of methane emissions include landfills and water treatment

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microbes (bacteria, protozoa, fungi, and yeast). Methane is a byproduct of the fermentation process (Reese et al. 2011).

facilities. The extraction, processing, transportation, and distribution of fossil fuels accounts for approximately 19 percent of global methane emissions. Some of the methane is released during the extraction process. Methane can form alongside deposits of coal and petroleum, and is emitted when trapped gas is released during the mining process. Some mining processes are more efficient in capturing this gas than others. The primary source of methane emissions from fossil fuels is leaks that occur during the processing, transporting, and distributing of natural gas. Leakage percentages depend on the quality of the pipelines and extraction processes. They also vary greatly by region, with averages ranging around 1 to 2 percent in developed nations, but up to 15 percent in developing nations (Wuebbles and Hayhoe 2000).

While fossil fuels are the largest single anthropogenic source of methane emissions (accounting for 26 percent of all human generated methane), their contribution is outweighed by the various different mechanisms through which agricultural activities produce methane. The largest of these contributions is the production of methane from domestic ruminants (accounting for 23 percent of all anthropogenic methane emissions). Methane is a byproduct of microbial breakdown of carbohydrates in all plant consuming species (including humans). However, the greatest amounts are generated by ruminants, which include cattle, sheep, goats, and other domestic animals (Crutzen, Aselmann, and Seiler 1986). Interestingly, the composition of the diet fed to ruminants has a large impact on the amount of methane produced. Animals that are fed protein-rich diets that are heavy in grain do not produce as much methane as animals fed lower-quality diets that are heavy in straw and crop-residues

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[17] Carbon dioxide's atmospheric lifetime is poorly defined as the gas does not break down over time, but instead

(Ward et al. 1993). In general, animals raised in developing nations have poorer-quality diets and depend upon forage for a greater proportion of their nutrition than animals raised in developed nations. This increased reliance upon cellulose for feed leads to a larger emission of methane for each unit of useful animal product generated. In short, a given amount of meat or milk produced in developing nations tends to generate a much larger amount of methane produced directly from the animals than the same amount of meat or milk produced in developed nations (Wuebbles and Hayhoe 2000).

Another way in which agriculture contributes to methane emissions is the storage and disposal of animals wastes. Animal manure is rich in organic matter and when that organic matter is broken down by microbes through anaerobic decomposition, methane gas is one of the byproducts. The amount of methane emitted from animal wastes varies greatly with the waste type and management practices. In general, the manure from animals fed a high-quality diet generates greater emissions of methane than those from animals fed a low-quality diet (Crutzen et al. 1986; Mosier et al. 1998; Wuebbles and Hayhoe 2000). Additionally, when animal wastes are managed intensively they tend to produce more methane. Indeed, the amount of methane generated by animal manure has been greatly amplified in recent decades due to the increased prevalence of confined animal feeding operations and the methods those operations employ to dispose of animal wastes (Bogner et al. 1995; Steinfeld et al. 2006). When animal wastes are dispersed in fields and wilderness areas, they tend to dry up and break down aerobically, producing relatively little methane. However, industrialized livestock production involves concentrating manure to a small, local area, often a simple pit

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is slowly absorbed by both living systems (i.e. plants and algae) and abiotic sinks (i.e. oceans).

dug into the ground (Thorne 2007). When stored in this manner, the organic matter cannot break down aerobically and instead is primarily consumed through anaerobic decomposition by microbes, resulting in a much greater amount of methane being generated and released. When animal wastes are pooled and stored for extended time periods before release, the methane emissions generated by them can rise by a factor of 10 (Bogner et al. 1995). With over 50 billion land animals being currently raised for human consumption and that number expected to double by 2050, animal wastes, particularly those generated within confined animal feeding operations, are an important contributor to global methane emissions (Steinfeld et al. 2006).

Given the higher prevalence of confined animal feeding operations in more powerful nations and the tendency for domestic animals in those nations to be fed higher-quality diets, there are two potentially off-setting relationships between a nation's position in the world-system and the amount of methane produced by domestic animals (Steinfeld et al. 2006).[18] On one hand, animals themselves are likely to produce greater amounts of methane gas in developing nations due to the poor-quality, high cellulose composition of their diets. On the other hand, the manure from animals in more powerful nations is likely to produce greater amounts of methane due to the richness of their diets and the way in which those wastes are treated (concentrated into lagoons rather than dispersed over pasture). Given the cumulative effects of both diet and processing of manure and the fact that manure from non-ruminant animals (e.g. hog and poultry) also contributes to methane emissions, it is expected that the

[18] While numerous minor differences exist in dispersion and concentration, in general the same primary domestic animals (pigs, cows, sheep, goats, horses, and chickens) can be found throughout the globe (Diamond 1995; Steinfeld et al. 2006).

higher methane production from animal manure in more powerful nations will outweigh the greater amounts of methane emissions per animal in weaker nations (Jorgenson and Birkholz 2010; Koneswaran and Nierenberg 2008).

Finally, the cultivation of rice is an important process that generates methane emissions. While not as prevalent in developed nations, rice production is far more common among developing nations and contributes approximately 17 percent of global anthropogenic methane emissions (Wuebbles and Hayhoe 2002). The production of rice generates methane due to the fact that rice is grown in warm, waterlogged paddies. The soil under the water provides an ideal environment for anaerobic bacteria to break down organic matter into methane through methanogenesis. The amount of methane generated from rice production varies considerably around soil type, the amount and type of fertilizers applied, climate, and cultivation practices. A worrisome connection exists between temperature and methane production, as rice production tends to produce greater amounts of methane at warmer temperatures. Consequently, there is a positive feedback between global warming and the production of methane from rice fields (Mosier et al. 1998).

The Social Drivers of Methane Emissions

Similar to our understanding of nitrous oxide, the majority of research on methane emissions as a form of environmental degradation has focused on measuring and estimating the amount of anthropogenic emissions and documenting the different sources of those emissions (Crutzen et al. 1986; Frankenberg et al. 2005; Wuebbles and Hayhoe 2002). However, the social dynamics and structures that drive and shape those activities have been downplayed or outright ignored within this literature. Alternatively, while there has been a great deal of research in the social sciences investigating the social antecedents of carbon dioxide emissions, the leading contributor to global climate change (i.e. Clark and York 2005; Jorgenson and Clark 2012; Roberts and Grimes 1997; Schofer and Hironaka 2005), far less attention has been paid to understanding the social dynamics and structures that underlie the anthropogenic production of methane. However, there has been a small amount of research within environmental sociology that examines the social antecedents of methane emissions. This work primarily falls within world-systems and dependency approaches to the environment and uses a political-economic lens to examine the social-structural causes of methane emissions at the global level.

The questions driving these social science examinations of anthropogenic methane emissions revolve around determining what types of nation-states are prone to generate more methane than others and why. One of the most consistent and straightforward answers is that more populous nations tend to produce more methane (Burns, Davis, and Kick 1997; Rosa, York, and Dietz 2004). This relationship is due to a simple size affect, where nations with more people will tend to engage in more of the activities that contribute to the production of methane (outlined above). The second consistent finding within this body of work is that controlling for population, more economically developed nations tend to have higher levels of methane emissions (Jorgenson 2006; Jorgenson and Birkholz 2010). Expanded economic activity involves increased production and consumption of resources and a corresponding increased production of wastes. Therefore, as nations build, grow, and consume more per person, the amount of methane produced also increases. Related to the positive connection between economic development and increased methane emissions, the amount of methane produced by a nation (net of differences in population and affluence) has also been shown to differ among the different strata of the world-system, with the core and semicore producing greater amounts than the periphery or semiperiphery (Burns et al. 1997). The logic behind this relationship stems from the general world-systems/dependency argument that the economic institutions and demographic dynamics of nations vary by world-system position and therefore so do the social antecedents of environmental degradation.

Other factors that have been shown to contribute to national-level methane emissions are the production of cereals, cattle, and oil or natural gas (Jorgenson and Birkholz 2010). These relationships are logical extensions from the origins of methane emissions described above. Nations that produce a greater amount of cereals include nations that specialize in rice production, a known contributor to anthropogenic methane (Jorgenson 2006). Additionally, as described above, domestic ruminants produce a substantial amount of methane gas. Therefore, nations specializing in cattle production (by far the more prevalent domestic ruminant) will produce greater amounts of methane gas (Burns et al. 1997). Lastly, as methane can be found alongside other fossil fuels and is the primary component of natural gas, it is logical that nations with a high degree of domestic production of oil or natural gas or a high degree of energy consumption would have elevated levels of methane emissions (Burns et al. 1997). One final factor that contributes to methane emissions is the reliance upon food exports as a proportion of total exports. While this relationship has been relatively under-theorized, Andrew Jorgenson and Ryan Birkholz (2010) suggest that this relationship reflects the broad impacts of increased international trade on environmental degradation.

Here it is argued that this relationship is driven by the power differentials that exist between nations that are relatively agriculturally dependent and those that are not, and the tendency for environmental harms and environmentally damaging processes in general to be shifted downward in that power hierarchy.

While this body of work has produced some suggestive findings as to the political-economic factors that shape the production of methane emissions, there are a number of shortcomings that need to be addressed. First and foremost, all of these studies used the total national production of methane as their dependent variable. As described above, methane can be produced by a wide range of human activities, many of which will be regulated and structured through different social mechanisms. Examining total methane production can lead to aggregation errors, wherein causal mechanisms are mis-specified due to independent processes being treated as single dynamics (e.g. assuming economic development will have one constant, joint effect on both rice production and the extraction of natural gas). This chapter avoids this error by only examining methane emissions from agriculture. By studying a single source of methane emissions, it is possible to more clearly illuminate the causal relationships at work. This strategy is particularly useful given agriculture's dominant role in contributing to anthropogenic methane emissions.

Additionally, unlike the prior works that broadly assess the causes of anthropogenic methane emissions, this chapter focuses specifically on one causal mechanism, the structure of the global food and agriculture system. Through focusing upon one specific causal pathway, it is possible to more clearly identify the relevant processes and relationships. Given the significance of agricultural activities in generating anthropogenic methane emissions, understanding how the form and nature of the global system through which people raise useful plants and animals for market exchange drives said emissions is of great importance. This chapter of the dissertation addresses this gap in the literature by examining the relationship between agricultural dependency and methane emissions that are specifically generated by agricultural activities.

Research Questions with Related Hypotheses

- How does agricultural dependency influence the amount of methane emissions produced from agriculture? As theorized in chapter one, agricultural dependency is expected to cause elevated levels of per capita methane emissions from agriculture. Therefore:
  - H1: Higher degrees of agricultural dependency will be positively associated with higher levels of per capita methane emissions from agriculture, net of all other effects
- How does modernization influence levels of methane emissions from agriculture?
  - H2: Higher degrees of modernization will not be significantly associated with greater or lesser amounts of per capita methane emissions from agriculture, net of all other effects
- How does modernization influence agricultural dependency? As theorized in the first chapter, the modernization process is expected to reduce agricultural dependency. Therefore:
  - H3: Modernization will be negatively associated with agriculturally dependency, net of all other effects

- How does position in the world-system hierarchy influence agricultural dependency? As described in the first chapter, positions of power within the world-system should enable nations to avoid agricultural dependency. Therefore:
    - H4: Positions of higher power in the world-system hierarchy will be negatively associated with agricultural dependency, net of all other effects
- How does position in the world-system hierarchy influence levels of methane emissions from agriculture? As described above, (See pgs. 6-7) positions of power within the world-system should allow nations to utilize more CAFO technology. Therefore:
    - H5: Positions of power within the world-system hierarchy will be positively associated with higher levels of per capita methane emissions from agriculture, net of all other effects
- How does position in the world-system influence modernization? As described in the first chapter, occupying a position of power in the world-system allows nations to modernize more rapidly than others. Therefore:
    - H6: Positions of power within the world-system hierarchy will be positively associated with higher degrees of modernization, net of all other effects

Unique Methodological Features

While the general methodology strategy used in this dissertation was covered in Chapter Two, in this section I will discuss the methodological features that are unique to the study of methane emissions from agriculture.

Sample

The sample for this study is limited to the 133 nations for which data on the dependent variable are available, minus the three nations that were dropped (See Chapter 2, pg. 10). I provide a list of the 130 nations included in this analysis in the Appendix.

Dependent Variable

Methane Emissions from Agriculture, Per Capita (ln), 2010. These data were obtained from the World Bank DataBank's World Development Indicators (World Bank 2013). They are reported in thousand metric tons of CO_2 equivalent, an indicator that describes the amount of methane in terms of the amount of CO_2 with an equal global warming potential. Importantly, this measure only reports methane emissions that arise from agricultural activities, which include animals, animal waste, rice production, agricultural waste burning (nonenergy, on-site), and savannah burning. These numbers are estimates of emissions derived from the amount of methane known to be produced by each activity and the amount of each activity occurring within a nation (IPCC 2007; Mosier et al. 1998). I divided these data by population to transform it into a per capita measure. I use the natural log (ln) of these data to correct for excessive skewness.

Independent Variables

The models in this chapter utilize independent variables described in Chapter 2 as predictors of *Methane Emissions from Agriculture* (see that chapter for more details). *Gross Domestic Product Per Capita, 2000 (ln)*; *Urban Population, 2000*; *Energy Use Per Capita, 2005(ln)*; and *Life Expectancy at Birth, 2000* are used as indicators of *Modernization*, which is treated as a latent variable (See Chapter Two, pgs. 13-14 for a more detailed explanation). *World-System Position, 1999* is used to measure a nation's structural position within the world-system hierarchy. *Agriculture as a Percentage of Gross Domestic Product, 2000* and *Agricultural Exports as a Proportion of Gross Domestic Product, 2000 (ln)* are alternatively used as measures of agricultural dependency (See Chapter Two, pg. 13 for a more detailed description of these measures).

Results

Table 1 reports key descriptive statistics and bivariate correlations for the sample as a whole. A cursory look at the bivariate correlations reveals that the modernization indicators (*Gross Domestic Product Per Capita, 2000 (ln)*; *Urban Population, 2000*; *Energy Use Per Capita, 2005(ln)*; and *Life Expectancy at Birth, 2000*) all correlate positively and significantly with one another as well as with *World-System Position, 1999*. All four modernization indicators and *World-System Position, 1999* have a significant negative relationship with *Agriculture as a Percentage of Gross Domestic Product, 2000* and three of the modernization indicators have a significant negative relationship with *Agricultural Exports as a Proportion of Gross Domestic Product, 2000 (ln)*. This preliminary finding appears to indicate that agricultural dependency is much higher in the less-developed and less-powerful nations. The positive, significant relationship between *Agriculture as a Percentage of GDP* and *Agricultural Exports* supports that these two measures are both capturing related aspects of agricultural dependency. Both of these variables have a statistically significant, positive bivariate relationship with the dependent variable, while *Energy Use Per Capita* has a negative one.

[Table 7 about here]

Before examining the full structural equation model, which examines the relationships specified by my theoretical framework, it is important to examine the measurement model to ensure that any latent variables are accurately capturing the intended underlying concepts. Figure 1 and Table 2 report the measurement model for *modernization*, a latent variable that represents the degree to which a nation is developed in terms of economics, technology, and standard of living.

[Figure 6 about here]

[Table 8 about here]

The measurement model is nearly identical to that of the prior chapter, as this sample only differs from that one by a few cases. All four of the loadings are substantial and significant at the p <0.001 level and the goodness of fit statistics all reveal an overall strong model fit. As with the measurement model in Chapter 3, the RMSEA and CFI are both reporting "perfect" fit scores which is the result of the chi-square being less than the degrees of freedom. Again, this indicates that the model is perfectly specified (Kolenikov 2012). Collectively, the model fit statistics support the specified latent variable being a good fit to the data.

With a confirmed indicator of modernization, it is possible to examine the relationships among the variables and compare between models that represent alternative explanations for methane emissions from agriculture. Figure 2 and Table 3 report a political economy model, which represents the primary factors that were found relevant in the previously reviewed work on the social drivers of anthropogenic methane emissions (that higher population and affluence lead to greater emissions of methane). Population is incorporated in the model as the denominator of the dependent variable. Affluence (GDP per capita) is included as one of the indicators of modernization. Additionally, this model includes the proposition that nations in higher structural positions in the world-system tend to generate greater amounts of methane (Burns et al. 1997). This model is essentially testing the second, fifth, and sixth hypotheses.

[Figure 7 about here]

[Table 9 about here]

The political economy model specifies world-system position as directly impacting both modernization and methane emissions from agriculture and modernization as directly impacting methane emissions. The model as a whole has questionable fit statistics, with a significant chi-square (which indicates that the covariance structure specified in the model is significantly different than the covariance matrix in the sample—or, in more simple terms, the relationships specified in the model are different than those that exist in the data) and an RMSEA slightly greater than 0.08. However, the CFI and SRMR both indicate strong fit. The modernization latent variable continues to strongly load all four of its indicators. Additionally, world-system position has the significant and positive impact on modernization that was expected, supporting the sixth hypotheses. Interestingly, modernization has a significant negative effect on the amount of methane emissions from agriculture, a finding that contradicts both the general results of previous research[19] and the second hypothesis.

[19] It should be noted here that the previous work explored total methane emissions (Burns, Davis, and Kick 1997; Jorgenson 2006; Jorgenson and Birkholz 2010; Rosa, York, and Dietz 2004) which are likely to include a

This suggests that development is associated with decreased levels of methane emissions from agriculture. Finally, world-system position has a positive direct effect on methane emissions from agriculture. It also has a negative indirect effect through modernization. These two effects are mutually offsetting, resulting in the absence of a significant total effect. These combined effects indicate that there are multiple dynamics at work which are addressed in the discussion.

Figure 3 and Table 4 report the first agricultural dependency model, which introduces agricultural dependency (indicated by *Agriculture as a Percentage of Gross Domestic Product, 2000*) as a mediating variable between modernization and methane emissions from agriculture. *Life Expectancy* is removed as an indicator of modernization as any models that included it failed to converge (see Chapter 2, pg. 16 for a discussion of this). This model represents the theoretical framework outlined in Chapter One. To summarize the hypothesized relationships: more powerful nations use their positions of power to become more internally developed (H6). Part of this development involves creating a diversified and well-articulated economy. Consequently the more modern nations have a lower degree of agricultural dependency (H3). Due to the associated amounts of external control and lower environmental regulations, higher degrees of agricultural dependency will lead to higher levels of per capita methane emissions from agriculture (H1). Finally, increased positions of power within the world-system hierarchy will also create higher levels of per capita methane emissions from agriculture (H5) through the increased use of CAFO technology.

[Figure 8 about here]

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large amount of emissions from industrial sources, while the current study is specifically examining methane

[Table 10 about here]

In the agricultural dependency model represented in Figure 3 and Table 4, the indicator of agricultural dependency has a significant positive effect on methane emissions from agriculture, which supports the first hypothesis. As with the political-economy model, world-system position has a significant and positive impact on modernization in this model, supporting the sixth hypothesis. Modernization has a significant, negative relationship with agricultural dependency, which supports the third hypothesis. Additionally, there is no significant direct relationship between modernization and methane emissions[20], which supports the second hypothesis. Finally, there is a significant and positive direct relationship between world-system position and methane emissions, which would support the fifth hypothesis. However, there is also a significant and negative indirect relationship; via modernization and agricultural dependency. When combined, these two relationships offset one another, resulting in an insignificant total effect which mirrors the results of the zero-order correlation. However, examining the direct and indirect relationships separately yields two significant relationships that both warrant explanation.

