AN INTERNATIONAL DIVISION OF NATURE: THE EFFECTS OF STRUCTURAL ADJUSTMENT ON AGRICULTURAL SUSTAINABILITY

by

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Representing a distinct contribution to the tradition of comparative international research in the environment, this dissertation studies the effects of national economic restructuring programs, implemented under the administration of multilateral development institutions, on the fertilizer intensity, energy intensity, and value efficiency of national commodity agriculture for the period 1980 to 2002. Known as structural adjustment, these conditional loan agreements have been thoroughly studied with respect to various social outcomes but in terms of environment impact, sociological investigation has been limited to case studies and to preliminary quantitative analyses of deforestation. Examining the consequences of structural adjustment on soil fertility management is a unique contribution to the field. Combining empirical work with theoretical explication, I frame the object of study using agrarian systems theory and the concept of societal

metabolism, examining how the problem of soil fertility in the modern era has become subsumed into industrial processes that are fossil-energy intensive. Relating this historical development to the ongoing dialectic between the forces, relations, and conditions of production, I investigate how the international division of labor, manifested in the uneven and combined development of national economies, facilitates an international division of nature and thereby reproduces the hierarchical system of appropriation that drives the ongoing global expansion of the metabolic rift. Laying out competing theoretical perspectives on the potential for rational management of agricultural modernization, in the empirical component of this project I employ cross-sectional time-series panel regression analysis of secondary data on national development indicators in order to evaluate the relative merits of these contrasting theories for the sustainable development possibilities of Third World nations. The cumulative effects of structural adjustment significantly and independently increase the negative externalities of agricultural modernization while at the same time diminishing the potential economic efficiency of intensive nutrient management.

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TABLE OF CONTENTS

Chapter | Page

Chapter Page

Chapter Page

LIST OF TABLES

Table Page

CHAPTER I

INTRODUCTION

For the vast majority of the world, food production is the base of societal development. At the same time, the direction of the development of a society feeds back upon how food is produced and distributed, how labor is freed up for other activities, and how the system of production and distribution is regulated and reproduced. The reproduction of food production is the nexus through which human societies engage, with their active capacities, the myriad natural processes and organisms that make up the soil, water, and air basic to the metabolic needs of their populations.

The current era is characterized by a contradiction between this active human propensity for industry and a crisis in the sustainability of the ecological dynamics that make such development possible. Yet, it is not simply the consequences of past mediation between industry and nature that is at stake. The way future production will be determined, and future possibilities realized, is contingent upon pathways chosen, or enforced, in the present.

The current possibilities and future paths toward sustainable food production have been conditioned by particular trends that dominated agricultural development in the mid to late twentieth century. These trends included the intensification of land, water, and nonrenewable resource use, combined with the formation of global networks of agricultural input markets, commodity trade, and food processing industries. Intensification affects many components of agriculture, including the practice of soil fertility renewal. Of the many factors involved in agricultural production the issue of soil nutrient export, transfer, and importation is crucial to the productivity of farming. The management of soil/plant nutrients is a necessity of agricultural production, amenable to human manipulation more so than other factors such as sunlight, climate, and rainfall, and this fact implicates the sociality of nutrient management. Only the management of irrigation water approximates the same degree to which soil nutrient management is coordinated and controlled. Both inputs involve relations of sharing or exclusion, and require some form of regulation, distribution, and exchange. Yet, the transport of water is limited by hydro-geography and energy usage in ways that nutrient transport is not. Water is quite massive for its volume, whereas fertilizer can be concentrated in salt and gaseous form and shipped around the world relatively inexpensively. Nutrient management therefore constitutes a distinct dynamic in agricultural sustainability and needs to be analyzed as such.

In order to more fully grasp the dynamics that contribute to changes in agriculture more generally and soil fertility renewal in particular—with the intent to identify those dynamics that facilitate as well as those that hinder sustainable agriculture—the present research engages the social dynamics of agriculture, using a combination of theoretical explication and quantitative analysis to examine the social factors specific to agricultural production at the cross-national scale, paying specific attention to the problem of soil fertility renewal (nutrient management). Engaging first in a meta-theoretical explication of the socio-material features of agriculture, I then examine empirically how the present dominant system of soil fertility renewal and its relation to industry has been influenced and shaped by the emergence in the late twentieth century of a global agro-food system. Working in the tradition of quantitative, macrosociological, international research on the environment, I compare middle-range theories about the relationship between global capitalist integration, environmental change, and sustainable development, assessing the relative merits of those theories in how well they predict the effects of national economic restructuring on the environmental impacts associated with agricultural intensification, specifically fertilizer and energy intensity. This is followed by an analysis of the relative economic benefits derived from agricultural intensification.

One of the central mechanisms by which economic restructuring links the variety of nations to international trade is the Structural Adjustment Program (SAP). Initiated, sponsored, and administered by multilateral institutions such as the International Monetary Fund (IMF) and the International Bank for Reconstruction and Development (IBRD or World Bank), structural adjustment has been implicated in a variety of social changes (Structural Adjustment Participatory Review International Network [SAPRIN] 2004). Focusing on the environmental consequences, I seek to answer the following research question: what is the net effect of structural adjustment programs, when compared with other factors, on the fertilizer intensity, energy intensity, and value efficiency of a nation's agriculture? To answer this question I employ panel analysis of cross-section time series data using existing international statistics in order to estimate the relationship between structural adjustment programs (SAPs) and the potential positive and negative outcomes of agricultural modernization.

Agricultural modernization is defined here as the technical intensification, social differentiation, and geographical fragmentation of the entire array of activities that contribute to food production and the recombination of these activities into a larger system of social reproduction (Bernstein 1990). As such it involves the radical transformation from direct subsistence or simple commodity exchange to the dominance of generalized commodity production.[1] Thus, agricultural modernization is comprised of independent, yet mutually conditioning processes, including *industrialization*—the substitution of energy- and capital-intensive machinery and raw materials needed for cultivation and plant growth—and *capitalist development*—the dominance of productive relations that tend toward the universal market as the medium of societal metabolism and a division of labor based on the alienated distribution and use of society's productive forces.[2] Because SAPs are specifically designed to integrate the so-called developing societies into global markets by increasing the processes of agricultural modernization within those societies, and because evidence of the ecological consequences of such integration has been largely understated in the literature on structural adjustment, the present analysis provides an important and warranted contribution to the body of research.

[1] Whether this be commodity production for internal or international market exchange has theoretical importance and will be part of the discussion below.

[2] This movement goes hand in hand with the transition from farm reliance on regionally sourced plant nutrients relative to the site of production toward the global sourcing of such nutrients.

The format for the dissertation follows standard organizational practice. Chapter II begins with an elaboration of the epistemological and meta-theoretical foundations of the research project, the theory of agrarian systems, and then moves on to an explication of the different substantive and middle-range theories that offer competing explanations and predictions regarding the environmental impacts of modernization processes generally, and international trade and structural adjustment specifically. Chapter III contains a review of the relevant empirical literature, followed by a detailed summary of research propositions derived from the discussion leading up to that point. Chapter IV details the methods used in the analysis, and describes the data, variable measurements, and model specification. Chapter V reports and discusses the results of the data analysis. Finally, Chapter VI presents conclusions and recommendations for further research.

Sociological Relevance of the Study

This study makes four distinct contributions to the discipline of environmental social science. First, previous research that has considered the environmental impacts from structural adjustment has been limited to case studies or to quantitative analyses of forest loss and have yet to examine the effects of SAPs on soil fertility renewal (Kaimowitz, Thiele, and Pacheco 1999; Redclift 1995; Reed 1992; Shandra, Shor, Maynard, and London 2008; Shandra, Shor, and London 2009). Assessing the influence of multilateral institutional change on agriculture, and on fertilizer in particular, represents a unique contribution to the field. Moreover, the study of fertilizer use is not just a study of environmental impacts *per se* but also a study of the social dimensions associated with the processes of agrarian production and reproduction that form the basis for societal mediation of biophysical existence.

Second, where the impacts from agriculture have been studied—such as analyses of fertilizer and pesticide consumption, CO_2 release, soil erosion, and water pollution—these studies have not included the relative effects of structural adjustment in comparison with other factors. Because of the close historical linkage between structural adjustment and other prominent factors found to contribute to global distribution of the negative externalities of agricultural modernization it is important to disentangle these factors from one another so as to estimate the net results of each. Structural adjustment constitutes a theoretically distinct social dynamic with respect to environmental change and should be investigated for its own contribution to the outcomes of interest.

Third, the present research extends and refines previous cross-national and longitudinal analyses of the social drivers of fertilizer and energy intensity. Work in this area to date has focused solely on the fate of developing nations, either when using case-study analysis, or even when applying advanced statistical techniques, or else it has been limited to analysis of cross-sectional patterns at one period in time (Jorgenson and Kuykendall 2008; Longo and York 2008). Such sample and timescale limitations make generalization to larger national and global processes difficult and hinder our understanding of how these processes develop over time. One benefit of the use of panel regression is that it can be used to make statistical inferences across entire populations while simultaneously estimating the influence of changes over time. The use of fixed effects model specification, which predominates here, also controls for unobserved time invariant factors that may influence national processes, such as preexisting variations in native soil fertility conditions, allowing for a more consistent and efficient estimation of the net effect of causal factors. Practically speaking, the issue of capturing changes in agricultural practices over time, and the ways these changes are influenced by international factors, is of crucial importance for assessing various development policies.

Comparative international research on the environment tends to frame pollution and resource consumption in terms of either the scale of production (Schnaiberg, Pellow, and Weinberg 2002) or the disproportionate distribution of environmental impacts (Frey 1995; Grimes and Kentor 2003). Consequently, the analysis is limited to social processes structured by extant social relations, whether these are the state-capital-labor triad of national economic growth regimes or the world system hierarchy of nations. However, the question of social drivers implies more than just scale and distribution, but also the historical production of institutional scale and uneven distribution. Examining the ecological consequences of structural adjustment shifts one's conceptual focus to the system properties that influence the organization and purpose of production (Foster 2005). Economic restructuring is arguably more than simply the rationalization of production, but is part of an ongoing process that involves the transformation of alternative modes of societal reproduction. Explaining how the social structure of productive activity conditions the possibilities for sustainability is a central goal of materialist environmental sociology. This work would represent a further effort in that direction.

Social Relevance of the Study

Long Term Structural Changes in Agriculture

The term agricultural modernization, as used here, involves the interplay and mutual conditioning of technical and social forces. The technical component of modernization as we know it today is the result of multiple agricultural revolutions (Mazoyer and Roudart 2006; Wood 2000). Revolutions in agricultural technology supported the European industrial revolution and led to the eventual mechanization of tillage and harvest, the motorization of traction and processing, large-scale automation of multiple farming tasks, chemicalization of fertility and pest management, and the development of plant and animal breeding making these organisms amenable to mechanization, predictability, and profitability.

Characterizing the dialectic between human instrumentality and natural conditions, the modern science of soil chemistry was spurred on in part by a decline in agricultural fertility that plagued late 18^{th} and early to mid 19^{th} century Europe (Foster 2000). In the face of declining rates of crop yields, the emerging soil science of the time contributed to a greater understanding of plant nutrient needs and the relationship between soil nutrient pools and cultivation practices. Efforts were made to apply this new knowledge to capitalist food production. The very momentum of this scientific revolution drew from and in turn feed back upon the industrial revolution, ultimately spurring on the growth of cities and a widening of the gap between large-landed property in the countryside where food was produced and the mass of industrial workers concentrated in the cities (Foster 1999a).

The discovery of the Nitrogen (N), Phosphorous (P), Potassium (K) nutrient complex and various ways to make natural occurring forms more economically feasible, instigated wars over the existing deposits of these minerals, for example in the plundering of saltpeter mines and the raiding of tombs and battlefields for new sources of mineral fertilizer (Foster and Clark 2004). Referring to these events, Marx observed that land like the land, soil itself had become a commodity, and like other commodities, the exploitation of soil was carried out according to the laws of competition and commerce (Foster 2000:156). More than this, the fact that Europe had increasingly become reliant on the long distance importation of the mineral constituents of agriculture was for Marx *prima facie* evidence that European agriculture had ceased to be self-sustaining. Capitalist agriculture disrupted practices by which soil nutrients were returned back to the site of cultivation, a condition of food production necessary in order to continue obtaining adequate yields, and instead had become dependent on the growing technical and military power that emerged from the industrial revolution to secure distant lands for exploitation. This expansion entailed disrupting the societal metabolism of other populations, at the great expense of overwhelming human misery. Thus, while the soil science flowering in capitalist society at that time could understand what was needed, it did not provide an adequate understanding of the social basis of the problem.