The goodness of fit statistics for this model indicate a decent fit; one that is a definite improvement upon the political economy model. Most importantly, the chi-square is not statistically significant, indicating no significant difference between the covariance structures specified in the model and the covariance matrix in the sample. Additionally, the RMSEA, CFI, and SMRM are all improvements over the scores for the political economy model.

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emissions from agriculture.

[20] Such a relationship was tested. It both failed to yield a significant effect and lowered the over-all model fit.

While the CFI (0.99) and SMRM (0.03) both indicate a strong fit to the data, the RMSEA is still higher than 0.08, which means these results should be interpreted with caution.

Figure 4 and Table 5 provide an alternative model of agricultural dependency, where *Agricultural Exports as a Proportion of Gross Domestic Product, 2000 (ln)* is used in place of *Agriculture as a Percentage of Gross Domestic Product, 2000* to represent agricultural dependency. Paralleling the logic of the previous chapter, this alternative indicator of agricultural dependency is used to provide a more extensive test of the internal validity of my findings and argument. The relationships specified test the same hypotheses as the original agricultural dependency model (see Figure 3 and Table 4), but life expectancy is left in as an indicator of modernization and the direct relationship between world-system position and agricultural dependency is tested.

[Figure 9 about here]

[Table 11 about here]

The alternative agricultural dependency model yielded a number of similar results as the original, but also some that were quite different. The alternative articulation of agricultural dependency has a significant positive effect on methane emissions from agriculture, which supports the first hypothesis. Additionally, world-system position still positively impacts modernization, which negatively influences agricultural dependency, and there is no significant direct relationship between modernization and methane emissions.[21] These results continue to support the first, second, third, and sixth hypotheses. Where the alternative agricultural dependency model differs from the original is in terms of the direct effect of world-system position on agricultural dependency and methane emissions from agriculture. World-system position has a positive and significant direct impact on agricultural dependency, which contradicts the fourth hypothesis. However, there is also a significant and negative indirect relationship (via modernization) on agricultural dependency. When combined, these two relationships offset one another, resulting in an insignificant total effect. However, again these two independent relationships both require explanation and are addressed in the discussion. Finally, unlike the original, in the alternative agricultural dependency model world-system position does not have a significant impact on methane emissions from agriculture, which contradicts the fifth hypothesis. The relationship remained in the model because when it was removed, the overall model fit dropped. Additionally, as this relationship was one that was being specifically tested, it is conceptually important that it be retained and its effect estimated.

The alternative agricultural dependency model had the strongest overall fit statistics of any of the models in this chapter. It had a non-significant chi-square, an RMSEA below 0.08 (which, again, indicates an adequate fit), a CFI above 0.95, and a SMRM below 0.05. Additionally, this model had the highest PCFI (0.387) of the three models presented. While still low, this indicates that when accounting for parsimony, this model is the best of the three in terms of representing the covariance structure of the sample.[22] Overall, the relationships

[21] As before, such a relationship was tested and it failed to yield a significant effect while lowering the over-all model fit.

[22] Paralleling what happened in the previous chapter's analyses, the model that used only three indicators for modernization had a markedly lower PCFI score than those that used four. This is logical as the PCFI penalizes model fit as a model approaches saturation and indicator variables only account for one parameter. Therefore, the more indicators of a latent variable you introduce, the less saturated your model will be and the higher your PCFI (or any other parsimony adjusted fit scores).

specified in this model best reflect the patterns of variance and correlation within the actual data. Unlike the previous chapter's analyses, there is a clear pattern of improved model fit through the progression of the models. While all three of the models have strong fits according to the CFI (all >0.98) and SRMR (all <0.04), the political economy and original agricultural dependency models both have questionable RMSEA scores (between 0.08 and 0.10) and the political economy model has a significant chi-square. However, the original agricultural dependency model has a better fit than the political economy model (primarily due to having a non-significant chi-square) and the alternative agricultural dependency model has the best fit of them all, with an RMSEA of 0.073 that indicates adequate fit by most standards and the highest PCFI.

Discussion

General Findings

This chapter of the dissertation examines how the division of labor in the global food and agriculture system impacts methane emissions from agriculture. Both of the agricultural dependency models show a significant and positive relationship between agricultural dependency and methane emissions, supporting the first hypothesis and the argument that methane emissions from agriculture are being produced disproportionately in nations with a high degree of agricultural dependency. While modernization demonstrates a negative direct effect on methane emissions from agriculture in the political economy model, it has no significant direct effect in the agricultural dependency models, demonstrating that agricultural dependency fully mediates that negative relationship (modernization negatively impacts methane emissions *by* negatively impacting agricultural dependency). In general, this supports the second and third hypotheses.

As in the previous chapter, world-system position demonstrates a consistent positive effect on modernization, supporting the sixth hypothesis. However, world-system position does not have a direct negative impact on agricultural dependency in the original agricultural dependency model and has a direct positive impact in the alternative agricultural dependency model, which contradicts the fourth hypothesis. In the original agricultural dependency model, world-system position has a negative indirect impact on agricultural dependency (via modernization) and in the alternative model it has offsetting negative indirect and positive direct impacts on agricultural dependency, which yield a cumulative lack of a significant total effect. Taken as a whole, it appears that nations that occupy positions of power within the world-system are still less likely to be agriculturally dependent, but the direct positive effect that exists independent of the effects of modernization is surprising. This finding is discussed below. The final substantive result of these analyses is that world-system position has a positive direct effect on methane emissions from agriculture in both the political economy model and the original agricultural dependency model. This effect is not significant in the alternative agricultural dependency model and in all three models the total effects are insignificant (the positive direct effects in the first two models were off-set by the negative indirect effects via modernization). However, the tendency remains that outside of development, there appears to be some mechanism through which agriculture in the rich and powerful nations is more methane-intensive than agriculture in developing nations. This finding supports the fifth hypotheses.

Interpretation of Findings

The relationship of central interest to this chapter is the positive connection between agricultural dependency and methane emissions from agriculture. As with the similar finding for nitrous oxide in the previous chapter, this finding supports the theoretical framework outlined in the first chapter. Nations with a high degree of agricultural dependency are those with an economy structured around the production of cash crops for export, typically due to a lack of viable economic alternatives. That position within the global division of labor involves a great deal of control by agro-TNCs that possess little incentive to protect the environment and every incentive to maximize profits by means that may prove detrimental to the environment. While the degree of foreign control is not directly captured by the measures of agricultural dependency used here, it is implied by the strong consistency among all of the measures of agricultural dependency (See Chapter Two, pg. 17-18). Additionally, nations that are agriculturally dependent will tend to have lower environmental standards and may permit agriculturally activities that damage the environment (such as improper or unregulated disposal of animal wastes) or not regulate those activities as strictly as more developed nations would.

An interesting finding in these analyses is the positive relationships (net of modernization and agricultural dependency) between world-system position and methane emissions from agriculture. As discussed above, there are somewhat opposing tendencies that connect a nation's degree of development to the amount of methane being directly released by domesticated animals. First off, the cellulose-rich diet that ruminants in developing nations tend to be fed leads to more methane being produced per animal (Ward et al. 1993).

However, the relatively protein-rich diet fed to agricultural animals in more developed nations leads to more methane being produced by the wastes of those animals (Mosier et al. 1998) (See pgs. 5-6 for details). Additionally, the fact that *all* domestic animals (not just ruminants) are more likely to be raised in confined animal feeding operations in developed nations (and consequently have their wastes pooled together) leads to a much greater volume of methane being produced per unit of waste. Therefore, it would appear that the greater volume of methane being produced by animal wastes in more powerful nations accounts for the positive relationship observed between world-system position and methane emissions from agriculture.

An unexpected finding that requires further discussion is the positive direct relationship between world-system position and agricultural dependency that exists in the alternative agricultural dependency model. In all of the analyses in both the previous and subsequent chapters, as well as in this chapter's original agricultural dependency model, world-system position has no direct impact on agricultural dependency, a negative indirect impact, and a negative total effect on agricultural dependency. These findings were expected and support the idea that agricultural dependency is a characteristic of weaker nations. However, the positive direct effect observed in the alternative agricultural dependency model contradicts those earlier findings to some degree. It is important to note that the positive direct effect exists alongside a negative indirect effect via modernization. Therefore, nations higher in the world-system only appear to have a greater degree of agriculturally dependence once modernization and development is controlled for. It is possible that this relationship is merely a statistically anomaly unique to that particular model. If not, than it means that when two nations are equally modern, the one that is higher within the world-system hierarchy is more likely to be agriculturally dependent. This effect could be distinguishing between developing nations that have an agricultural commodity to export and those that do not. It is possible that a slightly higher position in the world-system (net of development) allows nations to better place their commodities in global markets and establish a situation of agricultural dependency, while nations in somewhat lower positions are less able to effectively compete. This explanation is also supported by the specific measure used to indicate agricultural dependency in the alternative model (GDP in Agricultural Exports as opposed to GDP in Agriculture as a whole). If the positive effect of world-system position on agricultural dependency stems from the ability of a nation to better place commodities in global markets, it makes sense that this effect would only manifest itself in the model looking at agricultural exports and not the model looking at all agricultural activities.

Shortcomings and Future Research

This research shares a number of shortcomings with the analyses of the previous chapter. It lacks a true longitudinal design and treats nation-states as homogenous units. Correspondingly, future research could address these weaknesses by obtaining adequate panel data and utilizing a longitudinal analysis, such as growth curve modeling or by analyzing sub-national units.[23] Additionally, future research should attempt to better clarify the direct relationship between world-system position and methane emissions from agriculture. While this chapter has proposed one explanation of that relationship, a more nuanced examination of the dynamics involved (possibly using separate data for methane emissions from on the hoof animals and methane emissions from manure) may yield more definitive conclusions.

Alternative Measures and Variables Tested

In this section I briefly recount alternative models and variables that were tested but either failed to yield useful findings or produced models that failed to converge or did not adequately fit the data. In some cases, knowing what did not work and why can provide information that is useful in understanding the questions being explored. The purpose of this section is to both present that useful information as well as anticipate possible critiques and suggestions. As many of the alternative strategies and measures attempted in the nitrous oxide analyses and explained in detail in the previous chapter (pgs. 28-30), I only briefly revisit those now.

Similar to the nitrous oxide analyses, I initially explored using a measure of total methane emissions from agriculture as my dependent variable and using population as a predictor variable. I experienced the same pattern of results with population washing out all other effects. Therefore, I chose to use the rate method to account for the effects of population. I also attempted to use agricultural population as a third indicator of agricultural dependency, but again found it to not have a significant effect on the dependent variable. As before, I dropped the three nations in my sample with populations under 500,000 and re-ran all of my analyses. Dropping those nations did not change any of the substantive findings and yielded slightly worse model fit statistics, so they were left in the sample. Finally, I attempted

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[23] See Pg. 27 of the Chapter Three for a more detailed discussion of these avenues of future research.

to test world-polity arguments by including a measure of state environmentalism (Roberts, Parks, and Vásquez 2004). Again, while this variable was positively predicted by modernization and world-system position, it failed to have a significant impact on the dependent variable and lowered the overall model fit. For these reasons, it was not included.

Conclusions

As with the previous chapter, these analyses have demonstrated a clear linkage between agricultural dependency and a form of environmental pollution; in this case, methane emissions from agriculture. I argue that this linkage is due to agriculturally dependent nations suffering from a heightened degree of external control by agro-TNCs that are incentivized to maximize profits at the expense of the local environment. Again, the structure of our global food and agriculture system is causing environmental degradation to occur disproportionately in less-powerful nations. Additionally, controlling for the effects of agricultural dependency, more powerful nations in the world-system tend to be the ones to generate more methane from agriculture. I argue that these higher emission rates are driven by the composition and treatment of animal manure in the more powerful nations. The protein-rich diet leads to manure that generates greater amounts of methane and the pooling of animal wastes in industrial-style lagoons causes a greater amount of methane to be generated from those wastes.

The implications of these findings for reducing the amount of methane produced by agriculture and subsequently slowing down the global climate change are relatively straightforward. First off, attention must be paid to the type of diets being fed to domestic animals, both in the developing and the developed worlds. In the developing world, diets that are high in cellulose contribute to ruminants directly producing greater amounts of methane. In the developed world, diets that are high in protein produce manure with a greater potential to produce methane as it breaks down. Ostensibly, these diets are used respectively, due to a lack of alternatives in the developing nations and the high profit rate in the developed nations. However, it is plausible that through concerted effort and research, other possibilities may be discovered. More work is needed to develop diets that will lower the methane produced both directly from the animals and indirectly from their manure. Additionally, policies will need to be put into place that increase awareness of the consequences of animal diet and promote lower-methane producing alternatives. Of even greater consequence, attention needs to be paid to how animal wastes are being treated and disposed of in developed nations. While profitable, the lagoon system producers a greater volume of methane emissions per amount of manure than more traditional practices that dry and disperse the wastes. This is particularly problematic given the rising prevalence of confined animal feeding operations in developing nations (Burns, Davis, and Kick 1997; Steinfeld et al. 2006). Overall, greater attention needs to be paid to the environmental sustainability of the global system through which people raise useful plants and animals for market exchange.

Table 7- Descriptive statistics and bivariate correlations (n = 130) matrix

Parameter	*Mean*	*S.D*	*Skew*	*Min.*	*Max.*		
1- Methane Emissions from Ag., 2010 (ln)	-7.865	0.951	-0.077	-11.175	-5.147		
2- GDP per capita, 2000 (ln)	8.741	1.275	-0.281	5.017	11.143		
3- Urban Population, 2000	58.266	21.459	-0.246	10.833	98.110		
4- Energy Use per capita, 2005 (ln)	7.276	1.073	0.148	5.057	9.916		
5- Life Expectancy at Birth, 2000	68.713	9.271	-1.088	41.783	81.076		
6- World-System Position, 1999	5.400	2.480	0.134	1	10		
7- Agriculture as % GDP, 2000	13.230	12.119	1.277	0.355	57.239		
8- Agricultural Exports as % GDP, 2000 (ln)	0.572	1.419	-1.117	-4.619	3.135		
Correlations	*1*	*2*	*3*	*4*	*5*	*6*	*7*
1- Methane Emissions from Ag., 2010 (ln)	1.0000						
2- GDP per capita, 2000 (ln)	-0.1121	1.0000					
3- Urban Population, 2000	-0.0786	0.8003*	1.0000				
4- Energy Use per capita, 2005 (ln)	-0.1744*	0.8695*	0.7032*	1.0000			
5- Life Expectancy at Birth, 2000	0.0059	0.7517*	0.6516*	0.6465*	1.0000		
6- World-System Position, 1999	0.1636	0.4246*	0.2560*	0.2887*	0.3995*	1.0000	
7- Agriculture as % GDP, 2000	0.1934*	-0.8687*	-0.7284*	-0.6937*	-0.6032*	-0.3795*	1.0000
8- Agricultural Exports as % GDP, 2000 (ln)	0.4459*	-0.2594*	-0.2397*	-0.2285*	-0.1068	0.0499	0.3219*

***p <.05, two-tailed**

Table 8- Structural equation model of modernization latent variable, measurement model

	Unstandardized Value	*Standardized Value*
Loadings		
Per Capita GDP (ln)	1.00 (fixed)	0.99***
Energy Use pc (ln)	0.74***	0.88***
Percent Urban	13.71***	0.81***
Life Expectancy	5.56***	0.76***
Variances		
e. Per Capita GDP (ln)	0.03	0.02
e. Energy Use pc (ln)	0.27	0.23
e. Percent Urban	158.69	0.35
e. Life Expectancy	36.23	0.42
Modernization	1.59	1.00 (fixed)

*****p <.001, two-tailed**

Table 9- Structural equation model of methane emissions from agriculture, political economy model

Outcome	*Direct Effects*	*Indirect Effects*	*Total Effects*	*Stnd. Error*
Measurement				
Modernization →				
Per Capita GDP (ln)	1.00 (fixed)	---	1.00 (fixed)	(constrained)
Energy Use pc (ln)	0.73***	---	0.72***	0.040
Percent Urban	13.51***	---	13.51***	0.952
Life Expectancy	5.48***	---	5.48***	0.447
Structural				
Modernization ←				
World-System Position	0.22***	---	0.22***	0.041
Methane Emissions ←				
Modernization	-0.17*	---	-0.17*	0.070
World-System Position	0.10**	-.04*	0.06	0.033

Numbers in cells are unstandardized coefficients. Standard errors are reported for the total effects only.
***p <.05, **p <.01, ***p <.001, two-tailed.**

Table 10- Structural equation model of methane emissions from agriculture, agricultural dependency model

Outcome	*Direct Effects*	*Indirect Effects*	*Total Effects*	*Stnd. Error*
Measurement				
Modernization →				
Per Capita GDP (ln)	1.00 (fixed)	---	1.00 (fixed)	(constrained)
Energy Use pc (ln)	0.67***	---	0.67***	0.042
Percent Urban	13.83***	---	13.83***	1.017
Structural				
Modernization ←				
World-System Position	0.22***	---	0.22***	0.040
GDP in Agriculture ←				
World-System Position	---	-1.89***	-1.89***	0.352
Modernization	-8.46***	---	-8.46***	0.521
Methane Emissions ←				
GDP in Agriculture	0.02**	---	0.02**	0.007
Modernization	---	-0.20***	-0.20***	0.012
World-System Position	0.11**	-0.04**	0.06	0.033

Numbers in cells are unstandardized coefficients. Standard errors are reported for the total effects only.
***p <.05, **p <.01, ***p <.001, two-tailed.**

Table 11- Structural equation model of methane emissions from agriculture, alternative agricultural dependency model

Outcome	*Direct Effects*	*Indirect Effects*	*Total Effects*	*Stnd. Error*
Measurement				
Modernization →				
Per Capita GDP (ln)	1.00 (fixed)	---	1.00 (fixed)	(constrained)
Energy Use pc (ln)	0.72***	---	0.72***	0.042
Percent Urban	14.01***	---	14.01***	1.125
Life Expectancy	5.71***	---	5.71***	0.518
Structural				
Modernization ←				
World-System Position	0.22***	---	0.22***	0.041
GDP in Ag. Exports ←				
Modernization	-0.39***	---	-0.39***	0.108
World-System Position	0.11*	-0.09**	0.03	0.050
Methane Emissions ←				
Modernization	---	-0.12***	-0.12***	0.032
GDP in Ag. Exports	0.29***	---	0.29***	0.052
World-System Position	0.05	-0.01	0.06	0.033

Numbers in cells are unstandardized coefficients. Standard errors are reported for the total effects only.
***p <.05, **p <.01, ***p <.001, two-tailed.**

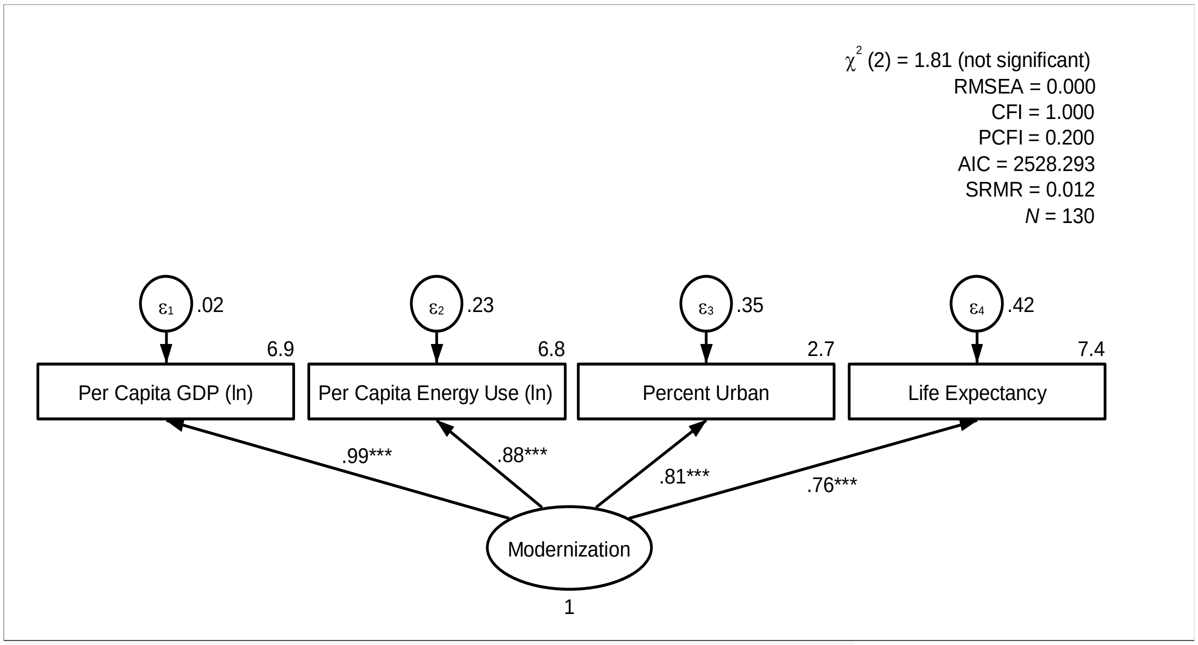

Figure 6- Structural equation model of modernization latent variable, measurement model. Path coefficients are standardized betas, ******p* **<.001, two-tailed.

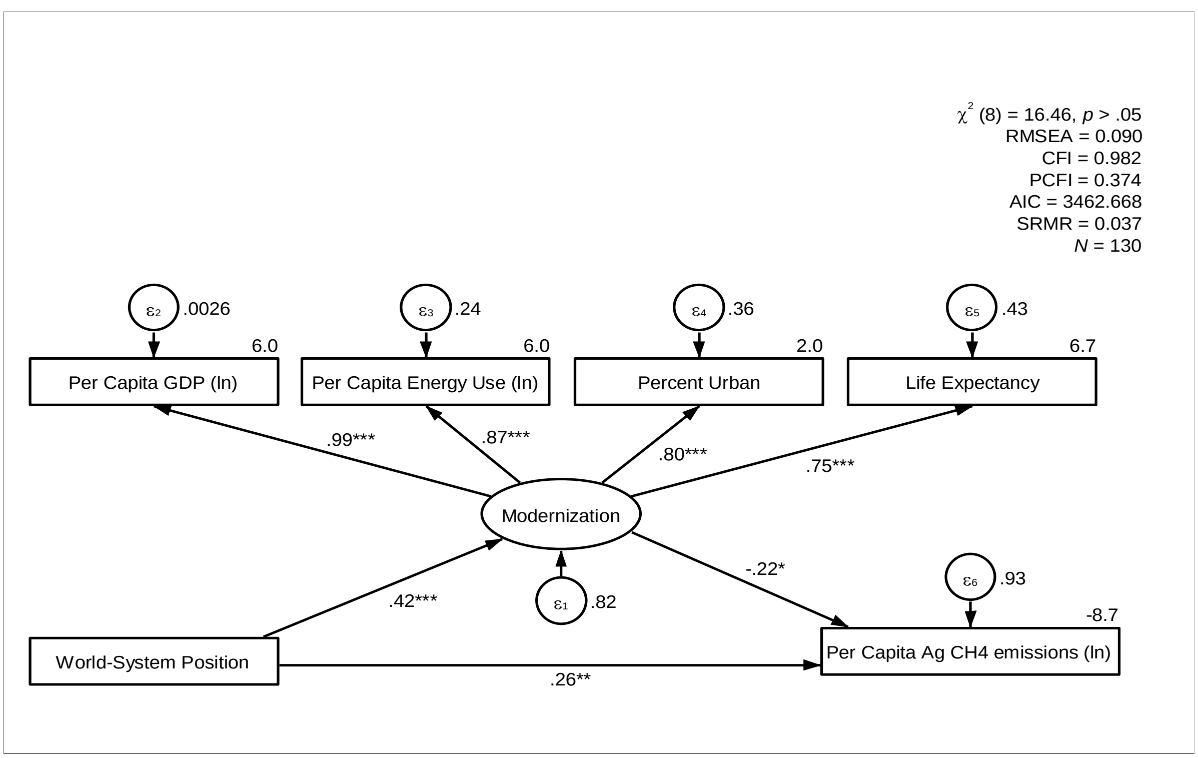

Figure 7- Structural equation model of methane emissions, political economy model. Path coefficients are standardized betas. ****p* **<.05, *****p* **<.01, ******p* **<.001, two-tailed.

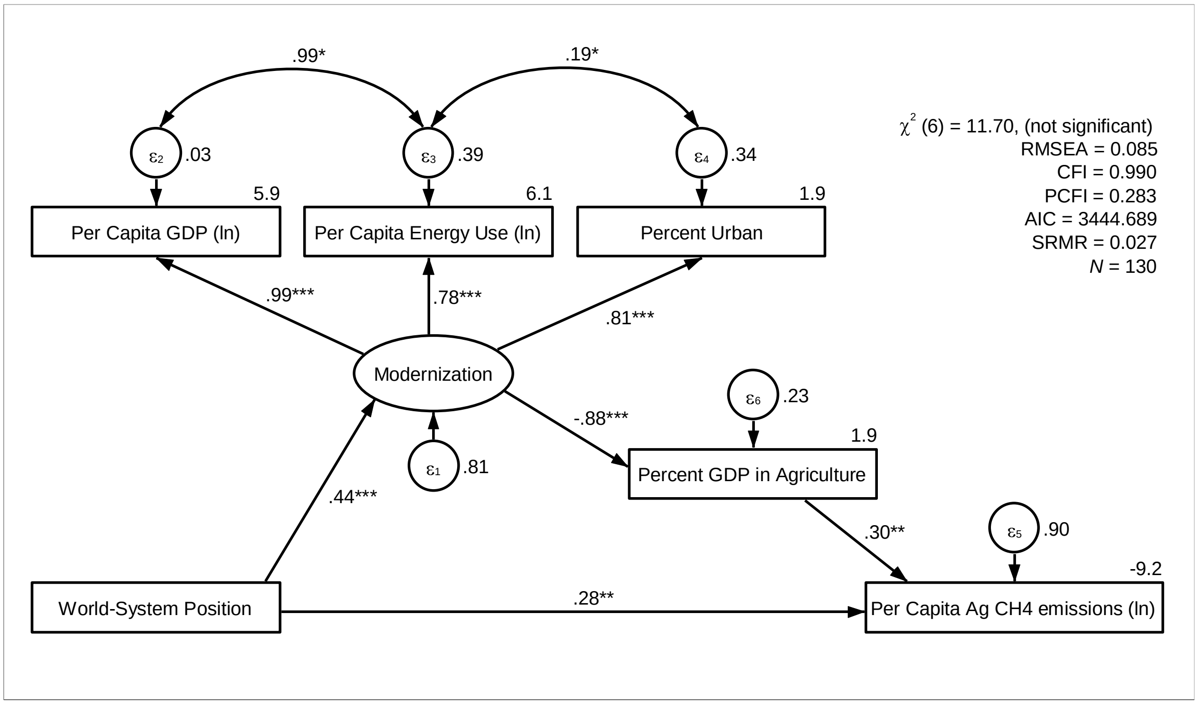

Figure 8- Structural equation model of methane emissions from agriculture, agricultural dependency model. Path coefficients are standardized betas. *p <.05, **p <.01, ***p <.001, two-tailed.

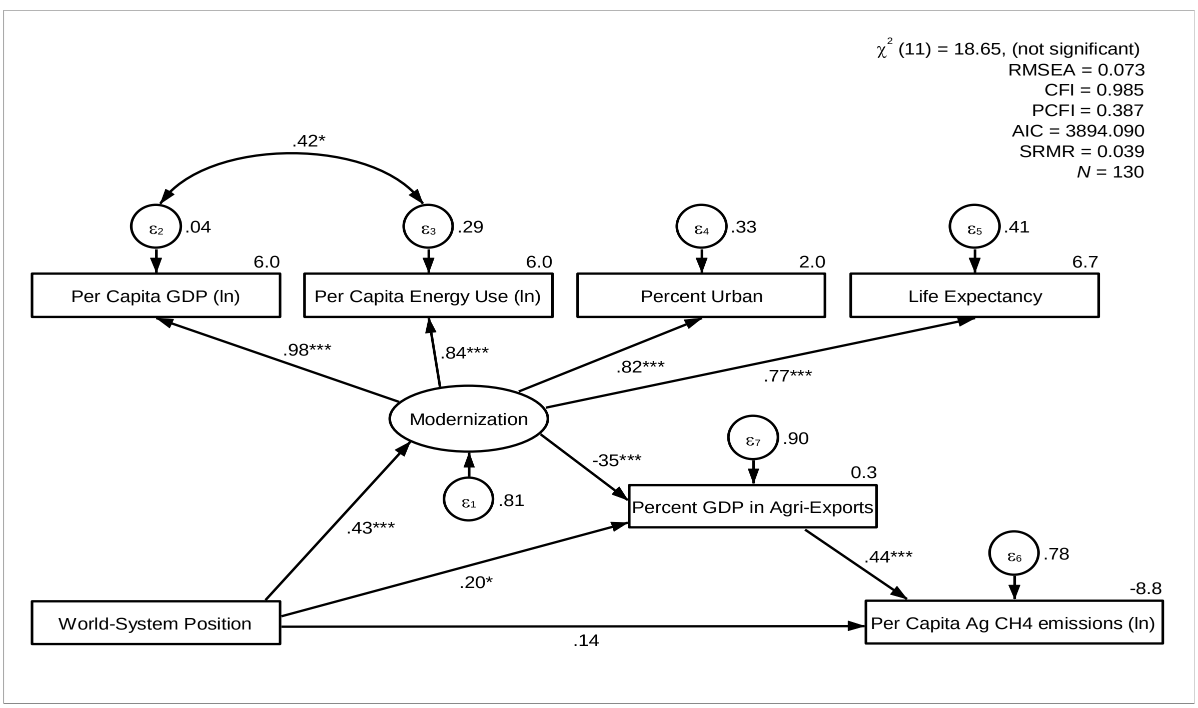

Figure 9- Structural equation model of methane emissions from agriculture, alternative agricultural dependency model. Path coefficients are standardized betas. *p <.05, **p <.01, ***p <.001, two-tailed.

CHAPTER FIVE- BIODIVERSITY LOSS

Introduction

This chapter tests the relationship between agricultural dependency and biodiversity loss. Specifically, the analyses presented here examine the degree to which the division of labor in the global food and agriculture system contributes to biodiversity loss in agriculturally dependent nations. Biodiversity loss is an important form of environmental degradation, as species diversity is essential for the functioning of many of the Earth's ecosystems and biodiversity serves as an important indicator of ecosystem health (Rockstrom 2009b). Biodiversity is currently threatened by a number of anthropomorphic activities including population growth, economic development, the introduction of invasive species, and changes in land use (Sponsel 2013). As the co-optation of land for agricultural use is one of the biggest changes in land use, the role of agricultural dependency in promoting biodiversity loss needs to be better understood. This chapter directly contributes to that understanding by empirically examining the relationships between agricultural dependency, world-system position, modernization, and biodiversity loss. This work also broadly contributes to our knowledge of the social and natural antecedents of biodiversity loss and how social and political-economic dynamics and structures can contribute to environmental degradation.

I start this chapter by describing biodiversity, its importance to natural ecosystems, and the various sources of its loss. I then review existing research on the social factors that contribute to biodiversity loss. Following that, I re-state my research questions and related hypotheses, as they specifically apply to biodiversity loss. Next, I briefly discuss the unique methodological aspects of this chapter. I then present my findings and interpret them. After that, I discuss the meaning of my findings, the shortcomings of this research, and avenues for future research. I then briefly describe some alternative models and variables that were tested but failed to yield any substantial findings. I conclude this chapter with a brief discussion of the implications of its findings and possible strategies for reducing biodiversity loss in the future.

Biodiversity Loss as a Form of Environmental Degradation

Biodiversity Loss and the Environment

Biodiversity is an ecological characteristic that describes the variety of life to be found within a given ecosystem (Gaston 2000). The term biodiversity is often used to represent the more specific and clearly defined characteristics of species richness, species density, and species evenness. Species richness refers to the number of different species represented among the number of individual animals within a given community. Species density is the number of different species that are present within a given geographic unit. Species evenness is the proportional representation of different species, or how equally all the different species in a given community are represented numerically (Tolimieri 2007). In general, the term biodiversity represents the amount of genetic variation to be found within a given ecological or geographic unit. This study examines species density, as it is the most commonly used indicator of biodiversity (see Hoffmann 2004; Kerr & Currie 1995, McKinney, Fulkerson, and Kick 2009) and it best captures the genetic variation that provides ecosystems with resiliency. The amount of biodiversity within an ecosystem is an important ecological parameter, as species diversity and the stability it provides is essential for the functioning of many of the earth's ecosystems (Hooper et al. 2005). "Ecosystems that depend on a few or single species for critical functions are vulnerable to disturbances, such as disease, and at a greater risk of tipping into undesired states" (Rockstrom 2009a:474). Accordingly, ecosystems with a rich biodiversity are relatively resilient to different environmental perturbations as the various species can respond to the changes differently.

The amount of biodiversity that exists within different ecosystems is quite varied, with some (e.g. coral reefs and rainforests) being extremely rich, while others (e.g. deserts and polar regions) are practically devoid of variation. In general, higher levels of biodiversity tend to be found near the equator, likely due to higher levels of primary productivity (Gaston 2000). The biodiversity of an ecosystem declines as species become extinct or impaired (drastically lowered in number as to no longer perform the same ecosystem functioning). Species becoming extinct is a regular part of the evolutionary process, commonly balanced against speciation (the process by which new species arise) (Darwin [1859]1999). However, currently global biodiversity is being lost at an estimated 100 to 1000 times greater than the natural rate (Rockstrom 2009a). The loss is happening so rapidly that paleontologists are describing us as in the midst of a sixth mass extinction event, on par with the loss of the dinosaurs (along with two-thirds of the other species on Earth at the time) during the K-T extinction (Barnosky et al. 2011; Wake and Vredenburg 2008). This drastically elevated rate of loss is outstripping the speciation rate and leading to a global drop in biodiversity; a trend that threatens the stability of the global ecosystem and its ability to maintain our way of life (Stork 1997).

While the evolutionary process is constantly resulting in a number of species becoming extinct (referred to as the “background rate” of extinction), the current drastically elevated rate of biodiversity loss is being facilitated by a number of anthropomorphic activities (Kerr and Currie 1995). Most prominent among those activities are population growth, economic development, the introduction of invasive species, and changes in land use (Forester and Machlis 1996; Sponsel 2013). Population growth is the most straightforward of these factors. While the global human population has been growing since prehistory, in more recent centuries it has virtually exploded, increasing from 500 million in 1500 to 1 billion by 1900 and over 7 billion currently. As human populations continue to grow, they consumer a greater portion of Earth’s viable land and total primary biological production. This co-option of space, energy, and nutrient sources from other species directly threatens their ability to survive and reproduce themselves (McKee et al. 2003). Increases in human population also tend to magnify the impact of other factors on biodiversity loss.

Economic development tends to negatively affect biodiversity by raising the per-capita impact of each individual on the environment—increasing the amount of resources consumed, space occupied, and wastes/pollution generated (Naidoo and Adamowicz 2001). Similar to the effects of population growth, economic development tends to interact with multiple proximate causes of biodiversity loss (invasive species, urbanization, agriculture, pollution, industrial activities). As each individual in a society has greater financial resources at their disposal, they consume more and cycle more financial resources through the economy, creating opportunities for biodiversity loss at each stage (Czech, Krausman, and Devers 2000). In some ways, the per capita gross domestic product can be viewed as a societal measure of the average capacity to engage in activities that can lead to biodiversity loss.

Another contributor to biodiversity loss is the introduction of invasive species—plants and animals not indigenous to a native ecosystem. Human beings have been introducing foreign plants and animals to new regions since the advent of agriculture. In many cases, this was done deliberately in an attempt to grow or raise a commercially useful or ascetically desirable species in a new region (Pimentel 2013). However, this also occurs by accident, as various species are transported inadvertently through trade and human migration (Bernstein 2008). When new species are introduced into an ecosystem that has not evolved to accommodate them, they can disrupt existing balances and supplant indigenous species that lack defenses against the newcomers. The presence of an alien invader can result in the extinction of many native species, as seen in the impacts of the Nile Perch in Lake Victoria (Goldschmidt, Witte, and Wanink 1993), the European Rabbit in Australia (Johnson 2006), or Kudzu in the Southern United States (Pimentel et al. 2000). These examples all demonstrate how the introduction of new species into an environment can severely disrupt ecological balances and drive existing species to extinction.

Changes in land use have been argued to be the most significant contributor to biodiversity loss (Rockstrom et al. 2009a). Changes in land use is a broad category that includes, among other processes, urbanization, the co-optation of wilderness areas for agricultural use, and habitat fragmentation. These changes in land use directly impact biodiversity through the loss of suitable habitat for a number of species. A great number of plant and animal species have evolved to fit a specific ecological niche. In many cases, that niche is limited to a specific area and set of conditions. If humans alter those conditions (such as chopping down a forest to replace it with grazing lands), than the species that evolved to fit that particular niche cannot survive and becomes extinct (Sponsel 2013). Habitat fragmentation does not alter the conditions throughout a niche, but instead divides that area with barriers impassible to certain species (such as roads for a number of ground-based insects), therefore shrinking the amount of space (and mates) available to that species. One of the most important types of change in land use is the conversion of wilderness areas to agricultural use (Czech, Krausman, and Devers 2000). Besides directly making the habitat unsuitable to many indigenous species, agriculture can impact nearby areas through soil erosion, pesticide drift, and fertilizer run-off. It is the fact that changes in land use are such an important contributor to biodiversity loss that drives a number of states to create protected areas that are intended to guard threatened species. In this manner, the actions of the state can be viewed as an important factor in determining the amount of biodiversity loss (Kerr and Currie 1995).

As the conversion of wilderness areas into agricultural areas is such an important contributor to biodiversity loss, than it stands to reason that nations that are engaged in a greater amount of agricultural activities will experience a corresponding greater amount of biodiversity loss. This dissertation is centered upon the idea of agricultural dependency, which is a concept that describes a nation's degree of economic dependence upon the export of agricultural products to global markets (See Chapter One, pgs. 16-18 for elaboration).

Nations that are highly agriculturally dependent should engage in a greater amount of agricultural activity than those that are not (all else being equal). Those nations should be shifting more land from a state of wilderness to agricultural use, reducing the amount of land available to support other species. Therefore, nations that have a high degree of agricultural dependence should be experiencing greater amounts of biodiversity loss.