With the onset of the twentieth century and the growth in large-scale chemical industries, new developments in agriculture resulted in new and serious consequences above and beyond problems associated with nutrient cycling. The formation of synthetic biocides unleashed a new moment in the rift between humans and ecosystem processes, this time disrupting the very structure and form of those processes, rather than simply disrupting the flow of nutrients necessary for their ongoing dynamism. Agrochemicals in various forms percolate through the food chain, and further on throughout the biosphere, having toxic effects at multiple scales. To this extent, the twentieth century development of large-scale agrochemical manufacturing introduced a growing rupture in the biological basis and ecosystem integrity of organic life.

The system of agriculture emerging at this time was, along with many other productive activities, characterized by a division of labor that separated the majority of producers from direct access to the agrarian means of production and a recombination of this divided labor force with industrial capital. In addition to the rural to urban exodus that has remained a persistent feature of the capitalist era, along with the rise of factories in the cities and the industrial proletariat, the recombination of labor and the industrial means of production also took place, initially at a slower pace and in a more indirect way, at the very heart of agricultural production in the countryside. The increasing technical power of industry and the ability to scientifically manage the labor process grew from and contributed to the concentration and centralization of capital in the period of the rise of monopoly capital. These events then facilitated the "conquest of the labor processes formerly carried on by farm families" (Braverman 1974:190). Despite being able to cling to the land, farmers became increasing situated between the extractive, mechanical, and chemical industries located upstream, which supplied new and ever revolutionized means of agricultural production, and the processing, distribution and marketing industries downstream, which turned raw farm output into value-added items. The vertical division of the food production commodity chain (between agricultural upstream and downstream activities) specific to these developments was coupled with an extensive separation of the tasks of conceptualizing, developing, promoting, and distributing the new means of production, further augmenting dramatic social changes in the way farm labor was carrier out (Heffernan 2000; Mazoyer and Roudart 2006:376).

These technical developments have contributed to the development of what in the late twentieth century had became the typical large-scale form of agriculture: specialized cropping (monoculture), the simplification and reduction in farm labor (mechanization), and massive increases in agricultural productivity placing downward pressure on real agricultural prices in a long term, secular trend (Mazoyer and Roudart 2006:378). Farming activity and economic viability became increasing determined by how well these changes could be exploited to gain enough income above the threshold of capitalization required for reinvestment in equipment and material. The uneven development of farms and a decline overall in the number of farm families was the result (Buttel, Larson, and Gillespie 1990). This decline of farm units relative to food production contributed to the conversion of agriculture from a practice of mixed farming, engaged with ecologically diverse landscapes and organisms, to an operation of reduced complexity and genetic diversity, focusing on carefully engineered proprietary staple crops that have come to supply the majority of the world's calories.

One of the modernization processes that increasing agricultural productivity augments is the development of urban centers and social differentiation. An important feature of all urban centers is the rural, peripheral hinterlands they rely on for raw materials such as food, fuel, and fiber. During the colonial period, the urban-hinterland relationship extended across the globe in the center-periphery model of accumulation, concentrating production in the center while drawing upon the agriculture and extractive industries of the periphery. In turn the products of the industrial centers were recombined with the peripheral regions. In the case of agriculture, the preeminent example of this recombination was the proliferate "diffusion" of Green Revolution seed-chemical-machinery packages into the potential and emerging markets of the newly awakened post-colonial world (Magdoff 1978; Ross 1998). With the rise of corporations, surplus farm labor and land across the globe became increasingly integrated into commodity chains of agricultural products that spanned the globe, networks of supply and distribution that are increasingly controlled by massive agribusiness conglomerates that provision the majority of farm inputs and that gain the lion's share of profitable outlets in the food industry (Buttel 1997; Friedmann 1991; Schulman 1981; McMichael 1994). Thus, as the interdependence of global food production becomes increasingly apparent, so do contradictions the between the profit drive of these monopoly-type firms and the social motive to share the world's harvest for the adequate nourishment of the globe. At stake is the very nature of the emerging agro-food system. Does it replicate the accumulation model of the past or does it contain new possibilities for universal, sustainable development?

Global Ecological and Agrarian Crises

As noted above, in the scientific and industrial age the problem of soil fertility replenishment has become subsumed under the aegis of technology. Soil fertility has now become a matter of industrial management, temporarily bypassing the geographical and biophysical limits to replenishment that previous generations have faced (Mayumi 1991). Such gains in technical mastery come with a price, however. Contemporary fertilizer production is resource intensive, and in the case of ammonia synthesis is dependent on natural gas for feedstock and on high flows of energy to drive the process (Constant and Sheldrick 1992; McLaughlin et al. 2000). Thus, soil fertility renewal in the modern era is plagued by a reliance on what Catton (1980) called *drawdown*, the use of existing and finite stocks to make it possible to carry out intensified production at scales and at rates that exceed the natural regenerative capabilities of a solar-based cultivated ecosystem. Also, soluble nutrients applied in overabundance to fields contribute to the pollution of watersheds and accelerate the leaching, erosion, and ultimate decline of soil minerals, the very problem that nutrient management is supposed to solve. This oversaturation effect, or *nutrient pollution* as it is sometimes called, ultimately has a disrupting effect on the ecosystem services that humans rely on, including the complex, microscopic networks that make up soil ecology, a vital factor in the processing of organic matter (Altieri 2000; Magdoff, Lanyon, and Liebhardt 1997). A diverse soil ecosystem is needed to retain nutrients in the soil and to maintain the conditions for healthy plant life, including the formation of stable humic compounds that provide a sustained release of nutrients for plants, while the plants in turn provide habitat for the bacterial symbionts they rely on (Magdoff et al. 1997). In addition to nutrient management, soil organisms build soil structure, allowing for optimal oxygenation and water infiltration to plant roots (Tivy 1990). Thus, living soil is vital for sustainable agriculture (Francis 2004). Intensive management in combination with mechanical cultivation and other agrochemical inputs degrades soil structure, causing the loss in a matter of years what has taken lifetimes to build (Gliessman 1998). Once this loss has occurred, continued fertilizer applications become necessary in order to maintain rates of production. In turn, continued reliance on these industrial inputs thwarts the social potential for regenerating soils through a system of cultivation that emphasizes organic matter management (Brussaard and Ferrera-Cerrato 1997).

Since the discovery of ammonia synthesis, which converts atmospheric nitrogen to reactive form, humans have doubled the volume of reactive nitrogen (N_r) released into the biosphere, with more than half that amount lost since the 1980s, the beginning of the period of time studied here (Vitousek et al. 1997). Reactive nitrogen accumulates in the biosphere, having a cascading effect as it works its way through various ecosystem processes occurring at various scales (Galloway et al. 2003). It is now thought that the global nitrogen cycle is being altered in ways that present as serious a challenge as abrupt climate change (Smil 2001). Because of the central importance of nitrogen for living organisms, change and instability in the global system threatens the ecological integrity of the biosphere and the stability of the global agrifood system (United Nations Environment Program 2005). Facing limits to technical innovation and declines in the conditions of production, the future of farming and hence the extant social order is in question.

These ecological problems coincide with dramatic social contradictions. As more and more of the earth's productivity and social labor are integrated into an economic system of generalized commodity production—also known as globalization—persistent unemployment and underemployment, rising urban squalor, and unmerited inequality result (Magdoff 2008). Global distribution of economic and necessary goods has taken what was once the locally sourced and managed capacity for social reproduction and exploded it across the globe, in what Giddens (1990) has called time space distantiation, and Harvey (1990) named time space compression, and which Hornburg (2007) noted should be recognized as time space appropriation.[3] Wherever rising gross domestic product (GDP) has improved the quality of life for regions of the world, the increased throughput of energy and matter that accompanies an increase in per capita income places greater and greater stress on the world's resources and ecosystems (York, Rosa and Dietz 2003a).

Furthermore, nearly half of the planet's six and half billion human beings live in poverty, with a purchasing power equivalent to less than two U.S. dollars per day (United Nations Food and Agriculture Organization 2008; International Bank for Reconstruction and Development 2007). Employment is precarious, and farming for subsistence, much less to compete in global markets, is difficult at best for many who lack access to adequate means of production and land. Consequently, about one billion people in the world are undernourished, with women and girls making up 60% (Bryson 2009).

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[3] Acknowledgement goes to Brett Clark for bringing Hornburg's contribution to my attention.

In contrast to traditional peasant production, the agricultural productivity per worker of modern, input-intensive agriculture is 100 times that of manual cultivation using land-based resources (Amin 2003). Differences in productivity per land unit are less dramatic, but substantial nevertheless, with the wide-scale adoption of high-yield varieties reducing the absolute per capita acreage required to feed growing global populations and generate the surplus necessary for increased social differentiation and economic development.

The combination of agricultural productivity and changing land tenure has led up to the point where half of the of the world's population now dwell in cities, and as urban areas grow and the limits of arable land are reached, the main past strategies for dealing with soil fertility crises—migration and importation—become more complicated (Worldwatch Institute 2007). Sedentary dwellers and migrants often conflict, and as land and water become scarcer, such conflict is bound to increase. The mobile flows of resources from rural and global hinterlands to urban and metropolitan centers, means that access to nutrients and ultimately food is distributed according to the capacity to effect demand (Sen 1981). Such a system requires the stability and predictability of a complex array of factors to maintain. With each new change, stressor, and disruption the potential for social unrest grows.

Agricultural intensification and concentrated population, strategies which have to some extent been associated with technical control over the conditions of material production and social reproduction, will likely make it more difficult in the long run to weather changes in climate, loss of arable land, declining aquifers, and other factors that the planet now faces and that will affect normal patterns of cultivation and civilization (Brown 2004; Fagan 2004; Rosenzweig and Parry 1994). Without land to migrate to, and resources to intensify agriculture with, a degrading soil base and changing climate system will challenge the world, especially the poor, to respond to losses in productivity. The combined scale and ecological irrationality of the global trade in agricultural nutrients has created a path dependency which server constrains current action and slows down or outright hinders the potential resilience of communities in the face of these changes. All of this combines to make for a difficult passage if the outlook on global environmental change coming from the world's leading experts on are even close to what is expected (Drinkwater and Snapp 2007).

Opposing Narratives

Agricultural modernization and the philosophy of trade liberalization that has facilitated its diffusion continue to be promoted as effective strategies for poverty eradication, food security, and sustainable development, "promised as a recipe for lifting millions of people out of poverty" (Klapper 2008). Agricultural modernization is said to be compatible with sustainable development because increased productivity minimizes the clearing of forests and further pressure on marginal lands, which would otherwise contribute to land degradation and the loss of biodiversity (Finlayson 2004). Through the introduction of capital-intensive inputs and cultivation technology, improvements in the technical efficiency of agriculture expand yields and give greater rational control of production through proper management, which can actually lessen agriculture's relative impact on the environment. In combination with trade liberalization and intellectual property rights, the globalization of agricultural production underwrites the national integration of Third World countries into the global economy and consequently boosts their national development (Gueorguieva and Bort 2003). Where the pain of economic shock therapy appears too much, world economic growth, the superior efficiency of free enterprise and trade, political democracy, and the prospects of shared prosperity are evoked to justify the pain (Sachs 1989). Where the threat of ecological instability looms large, as it does in projections of the impact of climate change on the African continent, multilateral development agencies are at the ready with a new agenda, the "second Green Revolution," involving among other things the promotion of proprietary transgenic 'climate ready' seed destined for producers armed with micro-credit (Klapper 2008).

An alternate narrative regarding the problems generated by agricultural modernization is available. From this perspective, feeding the world sustainably is not a problem of production, but of distribution, and ultimately of social reproduction. There is currently enough food for the world's population, but entitlements to food are structured via the commodity system, which in turn requires adequate employment. As adequate employment is a persistent problem under capitalism, access to food remains unequal and unsatisfactory (Sen 1981). Likewise, rapid and unsustainable environmental change is neither simply a necessary price of development, improvement, or progress, nor solely to be addressed with a reliance on technological innovation alone. Organic polyculture is at least as productive as industrialized monoculture, holds the potential for generating social conditions for self-determination and productive opportunity, especially for rural populations, and avoids many of the serious ecological effects of intensive biocide and fertilizer use (Badgley et al. 2007; Flora 2001; Levins 1986). Rather than being part of the solution, under present global inequalities the diffusion and transfer of technology developed in accord with intellectual property rights and capitalist profits (and produced with the specific goal of integrating farmers into the corporate agro-food system) does less to improve the lives of the majority than it does to reproduce and intensify existing social conflict (McMichael 1994).

Consequently, as agricultural producers worldwide are integrated into global markets, agrarian systems that provide alternatives for the inhabitants of the Third World are unceremoniously supplanted (Sevilla-Guzman and Woodgate 1997). The new world order of global commodity production reproduces the same path dependency currently faced by the capitalist core, subjecting the national production sectors of Third World societies to repetitive economic financial crises and now a growing biosphere crisis, which threatens the stability of the international trade in farming and food. Agricultural modernization and progressive technological intensification therefore represent limited and one-sided approaches to sustainable agricultural development (Clark and York 2008; Magdoff, Foster, and Buttel 2000). Addressing the social contradictions that generate ecological and economic crises would instead entail eliminating the class basis of these contradictions, and that would strike at the very heart of private accumulation itself.