As mentioned above, species diversity is essential for the functioning of many of the Earth's ecosystems. The loss of biodiversity can increase the vulnerability of ecosystems to a wide range of disturbances, including disease, climate fluctuations, and invasive species (Rockstrom 2009b). Biodiversity is also an important ecological parameter due to its strong effects on productivity and nutrient retention, two essential ecosystem properties (Tolimieri 2007). In addition to its direct effects on ecosystem health, biodiversity constitutes an important indicator of ecological disruption and understanding patterns of biodiversity can help us to understand larger ecological patterns. Many bird and mammal species are sensitive indicators of human disturbance and their loss can serve as a proxy of other environmental disruptions and consequences (Diamond 2005:445). In general, biodiversity is both an important ecological parameter in its own right, and a critical indicator of many other important ecological dynamics.

In addition to the ecological importance of biodiversity, there are also a number of ways in which biodiversity has direct value for human societies. First, given that the ultimate sources of human food and medicine are found in natural ecosystems, maintaining a healthy level of biodiversity ensures that future useful plants and animals will be available (Donahoe 2003). Second, biodiversity has important historical, cultural, and aesthetic values to human beings. Many societies attach spiritual or nationalistic value to various species and the rising prevalence of ecotourism attests to the direct aesthetic value humans place on rich and varied ecosystems (Takacs 1996). Finally, it has been argued that non-human animal and plant species have their own intrinsic rights that deserve to be respected and protected (Hoffman 2004). These various motivations add to the overall importance of understanding and reducing the current rapid decline in global biodiversity.

The Social Drivers of Biodiversity Loss

As with the majority of research within the natural sciences on environmental degradation (including those bodies of literature reviewed in the previous two chapters), much of the research on biodiversity loss has confined itself to the ecological or biological realm. While this work is important to our understanding of the mechanics of biodiversity loss and its repercussions, it tends to downplay or outright ignore many of the social dynamics and structures that lead to biodiversity loss. “Purely biological approaches to understanding biodiversity loss are limited to analyses of proximate causes” (Forester and Machlis 1996:1254). However, researchers within the social sciences have begun to examine that which the natural sciences are missing. This body of work explores the social antecedents of biodiversity loss at the cross-national level, primarily using a political-economic lens. It seeks to determine what structural features make a nation more or less likely to experience a loss of their biodiversity.

Consistent with the findings of the natural science examinations of the causes of biodiversity loss, works within the social sciences also find that nations’ population and level of affluence are important determinants of their level of biodiversity loss (Hoffman 2004; McKinney, Kick, and Fulkerson 2010). Population clearly has a significant impact upon biodiversity loss, but the exact nature of that impact is not clear. While there is a positive direct relationship between population size and biodiversity loss (McKinney et al. 2009; McKinney et al. 2010), York et al. (2003) argue that examining overall population or overall population growth rates in a cross-national context fails to capture important demographic factors. Therefore, it is important to decompose population into its more nuanced components in order to more clearly illuminate population dynamics. Studies that have done this have found that while overall population does not impact biodiversity loss, growth in non-dependent population (population aged 15-64) positively predicts biodiversity loss, net of overall population growth (Shandra et al. 2009) as does population density (Hoffman 2004).

In terms of the impact of level of affluence on biodiversity loss, the findings of this body of literature are mixed. Some studies find no direct relationship between GDP per capita and biodiversity loss (McKinney et al. 2009), some find a negative relationship (Shandra et al. 2009), and yet others find a clear positive relationship (Hoffman 2004). There is also support that different economic sectors have different impacts upon biodiversity loss (McKinney et al. 2010). Likely, the mixed findings are the result of the wide range of other variables being examined conjointly with GDP per capita. In particular, the inclusion of indicators of world-system position in a regression model along with indicators of affluence has been shown to suffer from issues of multicollinearity (Babones 2014; McKinney et al.

2009). Despite the mixed findings, this body of literature does generally argue that economic development and modernization tend to worsen biodiversity loss.

Research within the social sciences has also examined the influence of global political-economic structures on biodiversity loss, examining the impact of nations' position in the world-system and their degree of integration into the global environmental regime.[24] The influence of a nation's position in the world-system on their amount of biodiversity loss is complex. There is some evidence that higher positions in the world-system lead to greater amounts of biodiversity loss (McKinney et al. 2009; McKinney et al. 2010), but that evidence is far from conclusive. This effect is possibly due to the more extensive history of internal resource exploitation for the more powerful nations. As nations in positions of power often arrived at them by first exploiting their own internal resources and consequently despoiling their own environment (Bunker 1984, Wright 1990), it follows that the more powerful nations would have a greater history of habitat loss and corresponding higher levels of biodiversity loss. Other studies that test world-system position indirectly, by examining the flow of primary sector exports from rich to poor nations (Shandra et al. 2009), find the opposite. This measure of the relative extent to which a nation is sending primary sector exports to richer nations is an indicator of lower position in the world-system hierarchy. As it positively impacts biodiversity loss, it contradicts the findings of other work. A stronger consensus exists that the relationships between a number of national-level factors and

[24] The term "global environmental regime" comes from world-polity arguments that globalization is leading nations adopting environmental protection as a government responsibility. The global environmental regime is defined as 'a partially integrated collection of world-level organizations, understandings, and assumptions that specify the relationship of human society to nature' (Meyer et al. 1997:623). For an overview, see Frank, Hironaka, and Schofer (2000).

biodiversity loss vary by world-system position. GDP per capita, growth in GDP per capita, growth in energy use per capita, and state environmentalism all impact biodiversity loss differently in the core, semiperiphery, and periphery (Hoffman 2004; McKinney et al. 2009; McKinney et al. 2010). Therefore, while the exact nature of the relationship may require further clarification, the fact that position in the world-system influences biodiversity loss in some manner has been relatively well corroborated.

The second political-economic structure that can influence a nation's level of biodiversity loss is its degree of state environmentalism, or its integration into the global environmental regime. According to world-polity theory, there is an emerging global environmental regime that encourages nation-states to assume responsibility for protecting the environment. Nations that are more integrated into this regime should protect their biodiversity more than nations that are not (Frank, Hironaka, and Schofer 2000). Integration into the global environmental regime can come through national participation in environmental international government organizations, environmental international non-government organizations, or environmental treaties (Schofer and Hironaka 2005). In general, participation in the global environmental regime appears to reduce the amount of biodiversity loss, as nations with higher levels of state environmentalism tend to experience lower amounts of biodiversity loss (Shandra et al. 2009). However, some studies do not support this (McKinney et al. 2010) while other show that state environmentalism tends to operate differently among the different tiers of the world-system (McKinney et al. 2009).

While not the specific focus of any of the social science studies of biodiversity loss, these works consistent find that geographic variables (land area and geographic location) exert a strong influence upon the amount of biodiversity loss that occurs within a nation. Ecological research has established that the number of species present on a given landmass is a direct function of its size (Hooper et al. 2005). As a greater number of species creates a greater opportunity for biodiversity loss, it is logical that nations with larger landmasses should experience greater biodiversity loss. This relationship has been verified, even net of the effects of population, affluence, and political-economic structures (McKinney et al. 2010; Shandra et al. 2009). Other studies that did not include land area as an independent variable treated it as the exposure variable in negative binomial regression analysis, indicating that it is an important predictor of biodiversity loss (Hoffman 2004).

Geographic location influences biodiversity loss in a similar fashion as land area, as more species occur (and therefore can be threatened) nearer to the equator, at lower elevations, and in areas with higher amounts of annual rainfall (Gaston 2000). Again, social science research on biodiversity loss supports this relationship, as nations located at lower latitudes (closer to the equator) have higher levels of biodiversity loss (McKinney et al. 2009; McKinney et al. 2010). Other research found that nations in Asia have higher levels of biodiversity loss, however this finding is argued to be driven by the "mega-diverse" countries in Asia (India, Indonesia, Malaysia, and Papua New Guinea) that all fall relatively close to the equator (Shandra et al. 2009). Thus, although cross-national social science research on biodiversity loss has largely focused upon social, structural, and political-economic factors, it has also found that geographic factors strongly influence where biodiversity loss occurs.

While social science research on biodiversity loss has contributed greatly to our understanding of its social-structural antecedents, some of this research suffers from methodological issues and a number of important questions remain unanswered. Like so much cross-national research, a number of these studies have issues with parameter estimation and multicollinearity. Studies that include 12 variables in a multivariate regression model with only 74 cases (Shandra et al. 2009) or 19 variables for only 120 cases (Hoffman 2004) run the risk of inaccurate parameter estimation and type II errors (Kelley and Maxwell 2003). While the proper ratio of variables to cases is somewhat subjective in quantitative macro-comparative research (Babones 2014:121-121), some of these studies include so many variables with so few cases as to call the accuracy of their conclusions into question. Additionally, a number of studies in this area simultaneously include indicators of world-system position and indicators of average national income level, two variables that have been shown to be highly multicollinear (McKinney et al. 2009). Many of the issues with multicollinearity can be addressed by explicitly modeling covariances in SEM, but the one study in this body of research that uses SEM to do such (McKinney et al. 2010) has a number of unaddressed Heywood cases (negative error variance estimates) that may indicate model misspecification model or an arbitrary solution (Garson 2014). Given the impossibility of having a negative amount of unexplained variance, any model with Heywood cases needs to be accompanied by some manner of explanation or else the results should be deemed untrustworthy (Kolenikov and Bollen 2012).

In addition to some of the methodological questions within this body of research, there are also some substantive questions that remain unaddressed. Most important to this dissertation is the fact that none of these studies have explicitly examined the impact of agriculture within the context of the global division of labor. Given that the co-optation of land for agriculture is one of the main types of changes in land use that generate biodiversity loss, this relationship warrants considerable attention. Hoffman (2004) examined the percent of agricultural land as a national indicator, but framed its impact within neo-Malthusian arguments about population. He did not examine the impact of agriculture within a political-economic context or explore any of the inter-relations between agriculture, world-system position, and development. Shandra et al. (2009) examined flows of primary sector exports, of which agricultural products are an important component. However, this indicator also includes natural resource exports such as fossil fuels and logging. These exports are generated by very different mechanisms than agricultural products and likely have a very different impact on biodiversity loss. This chapter addresses these various shortcomings by focusing upon agricultural dependency and explicitly examining its impacts upon biodiversity loss. By using a more appropriate variable to case ratio (a maximum of six variables with over one hundred cases for each model), it avoids the issues with parameter estimation that affect a number of the prior studies. It also addresses some of the multicollinearity issues by explicitly modeling any of the shared variance among the predictors. Finally, it does not generate any models with Heywood cases, and therefore avoids calling its findings under suspicion.

Research Questions with Related Hypotheses

- How does agricultural dependency influence biodiversity loss? As theorized in chapter one, agricultural dependency is expected to cause elevated levels of biodiversity loss. Therefore:

    - H1: Higher degrees of agricultural dependency will be associated with greater amounts of biodiversity loss relative to the number of existing species, net of all other effects (See pgs. 6, 12, and Chapter 1, pgs. 29-30)

- How does modernization influence biodiversity loss?
    - H2: Higher degrees of modernization will not be significantly associated with greater or lesser amounts of biodiversity loss, net of all other effects (See pgs. 4 and 8-9)

- How does modernization influence agricultural dependency? As theorized in the first chapter, the modernization process is expected to reduce agricultural dependency. Therefore:
    - H3: Modernization will be negatively associated with agriculturally dependency, net of all other effects (See Chapter 1, pgs. 17-19, 29)

- How does position in the world-system hierarchy influence agricultural dependency? As described in the first chapter, positions of power within the world-system should enable nations to avoid agricultural dependency. Therefore:
    - H4: Positions of higher power in the world-system hierarchy will be negatively associated with agricultural dependency, net of all other effects

- How does position in the world-system hierarchy influence biodiversity loss?
    - H5: Positions of higher power in the world-system hierarchy will be positively associated with greater levels of biodiversity loss, net of all other effects (See pg. 9)

- How does position in the world-system influence modernization? As described in the first chapter, occupying a position of power in the world-system allows nations to modernize more rapidly than others. Therefore:
    - H6: Positions of power within the world-system hierarchy will be positively associated with higher degrees of modernization, net of all other effects

Unique Methodological Features

While the general methodology strategy used in this dissertation was covered in Chapter Two (see above), in this section I will discuss the methodological features that are unique to the study of biodiversity loss.

Sample

Unlike the previous chapters, the sample for this study was not limited by the availability of data on the dependent variable, as the *Red List of Threatened Animals* (IUCN 2014) contained data on threatened species for nearly every nation in the world. Instead, the number of nations included in this sample is limited by the availability of data on world-system position and energy use per capita. Kick et al. (2011) provide world-system position data for 166 nations. With adjustments for shifts in state structure and composition (such as the dissolution of the Soviet Union) and the removal of Singapore and Hong Kong (see Chapter 2, pg. 11), I am left with 161 nations. I provide a list of these nations in the Appendix.

Dependent Variable

Biodiversity Loss. These data were obtained from the International Union for the Conservation of Nature and Natural Resources *Red List of Threatened Animals* (IUCN 2014). The *Red List* is a comprehensive listing of threatened, endangered, and surveyed species in most nations and is the most widely used source of national-level biodiversity loss (Hoffman 2004; Shandra et al. 2009). I construct a measure of species density that captures the relative decline in the number of species present in each nation. For each nation I added the total number of threatened bird and mammal species (threatened species are the number of species classified by the IUCN as critically endangered, endangered, vulnerable, or extinct) and divided that number by the total number of assessed bird and mammal species.[25] Therefore, my measure is the proportion of existing species that are currently lost or close to being lost. There is ample precedence of operationalizing biodiversity loss in this manner (Kerr and Currie 1995; Hoffman 2004). Given that both the number of existing species and population are a direct function of the size of a landmass, this measurement indirectly includes ratio controls for both population and land area. I use the natural log (ln) of these data to correct for excessive skewness.

Others have operationalized biodiversity loss in different manners, including the total count of threatened species (Naidoo and Adamowicz 2001), the total number of threatened mammal species (Shandra et al. 2009), the number of threatened bird species as a percentage of total known bird species (McKinney et al. 2009), and the relative proportion of the global total of threatened bird and mammal species (McKinney et al. 2010). To ensure that my findings were robust and not an artifact of how I chose to measure biodiversity loss, I also constructed measures of separate *Threatened Bird Species* and *Threatened Mammal Species* as percentages of total known respective species. I also created a *Proportional Threatened Species*, which was the number of threatened bird and mammal species divided by the total number of threatened bird and mammal species worldwide. Finally, I constructed a measure of *All Species* which included known plants, reptiles, amphibians, and fish species taken as a percentage of all known species. The following analyses were frequently repeated with these alternative measures.

Independent Variables

The models in this chapter utilize independent variables described in Chapter 2 as predictors of *Biodiversity Loss* (see that chapter for more details). *Gross Domestic Product Per Capita, 2000 (ln)*; *Urban Population, 2000*; and *Energy Use Per Capita, 2005(ln)* are used as indicators of *Modernization*, which is treated as a latent variable (See Chapter Two, pgs. 13-14 for a more detailed explanation). *World-System Position, 1999* is used to measure a nation's structural position within the world-system hierarchy. *Agriculture as a Percentage of Gross Domestic Product, 2000* and *Agricultural Population, 2000* (the percentage of a nation's economically active population that is employed in agriculture) are alternatively used as measures of agricultural dependency. *Surface Area (ln)* and *Latitude* are used to test the relevance of geographic factors (CIA World Factbook 2014). Finally, *Population, 2000*

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[25] While it is estimated that over 95 percent of bird and mammal species are documented, data concerning other types of animal species is less reliable (Wilson 1999). Therefore, most studies of biodiversity loss use mammals

(ln) (the natural log of a nation's total population in the year 2000) is also included in some models as a control variable (World Bank 2013).

Results

Table 1 reports key descriptive statistics and bivariate correlations for the sample as a whole. Again, all of the modernization indicators and the indicator of *World-System Position, 1999* correlate positively and significantly with one another. Additionally, the three modernization indicators and *World-System Position, 1999* all have a significant negative relationship with *Agriculture as a Percentage of Gross Domestic Product, 2000* and *Agricultural Population, 2000,* indicating that agricultural dependency is much higher in the less-powerful, less-developed nations (Supporting hypotheses 3 and 4). The positive, significant relationship between *Agriculture as a Percentage of GDP* and *Agricultural Population* supports that these two measures are both capturing related aspects of agricultural dependency. *GDP per capita* and *Energy Use per capita* both have significant negative relationships with *Biodiversity Loss,* which indicates that more modern nations are likely to experience less loss of their biodiversity. *Agricultural Population* has a significant positive relationship with *Biodiversity Loss,* indicating that nations with a high proportion of their economically active population working in agriculture tend to experience greater losses of biodiversity. *Surface Area* and *Population, 2000 (ln)* correlate quite highly with one another as well as with Biodiversity Loss; indicating that larger nations (in terms of both area and population) tend to experience greater losses of their biodiversity. Interestingly, *Latitude*

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and birds as proxy species for all other potentially threatened species (Stork 1997).

correlates negatively with *Biodiversity Loss* and the two indicators of agricultural dependency, but positively with all three indicators of modernization and *World-System Position*. It would appear that there is a strong geographic effect, where in general, the further a nation is from the equator the greater its power and development, the lower its degree of agricultural dependency, and the higher its loss of biodiversity.

[Table 12 about here]

As with prior analyses, it is important to first examine the measurement model to ensure that the modernization latent variable is accurately capturing the intended underlying concept, which is the degree to which a nation is developed in terms of economics, technology, and standard of living. Figure 1 and Table 2 report this model.

[Figure 10 about here]

[Table 13 about here]

Unlike prior chapters, this measurement model only has three indicators of modernization. With only three items, the model has no degrees of freedom (6 elements and 6 calculated parameters), so a number of the model fit statistics are rendered meaningless. However, all three indicators load significantly and strongly onto the latent and the error terms are low, showing that the majority of the variance in the indicators is explained by the latent variable. This provides adequate support to include the latent variable in the subsequent structural models.

Figure 2 and Table 3 report the political economy model, which represents two of the main factors that were found relevant in the previously reviewed work on the social drivers of biodiversity loss (that nations higher in the world-system and more affluent nations experience greater amounts of biodiversity loss). This model is essentially testing the second, fifth, and sixth hypotheses.

[Figure 11 about here]

[Table 14 about here]

The political economy model specifies world-system position directly impacting modernization and indirectly impacting biodiversity loss through modernization's direct effects. The model as a whole has strong fit statistics; although the RMSEA and CFI are both reporting "perfect" fit scores as a the result of the chi-square being less than the degrees of freedom. This indicates that the model is perfectly specified (Kolenikov 2012). Interestingly, both modernization and world-system position have negative impacts on biodiversity loss (direct and indirect respectively), which contradicts both previous research as well as the second and fifth hypotheses. However, it is important to note the size of the error term for biodiversity loss in this model, which is quite high. This indicates that the amount of variance in biodiversity loss being explained by the model is rather low. While the predictors may have a significant negative effect on biodiversity loss, they are not accounting for a substantial portion of the variance in the dependent variable. This model is suffering from omitted variable bias, where the factors that are driving biodiversity loss are not adequately specified in this model.