As the competing narratives with respect to agricultural modernization have almost incommensurate and opposing recommendations for how to proceed, and as fertilizer and the energy consumption necessary for its production represents a central feature of current modernization practices, it is especially important to assess the relative merits of the explanatory and predictive power of those perspectives. In the next chapter I prepare the ground for the empirical component of the dissertation, in two stages. First, I draw on metatheoretical foundations that take a materialist approach to the issue of agricultural production and social change, drawing together agrarian systems theory, historical materialism, and societal metabolism into one comprehensive framework. Then, I examine the arguments of substantive middle-range theories that offer contrasting views on sustainable development in international context.

CHAPTER II

THEORY

In this chapter I lay out the metatheoretical approach that guides the research, followed by a discussion of the relevant substantive theories. Because my research is epistemologically grounded in both the human ecology and historical materialist traditions, I describe the conceptual foundations used to comprehend the object of focus (and unit of analysis): national agriculture. The discussion then turns to the explication of two prominent theoretical perspectives in the field of comparative international work on the environment, mainstream and neo-Marxist approaches, including variants within each.

Agricultural modernization has to date been a highly contradictory process, including positive and negative outcomes from both technical intensification and commodification. Land degradation and increased dependency on fertilizers represents a special case of the ongoing challenge to replenish soil fertility, a problem for all agrarian systems. The way in which soil fertility replenishment is carried out is in turn related to the social character of the agricultural productive system. Therefore, in order to frame the analysis and prepare the way for a discussion of competing sociological theories that address the issue of sustainability, I turn first to the theory of agrarian systems, as explicated by Mazoyer and Roudart (2006), which serves as the starting point for comprehending the dynamics of agricultural in general.

The Theory of Agrarian Systems: Soil Fertility as a Perpetual Challenge for Agriculture

Since the Neolithic revolution, food production has surpassed food harvesting as the basic operative means by which human societies are sustained, and rising per capita food production has literally fed the growth of cities, empires, and civilizations (Lenski 2005). The production of a surplus, material and economic value above the threshold required for the reproduction of direct labor, facilitates the development of task specialization and social differentiation, as well as the concentration of populations in urban centers. To maintain a surplus, civilizations have always been confronted with the issue of maintaining yields, and just as importantly, the soil basis for those yields (Hillel 1991). The history of the development of agriculture therefore reveals a dialectical process between technology and labor productivity, the organization and division of labor, and the carrying capacity of a given productive system.

In order to comprehend the current manifestation of this process—the agro-food system of production and the consequences of its development for global ecological change—it is necessary to grasp these developments in the historical context of food production generally in order to be able to return to the concrete manifestations of the present. Using a basic human ecological framework makes it possible to examine the interdependent structures that make up the overall anatomy of agricultural systems and their historical production. These structures, the producers embedded within them, and the globalized nature of the current food system make up a complex whole. Analyzing cross-national statistics, as is done here, treats the nation-state as individual unit, and yet national agriculture is an aggregate made up of multiple producers at various levels of development. Thus, it is important to identify what is similar across agricultural production systems at the producer level in order to be able to compare them at the national level. National production is in turn nested within dynamic patterns of the global movement of resources, pollution, technology, and value in a manner similar to the relationship between individual production units and regional dynamics, or farm units generally and corporate firms. The theory of agrarian systems assists in the effort to organize this complexity.

Basic Components of Agrarian Systems

In their book, *A History of World Agriculture*, Mazoyer and Roudart (2006) define an agrarian system as "a combination of interdependent and complementary functions, which ensure both internal circulation and external exchanges of matter, energy, and, if it is a question of an economic object, value . . . [comprising] two principal subsystems, *cultivated ecosystem* and *social productive system*" (p. 47). These systems are "composed of several complementary and proportionate subsystems" and must be renewed through cultivation and soil fertility management in order to "ensure the internal circulation of matter and energy in the cultivated ecosystem" (p. 48). The cultivated ecosystem is open to "external exchanges with near or distant ecosystems" and it is "through these exchanges [that] the transformations of a cultivated ecosystem can influence remote ecosystems [or conversely] be affected by vast changes in the greater environment" (p. 48). The social productive system is "composed of *human resources* (labor power, knowledge, and know-how), *inert resources* (productive implements and equipment), and *living resources* (cultivated plants and domestic animals)" that are used by the agricultural population in "renewing and exploiting the fertility of the cultivated ecosystems, in order to satisfy its own needs directly (by consumption) or indirectly (by exchanges)" (p. 48–49).

Any given unit of production puts the means of production to work on the ecosystem depending upon the "social category" of the labor and mode of access to land and, as we shall see, the mode of production of the means of production (Mazoyer and Roudart 2006:49). Farm unit reproduction is accomplished through self-supply or exchange, including financial obligations such as "tribute, quitrent, farm rent, taxes, interest on capital, etc." (p. 49). These outflows can be "partially reinvested…in the productive system itself and thus contribute to its development, but they can also be purely and simply transferred to the profit of other social spheres and contribute to the impoverishment of the agriculture system" (p. 50). The various mechanisms for the appropriation of surplus can not only negatively affect the reproduction of the farm production unit, including labor and means of production, but there is also the potential for undermining the resource base of the cultivated ecosystem. Indeed, both potentialities are sometimes intimately linked.

Dynamics of Agrarian Systems: Development of the Means of Bio-Appropriation

Agrarian systems are not static, but are engaged in either reproduction for self-maintenance, general development by the universal adoption of new agricultural technology, i.e., "developing their operations, and increasing their economic size and income," or decline. Development is therefore "unequal when some units grow much quicker than others" and "contradictory when some units progress while others are in crisis and regress" (Mazyoer and Roudart 2006:50). This stems from the fact that the "production system is characterized by the types of tools and energy used to prepare the soil of the ecosystem in order to renew and exploit its fertility [whereas] the types of tools and energy used are themselves conditioned by the division of labor *dominant in a society of a particular epoch*" (2006:51, emphasis added). This implies, in the final analysis, that to comprehend the dynamics of an agrarian system, including technological revolutions in production, requires that one take into account the factors and events that condition the way upstream inputs are provisioned as well as how and under what conditions downstream products are controlled, processed and consumed (Mazoyer and Roudart 2006:51).

Cultivated ecosystems based on food production harvest nutrients in the form of crops. In stationary cultivation, soil nutrients must eventually be renewed. This demand creates both a technical and a social problem to be solved. Technically, replenishment depends on supplying soils with biomass and/or mineral synthetic fertilizers. The relative availability of these sources interacts with the cultivation system at hand. Each system has a particular profile of transport, energy, and instruments implicated in and ultimately required for the renewal of soil fertility under that particular system (Mazoyer and Roudart 2006; see also Fischer-Kowalski, Krausmann, and Smetschka 2004). These natural changes also mean that, except for the very simplest modes of cultivation (swidden, hoe and mound), which tend to have the lowest carrying capacities, if there is not some natural process for replacement, such as river flooding, volcanic activity, or the like, key macro- and micro-nutrients are slowly lost to the system. This entails, therefore, a trans-historical technical problem to be solved in order to meet the ongoing maintenance and sustainability of the production system.

Thus, a point that is often overlooked in the sociological study of agriculture is that "in most agrarian systems, renewal of the fertility of the cultivated lands is provided by organic and mineral resources originating in the uncultivated parts of the ecosystem" (Mazoyer and Roudart 2006:64). There are two distinct ways that nutrient replenishment is carried out: land extensive methods versus input intensive methods. Some systems are land extensive, transferring nutrients from places immediately beyond the cultivated area, taking biomass that is not directly used for crops out of one location and moving it to the cultivated location. This can include transporting the converted biomass in the form of actual or potential animal excrement. Other systems depend on the importation of nutrients in a more basic, inorganic chemical state, from places such as guano deposits, through the harvesting of ocean biomass and minerals, by the mining of rock phosphate and potash deposits—such deposits being the result of prehistoric biological activity—and from the process of ammonia synthesis. In the land extensive system, the flow of nutrients is limited to the *fund* of nutrients in the immediately available and workable area. In the intensive system, the flow of nutrients is limited only to the procurement of *funds* sourced globally. The key link is in the availability of energy, over and above that which could be generated and maintained on farm if used directly for the process of soil nutrient transfer, that is, if the movement of mass is carried out strictly by using renewable and locally recharged sources (Mancus 2007). Qualitatively, the reduction from complex organic substance to inorganic mineral form facilitates the intensive sourcing of nutrients, due to their concentrated form.

In addition, the agricultural potential of the system, influenced by the type of soil, climate, availability of water, crop and cropping system, method of fertility renewal, and infrastructure, combines with the labor productivity of the means of production such that "the gross productivity of a system is the result of the output per hectare multiplied by the cultivated area per worker, an area that depends on the effectiveness of the tools and the power of the energy sources (human, animal, motomechanical) that this worker uses" (Mazoyer and Roudart 2005:69). For instance, the overall caloric output of hand worked paddy rice cultivation is higher per hectare than swidden (slash and burn) agriculture, but requires more labor per unit area than the latter even though both use hand implements. Compare this to the output of one worker using a combine-tractor on irrigated, high-yield wheat. The industrially augmented yield surpasses many times the total labor productivity of paddy and swidden combined. "The extent and fertility of actually cultivated lands," the authors conclude, "are therefore the two variables that determined the production capacity of a cultivated eco-system, and hence the maximum population density it can support. At each moment, these two variables are conditioned by the characteristics of the original ecosystem, more or less modified by prior successive agrarian systems, and governed by the mode of renewing the fertility of the current system" (Mazoyer and Roudart 2006:64).

Analytical Relevance

The gross productivity of an agrarian system allows for a comparison of different levels of national agricultural productivity (comparing the potential economic benefit generated by agriculture relative to the environmental impact) while also facilitating analysis of the social dynamics that influence overall productivity and sustainability. One crucial dynamic is the fact that productivity is conditioned by more than just face-to-face interaction and direct mediation with the biophysical environment. Even considering the fact that farming is a land-based activity the overall social dynamics that influence on-farm activity are broader and more comprehensive than simple cultivation. Moreover, given that the technical aspects of existing cross-national commodity agriculture have been converging for some time now, and these technical aspects link farm producers to the larger political economy of agrochemical corporations, there is a powerful social influence on farm labor exerted at the system level, coming from outside the production unit.

Agrarian systems theory as a whole also establishes a materialist explanation as to how agro-technological development and soil fertility management condition one another. The key is found in the link between agricultural production and uncultivated land (or industrial substitution for that land). Just as with social dynamics, the theory takes the analysis of ecological dynamics beyond the farm gate—so to speak—beyond the simple interaction and exchange between societies and soil nutrients to include the broader network by which farm unit fertility and cultivation is reproduced. The micro and the macro are connected as the various flows of resources and products in the total political economy influence the development of production units. In turn, the differential productivity of variously equipped agrarian systems feeds back into the system as a whole.

Finally, because agrarian systems theory emphasizes the interrelation between the social and technical components of a production unit, including ecosystem processes at large, it also facilitates conceptually disentangling these components so that one may distinguish activities that are determined by the biophysical events characteristic of the cultivated ecosystem itself from the social relations that condition such activity. This distinction becomes more practically (and therefore conceptually) relevant the larger the agro-food system gets, the more dispersed the production of farm technology becomes, and the greater the geographical separation of the flows of resources in and out of the farm unit. Ultimately, the task of the ecologically minded analyst is to identify the points of stress that contribute to the degradation of the productive resource base, or to the decline of the producers themselves, and how such activity is linked to larger social forces, revealing the forces that contribute to sustainability, or lack thereof.

Bridging Agrarian Systems Theory and Historical Materialism

The connection between agrarian systems theory and historical materialism is found in Marx's identification of the components of a mode of production: the forces, relations, and conditions of production, expressed in Marx's early work as industry, man and nature (Mészáros 1970:105). A crucial part of Marx's approach is that in his scheme the forces of production include implements, technique, knowledge, and skill, as well as the division of labor. Relations of production on the other hand comprise the customary and legal property rights, social obligations, and territorial boundaries, i.e., objective material positions with respect to access and control of the forces of production. Conditions of production, used sometimes in different ways by Marx, is restricted here to refer to the biophysical properties involved in crop production and husbandry, including biomass and soil organic matter, ecosystem interactions, the management of landscape, hydrology, and soil type, and responses to rainfall, sunlight. and climate. It additionally refers to existing circumstances that have been laid down by previous generations (i.e., what is necessary as a result of past contingency) (Burkett 1999:26–54; Marx 1973:85–111; Marx and Engels 1978:146–200; Polychroniou 1991:11–13). These components form Marx's analytic framework for identifying the interconnected features of any *mode* of production, as well as how those features contribute to societal, and as elaborated here, ecological change.