Figure 3 and Table 4 report the first agricultural dependency model, which introduces a measure of agricultural dependency (indicated by *Agriculture as a Percentage of Gross Domestic Product, 2000*) as a mediating variable between modernization and *Biodiversity Loss*. This model represents the theoretical framework outlined in Chapter One. To summarize the specified relationships: more powerful nations use their positions of power to become more internally developed (H6). Part of this development involves creating a diversified and well-articulated economy. Consequently the more modern nations have a lower degree of agricultural dependency (H3). The process of development involves changes in land use that reduce biodiversity. Therefore, more developed nations will experience greater amounts of biodiversity loss (H2). Due to the associated amounts of external control and lower environmental regulations, higher degrees of agricultural dependency will lead to higher levels of biodiversity loss (H1). Finally, increased positions of power within the world-system hierarchy will also create higher levels of biodiversity loss (H5), net of other effects, due to the stronger history of internal resource exploitation that more powerful nations possess. These relationships are all tested in the agricultural dependency model.

[Figure 12 about here]

[Table 15 about here]

While the agricultural dependency model demonstrates a strong fit to the data, the relationships described in the model do not match all of those that were hypothesized. As with the prior chapters, the hypothesized relationships between world-system position, modernization, and agricultural dependency are all supported (Hypotheses three, four, and six). However, while agricultural dependency has the hypothesized positive effect on biodiversity loss, the effect is insignificant and therefore does not provide adequate support for the first hypothesis. As with the political-economy model, modernization has a significant negative effect on biodiversity loss, contradicting the second hypothesis. Finally, world-system position does not have a significant effect on biodiversity loss, contradicting the fifth hypothesis. Taken as a whole, this model does not provide much support for the theoretical framework being examined in this dissertation. As with the political-economy model, the error term for *Biodiversity Loss* is quite high, indicating that again the factors that are driving biodiversity loss are not adequately specified in this model.

Figure 4 and Table 5 provide an alternative model of agricultural dependency that uses *Agricultural Population, 2000* in place of *Agriculture as a Percentage of Gross Domestic Product, 2000* to represent agricultural dependency. Paralleling prior logic, this alternative indicator of agricultural dependency is tested to boost the internal validity of the findings and arguments. Other than the alternative indicator of agricultural dependency, this model specifies the same relationships and tests the same hypotheses as the previous agricultural dependency model.

[Figure 13 about here]

[Table 16 about here]

The alternative agricultural dependency model yields very similar results as the original, but with a few minor differences. The overall model fit was slightly improved, indicating a strong fit to the data. The relationships between world-system position, modernization, and agricultural dependency were all the same. However, in this model agricultural dependency (operationalized as the proportion of a nation's workforce employed in agriculture) does show the hypothesized positive impact on biodiversity loss, supporting the first hypothesis. Both modernization and world-system position demonstrate a negative impact on biodiversity loss, contradicting the second and fifth hypotheses. Additionally, as with the previous two models, the error term for *Biodiversity Loss* is quite high, indicating that again the factors that are driving biodiversity loss are not adequately specified in this model. Therefore, while this alternative agricultural dependency model provides support for the hypothesized nature of the primary relationship under investigation here, that support is minimal. The overall findings of all three of these models indicate that biodiversity loss is not strongly influenced by either agricultural dependency or broader political-economic structures and dynamics.

In light of the general lack of support for agricultural dependency or broader political-economic dynamics influencing biodiversity to a substantial degree, an alternate model was examined. Figure 5 and Table 6 report the human ecology model, which tests the relative influence of the geographic factors that have previously been found to exert a strong influence upon biodiversity loss (See pgs. 3, 8, 10-11). The model also includes measures of population and affluence, as these variables have been consistently found to predict biodiversity loss in both natural and social science studies. Finally, in order to continue testing the relevance of political-economic structures, the model includes world-system position. Rather than building this model deductively from hypotheses drawn from the theoretical framework outlined previously, the relationships in this model were derived from existing literature and specified through the model development approach (Garson 2012). Within the timeframe examined here, social factors cannot influence geographic features such as surface area and latitude. Therefore, those features are treated as exogenous variables. Additionally, as positions of power are thought to drive developmental factors, world-system position is also treated as an exogenous variable that impacts all social factors and biodiversity loss.

[Figure 14 about here]

[Table 17 about here]

The human ecology model is a distinct improvement over previous models in terms of the amount of variance in biodiversity loss being explained. While still high, the error term for biodiversity loss (0.81) is much lower than the previous models (0.98 and 0.97) and indicates that the variables in this model explain approximately 20 percent of the cross-national variation in biodiversity loss. Additionally, the model fit statistics are quite strong. However, like the political economy model, this model reports perfect scores for the RMSEA and CFI as the result of the chi-square being less than the degrees of freedom, indicating that the model is perfectly specified (Kolenikov 2012).

In terms of the substantive findings of this model, latitude demonstrated the expected negative effect on biodiversity loss. As greater amount of biodiversity tend to be found closer to the equator, there is a greater opportunity for biodiversity loss. Surface area had a positive direct effect on population size and through that, a positive indirect effect on biodiversity loss. This also supports previous findings. Population has a strong positive impact on biodiversity loss as an increased number of humans create increased demand for space, energy, and nutrient sources that other species need to survive and reproduce themselves. World-system position has the expected positive impact on affluence. Interestingly, it also has a positive impact on population, a result that runs contrary to the perception of the developing world housing the majority of the global population. However, when we consider that this is a national measure of population (as opposed to a cumulative score for all nations lower in the world-system hierarchy) as well as the fact that the five most populous nations in the world (China, India, The United States, Indonesia, and Brazil) all rank quite highly in the world-system according to the criteria used here (Kick et al. 2011), this finding is less surprising. In terms of world-system position's impact on biodiversity loss, there are offsetting effects. World-system position has a negative direct effect, which contradicts the fifth hypothesis. However, it also has a positive indirect effect, which supports the fifth hypothesis. Taken collectively, world-system position fails to generate a significant influence over biodiversity loss net of the other predictors. Finally, affluence was found to not have a significant effect on biodiversity loss, although the removal of that relationship from the model led to it not resolving. Clearly, it is an important factor, but it does not appear to be as important a predictor as latitude, surface area, and population.

The majority of the models reported above were also tested using the alternative indicators of biodiversity loss (*Threatened Bird Species*, *Threatened Mammal Species*, *Proportional Threatened Species*, and *All Species*. See page 15 for a full explanation.) The results of these additional analyses were mixed, but largely supportive of the general trends noted above. A number of the models failed to resolve outright. Those that did resolve often yielded poorer model fit statistics or fewer significant relationships than models using the original *Biodiversity Loss* indicator. Most importantly, none of the models that used the alternative ways of measuring biodiversity loss presented any findings that contradicted those presented here. While these findings did not present any additional insights, they did tend to confirm that the findings reported here were not an artifact of the particular manner in which biodiversity was operationalized.

Discussion

General Findings

This chapter of the dissertation examines the relationship between the division of labor in the global food and agriculture system and biodiversity loss. The findings generally do not support the strength or importance of that relationship and contradict the first hypothesis. More broadly, the findings of this analysis indicate that geographic and human ecology factors play a much greater role in determining biodiversity loss than political-economic ones. The first three structural models all had a very large error term for the dependent variable (*Biodiversity Loss*), indicating that they failed to explain a significant portion of the cross-national variation in that factor. However, the human ecology model has a substantially lower error term for biodiversity loss, indicating that geographic and human ecology factors explain a much greater portion of that variance. Like the prior chapters, these analyses find that world-system position positively affects modernization and negatively affects agricultural dependency, while modernization also negatively affects agricultural dependency. These findings collectively support the third, fourth, and sixth hypotheses. However, the political-economic structure that those findings represent does not appear to have a strong influence over biodiversity loss. Instead, latitude, surface area, and population are the more important factors in determining the amount of biodiversity loss a nation experiences.

Interpretation of Findings

The rationale behind the hypothesized positive impact of agricultural dependency upon biodiversity loss centers upon the logic that those nations which are economically dependent upon export agriculture will be more likely to co-opt land for agricultural use. That land will then be unavailable to support the various species that relied upon it for habitat and resources. This was not found to be the case. One possible explanation is that the co-optation of land for agricultural use is being driven more by domestic agriculture than export agriculture. Even as trade in agricultural products increases, nations still tend to consume more of what they grow than the amount that they export, particularly in developing nations (Clapp 2012; Weis 2007). Therefore, a greater amount of agricultural land is going to be devoted toward feeding a nation than producing agricultural exports. This explanation is somewhat supported by the different results obtained for the two different indicators of agricultural dependency. Where *Agriculture as a Percentage of Gross Domestic Product, 2000* did not show a significant impact upon biodiversity loss, *Agricultural Population, 2000* did. It is possible that the latter measure (the amount of people working in agriculture) is capturing a greater portion of agricultural activities oriented toward domestic consumption than the former (the relative amount of money being generated by agriculture). The argument that domestic agriculture is more relevant for biodiversity loss than export agriculture is also supported by the positive effect that population size has on biodiversity loss. The destruction of natural habitat for agriculture is one of the primary pathways through which increased human populations edge out other species (McKee et al. 2003). While this explanation is only offered as a post-analysis possibility, the central fact remains that agricultural dependency does not seem to have an impact upon biodiversity loss and the first hypothesis of this chapter is not supported.

While the political-economy and agricultural dependency models fail to explain a substantial portion of the variance, the human ecology model does account for approximately twenty percent of the cross-national variation in biodiversity loss. Given that the human ecology model also has excellent fit statistics, it would appear that geographic and demographic variables explain cross-national differences in biodiversity loss much better than political-economic ones. Surface area, population, and latitude are the three variables that significantly predict biodiversity loss. Given that surface area only influences biodiversity loss indirectly through its direct effects on population, it stands to reason that those two variables are both demonstrating a joint size effect, where the physically largest nations tend to have the largest populations and the greatest amounts of biodiversity loss. If biodiversity loss was occurring with a perfectly even geographic distribution (every square kilometer was losing the exact same number of species as every other square kilometer), than one would expect to see the same general effects for both surface area and population.

The negative effect of latitude on biodiversity loss is likely due to the ecological fact that, in general, more species occur closer to the equator than further away. The tropical regions that fall between positive and negative 23.5 degrees latitude are warmer and receive more solar energy than any other regions of the planet. These conditions are ideal for life and generate much higher levels of primary productivity that support a much wider range of species (Gaston 2000). Where there is a greater amount of biodiversity, there is a greater opportunity for biodiversity loss. With the human ecology model explaining so much more of the variation in the dependent variable than either the political-economy or agricultural dependency models, the broad conclusions that can be drawn from these analyses are that biodiversity loss tends to occur where there is dense biodiversity and lots of people.

The finding that ecological and geographic factors are more important than political-economy ones in explaining biodiversity loss is highly relevant and supports numerous arguments made elsewhere about the significance of physical variables in explaining social phenomena. The work of Jared Diamond (1997, 2005) may be the most prominent of such research, but there are a number of other scholars whose work examines the role of geography and ecology in shaping human actions and history (e.g. Cronon 2003; Davis 2000; Easterly and Levine 2003; McNeill, Padua, and Rangaragan 2010; Ponting 1991; Silver 1990; Turchin, Adams, and Hall 2006). While such work is often criticized as environmentally deterministic, a careful reading of it reveals that these analyses tend to give equal causal weight to both the actions or choices of human beings and the physical environments in which those actions or choices take place. This type of nuanced analysis has a long-standing tradition that traces back at least through the foundational work of Fernand Braudel (1992, 1995) that formed the basis of much of world-systems theory as well as the historical materialism of Karl Marx ([1876] 1976, [1894] 1981). The findings of this chapter lend support to the argument that social research should not limit itself solely to the social realm when seeking explanations.

The effects of world-system position and modernization on biodiversity loss are mixed, and do not offer much support for either the second or fifth hypothesis. In the political-economy model and both of the agricultural dependency models, world-system position and modernization either had negative effects on biodiversity loss or they did not have a significant effect at all. While these models fail to explain a substantial portion of the variance in biodiversity loss, the observed relationships do contradict the second and fifth hypotheses. Interestingly, in the human ecology model, which did explain a substantial portion of the variance in biodiversity loss, both world-system position and GDP per capita (one of the main indicators of modernization) fail to yield a significant total effect. This could indicate that the negative effects observed in the earlier model are actually a spurious relationship driven by the richer, more powerful nations tending to be found at higher latitudes (as demonstrated by the bivariate correlations described on pgs. 16-17). When latitude and population are controlled for in the human ecology model, the total effects of world-system position and GDP per capita no longer appear. It is entirely possible that the earlier effects of world-system position and GDP per capita are entirely driven by the same geographic feature that gives the "Global North" and "Global South" their respective names.

Shortcomings and Future Research

This research shares a number of shortcomings with the analyses of the previous chapter. It lacks a true longitudinal design and treats nation-states as homogenous units. Correspondingly, future research could address these weaknesses by obtaining adequate panel data and utilizing a longitudinal analysis, such as growth curve modeling or by analyzing sub-national units.[26] Future research should also explore the possibility that domestic agriculture rather than export agriculture is the primary driver behind the co-optation of land for agricultural use. As this may be the primary explanation behind the null-findings found in this chapter, it warrants greater attention. This possibility could be examined through national-level case studies that examine land cooptation and the destination of agricultural products. Or potentially a cross-national measure could be found that captures the relative proportion of domestic vs. export agricultural production. Such a measure would be problematic however, given that most statistics are recorded as measures of value while the subject of interest here would be the proportion of land-area being devoted toward one market or the other. As products that are exported tend to receive higher prices than those that are sold domestically, any value-based measure would overweigh the contribution of exports to land cooptation. (e.g. If a farmer cleared an acre of land to grow potatoes, that is a set contribution to biodiversity loss. However, if half of those potatoes are sold domestically, and the other half was exported for double the price, than any domestic/export ratio based on value would record the exported potatoes as contributing twice as much to biodiversity loss, despite both halves contributing equal amounts.)

More importantly, as this chapter has largely generated null findings and found that agricultural dependency is not a relevant factor in explaining biodiversity loss; future research should work on expanding and clarifying the human ecology model. In this analysis, that model was generated and presented as an alternative explanation for biodiversity loss. However, it was not as thoroughly developed, either empirically or theoretically, as the agricultural dependency model was. Future work should expand upon it and attempt to more thoroughly theorize and test the complex relationships between social, demographic, political-economic, and geographic features and how those factors influence a nation's amount of biodiversity loss.

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[26] See Pg. 27 of the Chapter Three for a more detailed discussion.

Alternative Measures and Variables Tested

In this section I briefly recount alternative models and variables that were tested but either failed to yield useful findings or produced models that did not resolve or adequately fit the data. In some cases, knowing what did not work and why can provide information that is useful in understanding the questions being explored. The purpose of this section is to both present that useful information as well as anticipate possible critiques and suggestions.

Initial attempts to construct the above models followed the first two empirical chapters in including life expectancy as a fourth indicator of modernization. For an unknown reason, including it in the models that were predicting *Biodiversity Loss* as the final endogenous variable caused the models to fail to resolve. This was discovered only through a process of trial and error where each indicator of modernization was removed in turn and the model tested without it. None of the other three indicators caused this problem. Additionally, as in the other two sets of analyses, I attempted to construct a model that used *Agricultural Exports as a Proportion of GDP* as a third indicator of agricultural dependence. While the models resolved and the measure of agricultural dependence was significantly related to both world-system position and modernization, it did not predict *Biodiversity Loss* to a significant degree. In some of the versions of the model including it, it even had a negative effect on *Biodiversity Loss*. Given the lack of consistent or significant findings, none of the models that used it as a measure of agricultural dependency were included in the final analyses.

As described above (see pgs. 15 and 27 for elaboration), I attempted to recreate my models with a number of alternative measures of biodiversity (*Threatened Bird Species*, *Threatened Mammal Species*, *Proportional Threatened Species*, and *All Species*). These additional analyses either failed to resolve or yielded similar findings but with poorer model fit statistics or fewer significant relationships. Given that these additional analyses did not contradict any of the findings of the models using the original *Biodiversity Loss* indicator or present any additional insights, they were not included.

As with the prior two chapters, I dropped the nine nations in my sample with populations under 500,000 and re-ran all of my analyses. Again, dropping those nations did not change any of the substantive findings, in some cases caused the models to fail to resolve, and yielded slightly worse model fit statistics in the cases where the model did arrive at a solution. As the removal of these cases did not contribute anything to the substantive findings of these analyses and in some cases weakened, or convoluted the findings, they were left in the models. Finally, as with the prior two chapters, I again attempted to test world-polity arguments by including a measure of state environmentalism (Roberts, Parks, and Vásquez 2004). Once more, this variable was positively predicted by modernization and world-system position, but failed to have a significant impact on the dependent variable and lowered the general model fit. For these reasons, it was not included.

Conclusions

Unlike the previous chapters, these analyses have not established a linkage between agricultural dependency and a form of environmental degradation. Instead, the findings presented here indicate that agricultural dependency is not a relevant factor in driving the loss of species. Instead, human ecology (e.g. population) and geographic features (e.g. latitude and land area) are more important in determining cross-national variation in biodiversity loss.

I argue that this is due to domestic agriculture (rather than export agriculture) being the dominant force in shaping the cooptation of wilderness areas for agricultural purposes. Furthermore, larger nations located closer to the equator are going to possess greater levels of pre-existing biodiversity, and therefore greater potential for biodiversity loss. While not supporting the theoretical framework of this dissertation, these findings demonstrate how environmental degradation is a complex and nuanced phenomenon that contains multiple causes and dynamics. Therefore, efforts to treat it as a homogenous outcome are fundamentally flawed in their logic and instead, the various different forms of environmental degradation need to be studied and understood separately.

The implications of these findings for ameliorating biodiversity loss primarily revolve around reducing population growth. While geographic regions cannot be adjusted, the actions of the human beings occupying those regions can. The important of population to environmental degradation has been well corroborated (e.g. Cohen 1995; Ehrlich 1968; York et al. 2003) and the findings of this chapter further support that importance. How best to reduce population growth (or population outright) is a topic of great debate, but some potential avenues for doing so include educating and empowering women (Malhotra and Schuler 2005), improving economic conditions in developing nations (Blackden 1999), and increasing sexual education and the availability of contraceptives (Casterline and Sinding 2000). At the same time, these findings do imply that efforts to preserve biodiversity loss would be most effective if targeted on specific regions. If geographic factors are determining where biodiversity loss is occurring the most, than those same factors need to be taken into consideration when determining how to best protect against further loss. Overall, a greater, more nuanced understanding of how social and natural systems interact is needed if we are to avert a sixth great extinction.

Table 12- Descriptive statistics and bivariate correlations (*n* = 161)

Parameter	*Mean*	*S.D*	*Skew*	*Min.*	*Max.*				
1- Biodiversity Loss, 2013 (ln)	-3.096	0.584	-0.083	-5.476	-1.232				
2- GDP per capita, 2000 (ln)	8.498	1.342	-0.091	5.017	11.143				
3- Urban Population, 2000	53.687	22.924	-0.073	8.246	98.110				
4- Energy Use per capita, 2005 (ln)	6.994	1.241	-0.311	2.841	9.916				
5- World System Position, 1999	5.068	2.369	0.351	1	10				
6- Agriculture as % GDP, 2000	16.295	14.823	1.201	0.355	76.074				
7- Agricultural Population, 2000	0.137	0.118	0.818	0.003	0.432				
8- Surface Area (ln)	11.477	2.473	-0.685	5.768	16.117				
9- Latitude	25.406	17.079	0.520	0	65				
10- Population, 2000 (ln)	15.451	2.049	-0.291	12.497	20.956				
Correlations	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
1- Biodiversity Loss, 2013 (ln)	1.000								
2- GDP per capita, 2000 (ln)	-0.183*	1.000							
3- Urban Population, 2000	-0.107	0.802*	1.000						
4- Energy Use pc, 2005 (ln)	-0.177*	0.824*	0.711*	1.000					
5- World System Pos., 1999	-0.045	0.445*	0.329*	0.335*	1.000				
6- Ag. as % GDP, 2000	0.138	-0.860*	-0.714*	-0.620*	-0.392*	1.000			
7- Agricultural Pop., 2000	0.171*	-0.809*	-0.774*	-0.731*	-0.328*	0.724*	1.000		
8- Surface Area (ln)	0.290*	-0.186*	-0.053	-0.006	0.178*	0.134	0.170*	1.000	
9- Latitude	-0.218*	0.548*	0.487*	0.583*	0.313*	-0.436*	-0.574*	-0.047	1.000
10- Population, 2000 (ln)	0.342*	-0.149	-0.092	-0.019	0.457*	0.069	0.141	0.732*	0.012

***p* <.05, two-tailed**

Table 13- Structural equation model of modernization latent variable, measurement model

	Unstandardized Value	*Standardized Value*
Loadings		
Per Capita GDP (ln)	1.00 (fixed)	0.96***
Percent Urban	14.74***	0.83***
Per Capita Energy Use (ln)	0.82***	0.85***
Variances		
e. Per Capita GDP (ln)	0.13	0.07
e. Percent Urban	160.89	0.31
e. Per Capita Energy Use (ln)	0.41	0.27
Modernization	1.66	1.00 (fixed)

********p* **<.001, two-tailed**

Table 14- Structural equation model of biodiversity loss, political economy model

Outcome	*Direct Effects*	*Indirect Effects*	*Total Effects*	*Stnd. Error*
Measurement				
Modernization →				
Per Capita GDP (ln)	1.00 (fixed)	---	1.00 (fixed)	(constrained)
Percent Urban	14.35***	---	14.35***	0.972
Per Cap. Energy Use (ln)	0.80***	---	0.80***	0.051
Structural				
Modernization ←				
World-System Position	0.25***	---	0.25***	0.040
Biodiversity Loss ←				
Modernization	-0.08*	---	-0.08*	0.035
World-System Position	---	-0.02*	-0.02*	0.009

Numbers in cells are unstandardized coefficients. Standard errors are reported for the total effects only.
******p* **<.05, *****p* **<.01, ******p* **<.001, two-tailed.**

Table 15- Structural equation model of biodiversity loss, agricultural dependency model

Outcome	*Direct Effects*	*Indirect Effects*	*Total Effects*	*Stnd. Error*
Measurement				
Modernization →				
Per Capita GDP (ln)	1.24***	---	1.24***	0.080
Percent Urban	20.34***	---	20.34***	1.794
Per Capita Energy Use (ln)	1.00 (fixed)	---	1.00 (fixed)	(constrained)
Structural				
Modernization ←				
World-System Position	0.18***	---	0.18***	0.034
Percent GDP in Ag. ←				
Modernization	-12.13***	---	-12.13***	1.166
World-System Position	---	-2.21***	-2.21***	0.416
Biodiversity Loss ←				
Percent GDP in Agriculture	0.01	---	0.01	0.003
Modernization	---	-0.07***	-0.07***	0.006
World-System Position	---	-0.01	-0.01	0.007

Numbers in cells are unstandardized coefficients. Standard errors are reported for the total effects only.
***p <.05, **p <.01, ***p <.001, two-tailed.**

Table 16- Structural equation model of biodiversity loss, alternative agricultural dependency model

Outcome	*Direct Effects*	*Indirect Effects*	*Total Effects*	*Stnd. Error*
Measurement				
Modernization →				
Per Capita GDP (ln)	1.21***	---	1.21***	0.071
Percent Urban	19.45***	---	19.45***	1.528
Per Cap. Energy Use (ln)	1.00 (fixed)	---	1.00 (fixed)	(constrained)
Structural				
Modernization ←				
World-System Position	0.18***	---	0.18***	0.034
Percent Pop in Ag. ←				
Modernization	-0.10***	---	-0.10***	0.008
World-System Position	---	-0.02***	-0.02***	0.003
Biodiversity Loss ←				
Percent Pop in Agriculture	0.84*	---	0.84*	0.384
Modernization	---	-0.09***	-0.09***	0.007
World-System Position	---	-0.02*	-0.02*	0.008

Numbers in cells are unstandardized coefficients. Standard errors are reported for the total effects only.
***p <.05, **p <.01, ***p <.001, two-tailed.**

Table 17- Structural equation model of biodiversity loss, human ecology model

Outcome	*Direct Effects*	*Indirect Effects*	*Total Effects*	*Stnd. Error*
Structural				
Population ←				
Surface Area (ln)	0.57***	---	0.57***	0.041
World-System Position	0.23***	---	0.23***	0.033
Per Capita GDP (ln) ←				
Population	-0.31***	---	-0.31***	0.052
Surface Area (ln)	---	-0.18***	-0.18***	0.032
Latitude	0.03***	---	0.03***	0.005
World-System Position	0.28***	-0.07***	0.21***	0.035
Biodiversity Loss ←				
Population	0.17***	-0.01***	0.15***	0.032
Per Capita GDP (ln)	0.05	---	0.05	0.043
Surface Area (ln)	---	0.09***	0.09***	0.017
Latitude	-0.01*	0.00	-0.01*	0.003
World-System Position	-0.06*	0.05**	-0.01	0.019

Numbers in cells are unstandardized coefficients. Standard errors are reported for the total effects only.
$^*p$ <.05, $^{**}p$ <.01, $^{***}p$ <.001, two-tailed.

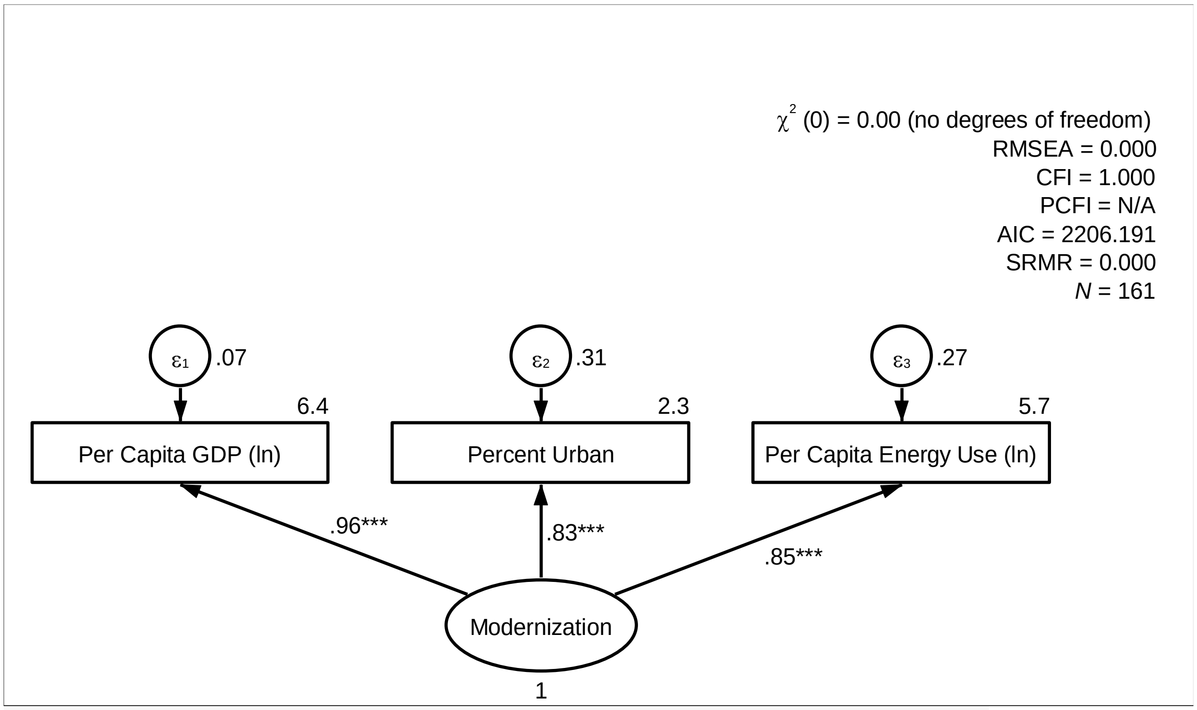

Figure 10- Structural equation model of modernization latent variable, measurement model. Path coefficients are standardized betas, ******p* **<.001, two-tailed

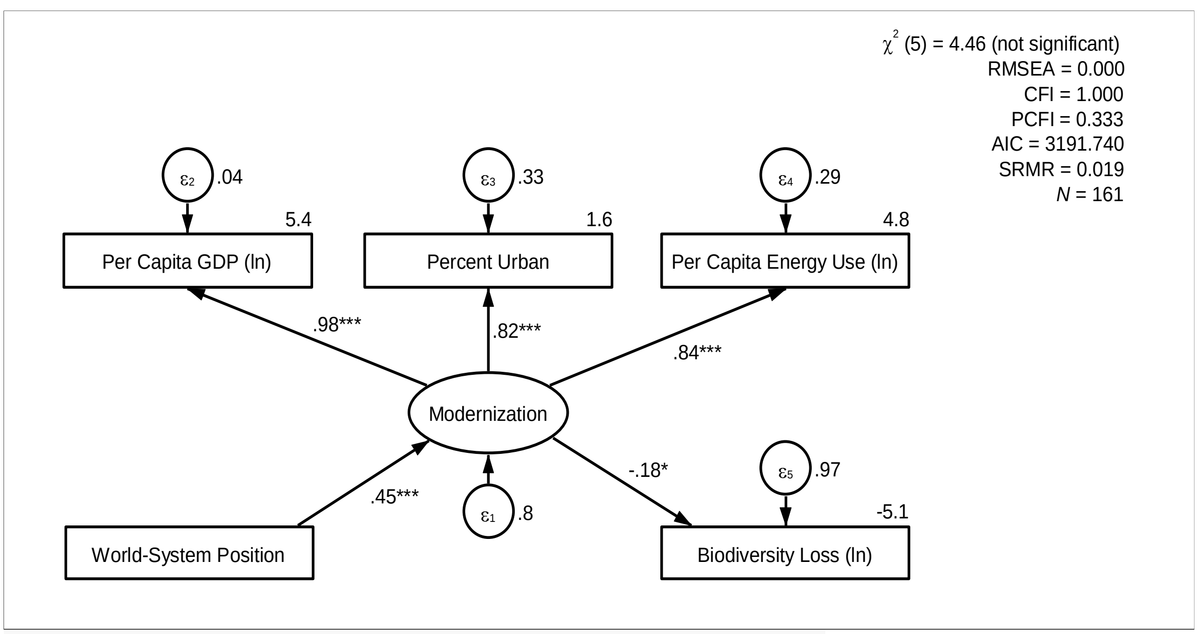

Figure 11- Structural equation model of biodiversity loss, political economy model. Path coefficients are standardized betas. ****p* **<.05, *****p* **<.01, ******p* **<.001, two-tailed.

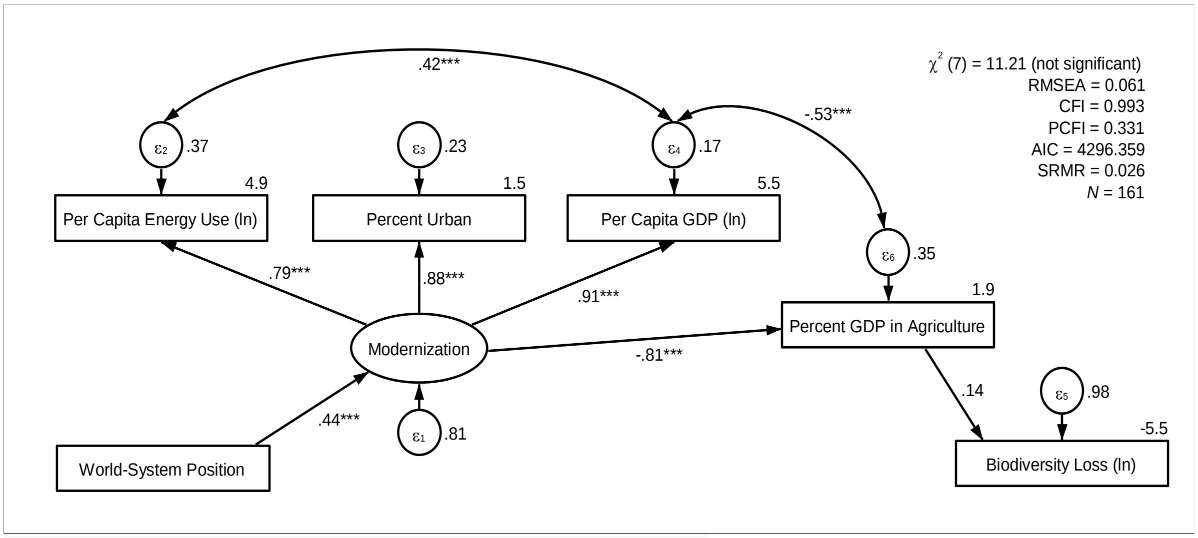

Figure 12- Structural equation model of biodiversity loss, agricultural dependency model. Path coefficients are standardized betas. *p <.05, **p <.01, ***p <.001, two-tailed.

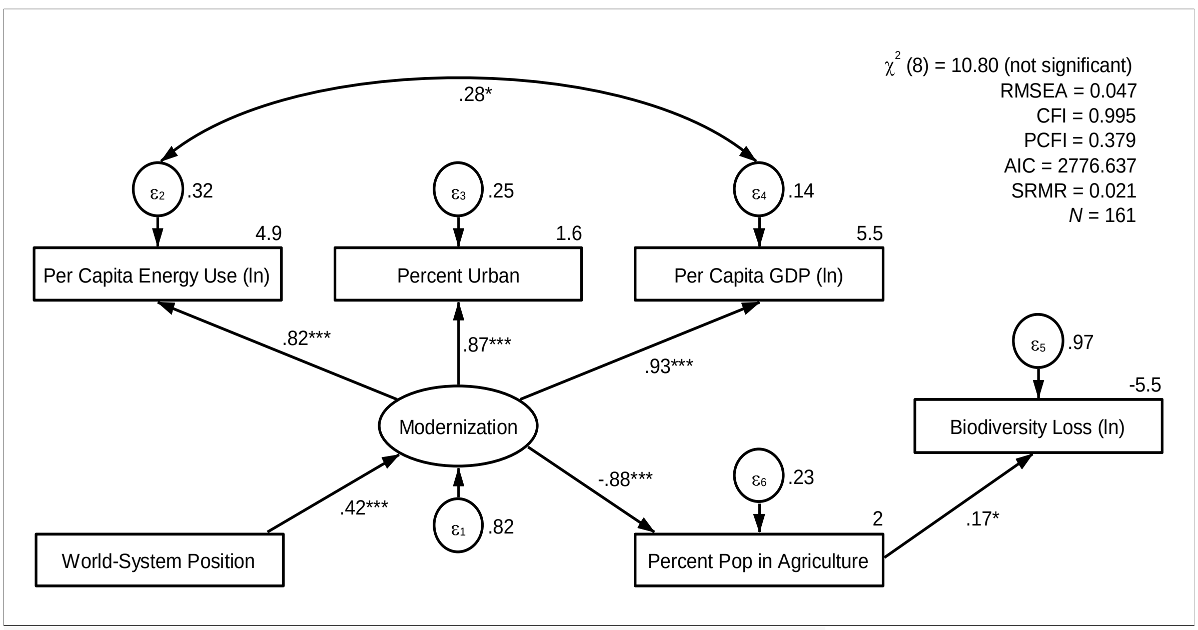

Figure 13- Structural equation model of biodiversity loss, alternative agricultural dependency model. Path coefficients are standardized betas. *p <.05, **p <.01, ***p <.001, two-tailed.

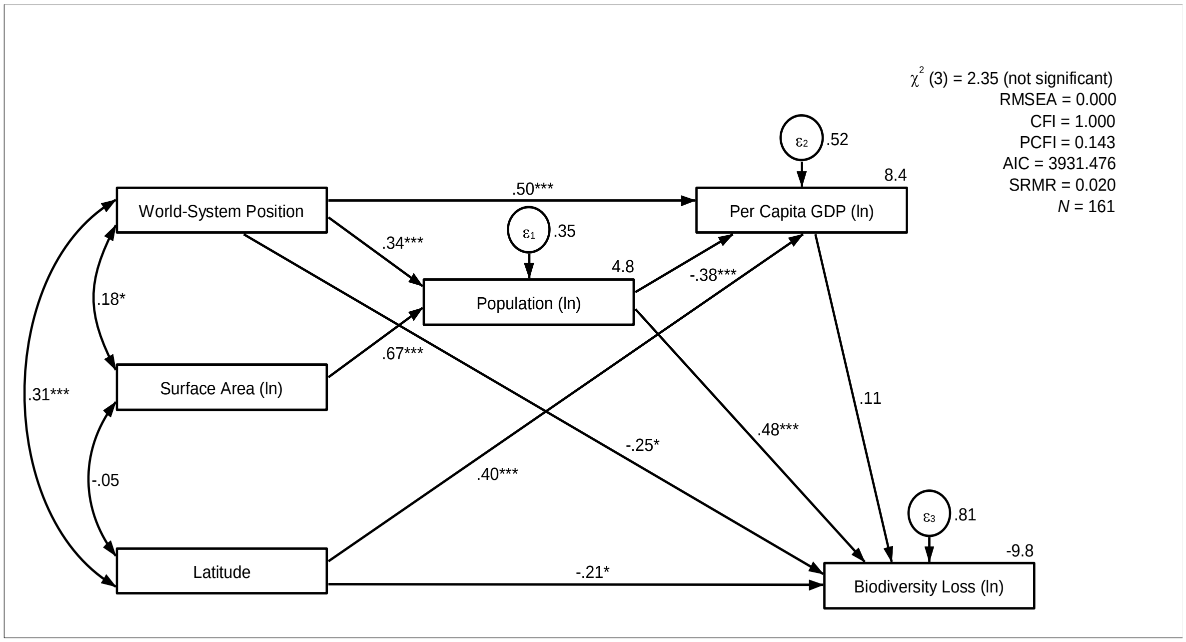

Figure 14- Structural equation model of biodiversity loss, human ecology model. Path coefficients are standardized betas. *p <.05, **p <.01, ***p <.001, two-tailed.

CHAPTER SIX- CONCLUSIONS AND IMPLICATIONS

Introduction

This final chapter will address the findings of the dissertation as a whole, stress the contributions of this work, and discuss its implications. I will review the central questions being asked in this dissertation and discuss how the analyses have provided answers to them. This discussion will apply to the dissertation as a whole, where earlier discussions have largely been limited to the separate chapters. I will discuss the arguments that are either supported or contradicted by these findings and what the greater conclusions are that can be reached from this work. Following this, I highlight the contributions of this study to environmental sociology, sociology as a whole, and our broader understanding of the relationships between the structure of the global food system and environmental degradation. After that, I discuss the implications of this work for the future and potential changes necessary to ameliorate future environmental degradation. I then review the shortcomings and limitations of this work and conclude with a discussion of future directions for this research agenda.