Compared with the agrarian systems approach, where production units are comprised of means of production (inert resources), labor relations (human resources), and cultivated ecosystems (living resources), Marx's system aids in disentangling the problem of producer use from producer control with respect to agricultural technology. This is because for Marx the means of production and the division of labor are both inclusive within the category of forces of production. Because it is the dialectic between the forces and relations of production that forms the basis for comprehending the 'laws of motion' of the system, a focus on means of production alone is insufficient. It is the production, distribution, and use of the means of production that requires explanation as the systematic expression of the co-conditioning influence between technological development, social relations, and the socio-ecological (eco-historical) conditions of production (Haila and Levins 1992; Hughes 2000).

Mainstream Approaches to Capitalist Development and Ecological Change

In this next section, the discussion moves from metatheoretical issues to the task of elaborating the more concrete, middle-range level of explanation. The historical context of structural adjustment covers a period of time when trade liberalization theory grew in prominence, sweeping through the narrative and policies of development institutions during the Third World debt crisis (Ambrose 2001; Harvey 2004). As such, liberalization theory forms the backdrop for the discussion on structural adjustment. While representing a philosophically distinct policy approach when compared with other liberal reform theories of environmental change, such as ecological modernization theory, which is described below, ecological modernization and trade liberalization are nevertheless linked in a common commitment to overall institutional restructuring as the primary means to attain sustainability, although they have different means by which such restructuring should take place. To flesh out these differences, I first begin with the recent history of trade liberalization theory.

Historical Context of Trade Liberalization

Friedmann and McMichael (1989) were among the first in the sociology of agriculture to describe the features of what they saw as a global restructuring of agricultural production, in line with a global crisis of capital accumulation. Describing the latter fourth of the twentieth century as "evidently a transitional period, possibly the end of an era," national models of capitalism based on Keynesian economics were scrapped for a reassertion of monetarist and deregulationist forms of state policy in accord with the economic imperative to maintain economic growth (McMichael 1994:v). Beginning with the breakdown of the Bretton Woods agreement and a shift in the mission and activity of those institutions transnational capital became more mobile and flexible through the use of neoliberal mechanisms of global trade policy reform. Neoliberalism as a philosophy rose on the social and political agenda represented by the ascendancy of Margaret Thatcher in Britain and Ronald Reagan in the United States, political changes that corresponded with policy changes at both the World Bank and IMF. These changes reasserted the rights of center-nation investors over and against those of domestic and international labor (Harvey 2004). During this time period, beginning in the 1970s but accelerating rapidly in the 1980s, the IMF and World Bank increasingly became involved with directing radical changes in the economic policies of heavily indebted and impoverished nations.[4]

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[4] Collectively the Bank and Fund are part of the larger category of International Financial Institutions (IFI).

The crisis of Third World leading up to this period began in the early 1970s from a confluence of preexisting internal conditions with abrupt and somewhat unpredictable external shocks. In addition to the colonial experience of many of these nations, the era of 'catching up' development led to heavy external debts (international finance being the main source of funding). Other factors, such as the OPEC oil embargo, the collapse of stable currency exchange, "petro" dollars, and overall fiscal and capital accumulation crises generated soaring interest rates that led many of the poorer debtor nations to begin defaulting on loans from private, international commercial banks. From 1976 to 1982 Third World debt tripled. In 1982 Mexico declared bankruptcy on its publicly guaranteed debt (McMichael 2004). In similar fashion, Peru and Jamaica went into economic tailspins and underwent a series of conditional bailouts (SAPRIN 2004).

In response to the debt crisis of developing countries, structural adjustment stabilization policies of the Fund and Bank sought to refinance Third World countries' debts under the conditions of institutional reforms favorable to the monetarist, trade liberalizing, privatization ideology of neoliberalism, justified in terms of comparative advantage. Because much Third World debt was owed to the banks of the dominant, core countries, the concerns of banking interests and the economies of the advanced capitalist core took precedence over the development potential of the debtor nations (Harvey 2004).

While SAPs had been experimented with in Africa, Turkey was the first country to undergo an official World Bank administered structural adjustment in 1980 (Reed 1992). Mexico, Brazil, Argentina and eventually three fourths of all Latin American countries and two-thirds of African countries were under some type of rationalization agreement with the IMF by the 1990s (Peet 1999). With the second wave of structural adjustment geared toward integrating post-Soviet societies into the global economy, most eligible countries were receiving conditional loans from the IMF or the World Bank by the end of the twentieth century (Stiglitz 2002).

Prior to this time, Keynesian policies had emphasized government spending as the key to improving the real productive economy (Peet 1999). Agricultural strategy at one time meant an increase in food and raw materials so as to supply primary goods sectors and to increase savings and tax revenues. These in turn were to contribute to a surplus for the development of other sectors, increasing tradable goods, and building the internal articulations necessary for economic development, with the potential through trade to earn foreign exchange, bringing returning income for industrial goods. This was to be carried out through an emphasis on intensification and made up much of the logic of and justification for the Green Revolution. While as a result of these policies there was some considerable increases in yield, there were likewise considerable declines in economic and human development indicators, eroding the theoretical basis for the state-led development strategy of the Bretton Woods era. Rather than addressing the historical legacy and unequal terms of trade that contributed to the plight of the Third World, critics used these failures to take aim at the Keynsian development paradigm, arguing that government involvement generated distortions in the market, and only by further removing regulation could countries get out of the 'rut' of underdevelopment (Peet 1999).

Trade Liberalization in the Context of Global Restructuring

Trade liberalization theory suggests that when countries remove barriers to trade, their comparative advantage in the export of one or two commodities earns foreign currency with which they can buy goods they would otherwise not have access to or would be more expensive to produce domestically (Peet 1999). Further reductions in barriers to capital investment, (allowing unfettered repatriation of profits to the corporation, for instance), attracts capital in-flows for the development of infrastructure and production, leading to job growth and increased purchasing power for domestic residents. Trade is a means to economic growth, and economic growth lifts a country out of poverty, thereby enabling it to improve its production system, including its efficiency of resource use. "Integration into the world economy has proven a powerful means for countries to promote economic growth, development, and poverty reduction," writes the International Monetary Fund,

> Most developing countries have shared in this prosperity; in some, incomes have risen dramatically. As a group, developing countries have become much more important in world trade—they now account for one-third of world trade, up from about a quarter in the early 1970s. . . . Progress has been very impressive for a number of developing countries in Asia and, to a lesser extent, in Latin America. These countries have become successful because they chose to participate in global trade, helping them to attract the bulk of foreign direct investment in developing countries. . . . But progress has been less rapid for many other countries, particularly in Africa and the Middle East. The poorest countries have seen their share of world trade decline substantially, and without lowering their own barriers to trade, they risk further marginalization. (International Monetary Fund 2001:1)

Trade liberalization theory rests on the notion of comparative advantage, which essentially holds that if a country can produce an excess of goods at a relatively lower cost than other countries, that it is beneficial for that country to specialize in such production and forgo producing other goods which might be needed, but which, through trading the commodity in which it has comparative advantage for those other needed commodities, it can gain marginal surplus returns (Ricardo [1817] 1911). The theory of comparative advantage was thought to be particularly important for countries trying to increase foreign exchange so that they could service their external debt, usually owed in foreign currency. Thus, as Third World nations found themselves politically independent and strapped for cash and capital with which to pursue the path of 'catching up' development, servicing debt then amounted to emphasizing export oriented economies that would in theory capitalize on the 'natural endowments' of the country (Valenzuela and Valenzuela 1978). As these nations needed foreign owned capital with which to develop, advocates of trade liberalization theory argued that the most efficient way to do so would be to open internal markets to foreign capital investment, thereby increasing the potential for internal development through the build-up of infrastructure, employment opportunities, and increased exchange (Stiglitz 2002).

Opponents to trade liberalization argued that the mechanisms involved do little to boost the overall wellbeing of the poorer countries. As liberalization entails removing protections for domestic producers and local currency, host countries have no internal producers to compete with subsidized import packages from the more advanced nations (SAPRIN 2004). Hence, consumers end up paying higher prices for imports, while local producers decline. In the agricultural sector, oriented for export, producers are also subjected to a price-cost squeeze between the cost to buy the capital intensive inputs required to convert to the industrialized agriculture needed to utilize their comparative advantage and the prices that the relatively low value-added commodities they produce can bring (Burbach and Flynn 1980; Magdoff 2004). Given that many producers must gain loans to buy the inputs necessary to compete, and that the rent on those loans is exacerbated by liberalization policies, the debt mechanism places additional pressure on this cost-squeeze crisis, bankrupting many domestic farmers, leading to expropriation and land concentration (Bernstein 1990).

Furthermore, since capital investments in the host country tend to go toward infrastructure that emphasizes primary sector activity rather than articulated production, the country must continue to borrow foreign currency to bankroll its needs, even while servicing existing lines of credit (McMichael 1994). Payments on imports and on debts must be made in foreign currency, requiring further dependency on export-based, cash-crop agriculture, even in the face of declining domestic consumption and undernourishment. Moreover, the theory that workers will have cash to buy imports overlooks the fact that, with a surplus population relative to failed internal, un-articulated economic development, wages are suppressed enough so that they can't buy these products at international prices without increases in credit. With relatively lower domestic income, there is no revenue for the state, and the state can't repay publicly guaranteed loans (Harvey 2004).

McMichael (2004) views liberalization policies as an ongoing project of global capital restructuring, a process run mainly by corporate entities and their government staff to subordinate the agricultural potential of the globe to the contingencies of capital accumulation, carried out through the institutional global frameworks for trade regulation. Accordingly, the restructuring of global capitalism via the WTO and World Bank/IMF is largely driven by the need to maintain global dominance of what are known as *food regimes*.[5] Accordingly, the regime of seed-oil, sugar, and livestock stabilized US hegemony during the "Fordist" period of accumulation specific to the post WWII Bretton Woods period (Friedmann 1982; Friedmann and McMichael 1989). With the collapse of Bretton Woods in the early 1970s, a new phase of global expansion and reorganization of global production was initiated, driven on by the ongoing stagnation crisis of monopoly capitalism, leading to the explosion of the financial sector and to flexible accumulation strategies that required secure global sourcing of raw materials, in addition to labor, used by agro-chemical and food processing corporations for industrial production downstream. This ongoing process/project culminated in the reorganization of the General Agreement on Tariffs and Trade (GATT) into the World Trade Organization (WTO), a project for the establishment of trade liberalization on a worldwide scale, representing yet another step toward stabilizing the new regime.

McMichael (2004) notes that the consequence of restructuring for national producers is that they are increasingly affected and must be responsive to a structure of "transnational space integrated by corporate circuits" entailing "the elimination of

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[5] Food regime as an organizing concept places emphasis on periods of "institutional norms and procedures through which a society organizes and conducts production and reproduction and how social relations are maintained given the class and other antagonisms which they produce" (Kenney et al. 1989). In this interpretation, "national regulatory frameworks and state rules are the product of class forces, while international regulatory structures are created from and are sustained by nations and other transnational entities" (Atkins and Bowler 2001).

boundaries—either spatial or temporal" which "violently reconstitutes humans through reconstituting the natural order, in the name of food security and peace" (McMichael 2004:11). This is an extremely important point considering that food security, both in terms of hunger and in terms of available calories, is framed as a global crisis by advocates of agricultural modernization, assuming that a unified global populous, but especially developing countries with high rates of population growth, faces extraordinary pressures as some kind of collective at the global level. McMichael (2004) challenges this narrative, instead pointing out that the consequences of relative and absolute scarcity are unequally distributed, including the disruption of alternative agrarian systems and the potential for endogenous (national or otherwise) development. Such unequal distribution is not an accident, or an externality of capitalism, but dependent upon the logic of the accumulation regime, where the beneficial outcome for some nations depends on the dire circumstances produced in others.

Ecological Modernization

Ecological modernization theory emerged during the period when development theory in general was challenged on environmental grounds. Initial work in this area dovetailed neatly with the liberalization paradigm, emphasizing the potential for market-based incentives to lead to industrial reorganization based in ecological principles. Over time the theory has shifted but the "basic premise" of ecological modernization remains that modern industrial societies can radically restructure their production in an ongoing process of reform using the central institutions of modern society (Mol 2001:59). In their wake, technology transfer will aid the developing societies to leapfrog past the dirtier industries to adopt the clean technologies emerging from the ecological restructuring of production taking place in the leading industrial countries.

Ecological restructuring is the outcome of multiple sites of action converging upon various "triggers" that instigate restructuring, effecting changes as far reaching a science, policy analysis, public concern, market forces, and social movements. This confluence of dynamics directs reflexively modern societies to address the pollution and degradation problems caused by industrialization, once the social powers of production have reached a certain level. Central to the theory is the idea that the path of modernization represents the best way out of the present crisis.

> Ecological modernization stands for a major transformation, an ecological switchover of the industrialization process into a direction that takes into account maintaining the sustenance base. Like the concept of sustainable development, ecological modernization indicates the possibility of overcoming the environmental crisis without leaving the path of modernization. Ecological modernization can be interpreted as the ecological restructuring of the process of production and consumption . . . . (Spaargaren 1997:77)

In essence, this involves the growing autonomy of the "ecological sphere and ecological rationality with respect to other spheres and rationalities" (Mol 2001:59). As evidence for such a growing rationality, proponents of ecological modernization theory point to the emergence and proliferation of green social movements, which, they argue, are irreducible to the political categories of left and right, and which are changing the ideological landscape of modern societies. While not a linear and inevitable process, these and other events are evidence that the beginnings of profound institutional changes are underway. Environmental management schemes, public and market demand for environmental quality, and the diffusion of clean technologies represent some of these changes (Mol 2001). Thus, the modernization process itself is identified in Ecological Modernization theory as potentially capable of overcoming its own self-made negative consequences.

From this point of view, capitalism is not intrinsically an obstacle *or* a path to sustainability, requiring no obvious commitment to radical transformation of existing social relations. Class, appropriation, inequality, imperialism; these concepts have no place in ecological modernization theory. Following Beck (1992) in this regard, class is considered an outmoded basis for political identity or for social mobilization because social conflict over the distribution of wealth, characteristic of the ‘first modernity,’ is replaced by the welfare state and the disembedding mechanisms of globalization making social conflict in the ‘second modernity’ predominantly an individualized struggle over managing and avoiding environmental hazards (Spaargaren and Mol 1992, see also Giddens 1984).

Mol (1997) argues that it is important to distinguish between the structural modernization and political modernization variants of EMT. Structural modernization is based in what Huber (1982) called the “ecological switchover,” a process of reassessing the “structural design faults of the industrial system” and economizing nature by placing economic values on its productivity (Spaargaren 1997:76). This early expression of ecological modernization theory depended heavily on a functionalist account of institutional change, and was summarily criticized on this point from multiple corners. However, evolving with these criticisms has been something at which ecological modernization theorists have excelled. The result, as Buttel (2000) suggests, is that the "more sophisticated versions of ecological modernization revolve around the notion that political processes and practices are particularly critical in enabling" the integration of ecological principles into the modernization process (p. 57).

Political modernization variants of EM stress "the specific sociopolitical processes through which the further modernization of capitalist liberal democracies leads to (or blocks) beneficial ecological outcomes" (Buttel 2000:59). Capital is neither central to nor an obstacle to "stringent radical environmental reform" (Buttel 2000:41). Environmental conflicts are not the linear result of opposing parties, but evolve from shifting alliances and coalitions. Ultimately, political hope rests with an educated population that can influence the production system through consumption patterns and political activity (Ehrhardt-Martinez, Crenshaw, and Jenkins 2002). This in turn requires a strong democratic state, free speech and assembly, and relatively undistorted media, so that ecological needs may diffuse through the cultural sphere, inducing public mobilization via the political sphere, and reforming the economy (Ehrhardt-Martinez et al. 2002).

Some of the latest developments within EM theory emphasize the complexity of globalization as the new locus for ecological modernity. To that point, EM theorists argue that an important issue for environmental social theory centers on distinguishing the role of markets, state institutions, and global governance. The ubiquitous and unbounded extra-national flows of capital, labor, information, resources, and especially pollution necessitate an analytical perspective that requires comprehending varying units of analysis within the global *flowscape* (Spaargaren, Mol, and Buttel 2006). Because actors within the global flowscape can be of any level of aggregation—social movements, global cities, transnational corporations, trade organizations, etc.—and because global environmental flows elude the purview and sovereign control of individual countries, the nation-state is increasingly seen as an obsolete unit of analysis with respect to environmental problems related to globalization. Ecological modernization is thus (at least implicitly) a process governed by trans-national institutions, alliances, and frameworks within the overarching process of globalization (Spaagaren et al. 2006:19–22).

Despite how emphatic the authors are about the new globalization and the propensity for ecological modernization theory to adapt its explanatory apparatus to it, EM nevertheless approaches its subject with traces of its modernization lineage still left intact. And despite exhortations regarding the rising importance of social mobilization perspectives within the theory, the focus on institutional reform still carries expectations of an ongoing process that is made possible by those very institutions themselves. Ehrhardt-Martinez et al. (2002) lay out this argument, stating that the "core of EMT" is the

> . . . proposition that the social problems created by structural modernization are temporary by-products of rapid social-transformation and are gradually alleviated by adaptive upgrading processes . . . [and while] social problems may grow from low to intermediate levels of development, such problems should subside as modern/industrial institutional matrices gradually replace older, pre-industrial social arrangements. (Ehrhardt-Martinez et al. 2002:228)

Furthermore, what the flows version of EM essentially does is to take the modernization acceptance of capital and labor as sociologically given, and then expand the sphere of the state to the level of multi-national and global governance. Yet, their implicit criticism of a cross-national level of analysis does not entail an elision of the nation state from consideration. Trade and payments balances are still registered according to national localities and regulatory practices begin and end at the borders of countries. Moreover, multi-lateral governance institutions are by their very construction multi-*national.* Indeed, representation on these institutions, such as the World Bank, is proportional to the level of economic development of those nations. Therefore, while ecological modernization as a theoretical agenda may be trying to move away from the nation state, as a set of theoretical propositions it dovetails neatly with the cross-national approach used here since the conceptualized role of multinational institutions in facilitating ecological sustainability is of central concern. Also, within the historical time period of relevance SAPs were leveraged upon individual, sovereign nations through the mechanisms of policy reform. While environmental concerns were never the major focus of these imperatives, at least in the first wave of structural adjustment throughout the 1980s, policy implementation nevertheless had environmental consequences resulting in part from the diversion of national resources away from alternative development pathways that may have done more to steward the resource bases of the Third World. With the new wave of restructuring in the 1990s, environmental concerns became part of the narrative of structural adjustment, begging the question of the actual efficacy of these policies for precipitating sustainable development.

The heart of the issue is whether or not such institutional reform actually improves economic development and at the same time facilitates overall and long-term sustainability. The expectation that reform through political and economic means plays a role in ecological modernization also presents an opportunity to compare its predictions with those of neo-Marxist approaches concerning the question of the affect of multilateral restructuring of production on sustainability. Specifically, examining the influence of structural adjustment programs (SAPs) on the impacts of agricultural modernization can help to evaluate empirically the veracity of claims regarding the theorized process of a potential within the so-called modernization process to move toward (sustainable) ecological rationality. This is especially important considering that institutional restructuring, according to EM theorists, has accelerated in the phase of late or reflexive modernity (Mol 2001:59). EMT identifies this period as beginning in the 1980s, corresponding to the emergence of the first wave of SAPs, but also somewhat later with the articulation of the sustainable development paradigm by the Brundtland Commission (World Commission on Environment and Development 1987). These correspondences are convenient because the data on structural adjustment used in the present analysis are limited in range to the beginning of the 1980s, facilitating assessment of whether the trends of agricultural modernization with respect to fertilizer use are indeed in the direction predicted by EMT.

The Environmental Kuznets Curve

The main way of conducting such an assessment is by looking for the presence of an Environmental Kuznets Curve (EKC) in national agricultural data. The environmental Kuznets curve hypothesizes a specific relationship between per capita income and environmental pressures (Grossman and Krueger 1992). Accordingly, in poorer countries resource depletion and pollution of the commons take second priority behind public demands for goods and services. As a country's industrialization progresses, its economy grows in scale, increasing throughput, and the society generates increasing impacts on the same relative regional space. "As economic development accelerates with the intensification of agriculture and other resource extraction, at the take-off stage, the rate of resource depletion begins to exceed the rate of resource regeneration, and waste generation increases in quantity and toxicity" (Dinda 2004:434). Developing countries cannot initially address the increase in environmental impacts with abatement measures, but as incomes increase and consumption levels are satisfied, greater public interest in quality of life issues—including concerns for environmental quality—take increasing priority. "In later stages of industrialization, as income rises, people value the environment more, regulatory institutions become more effective and pollution level declines" (Dinda 2004:432). Thus, income growth comes prior to effective implementation of environmentally friendly policy.

In addition to income elasticity for environmental demand and technological effects, there are also composition effects (Dinda 2004). Income elasticity poses that people will not demand environmental quality until they get other needs met first. Technological effects refer to the development of hyper-efficient, clean industries. However, composition effects refer to the structure of the society's growth, and as modern societies transition to 'post-industrial' status, the economy is thought to require less material throughput (Dinda 2004). In the EM literature, this is known as delinking economic growth from natural resource impact (Mol 1997). From the logic of ecological modernization, underdeveloped countries can build alliances with trading partners that provide technology transfers through foreign direct investment, thus reducing those countries' reliance on a pollution intensive path to development (Sonnenfeld 1998). Accumulating the capital necessary for research and development, or at least investment in clean technologies, allows for these countries to either modernize with the latest infrastructural systems from abroad or to implement their own. Thus, when applying ecological modernization theory to the cross-national context, trade becomes a key mechanism by which such ecologically friendly practices can spread.

Examining the data on agricultural modernization in order to find a potential Kuznets curve, it is worth noting that agriculture modernization is considered part of the "early stages" of modernization theory's stages of economic growth (Rostow 1960). Thus, there should be differences in the changes in fertilizer intensity over time for the same time period if a country is less developed than if a country is an advanced capitalist nation. Increasing machinery, irrigation, and wealth should, according to the theory, allow all countries to switchover to the more capital-intensive technologies that may save on per hectare fertilizer impacts. Indeed, the developing nations should as a whole show faster improvements, particularly as they enact open trade policies, since they will then benefit more dramatically from the improvements in agricultural technology. Overall, changes in GDP when comparing all countries across the development spectrum should also demonstrate a decline in the rates of fertilizer intensity, if not the absolute consumption of fertilizer.

Alternative Views of Agricultural Modernization: Neo-Marxist Approaches

Dependency and World-Systems Theory

A materialist theory of capitalism and development, arguing for the necessity of taking a long historical view in order to comprehend national inequality, world-systems theory (WST) presents a comprehensive and empirically examined sociological theory on development, and in recent years, the environment, one that offers a contradictory position on the relationship between existing modernization and the environment. Several postulates of WST unite the relatively loose assemblage of approaches to it: that the current structure of the world economy emerged in the colonial period of 1500 to 1650, that it is a stable hierarchy of wealth and power even though nations have relative mobility within it, that upward mobility is constrained by position within the hierarchy, and that such position greatly influences class structure and political struggles within countries (Roberts and Grimes 2002). These postulates form a historical-conceptual framework for explaining current geo-political and economic inequalities between nations, inequalities that have continued to persist and get worse over the last 50 years of development programs advanced mainly by industrialized nations.

In WST, because there exists a world-system, analysis of a single country or region's relationship to the natural environment must include how those regions are linked together. In turn, the secular trends of capitalism, including increasing commodification, greater proletarianization, the growth of corporate power, and the increase of globalized linkages between countries, are crucial for comprehending the present state of international trade and intra-national environmental degradation. The effects on social reproduction are structured by these secular trends. Producers are increasingly removed from the land, and from distant sites of consumption, breaking with the cognitive and physical feedback that connects the consequences of degradation with production practices, therefore causing producers to adjust current practices in response to perceived problems. Monoculture cultivation of specialized crops is favored, increasing the requirements for inputs such as fertilizers and pesticides. Production for use is pushed aside in favor of production for profitable exchange, removing workers from the capacity to exert a rational control over their own labor power, their environments, and their health and safety. Ultimately, the substitution of capital-intensive mechanization for labor raises both energy consumption and pollution (Roberts and Grimes 2002:180).

Derived from the dependency tradition (Amin 1974; Baran 1957; Cardoso and Faletto 1979; Dos Santos 1970; Emmanuel 1972; Frank 1969), WST developed its criticism of existing modernization theory on the basis of a theorized unequal exchange between politically coerced and structurally disadvantaged labor in the periphery and capital in the core (or center). These structural features are said to contribute to an exchange of differently priced goods, contingent on (1) the lower value-added status of primary sector commodities, which dominate the economies of peripheral nations; (2) an oversupply of labor in the periphery, depressing labor market wage levels, and (3) a superexploitation of labor *relative to* surplus value, keeping the rate of exploitation high (Chase-Dunn 1975; Sweezy 1982). Informal economies, and gendered, unpaid work, as well as subsistence, marginal, and precarious land tenure subsidizes wage labor by keeping the costs of the reproduction of labor power low (Dunaway 2001). In addition, outward oriented economies specializing in primary sectors for export fail to develop the differentiated inward linkages in the economy that would circulate capital internally. Even if mobile international capital invests in the domestic sphere of these disarticulated economies, capacity build up has largely been oriented toward raw material export and finished commodity import (Bunker 1984). The only other option for 'catching up' development, foreign credit, is exacerbated by currency inflation and global shocks (such as the oil crisis of 1973), potentially eroding any marginal savings needed for development (Chase-Dunn 1975).