Discussion of Findings

Review of Findings

This dissertation has examined the relationships between positions of power within the world-system, modernization, agricultural dependency, and three specific forms of environmental degradation (nitrous oxide emissions, methane emissions, and biodiversity loss). The dynamic of central interest has been the connection between agricultural dependency and environmental degradation. Agricultural dependency is a term used to denote the degree to which a nation's economy is predicated upon the production of agricultural products for global markets. Agricultural dependency involves a substantial degree of external control by agro-TNCs. These agro-TNCs invest in nations with lower environmental standards as a consequence of their profit-seeking activities, do not possess incentives to protect the environments of the agriculturally dependent nations they are investing in, and are more likely to use outdated and ecologically inefficient technology in the production of agricultural goods for global markets. Therefore, agricultural dependency was expected to contribute directly to various forms of environmental degradation, including increased greenhouse gas emissions and biodiversity loss.

The findings of this dissertation both support and contradict the effect of agricultural dependency on environmental degradation. Among numerous other secondary findings, agricultural dependency was found to directly contribute to increased per capita emissions of nitrous oxide and methane gasses from agricultural activities. This means that the more a nation's economy was based upon the production of agricultural products for external markets, the greater amounts of two greenhouse gases (the second and third most important anthropomorphic contributors to global climate change) were produced by that nation's agricultural activities. These findings support the arguments of this dissertation. Alternatively, agricultural dependency was found to not substantially impact biodiversity loss. Instead, a nation's amount of biodiversity loss was driven by its latitude, surface area, and population. Taken broadly, this finding contradicts the arguments of this dissertation and instead supports general human ecology arguments about human societies being bounded by ecological constraints (see York, Rosa, and Dietz 2003).

Interpretation of Overall Findings

The key finding of this dissertation is the clear connection between agricultural dependency and increased levels of methane and nitrous oxide emissions from agriculture. As these two gasses are important anthropomorphic contributors to global climate change, one of the most critical environmental issues facing humanity today, this connection is of great importance. The nature and structure of our global food and agriculture system is the result of a history extending back (at least) to the era of colonialism (Mazoyer and Roudart 2006). As different nations and corporations have found and created new locations to grow various agricultural products, a vast and complex division of labor has been created. One of the consequences of this division of labor is that some nations end up engaging in more environmentally harmful behavior than others. Nations that are characterized by a high degree of agricultural dependency engage in agricultural practices that generate elevated amounts of both nitrous oxide and methane emissions. As increased amounts of these gasses are released into the atmosphere by human activities, an increased amount of heat is trapped on the planet. In this way, the nature and structure of our global food and agriculture system is directly contributing to anthropomorphic global climate change.

As discussed before, the agricultural activities conducted in nations with a high degree of agricultural dependence are controlled to a significant degree by outside interests. While data limitation prevented the direct measure of foreign control (See Chapter Two, pgs.

17-18), it is strongly implied by the measures of agricultural dependency that were used. Agro-TNCs that invest in agriculturally dependent nations have a structured profit motive that drives them to produce the most commodities that they can with the lowest amount of costs possible. While these agro-TNCs control (both directly and indirectly through contracts) farms throughout the world, there is much that they can do in agriculturally dependent nations that would encounter greater resistance if attempted in nations that did not rely so strongly upon export agriculture as their primary economic activity. They can use more nitrogen-intensive forms of agriculture that ultimately result in increased production of nitrous oxide (Snyder et al. 2009). Animal wastes can be improperly treated and stored, generating more nitrous oxide emissions than would be produced otherwise (Davidson 2009). Animals can be fed more cellulose-intensive diets, creating more direct methane emissions from those animals than if they were fed a more balanced diet (Ward et al. 1993). All of these various practices lead to greater amounts of greenhouse gasses being produced than would be if more environmentally sustainable agricultural practices were employed. As these practices are made possible due to these nations' degree of agricultural dependence, the contribution of the nature and structure of our global food and agriculture system to global climate change is clear.

An important secondary finding of the third and fourth chapters of this dissertation is the strong relationship between meat consumption, animal rearing, and greenhouse gas emissions. While not a connection of central interest to this research, or an effect that was directly measured in any of my models, this dynamic plays a key role in explaining a number of the findings in those chapters. Net of the effects of agricultural dependency, modernization has a positive impact on nitrous oxide emissions from agriculture and world-system position has a positive effect on methane emissions from agriculture. These findings are argued to be respectively driven by the relatively higher amounts of meat eaten in more modern nations (nitrous oxide emissions) and the greater prevalence of confined animal feeding operations in more powerful nations (methane emissions). Individuals within modern nations tend to consume much higher amounts of animal products than those within developing nations (Weis 2013). On a per-calorie basis, the rearing of animals generates far more nitrous oxide emissions than the raising of plant crops (Davidson 2009). Similarly, animals raised in more-powerful nations are far more likely to have been raised in some manner of confined feeding operation than those raised in less-powerful nations (Steinfeld et al. 2006). Animal manure in such operations is managed intensively, which results in a much greater amount of methane being generated per volume of waste (Bogner et al. 1995). In these ways, both increased modernization and positions of power within the world-system lead to greater production of important greenhouse gasses. Distinct from the effect of agricultural dependency on greenhouse gas emissions, these additional findings show how global meat consumption is another important contributor to anthropomorphic global climate change. This connection is of increased importance as world-wide meat consumption is projected to increase greatly over the next fifty years (FAO 2012; Nierenberg 2005).

While the findings of the fifth chapter of this dissertation do not support the connection between agricultural dependency and environmental degradation, they do demonstrate two important dynamics: 1) that environmental degradation cannot be accurately conceptualized or treated as a simple, homogenous outcome, and 2) that geographic and ecological variables are important for understanding the causes and consequences of environmental degradation. Addressing the first point, there is a strong tendency in environmental sociology to theorize and discuss environmental degradation as a single, unified outcome, rather than as an umbrella category for a wide range of different processes and outcomes. Many of the theorizations within environmental sociology describe how certain social processes either create or reduce environmental degradation; treating environmental degradation as a singular outcome (e.g. the treadmill of production theory [Schnaiberg 1980; Schnaiberg and Gould 1994] essentially argues that as profits are reinvested in the capitalist system, environmental degradation increases). Certainly, a great deal of focused work within the subfield includes more explanations of and explorations into the specific nuances surrounding the particular form of environmental degradation being studied. However, the broader versions of the theories have a tendency to discuss environmental degradation as a totality, rather than as a convenient term for grouping together a large number of divergent outcomes. [27]

As the results of the three empirical chapters of this dissertation have shown, some social processes or characteristics can have entirely different effects on different forms of environmental degradation. Agricultural dependency was shown to increase the amounts of nitrous oxide and methane emissions (two well-established forms of environmental

[27] There has also been a great deal of work within environmental sociology that looks at composite measures of environmental degradation. The most common of such measures is the ecological footprint, a national measure of the land requirements needed to meet a society's production, consumption, and waste storage needs (Wackernagel and Rees 1996). While this measure has been used in a number of prominent works within environmental sociology (e.g. Jorgenson and Clark 2009; York, Rosa, and Dietz 2003), it is somewhat problematic and has received a fair measure of criticism for its excessive focus on energy use, greenhouse gas emissions, and lack of factoring in the intensiveness of primary production (Fiala 2008; Gordon and Richardson 1998; van den Bergh and Verbruggen 1999; Wiedmann and Barrett 2010).

degradation), but have no effect on biodiversity loss (a different, but equally well-established form of environmental degradation). Collectively, those findings demonstrate how different forms of environmental degradation can respond quite differently to the same social processes and factors. This is not surprising when one considers the extreme complexity of ecosystems and the wide range of nuanced reactions those systems can have to anthropomorphic perturbations. If we consider environmental degradation as an anthropomorphic disturbance that disrupts a natural system's normal operation and reduces its capacity for self-renewal, then each form of environmental degradation will possess a wide range of unique aspects. While it is certainly useful to consider some human actions as collectively contributing to a negative environmental outcome (such as the production of greenhouse gasses contributing to global climate change), the findings in this dissertation reveal the need for caution when attempting to aggregate the large, complex amount of heterogeneous processes and outcomes that are often grouped together as environmental degradation.

In addition to demonstrating the heterogeneous and multi-faceted nature of environmental degradation, the findings of the fifth chapter also serve as a powerful reminder of the importance of geographic and ecological variables in explaining the causes and consequences of environmental degradation. This insight is far from new, having been presented by the Chicago human ecology school of thought (Duncan 1959; Duncan 1964; Hawley 1950), the founders of environmental sociology (Catton and Dunlap 1978; Dunlap and Catton 1979), and more recently by Jared Diamond (1997, 2005).[28] However, it is one that is often downplayed in environmental sociology and has yet to find purchase in the broader field of sociology (Catton 1994; Dunlap 2002, 2010). The relevance of physical variables to sociology has been greatly contested over the discipline's history, with many citing Emile Durkheim's (1951, 1984) arguments that social facts need to be explained by social facts or Max Weber's (1949, 1990) arguments that one needs to focus upon the "social meaning" behind the actions of individuals to understand those actions as grounds for dismissing any study of ecological or geographic factors as environmentally deterministic. However, this interpretation of the arguments of Durkheim and Weber largely stems from reliance upon secondary interpretations of the original writings which have largely been sanitized of ecological concepts (Buttel 1986). Careful reading of the original works reveals an awareness of the relevance of natural resources and environmental factors in shaping human history (Catton 2002; Foster and Holleman 2012; Murphy 2002; Rosa and Richter 2008; West 1985). However, the perception remains throughout the field of sociology that physical factors are not appropriate topics for sociological research.

This perception is especially problematic within environmental sociology, a sub-field largely concerned with understanding the social origins, contexts, and consequences of environmental degradation. Environmental degradation possesses a basis in material reality that requires the incorporation of physical variables and outcomes into both theory and

[28] While the insight that geographic and ecological variables can be highly relevant in explaining historical and social phenomena is downplayed in most of the social sciences, there are a number of sub-fields such as environmental history (see Cronon 2003, 1991; Davis 2000; McNeill, Padua, and Rangaragan 2010; and Silver 1990), as well as exceptional work in other disciplines that examines the role of such physical factors (e.g. Easterly and Levine 2003; Ponting 1991; Turchin, Adams, and Hall 2006).

empirical analyses that explore it. The importance of physical variables in explaining environmental degradation is demonstrated in the findings of Chapter Five. In those analyses, a substantial portion of the variance in a nation's amount of biodiversity loss is driven by its latitude and surface area; two geographic features. The models that attempt to explain biodiversity loss using only political-economic factors are greatly lacking. As with a great number of other forms of environmental degradation, ecological and geographic factors play important roles in explaining the origins and distribution of biodiversity loss and need to be included in research on that phenomenon. As environmental sociologists incorporate such variables into their work, it is important that they continue to read and draw from work being done in the natural sciences, which often focuses solely upon those physical elements. The natural sciences have generated a wealth of knowledge regarding the properties and operation of the physical world. As environmental sociologists integrate that physical world into the social, it is imperative that they draw from that existing body of knowledge. The findings of the fifth chapter of this dissertation, particularly relative to the third and fourth, provide strong evidence to this need.

Contributions

The primary contributions of this dissertation research are: 1) providing arguments and evidence as to the negative environmental impacts of agricultural dependency; 2) providing arguments and evidence as to the complexity of environmental degradation as an outcome; 3) making a number of methodological improvements upon existing research within environmental sociology; 4) providing an example of how environmental sociology can incorporate work from the natural sciences; and 5) demonstrated the utility of an integrative, rather than competitive approach to the construction of knowledge. The first contribution is of great importance as both the global population continues to grow (Cohen 2003; Meadows, Randers, and Meadows 2004) and our food and agriculture system becomes increasingly transnational in its organization and structure (McMichael 2005; Weis 2007). Some work within environmental sociology has pointed toward specific ways in which our global food and agriculture system may be environmentally unsustainable (e.g. Clapp 2003; Frey 1995; Jorgenson 2007a, 2007b; Jorgenson and Kuykendall 2008; Longo and York 2008). However, this dissertation attempted to more broadly examine the environmental consequences of the structure of our global food and agriculture system. By theorizing and empirically demonstrating the connection between agricultural dependency and multiple forms of environmental degradation (both nitrous oxide and methane emissions) this dissertation increases our understanding of the environmental consequences of how we grow and trade useful plants and animals. This increased understanding represents a contribution to both environmental sociology and our broader understanding of the nature and origins of anthropomorphic environmental degradation.

In addition to demonstrating the connection between agricultural dependency and environmental degradation, this dissertation research also provides evidence as to the multi-faceted nature of environmental degradation. It makes a strong argument that different forms of environmental degradation need to be theorized and studied independently, as they possess very different causal mechanisms and impact human societies in very different ways. This is evidenced by the very different results found for the causal mechanisms of nitrous oxide and methane emissions from agriculture verses biodiversity loss. This insight is highly relevant to theorization and research within environmental sociology as well as the broader field of environmental studies. While it is important that we continue to study environmental degradation broadly, it is equally important that all such work takes into account the fact that environmental degradation is not a uniform, singular outcome. Different processes can affect diverse forms of environmental degradation in very different ways. In some cases, a particular factor may help ameliorate some forms of environmental degradation while worsening others. For example, urban recycling programs have been shown to reduce household waste volume and natural resource depletion while at the same time increasing energy use and general consumption (Weinberg, Pellow, and Schnaiberg 2000). The findings of this dissertation serve as a clear reminder that environmental degradation is a complicated constellation of heterogeneous processes and outcomes that cannot be easily or accurately reduced to a simple number.

The third contribution of this dissertation research is the number of methodological improvements it makes upon previous research within environmental sociology that has explored similar topics. First off, through using structural equation modeling and combining a number of highly correlated independent variables into my modernization latent variable, this research has managed to avoid a great deal of the multicollinearity that plagues nearly all cross-national research (Babones 2014; Firebaugh 1983). Such an approach explicitly models the shared covariance among the predictors and treats that shared covariance as a separate variable in the model. As it actually examines the effects of the shared covariance among the collinear variables, this approach is a clear improvement over attempts to treat multicollinearity by either residualization (York 2012) or mean-centering (Echambadi and Hess 2007), two of the more common practices used to address issues of multicollinearity.

In addition to the improved treatment of multicollinearity, this dissertation is an improvement over prior work in the social sciences that has explored either nitrous oxide and methane emissions (Burns, Davis, and Kick 1997; Dick and Jorgenson 2010; Jorgenson 2006; Jorgenson and Birkholz 2010; Rosa, York, and Dietz 2004) in that it examines one specific source of those emissions, rather than aggregating together emissions from different sources. Both of these gasses are produced by a wide range of human activities, many of which are regulated and structured through a wide range of social dynamics and relationships. Examining total emissions can lead to errors of aggregation, wherein independent processes and causal mechanisms are treated as singular dynamics. By way of example, increased urbanization may reduce carbon dioxide emissions from transport, as individuals are living closer to their jobs and shopping centers. However, that same process may increase carbon dioxide emissions from deforestation and biomass burning as the vegetation must be cleared to create more urban space. These offsetting effects can be lost when a researcher examines total emissions. However, by studying a specific source of emissions, it is possible to more clearly illuminate the causal relationships at work. Through examining emissions from agriculture, it has been possible to more clearly identify the distinct contributions that agricultural dependency makes to those emissions. In this way, the research in this dissertation represents a clear improvement over prior studies of nitrous oxide and methane emissions in the social science.

The third methodological improvement this dissertation makes over prior work that has explored similar topics is that it utilizes a more representative sample of nations than a number of prior studies have. Given that cross-national analyses are typically using near-population data (all nations for which data is available) to make claims about the global system, it is important that these analyses include the majority of nations to avoid substantial selections effects or sample bias (Babones 2014). Some prior studies that have examined the effects of agricultural dependency at the cross-national level have used rather robust samples of up to 147 nations (Longo and York 2008). Others, however, due to data restrictions have used much smaller samples of 35 (Jorgenson 2007b; Jorgenson and Kuykendall 2008) or 40 nations (Jorgenson 2007a). With sample sizes ranging from 130 to 161 nations, the analyses in this dissertation represent a clear improvement upon the latter. Similarly, prior studies of methane emissions have ranged from robust samples of 105 (Burns et al. 1997) and 131 nations (Rosa et al. 2004) to samples as small as 36 nations (Jorgenson and Birkholz 2010). The one prior study of nitrous oxide emissions had a sample size of 44 (Dick and Jorgenson 2010). The analyses of nitrous oxide and methane emissions in this dissertation had sample sizes of 131 and 130 nations (respectively), which again represent clear improvements over the prior studies with smaller samples sizes. Previous cross-national work that has examined biodiversity loss has tended to use larger samples than those looking at nitrous oxide and methane emissions, with *n*’s ranging from 74 to 139 nations (Hoffman 2004; McKinney et al. 2009; McKinney et al. 2010; Shandra et al. 2009).

The fourth contribution of this dissertation is how it demonstrates the importance of incorporating research from the natural sciences and provides examples of ways in which such work can be integrated into social science research on environmental issues. All three of the empirical chapters in this dissertation drew heavily from research within the natural sciences on their respective forms of environmental degradation. That work informed both the understanding of the origins of each form of degradation as well as the negative consequences of each for human societies. As described above, ecological and geographic factors are highly relevant for understanding of the nature and origins of environmental degradation. If such factors are to be incorporated into social science research on the environment, then it is prudent to rely upon the work of scholars whose fields are focused upon the study of such factors. Those literatures and methodologies are well-developed and constitute a wealth of knowledge that can be drawn upon by the social sciences. While some work within environmental sociology does an excellent job of drawing upon the natural sciences to inform the integration of physical dynamics into their research (e.g. Clark and York 2005; Clausen and Clark 2005; Clausen and York 2008; Hoffman 2004; McKinney et al. 2010), this work tends to be the exception, rather than the rule. This dissertation provides an example of how both environmental sociology and sociology as a whole can benefit from crossing disciplinary boundaries and incorporating insights from the natural sciences.

Finally, this dissertation makes an important contribution to how we perform science as it provides an example of an integrative, rather than competitive, approach to the construction of knowledge. Many studies are organized around testing competing explanations with the goal of valorizing one particular theory at the expense of others. As the sociology of science informs us, the incentive structure of academia favors researchers who can continually demonstrate support for “their” theory (Merton 1973). This incentive structure can lead to an allegiance that is somewhat decoupled from the theory's scientific merit. Rather that structure this dissertation around providing support for one theory at the expense of another, I drew insights from two complementary bodies of theory; dependency/world-systems theory and food regime analysis. I used food regime analysis to provide a historical context to the global food and agricultural system and to establish a framework for interpreting my findings. I drew my concept of agricultural dependency from the dependency/world-systems theory school of thought and relied heavily upon arguments from that body of work as to the nature of exploitive core-periphery relations and the power structure of the global economy. In this way, I was able to draw insights from multiple bodies of work to better understand the operation of the global food and agriculture system and its consequences for the physical environment. Therefore, this dissertation provides an example of how an integrative, rather than competitive, approach to science can contribute to the construction of knowledge.

Shortcomings and Limitations

As a great deal of the shortcoming and limitations of this dissertation have been previously described in the empirical chapters, I only briefly review them now. As with so much of cross-national research, one of the biggest weaknesses of this dissertation has been the limited data availability. While my samples have tended to encompass all nations for which the required data were available (and even imputed some missing data points to preserve cases), there were still a number of nations omitted. As with other cross-national research, those nations tended to be the smaller ones or those facing challenges with data collection and/or sharing (e.g. North Korea). In addition to excluded nations, there were a number of variables that would have been highly relevant to the dynamics studies here (e.g. FDI in agriculture and forestry), but were not available for a sufficient number of nations and could not be included without severely restricting the sample size.