World systems theory ultimately gains its legitimacy from the reality of the failures of modernization in the Third World. Such attempts at early and independent modernization were justified along the lines that "commodification, mechanization, and industrialization were equated with modernization, development, and [apparent] progress. The message was that third-world countries should develop along the Western model" (Barbosa 1996:319). However, with both the economic failures of following the modernization development path and the massive environmental changes engendered in the process, doubts about the "validity of the map" as well as the "destination" arose (Sutcliffe [1995] 2000:329).

In this context, world-systems/dependency thinking has expanded to include the effects that structured and hierarchical inequality among nations has on the sustainability of the developing world. Incorporating the idea that the main causal mechanism of environmental degradation internal to national development is the growth coalitions that operate in the political sphere (Gould, Pellow and Schnaiberg 2004; York et al. 2003a), world-systems theory began to focus on the ecological aspects of dependency, not just on economic conditions (Roberts and Grimes 2002).

The relevance of an explanatory view of both ecological degradation and uneven development in the international sphere is clear given the history and legacy of structural adjustment. Today, the overall levels of per capita consumption are much higher in the wealthier nations than elsewhere, but land use impacts relative to consumption is relatively higher in the developing world. Converting the productive land of Third World societies to export-based growth diverts the potential use-values that could benefit domestic consumption toward sites of consumption in the core. Meanwhile, the wastes of the core conception are shipped back to the periphery (Srinivasan et al. 2008). In light of these observations WST responded with the theory of *ecological* unequal exchange.

Unequal Ecological Exchange

Currently, the most prominent world-systems theoretical framework for comprehending the relationship between international trade relations and environmental degradation is the theory of Unequal Ecological Exchange (UEE). Drawing on dependency theory, specifically the work of Emmanuel (1972), and extending through the work of Bunker (1984), unequal ecological exchange views international vertical trade as the material manifestation of an unequal international division of labor *and* nature (Jorgenson 2006; Rice 2007; Shandra et al. 2009). In short, environmental change across nations is unequally affected by patterns of resource use distributed according to the structural features of the world-system, characterized by an "uneven flow of energy and natural resources reinforcing disparities in production and material consumption" (Rice 2007:65). This in turn is related to unequal terms of trade. These unequal terms can take several forms, primary sector export intensity and export partner concentration being two prominent examples (Jorgenson 2006).

The theory of Unequal Ecological Exchange, also called Ecological Unequal Exchange, locates the structural mechanisms for the unequal consumption and distribution of environmental impacts related to that consumption in the uneven flow of energy and natural resources between those countries whose economies are mainly centered around primary sector and extractive industries and those countries where productive economies dominate. Core nations engage in environmental cost shifting and space appropriation because of their historically conferred structural position, giving them disproportionate access to natural resources. This legacy is the result of the differential effects of colonization: some colonies were historically used entirely as sites of resource extraction, while other settler colonies developed internally due to preferable relations with the European powers. The result is a historically generated differentiation in the world system, emphasizing 'modes of extraction' in some regions and modes of production in others, the former being organized toward the extraction and export of resources while the latter becoming internally complex through the chains of exchange value made possible by the consumption of matter and energy derived from extractive regions, permitting the substitution of nonhuman for human energy and an associated division of labor, scale, and coordination of production (Bunker 1984; Rice 2007).

Moreover, it is the use value embodied in matter and energy that leads nations to seek out the appropriation of resources, as an economic necessity of production. Historical control over resource appropriation is a self-reinforcing movement, as value appropriation through energy and resource consumption gives greater flexibility to productive economies. In contrast, extraction and export loses the use value embodied in the extracted resources, and given the historical undervaluing of such resources (facilitated by the underdevelopment of regions of extraction and therefore an overall willingness to accept inferior terms of trade), the difference between income earned for resource exchanged at the point of trade does not register the further augmentation of exchange value resulting from the consumption of that use value along the commodity chain (Hornburg 2007; Rice 2007). Consequently, extractive regions not only gain less economic value relative to the overall economic value produced with the extracted resource in the larger global economy, their dependency on the mode of extraction makes them less economically flexible, and therefore less resilient in the face of dramatic changes in the world market (Bunker 1984).

Drawing on this tradition, Jorgenson (2006) brings in an actor-focused version of unequal ecological exchange, one that explains the externalization of environmental degradation to less-developed countries in terms of resource flows, but also in terms of domestic elites working in concert with the transnational corporations that dominate global commodity chains. Working with domestic elites, TNCs gain favorable terms to appropriate the material resources of the world, which often originate in resource extraction (resulting in resource base degradation) in the periphery. Thus, the mechanism of unequal exchange is not simply the point of trade but involves the terms of trade (Jorgenson 2006:691). Likewise, Shandra et al. (2009) focus to some extent on the relationship between transnational corporations and local elites. The latter group assists with the domestic details, acting as brokers to organize the process of the 'vertical flow' of resources from periphery. In the reverse direction, TNCs depend on willing domestic elites of the Third World to coordinate the externalization of dirty industries to the periphery, either through foreign direct investment or government-sponsored tax and pollution havens. Shandra et al. (2009) cite the case of the Sandoz Company, where the costs of cleaning up a chemical spill in Germany that turned the Rhine River into a dead zone led to that company's relocation of their organophosphate production to Brazil. Another prominent example of this 'downward verticality' is exemplified in the spread of Confined Animal Feeding Operations (CAFOs). Breeding, slaughter, processing, refrigeration, and freight technology have made it possible to locate these pollution intensive enterprises either in the internal periphery of the core nations (rural North Carolina and the Midwest being prime examples) or overseas (Sanderson 1986). Since the process is controlled by TNCs from the point of feedlot to market (where the highest value-appropriation is possible) capital has the doubly negative impact of polluting local waterways while at the same time extracting from the resource base through the grazing and tending of animals before they are brought to the lots. In the more extreme cases where animal confinement, feed, and other inputs are completely controlled by companies, the site of production represents a pollution haven, linked to value appropriation from other regions, such as the transnational movement of concentrated feed in the case of soy, the cultivation of which is a prominent factor in the current destruction of Amazonian forests (Barkin, Batt, and DeWalt 1992; Hickman 2006).

These trends illustrate Bunker's (1984) thesis that the global character of exchange in the world-system not only structures "pairwise" exchange between differing levels of productivity (ostensibly, differing "modes" of production) but also that "the industrial center's predominance over markets and its accelerated capital accumulation and technological innovation derive from multiple exchange relations" and that this fact belies the shortcomings of a theory that explains underdevelopment solely in terms of indirect transfers due to labor differentials embodied in goods exchanged between poor and rich nations (Bunker 1984:1052, 1053). Using their leverage to access relatively low exchange-valued raw materials, which function as highly sought after use-values in production and serve as inputs for higher exchange-value production downstream, the core nations of the world through their corporations are ultimately dependent upon resource extraction, but are in a position to do more with the extracted resource once in possession of it. Peripheral nations are dependent upon whatever income they can generate through extractive and more generally primary sector exports that ecologically fund core activities. Underdevelopment associated with historically outward orientations, disarticulation, and radical changes in exploited ecosystems is therefore not simply a relation of more labor for less, or a consequence of political enforcement, but includes "exchange inequalities inherent in extractive economies, in which value in nature is appropriated in one region and labor value incorporated in another" (Bunker 1984:1053). "Once we acknowledge," he writes,

> that not only the value in labor but also the values in nature can be appropriated, it becomes clear that we cannot counterpose the exploitation between social classes and between geographical areas. Instead we must consider the effects of the exploitation of labor and the exploitation of entire ecosystems as separate but complementary phenomena, both of which affect the development of particular regions . . . . The appropriation of values in nature from the periphery in fact initiated unequal exchange between regions, and between ecosystems, long before the rise of wages and the expansion of consumer demand in the core. (Bunker 1984:1053).

Bunker points to the loss of "use values in the environment itself" that progressive underdevelopment sets in motion, within historical conditions contingent on previous modes of colonial exploitation. Undermining the diversity of the resource base of a region, for instance, creates depressed ecological, economic, and social conditions that pose little opposition to the ingression of new extractive economies (even welcoming them) and that links these regions once again to the incessant vicissitudes of the global markets, reproducing the social conditions for the continuation of that region's reliance on extractive economies and subsequent decline. Bunker's conclusion is that the basis of unequal exchange between core and periphery, essentially, is that "extractive economies geared toward world trade tend to impoverish themselves" and therefore, that

> Analyses of commodity circulation, and the means by which it is controlled, must be combined with analyses of the modes of production and extraction which provide specific commodities to world markets in particular periods of time if we are to understand the progressive underdevelopment of extreme, or extractive, peripheries. Unequal exchange is not itself a direct or sufficient explanation.

> Instead, it sets in motion dynamics inherent in the extractive economy itself. (Bunker 1984:1056)

Bunker arguments about extractive economies tend to focus on the problematic of explaining underdevelopment and are not treated in depth here.[6] However, his general theory of extractive economies establishes a potential linkage between foreign capital dependence and its relation to export intensity, with agricultural technology as a mechanism for unequal exchange. Agriculture is not necessarily an extractive economy. In the cases of "soil mining" perhaps, but generally speaking, pre-industrial agriculture relies *in situ* on the productivity of other organisms and the management of labor. However, with the advent of industrial agriculture, meeting the challenge of soil fertility renewal is *linked* with extractive industries, as well as with energy-intensive industrial processes. The exploitation of labor in commodity agriculture at the point of cultivation becomes more indirect as the energy-intensiveness of the production system increases. Thus the linkage between industry and agriculture provides a means of explaining how agriculture that undermines the productive base of a region does so in dialectical relation

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[6] He places central importance on the notion that extractive economies do not gain the benefits of scale that productive economies do, because rather than a reduction in the unit cost of production with increasing scale, there is in fact an increase in unit costs, particularly as the source reaches exhaustion. This factor, combined with the ways in which extractive infrastructures are export oriented, undermines the potential for domestic accumulation. Rather, capital seeks extra-regional substitution for the extractive resource and the entire development project is left in the dust. In addition, extractive economies are economies where profits are found in exchange, and hence the low capital to labor ratio also contributes to the lower investment in internal articulations. Combined with the frontier character of access to resources, rendering land tenure tenuous, and the tendency of elites to facilitate maximum extraction in lieu of domestic development, and considering how previous modes of extraction greatly influence present modes, Bunker concludes "extractive economies tend toward eventual stagnation, broken by new extractive cycles if and when new demands for material resources available in the region emerge" (Bunker 1984:1059).

with accumulation elsewhere. The competitive pressure that leads toward economies-of-scale are dependent on industrial agriculture, and market competition on the whole confers advantage to those most able to valorize capitalized production, in turn linking producers with the middle men and commodity processors that set standards and pricing for a uniform agricultural product. Over time, the more a national agriculture is integrated into this capitalist orbit of commodified and monopolized means of production on the one hand, and processors serving affluent markets on the other, the more dependent it becomes on industrial agriculture and the more it erodes its resource base.

However, explaining this linkage in the world-systems approach is primarily done with reference to colonial history and current geopolitical dynamics. Thus, WST is primarily a political theory with respect to pre-defined positions in the world of economy.[7] That is, the world-systems approach, and unequal ecological exchange in particular, tends to leave unexplained the relationship between social dynamics and the world-system, except by reference to its historical status *as* a world system, one that emerged in the long 16th century as a historically unique confluence of "a 'world'-wide division of labor and bureaucratic state machineries" leaving peripheral areas with relatively weak state apparatuses, precisely what is needed for mobile capital to leverage better terms of trade (Wallerstein 1972:355).

Unequal ecological exchange emphasizes extant structural inequality in terms of trade, terms that reflect how the history of extractive and natural resource based economies degrade not only the land but also the options of those societies to adapt to

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[7] The work of Jason Moore (e.g., 2000) is a notable exception to this trend.

changing global processes. Yet, UEE, focusing as it does on the role that "capital penetration" plays in undermining the development possibilities of a society, and in environmental terms facilitating the outsourcing of dirty industries to poorer nations while generating profit expatriation from the host countries, takes for granted the existing market, or at least the *potential* market for surplus investment.

In keeping with the argument that a *capital*-systems focus is necessary for comprehending the influences that exacerbate the impacts of agricultural modernization, I turn next to theoretical work that emphasizes the logic of capital accumulation and the ongoing project of capitalist development. The concept of societal metabolism is introduced to call attention to the socio-ecological and therefore structural character of food production generally, and the global food system in particular. From there, the section builds from primary accumulation and commodification, uneven and combined development, to the center-periphery model, the problem of accumulation, monopoly capital and scientific-technical management, and finally the theory of ecological imperialism. The point is to illustrate how agrochemical industrialization is part of an ongoing process of capital accumulation, how indirect control of the farm labor process and appropriation of surplus farm labor operates within the larger sphere of accumulation, how this is a consequence of historical conditions directly related to expropriation, resource appropriation, and land degradation, and how from this perspective, structural adjustment can be theorized as a vehicle for integrating more and more of the sphere of nature's productivity into the accumulation process with little regard to the human needs and endogenous sustainable development potential of the nation in question.

Societal Metabolism and World-Historical Capitalist Development

> Capital is not a thing, but rather a definite social production relation belonging to a definite historical formation of society, which is manifested in a thing and lends this thing a specific social character. Capital is not the sum of the material and produced means of production. Capital is rather the means of production transformed into capital, which in themselves are no more capital than gold or silver in itself is money. It is the means of production monopolized by a certain section of society, confronting living labor power as products and working conditions rendered independent of this very labor power, which are personified through this antithesis in capital (Marx 1981:814–815).

Both Fischer-Kowalski (1997) and Foster (1999a, 2000) trace the usage of metabolism as applied to societies back to *Capital* Volume I, in Marx's anthropological definition of the labor process. Accordingly, labor is the process through which "man [sic], through his own actions, mediates, regulates and controls the metabolism between himself and nature" (Marx 1976:284). Labor as a process is both a nature-imposed condition on humans—we must labor in order to live—as well that which confronts historically imposed conditions, natural and social. In this dialectical view, the labor process refers to "the material exchanges and regulatory action associated with ... 'nature-imposed conditions' *and* the capacity of human beings to affect this process" (Foster 1999a:381, emphasis added). Thus, the requirements of material intercourse include not only circulation but also regulatory action. Such action implies social constraints and social transformation. In *Wage Labour and Capital* Marx (1978) describes the nature of this relation:

> In the process of production, human beings work not only upon nature, but also upon one another. They produce only by working together in a specified manner and reciprocally exchanging their activities. In order to produce, they enter into definite connections and relations to one another, and only within these social connections and relations does their influence upon nature operate, i.e., does production take place. (Marx 1978:28)

And so while Marx conceives of the labor process *in general* as the mediating factor of our metabolic relation with the earth, the specific form this takes is contingent upon numerous factors, opening up multiple possibilities for human evolution. Because the labor process is organized in different ways, according not only to basic biophysical needs but also according to social needs, societal metabolism is intrinsically a *socially structured* mediation. This is why Marx emphasized labor as the *metabolic relation* between humanity and nature (Foster and Burkett 2000; Haila and Levins 1992).

The productive triad of forces, relations, and conditions is therefore subject to various configurations of relative stability and relative change, but the central pivot is the labor process, for it is through societal labor that we employ our industrial powers, developed from the range of productive capacities, delineated by conditions not of our own making, and in the process laying down conditions for future. As the division of labor is an expression of the development of those capacities, it forms an important means by which social needs are produced.

However, under capitalism the division of labor is not simply the consequence of functional task specialization. Task specialization is conditional upon social needs and social needs are determined by the appropriation and distribution of surplus. In capitalist development, appropriation and distribution of surplus is driven by the system imperative to accumulate surplus and find new outlets for its reinvestment. However, because appropriation of surplus *labor* requires labor's productivity above its costs of reproduction, the imperative is to find new ways to combine labor with capital. This is typically done through the use of machinery to employ labor (rather than labor employing machines) and through every opportunity to simplify and monopolize the labor process, or at least monopolize what labor needs for its own renewal (Braverman 1974; Lebowitz 2006).

Thus, the root, so to speak, of the capitalist division of labor is the separation of the majority of human beings from the productive means they need to survive, creating a condition where access to the necessities of life is mediated through capital. "Indeed for Marx, capitalism's alienation of labor was dependent on (and could only be developed in accordance with) the alienation of human beings from nature" (Foster and Burkett 2000:415–6). This servering of prior connections between people and the land (*previous, primary,* or *primitive* accumulation) underpins not only the exploitive relations that characterize capitalism as a class-based system, but also the ways in which nature is subdivided and simplified and directed toward accumulation.

The antagonism between urban centers and hinterlands that formed the basis for capitalist dominance of the countryside was the prototype for the antagonism between center and periphery that persists in the capitalist world to this day. However rather than simply the siphoning of useful values to the urban center for sustained consumption, as in prior class-based modes of appropriation, the hallmark of capitalist relations moves from the initial separation of labor and nature to their recombination in alienated form. It is this recombination that really establishes the possibility for continued appropriation of surplus labor and the economic surplus of the society as a whole. The buying and selling of labor as a commodity, the existence of a formally free class of propertyless workers, that class's necessity to sell their labor power, and the ultimate dependence of the class of private owners of industry on the proletariat for profitable investments derived from the appropriation of surplus value; all of these conditions worked together to create the means by which capitalist development established itself in the heart of its host country of England. From that inception to the present day primary accumulation and commodification act as twin moments in the ongoing process of capitalist development. From the separation of the worker from the means of production (not just the land) to the transformation of all aspects of the production process into commodities, to the recombination of these commodities, to the extension of commodity relations to new and expanding spheres, world historical capitalist development encounters the limits of accumulation and its renewal through this two-fold process.

Evidence from the twentieth century shows that rather than technological developments in agriculture being merely self-driven, research and development has repeatedly been conducted in service of increasing the potential for capital penetration into this sector (Kloppenberg 1988). This dialectic can be seen in the recursive nature of the development of machinery, techniques of cultivation, and plant breeding projects during the twentieth century. During this period agricultural modernization amounted to converting locally sourced seed, implements, draft power and soil fertility into commodities supplied by industrial firms (Heffernan 2000). On-farm activity once involved direct interface with dynamic landscapes of living plants and animals, with local geographical conditions, including weather and hydrology. Today it has became increasingly dependent on distant sources for farm unit renewal (Lewontin 2000). To give but a few examples that demonstrate the role of capital in the development of agriculture, taken from twentieth century: the relationship between plant cultivation and machinery (tomatoes), irrigation (high yield wheat), and capacity to consume soluble fertilizers (high yield maize); the breeding of soybeans able to withstand proprietary pesticides (Round Up Ready); and the selection pressure on and transgenic manipulation of plant germplasm in order to maintain residual income (the terminator gene) (Berlan and Lewontin 1986; Hightower 1973; Kloppenberg 1988; Lewontin 2000; Shiva 1997).

Primitive accumulation and commodification at the micro scale have at the macro level their counterpart in uneven and combined development (Dunaway 1995). Uneven development refers to the fact that the legacy of the protected and “experimental” development of capitalism in the core cannot be reproduced in the Third World because the accumulation process is already well under way, and that maintenance of the accumulation process requires by necessity maintaining the appropriation of nature’s productivity, drawn from whatever corner of the world that can be had. The wealth and power of the core historically grew from the wealth and labor of the periphery, and the massive consumption and process of capital accumulation within the capitalist world system depends now as it did then on the continued appropriation of raw material use values and labor. Specific to agriculture, comparing agricultural productivity levels between advanced capitalist nations and the rest of the world, the better-capitalized producers outdo their counterparts. The 'underdevelopment' of the periphery is in part therefore a legacy of this history of uneven development.

Combined development denotes both the existence of producers of unequal productivity side-by-side as well as the effects of transferring technology from core to periphery when the peripheral focus is mainly on core consumption and the global market is highly competitive. Agricultural modernization in this scenario facilitates the further appropriation of nature and labor, but indirectly through unevenly structured competition, rather than directly through the colonial system. Together, uneven and combined development describe the operation of the world system, and how the system at a structural level continues the perpetuation of unequal exchange.

In one sense, primary accumulation and commodification can be thought of as events analogous to uneven and combined development as processes. With regards to the agricultural development of the Third World, to farm labor generally, and to peasant labor specifically, Bernstein (1990) noted the process under World Bank structural adjustment that involved the separation and recombination of peasant societies, laying out a conceptualization of how primary accumulation and commodification could operate in the post-colonial world (in neo-imperialist fashion). In his analysis he noted how the processes of intensification and commodification led to the labor and land of peasant production becoming successively integrated into the capitalist sphere, whether forcefully or not, operating as primary accumulation; as ongoing moments by which modes of production are transformed, and the labor and natural resources previously not accessible to the capitalist core become accessible. Bernstein (1990) distinguishes between brute force (the "smashing" of the peasantry), exclusion ("bypassing" in the form of genuine uneven development within the same domestic economy), or third, the integration of agricultural labor into the capitalist orbit, "locking in" through the effective commodification of the means of production. This third form expedites "higher—and controlled—levels of input and credit use, and controlling (increased) output through the organization of marketing and processing, thus achieving greater commoditisation, specialisation, and standardization" (Bernstein 1990:8–9). The result is "the *concentration of resources* where conditions are most conducive to accelerated commoditization" such that "on the grounds of maximizing growth of output and returns to new technologies and project investment, agricultural 'modernisation' is likely to accelerate spatial or regional differentiation, social differentiation (or class formation), and gender differentiation" (Bernstein 1990:9). A second and related consequence is a strong emphasis on monoculture cropping in order to "reap the benefits of specialization and standardization" (Bernstein 1990:9). Of the negative effects of this differentiation and the recombination of specialized production units, Bernstein includes the observation that, as practiced, the "'technological treadmill' of high yield farming is sustained only by increasing social costs in terms of energy and chemical use, and of environmental pollution" (Bernstein 1990:9). Here, then, is the formal link between structural adjustment, agricultural modernization, and environmental degradation in the Third World.

Marx's Theory of Metabolic Rift

One of the central characteristics of capitalist development is the incessant drive to incorporate labor and nature into the pursuit of capital accumulation, in the process producing a "rift" between societal metabolism and the soil fertility renewal necessary to maintain productive land. Seen in this light, the ecological problems associated with modern agriculture date back at least to the large-scale agriculture that supported Europe's industrialization (Foster 1999a). Rooted in the enforced separation of the peasantry from the land, the consolidation of landed property and the implementation of intensive techniques of production—combined with the use of farm-rent tenancy—England's historical growth was fueled from the interplay between agricultural intensification in the country and industrial growth in the cities. These developments divided the mass of human endogenous metabolism from the soil basis of agricultural mediation, undermining the "eternal natural condition for the lasting fertility of the soil" (Marx 1976:637; see also Foster 2000; Foster and Magdoff 2000; Moore 2000; Wood 2000). Thus, the emergence of capitalist society amplified the historical divide between urban centers and their hinterlands, exacerbating the problem of unreciprocated nutrient transfer from the latter to the former. Marx viewed the rupture in nutrient cycling of his day as ultimately "tied to the accumulation process," a phenomenon that was "only intensified by large-scale agriculture, long-distance trade, and massive urban growth" and with the ongoing development of capitalism, "whether through colonialism, imperialism, or market forces" new rifts emerged, at larger and larger scales (Clark and York 2008:16).

Overcoming relative soil exhaustion (alternately: realizing the social necessity of maximizing yield) by returning to prior modes of soil fertility renewal was irreconcilable with the development of capitalism due to a combination of factors, not least the existing structure of center/periphery relations that formed the heart of capitalist appropriation from its very inception (Stavrianos 1981:62–73). Reproduced in the wage-labor/capital relationship, and in the uneven "hierarchical command structure" of the modern world system (Mészáros 1995:46), the unique and ongoing world-historical development of capitalism could not and to this day "cannot be actualized and 'realized' (and through its 'realization' simultaneously also reproduced in an extend form) without entering into the domain of *circulation*" (Mészáros 1995:46). That is, once the initial separation of alienated interests at the international scale takes hold, once the "functional/technical (and later highly integrated technological) division of labour" draws surplus labor and nature into its orbit (or expels it altogether in the form of misery and pollution), the contradiction between "maximal extraction of surplus-labour from the producers in whatever form might be compatible with its structural limits" and the necessity for the realization of value compels controlling classes at the command of the "hierarchical social division of labour" to seek out new labor and new qualitatively useful values from nature in order to overcome the inevitable economic crises that result from the asymmetry between appropriation and circulation (Mészáros 1995:47).