An additional shortcoming of this research is its lack of a longitudinal design, a problem that is common in quantitative macro-comparative research (Babones 2014). The examination of a single time point, even with lagged independent variables, makes it more difficult to establish convincing causal arguments (Singer and Willet 2003). However, even longitudinal methods such as panel regression and growth curve analysis possess a number of weaknesses concerning the establishment of causality and should not be automatically assumed as superior in that regard (Bollen and Brand 2010). In addition to the lack of a longitudinal design, this research is limited by its treatment of nation-states as homogenous units. As nation-states are political units that contain a wide variety of peoples and regions, any research that using the nation-state as its unit of analysis is accepting a certain amount of aggregation error. Therefore, research that uses the nation-state as the unit of analysis must be interpreted with the important caveat that sub-national variation and internal processes are unaccounted for in this research design. However, as the nation-state is an important political actor in a number of relevant processes and there are no consistent sub-national units of analysis to use as an alternative, the nation-state is the most appropriate unit of analysis (Babones 2014).

Future Research Directions

Having previously discussed some of the shortcomings of the dissertation, there is a necessary logic for future research that would address those shortcomings. As new sources of data become available, it may be possible to include more nations in future analyses as well as explore the effects of certain variables (such as FDI in Agriculture and Forestry) that were excluded from the dissertation analyses due to limited availability. It would even be informative to examine smaller samples for which data on such variables are available to see how those findings either support or contradict those found here. Additionally, if longitudinal data were to become available (as it likely will over time), these same dynamics could be examined in a longitudinal fashion, to explore how these relationships change over time and to better establish their causal nature. Such a desire for longitudinal data is nearly a ubiquitous feature of cross-national research (Babones 2014).

Aside from directly addressing the shortcomings of this research, there are a number of exciting avenues for future explorations. Given how many of the arguments in this dissertation revolved around meat consumption and the prevalence of confined animal feeding operations, it would be highly informative to attempt to measure those features directly. If data could be obtained on national level per-capita meat consumption or the proportion of animal products in a nation that were produced in an industrial operation, it would be possible to directly test some of the explanations offered in this research. Additionally, as the theoretical framework outline here makes the argument that agricultural dependency is broadly linked to environmental degradation, it would be worthwhile to examine a number of other forms of environmental degradation to see how well this argument holds true. Particularly as the results here demonstrate the relative multi-faceted nature of environmental degradation, there is ample cause for testing other forms of degradation.

Finally, the findings and arguments of this dissertation would be greatly bolstered if they were supplemented by in-depth case studies that helped flesh out the unique circumstances of the relationships that are described here. A triangulation of different methodologies can only strengthen the credibility and validity of findings, as long as the different findings corroborate one another (Babbie 2013). For this research agenda, identifying and studying a specific national agricultural export in a relatively agriculturally dependent nation (e.g. the cocoa industry in Cote d'Ivoire or the tobacco industry in Malawi) would potentially allow for the clear identification of the relationships between external control and environmentally destructive practices. In such a case study, it would be possible to directly establish foreign ownership of the industry, the organization structure involved, and the decision making practices that shape the type of agricultural methods used. Such in-depth understanding of a specific case would lend this research—and the arguments extended from it—a much greater degree of internal validity.

Implications

The findings of this dissertation research have numerous implications for the environmental sustainability of our current global food and agriculture system and how that system may impact global climate change in the years to come. First and foremost, the main finding of this dissertation—that the nature and structure of our global food and agriculture system is directly contributing to anthropogenic climate change—has important and dire implications for the near future. While world population growth has begun to slow, it is still increasing at an exponential rate and is expected to reach 8 to 10 billion individuals by the year 2050 (Cohen 2003, 2005; Meadows et al. 2004). As those individuals will need to be fed, our global food and agriculture system will need to experience a corresponding expansion. In addition to producing more food, that system is expected to become increasingly organized at the global, rather than national level (Clapp 2012; Weis 2007). As this dissertation has shown how the current structure of the international food and agriculture system is contributing to global climate change, the result of this expected growth in that system and intensification of its transnational structure would logically be an increased production of greenhouse gasses and elevated contribution to global climate change. Increased global emissions of methane and nitrous oxide since pre-industrial times already account for over 20 percent of the enhanced greenhouse effect (Scheehle and Kruger 2006). If current trends continue, these emissions will continue to increase and global climate change will continue to intensify.

While the exact consequences of global climate change and their severity remain under vigorous discussion, there is a growing consensus as to the general nature of those repercussions. Those impacts will vary greatly by region, being beneficial in some area and harmful in others. However, the overall effects are expected to be damaging and to increase over time (IPCC 2007). Global climate change is expected to contribute to the loss of major ice sheets, including both ocean and land-based glaciers. The loss of glacial freshwater supplies and mountain snowpack is expected to severely affect agriculture in regions that rely upon such water sources for irrigation. The melting of ocean glaciers and the polar ice caps will contribute to rapid sea-level rise and the associated loss of coastline areas (NASA 2014). Global climate change is also expected to create regional climate disruptions. These can include increased heat waves, increased and more severe droughts, and an increase in the number, duration, and intensity of tropical storms. Global climate change could even trigger the collapse of major climate dynamics such as the thermohaline circulation (Rockstrom et al. 2009b). Finally, global climate change may contribute to more frequent and severe wildfires and abrupt shifts in forest and agricultural systems as land and climate suitability for particular forms of plant growth are altered (Richardson, Steffen, and Liverman 2011).

The last possible consequence is particularly problematic with the dynamics being explored in this dissertation, as the potential exists for a positive feedback loop between our global food and agriculture system and global climate change (Rockstrom et al. 2009b). As shown in this dissertation, the nature and structure of the system in which we raise and trade useful plants and animals is already contributing to global climate change. As that change creates shifts in the location and productivity of agricultural regions, it is possible that the contribution of the global food and agriculture system to greenhouse gas emissions will increase, further exasperating the negative consequences of global climate change for agriculture. While this connection is largely speculative at this point in time, the possibility exists that how we feed ourselves today will potentially ruin the environmental conditions necessary for us to feed ourselves tomorrow. The precautionary principle would encourage us to address this possibility before confirming it as a certainty, given the nature of the consequences.

When contemplating possible solutions, there are no easy or immediate remedies. As a substantial portion of the problem has been demonstrated to stem from the structure of our global food and agriculture system, a necessary part of the solution would be radically restructuring of that system. A comprehensive review of such changes is beyond the scope of this dissertation, but it is possible to briefly describe some of the potential alterations that could help return that system to a more environmentally sustainable footing. In essence, there would have to be two main shifts: 1) a movement from global integration toward locally-based food systems, and 2) a shift toward traditional and alternative agricultural technologies. The first shift is somewhat straightforward, but still daunting. A more local-based food system would focus upon the production of staples for consumption by surrounding communities, rather than exotics for trade and export. It would also involve a radical change in consumers' diets, as individuals would be limited to the plants and animals that can be easily grown within their region. While such a shift would require a great deal of effort and organization on behalf of a wide range of actors (including but not limited to nation-states, agro-firms, non-government organizations, and consumers) elements of such a change do exist. Individuals and organizations world-wide are building a grassroots movement for a sustainable, local food and agriculture system (Henderson 2000). Additionally, such a local food system may be an inevitable outcome of rising fuel prices that would make transporting food across long distances cost-prohibitive (Steiner 2009).

In regards to the shift toward traditional and alternative agricultural technologies, a more environmentally sustainable global food system would need to reply upon increased amounts of integrated planting as opposed to mono-culture, which would reduce the amount of both pesticides and fertilizers required to raise crops (Altieri 2000). Furthermore, a more regular pattern of crop rotation would lead to better soil management and a reduced need for external fertilizers. The use of organic and green fertilizers (including animal manure) would help maintain farm output while releasing far less damaging chemicals and nutrient pollution into the surrounding environment (Butler, Vickery, and Norris 2007). Additionally, applying manure directly to fields would allow the manure to break down aerobically and be absorbed by crop plants, rather than breaking down anaerobically in lagoons to produce elevated levels of nitrous oxide and methane (Wuebbles and Hayhoe 2000). It is important to note that while these alternative agricultural technologies may prove more environmentally sustainable, they are likely to reduce the output and profitability of agriculture. A large portion of the transition to modern, industrial agricultural methods was driven by profitability concerns. While the current global food and agriculture system has serious problems with environmental sustainability and issues of equity and distribution, most scholars and policy makers agree that it is delivering the greatest volume of food ever while generating the greatest amount of revenue ever (Kiers et al. 2008).

The possibility of a viable, locally-based national food system is supported by the example of Cuba following the collapse of the Soviet bloc which, combined with the U.S. embargo, left Cuba virtually isolated in regards to international trade (Rosset 2000). Despite the lack of markets for their predominant agricultural export (sugar) and a severe decline in imports of food stuffs, pesticides, fertilizers, and fuel, Cuba managed to weather an internal food crisis and rebuild its food system to virtual self-sufficiency in just over five years. The combination of a sweeping land reform program that turned 80 percent of state-held land over to workers and a shift toward agroecological technologies (organic fertilizers, biopesticides, crop rotation, animal power, etc.) enabled Cuba to reach near independence from the global food and agriculture system (Funes et al. 2002; Wright 2012). It is debatable whether the Cuban case-study represents a viable alternative food system model to the global norm or is simple a unique case that cannot be generalized to other nations. Regardless, it does stand as strong evidence that there are workable alternatives to the current globally integrated system with its associated environmental issues (Rosset 2000).

The problems describe above concerning the impacts of the global food and agriculture system on global climate change (and the environment more broadly) are only magnified by the projected increase in global meat consumption over the next fifty years (FAO 2012; Steinfeld et al. 2006). As described earlier, both meat-intensive diets and the prevalence of confined animal feeding operations are strongly linked to increased production of greenhouse gasses. Therefore, as the amount of animal products consumed world-wide increases and more of those products are raised in industrial-style operations, we can expect to see a corresponding increase in global climate chance and all of its associated consequences. Given that the volume of animal products being consumed and the way in which those animals are being raised and cared for are the important contributors to global climate change, the potential solutions revolve around reducing world-wide meat consumption and reverting from confined animal feeding operations to more traditional methods of animal husbandry.

While meat and animal products are an important source of protein in many diets worldwide, the amount of such foods present in a typical Western diet greatly exceeds what is required for nutritional purposes (Cordain et al. 2005). A vegetarian diet based on cereals, pulses, nuts, vegetables and fruits has been demonstrated to provide sufficient nutrition, lower the risk of numerous diseases, and promote longevity among Westerners (Key, Davey, and Appleby 1999). Accordingly, a global diet with reduced levels of meat would be more than adequate to meet nutritional needs and would help diminish the amount of greenhouse gasses being produced, slowing global climate change (Nierenberg 2005; Popp, Lotze-Campen, and Bodirsky 2010). A shift to less meat-intensive diets would also yield benefits in that it would reduce the total amount of agriculture required to support a given population. It has been long known and well established that you can feed a greater amount of people on a plant-based vs. animal-based diet (Goodland 1997; Marlow et al. 2009; Pimentel and Pimentel 2003). Therefore, as less meat is consumed, less agriculture is needed and all of the associated environmental issues are reduced correspondingly.

Finally, a shift from confined animal feeding operations to more traditional, free-range modes of animal husbandry would help slow global climate change as animal manure in industrial operations tends to break down anaerobically, releasing more greenhouse gasses than manure that breaks down in aerobic conditions (Bogner et al. 1995). This is just one of the many environmental problems associated with confined animal feeding operations (see Burkholder et al. 2007; Kirby 2010; Niman 2009; and Steinfeld et al. 2006 for reviews). Current world-wide trends are in the direction of more widespread adoption of confined animal feeding operation (FAO 2013; Weis 2013). If this trend continues, the per-item impact of animal products on global climate change will only worsen. Raising more animals with traditional methods—where animals are outside and have room to ambulate—will help reduce the environmental impact of such operations, if reducing their profitability (Gurian-Sherman 2011).

While all of the changes broadly outlined here would help alleviate the problems demonstrated by this dissertation and make the global food and agriculture system more environmentally sustainable, none of them will occur easily, quickly, or without effort. A great deal of work and resources are required on multiple scales. There needs to be changes in the personal decisions of workers and consumers in both the developed and developing worlds, as well as broad alterations in the policies of governments, non-government organizations, and corporations. While this dissertation has focused on one small corner of the environment crisis currently confronting humanity, most of its findings and their implications can be extended to other realms of human action and other spheres of environmental degradation. How we, as individuals and societies, chose to alter our behavior will in no small way determine how humanity weathers the environmental crisis and the type of civilizations that will emerge from it.

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APPENDICES

Appendix A: Imputed Data Points

GDP pc, 2000	Energy Use pc, 2005	Agriculture as a % of GDP
Cuba	Burkina Faso	Cape Verde
Zimbabwe	Burundi	Greece
	Central African Republic	Guatemala
	Chad	Guinea-Bissau
	Lao, PDR	Haiti
	Liberia	Israel
	Madagascar	Libya
	Malawi	
	Mali	
	Mauritania	
	Niger	
	Rwanda	
	Sierra Leone	
	Uganda	

Appendix B: Nations in Chapter 3 Analyses

Albania
Algeria
Angola
Argentina
Armenia
Australia
Austria
Azerbaijan
Bahrain
Bangladesh
Belarus
Belgium
Benin
Bolivia
Bosnia and Herzegovina
Botswana
Brazil
Brunei
Bulgaria
Cambodia
Cameroon
Canada
Chile
China
Colombia
Congo, Dem. Rep.
Congo, Rep.
Costa Rica
Cote d'Ivoire
Croatia
Cuba
Cyprus
Czech Rep.
Denmark
Dominican Rep.
Ecuador
Egypt
El Salvador
Eritrea
Estonia
Ethiopia
Finland
France
Gabon
Georgia
Germany
Ghana
Greece
Guatemala
Haiti
Honduras
Hungary
Iceland
India
Indonesia
Iran
Iraq
Ireland
Israel
Italy
Jamaica
Japan
Jordan
Kazakhstan
Kenya
Korea, Rep.
Kuwait
Kyrgyzstan
Latvia
Lebanon
Libya
Lithuania
Luxembourg
Macedonia, FYR
Malaysia
Malta
Mexico
Moldova
Mongolia
Morocco
Mozambique
Myanmar
Namibia
Nepal
Netherlands
New Zealand
Nicaragua
Nigeria
Norway
Oman
Pakistan
Panama
Paraguay
Peru
Philippines
Poland
Portugal
Qatar
Romania
Russia
Saudi Arabia
Senegal
Serbia
Slovak Republic
Slovenia
South Africa
Spain
Sri Lanka
Sudan
Sweden
Switzerland
Syria
Tajikistan
Tanzania
Thailand
Togo
Trinidad and Tobago
Tunisia
Turkey
Turkmenistan
Ukraine
United Arab Emirates
United Kingdom

United States
Uruguay
Uzbekistan
Venezuela
Vietnam
Yemen, Rep.
Zambia
Zimbabwe

Appendix C: Nations in Chapter 4 Analyses

Albania
Algeria
Angola
Argentina
Armenia
Australia
Austria
Azerbaijan
Bahrain
Bangladesh
Belarus
Belgium
Benin
Bolivia
Bosnia and Herzegovina
Botswana
Brazil
Brunei
Bulgaria
Cambodia
Cameroon
Canada
Chile
China
Colombia
Congo, Dem. Rep.
Congo, Rep.
Costa Rica
Cote d'Ivoire
Croatia
Cuba
Cyprus
Czech Rep.
Denmark
Dominican Rep.
Ecuador
Egypt
El Salvador
Eritrea
Estonia
Ethiopia
Finland
France
Gabon
Georgia
Germany
Ghana
Greece
Guatemala
Haiti
Honduras
Hungary
Iceland
India
Indonesia
Iran
Iraq
Ireland
Israel
Italy
Jamaica
Japan
Jordan
Kazakhstan
Kenya
Korea, Rep.
Kuwait
Kyrgyzstan
Latvia
Lebanon
Libya
Lithuania
Luxembourg
Macedonia, FYR
Malaysia
Malta
Moldova
Mongolia
Morocco
Mozambique
Myanmar
Namibia
Nepal
Netherlands
New Zealand
Nicaragua
Nigeria
Norway
Oman
Pakistan
Panama
Paraguay
Peru
Philippines
Poland
Portugal
Qatar
Romania
Russia
Saudi Arabia
Senegal
Serbia
Slovak Republic
Slovenia
South Africa
Spain
Sri Lanka
Sudan
Sweden
Switzerland
Syria
Tajikistan
Tanzania
Thailand
Togo
Trinidad and Tobago
Tunisia

Turkey
Turkmenistan
Ukraine
United Arab Emirates
United Kingdom
United States
Uruguay
Uzbekistan
Venezuela
Vietnam
Yemen, Rep.
Zambia
Zimbabwe

Appendix D: Nations in Chapter 5 Analyses

Albania
Algeria
Angola
Argentina
Armenia
Australia
Austria
Azerbaijan
Bahamas
Bahrain
Bangladesh
Barbados
Belarus
Belgium
Benin
Bhutan
Bolivia
Bosnia and Herzegovina
Botswana
Brazil
Brunei
Bulgaria
Burkina Faso
Burundi
Cambodia
Cameroon
Canada
Cape Verde
Central African Rep.
Chad
Chile
China
Colombia
Comoros
Congo, Dem. Rep.
Congo, Rep.
Costa Rica
Cote d'Ivoire
Croatia
Cuba
Cyprus
Czech Rep.
Denmark
Djibouti
Dominican Rep.
Ecuador
Egypt
El Salvador
Equatorial Guinea
Eritrea
Estonia
Ethiopia
Fiji
Finland
France
Gabon
Gambia
Georgia
Germany
Ghana
Greece
Guatemala
Guinea-Bissau
Guyana
Haiti
Honduras
Hungary
Iceland
India
Indonesia
Iran
Iraq
Ireland
Israel
Italy
Jamaica
Japan
Jordan
Kazakhstan
Kenya
Korea, Rep.
Kuwait
Kyrgyzstan
Lao PDR
Latvia
Lebanon
Lesotho
Liberia
Libya
Lithuania
Luxembourg
Macedonia, FYR
Madagascar
Malawi
Malaysia
Mali
Malta
Mauritania
Mauritius
Mexico
Moldova
Mongolia
Montenegro
Morocco
Mozambique
Myanmar
Namibia
Nepal
Netherlands
New Zealand
Nicaragua
Niger
Nigeria
Norway
Oman
Pakistan
Panama
Paraguay
Peru
Philippines
Poland
Portugal
Qatar

Romania
Rwanda
Saudi Arabia
Senegal
Serbia
Sierra Leone
Slovak Republic
Slovenia
Solomon Islands
South Africa
Spain
Sri Lanka
Sudan
Suriname
Swaziland
Sweden
Switzerland
Syria
Tajikistan
Tanzania
Thailand
Togo
Trinidad and Tobago
Tunisia
Turkey
Turkmenistan
Uganda
Ukraine
United Arab Emirates
United Kingdom
United States
Uruguay
Uzbekistan
Venezuela
Vietnam
Yemen, Rep.
Zambia
Zimbabwe