Prior modes of production generated their own ecological crises, including that of soil fertility, but capitalism is unique in that it has the 'built in' tendency to accelerate the scale of ecological degradation, even as capitalist society tries to solve it. The heart of the contradiction lies in the overarching emphasis in capitalist society on technological development as the solution to ecological problems, even as these problems are in part a consequence of earlier technological developments, what Clark and York (2008) call a tendency to 'shift' the problem from one problem to another.

Ultimately, the social position where one is able to accumulate economic value above and beyond one's own labor is occupied precisely by setting in motion the forces that draws upon the labor of others. Not only is the transformative capacity of labor power necessary to increase economic *exchange value*, this activity must work on and work up material that can serve as the *bearer* of surplus value. In turn, accumulation of surplus is dependent upon its reinvestment. Once the reinvestment is made, the composition of capital to labor must be on the whole larger than before, so as to gain a return. As the expansion of capitalist development brings more and more of the globe into its orbit, this requires more and more of nature to consume.

Agrarian Labor in the Era of Monopoly Capital

The forces of production operate diffusively throughout the activity of a society, but are, under capitalism, concentrated and directed for the private appropriation and reinvestment of the surplus of a society. Distinguishing the means of production from the forces of production is therefore more than just an exercise in categorization, but instead has methodological relevance. Control over the productive forces of society, including the appropriation of labor at multiple sites along the commodity chain, frees up the need to directly control the means of production, so that they can be sold as commodities.

Outright possession and monopoly of use of the agricultural means of production is less important than the ability to integrate farmers into to the system of farming and food production for the valorization of capital.

This fact is obvious once one distinguishes farming from agriculture, with the labor process of the former structured by global system. "The real profits in agriculture," writes Magdoff (2004),

> are not made by growing commodities such as wheat, corn, rice, cotton, or apples. The profits of capital are generated by agribusiness at both sides (before and after) of farming. At the beginning of the 20th century, about 40 percent of the value of food purchases in the United States went to farmers; by the end of the century they received only 10 percent. The remaining money went to input suppliers (25 percent) and transportation, processing, and marketing (65 percent). (P. 13)

In contrast, farming is risky business (Lewontin 2000). Ownership of land cannot be depreciated, and investment in it has low liquidity. Economies of scale are limited to the maximum efficiency of middle-range farms (Buttel, Larson, and Gillespie, Jr. 1990). Weather, disease, and pests represent insurance costs. And the very process itself, turning seed into raw commodities, is limited to capital penetration by a reproduction cycle that cannot be shortened in order to increase a faster product-to-time turnover ratio (Lewontin 2000). For these reasons, the wholesale, direct takeover of farm ownership by large corporate enterprises is not likely, except in very lucrative luxury markets (Lewontin 2000).

While the split between farming and agribusiness gives some analytical clarity to the overall agro-food system, it nevertheless poses a theoretical challenge to theory of capitalist development. Insofar that capitalism is defined in terms of propertyless workers and owners of the means of production then farming seems to represent some middle ground between the two. Petty producers run their own farms much like petty merchants and business owners. However, in the era of monopoly capital, with the rise of the major corporation, the capacity for small and independent firms to withstand the advantageous position of corporate enterprise is weak. Why not farming then?

Braverman's (1974) identification of the scientific-technical management of the labor process under monopoly capital provides a bridge between the larger theory of monopoly capitalism and the problem of the persistence of petty and peasant farm producers, long seen as evidence against the notion that capital accumulation is a inexorable process that successfully incorporates more and more of labor and nature (Mann 1990). Following Braverman's delineation of the relationship between the industrial labor and the tendency toward control and simplification of the labor process, a link can be made between farm labor and accumulation that need not rely on value analysis alone and instead emphasizes the capitalist division of labor. Braverman's contribution to the theory of monopoly capital connected twentieth century changes in the labor process with the way the product of labor (economic surplus), under the direction and supervision of the corporation, is an organizing force of scientific and industrial production. Thus, his contribution to the theory elaborates the relationship between labor and capital at the point of production, as shaped by the totality of the society as a whole, in accord with Marx's analysis of the capitalist rate of exploitation.

However, in farming, the relationship of the petty producers to capital is one of exchange. This would seem to belie a theory of exploitation that relies on going beyond the veil of exchange into the heart of the production process itself. Yet, in its highly capitalized form, the coordination, scale, and energy-requirements for the production of intensified agricultural means of production complement corporate concentration and centralization in a unique way, doing so in a manner not that dissimilar from Braverman's descriptions. While petty and peasant producers appear autonomous, the farmer only has the *appearance* of control of the labor process once locked in with the commodified and monopolized means of production. With the extension agent as manager, and the trade publication as ideology, farm activity is delineated by the methods of production required to remain competitive, and these are determined by the overall profitability of the large firm. Consequently, monoculture, motomechanization, and uniformity determine the rationalized cultivation method, and dependence upon industrial production of commodities for seed, pest control, and the renewal of soil fertility links farmers to the universal market, constituting an indirect scientific management exercised by determining the type of development of the overall productive forces.

Thus, the logic that governs both industrial and agrarian labor in the period of monopoly capitalism derives from the system-properties of capital accumulation, upon which the social relation of capital depends. Appropriation of surplus labor through the assimilation of farm labor expands the conceptual framework of the exploitive labor process under capitalism beyond the factory gate to include the multiple points in the commodity chain that depend upon the commodified materials (related to, yet distinct from raw materials) needed in order to economically and profitably carry out farm activity in the context of the global political economy. Braverman (1974) describes the contours of development within this mode of reproduction of societal metabolism in terms of industrial labor:

> The first step in the creation of the universal market is the conquest of all goods production by the commodity form, the second step is the conquest of an increasing range of services and their conversion into commodities, and the third step is a 'product cycle' which invest new products and services, some of which become indispensable as the conditions of modern life change to destroy alternatives. In this way the inhabitants of capitalist society are enmeshed in a web made up of commodity goods and commodity services from which there is little possibility of escape. (Braverman 1974:194)

While it is clear that Braverman's "inhabitants" are characteristic of the advanced capitalist nations, the progression of capitalist development and its culmination in the circuit so described is generalizable to the uneven world system as a whole. The conversion of agrarian means of production into a commodity, the conquest of the services (i.e., labor process) of cultivation (including ecosystem services), and the enmeshment in a product cycle are all hallmarks of the effects on the farm labor process as it is integrated into the circuit of capital.

The transformation of farming involves transforming the farmer into an instrument of production, and thus under capitalism, an instrument for accumulation. In order for these conditions to exist, however, preexisting affairs must be overcome. Structural adjustment, from this theoretical perspective, represents an extra-economic procedure by which such transformation can be carried out, "freeing up" land and labor. To further illustrate this thesis, I discuss next the theory of ecological imperialism.

The Theory of Ecological Imperialism

In their discussion of "ecological imperialism" and unequal exchange, Clark and

Foster (2009) also link the global metabolic rift with primary (primitive) accumulation and its relationship to the world-historical development of capitalism, but in doing so they give an account of world capitalism that appears less about uneven development and more about domination. In their account, drawing on Marx, "the process of primitive accumulation established divisions between core and periphery nations, as the wealth of distant lands was appropriated through various mechanisms" (Clark and Foster 2009:314). Expropriation of the peasantry in Europe was complemented by the expropriation of the natural resources of the periphery. This "robbery" contributed to the genesis of the industrial capitalist, leading to the development of agricultural chemistry, in turn generating interest in guano as fertilizer that could be used to replenish European fields that were being depleted by the very methods of applied industrial agriculture in the first place.[8]

Thus, from its very inception, the *actual history* of capitalist development in Europe involved drawing the resources and labor of the globe into the circuit of the internal development of the capitalist nations. Resources siphoned off from the periphery were wrought up in core factories, to bear value as labor produced commodities, contributing to capital accumulation, setting in motion the process of self-expanding value, generating new conditions for increasing the exploitation of core agricultural labor, and soil, once again through the continued process of primary accumulation. Ecological imperialism allowed the "core capitalist states to compensate for the degradation of their

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[8] Clark and Foster cite the insights of Morton, who noted that the application of "industrial improvements increased the uniformity of land, making it easier to increase the scale of operations and to employ industrial power to agricultural operations" (Clark and Foster 2009:315).

own environments through the even more rapacious exploitation of the natural resources of periphery economies" (Clark and Foster 2009:316). South American guano, as an example, was mined with the superexploitation of imported Chinese labor, political intrigue, and military force, and shipped back to Europe.

At the world-historical level, ecological imperialism created a "new division of both labor and nature" and generated "a form of industrialized agriculture that industrially divided nature at the same time that it industrially divided labor" (Clark and Foster 2009:314, 315). What is especially important about this division is the link between agricultural labor supplying industrial processes and industrial labor feeding back into agricultural productivity. Comprehending capitalism as a system, they argue, requires the recognition of the co-respective divisions of labor and nature, divisions intrinsic to the development of the system as a whole, rendered under alienated form vis-à-vis the social divisions that capitalist private property entails. This 'dialectical systems' viewpoint requires analytically that we see the activity of individual agricultural producers not as distinct—which appears as their 'natural' condition in capitalist society—but in their very activity structured by the domination of merchant, industrial, and financial capital. The treatment of capitalism as a system makes it possible to see the international dynamics that play out in the division of agricultural producers from the means of production, despite the persistence of mixed forms of production (peasant, petty producer) which do not always appear at the point of production to involve the appropriation of surplus value (even though they often do).

This last point is important because it allows for the comparison of national agricultures within a framework that recognizes key structural differences within the world system that are not simply explainable through the mechanism of exchange. The difference between "independent development at the center and dependent development in the periphery" essentially begins with the fact that agriculture plays a very different role in the periphery than it did in the historical formation of the advanced capitalist nations (Sweezy 1982:213). It was the increased productivity of early capitalist agriculture that sustained capitalist development in the center, freeing the agricultural labor force, increasing rural to urban trade, and hence wage labor manufactures at a smaller scale, leading to an increasing division of labor and finally the development of large-scale machinery. At each stage in the process, industry fed back on agriculture, to improve its ability to exploit soil (Sweezy 1982).

In contrast, to explain the predominance of inefficient agriculture in the periphery it is necessary to note that peripheral nations have

> Centered on the cultivation of at most a few specialized crops for export, and in the process have tended to withdraw the best lands and other rural resources from vitally needed domestic production. The consequence is the paradox, almost universally observable in the periphery, of countries with predominantly agricultural economies unable to feed themselves and forced to import a large and increasing proportion of their requirements for grains and other staples from the countries of the center. (Sweezy 1982:217)[9]

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[9] Sweezy (1982) discusses another major difference between center and periphery relevant to the discussion here: the rate of exploitation. The exploitation of labor and appropriation of surplus value through wage labor are nearly identical in the center. In the periphery, exploitation takes other forms, "landlords, traders, and usurers," in addition to surplus value appropriation. Working conditions are more difficult and time consuming, relative wages lower, labor is reproduced by non-wage means, including gendered divisions of labor, all combining with mass unemployment to make for a higher rate of exploitation. Such conditions help to maintain the domestic elite's wealth and

Consequently, the exhaustion of the soil of Third World agriculture and the increased dependence on monopoly controlled inputs does not even have the benefit of feeding back into the articulated development of the country, including the reorganization of production to maintain the integrity of the soil resource base. Recognizing this implies that independent development for the Third World requires promotion of an agriculture articulated with industry at a different scale, composition, and ownership structure than what is currently at work, which in turn means, in the terminology of Amin (1990), delinking the relationship of Third World farmers from monopoly capital generally, and foreign investment specifically.

It is for these reasons that combined development, forced upon nations via structural adjustment, should not lead to the beneficial and sustainable outcomes suggested by ecological modernization. Periphery nations are induced to degrade their own environments in part because of preexisting degradation under colonial regimes and in part because it is profitable do so. In the process, they bear a disproportionate amount of the world's wastes. Nor should the sanguine expectations of liberalization theory work, not only because competition and trade are between unequally 'equipped' partners, but also because the nature of the periphery has already been divided, and primary accumulation has qualitatively changed the conditions of production, such that the forced exploitation of land for commodity production recombines exhausted space with alienated resources (Bernstein 1990).

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power, in addition to the continued export of surplus to the center. Ultimately, the masses in the periphery "are looked upon as costs, not as consumers: the lower their real incomes, the higher the profits from selling to the local upper class and the international market" (Sweezy 1982:217).

Therefore, when analyzing the alienated form of social production in the global capitalist system, and the question of how individual production units mediate their relations to one another, to their populations, and to the land, and how the relations of production mediate the relations between classes and between nations, we then are confronted with explaining the mechanisms by which ecological unequal exchange is perpetuated. Dependency/world-systems theory takes for granted the existence of inequality in the world system, tracing such unequal positions back to the colonial developments. By reinserting the issue of ecological imperialism into the discussion on unequal exchange, Clark and Foster (2009) have opened up the possibility for viewing nations not as various 'atoms' on their own trajectories toward agricultural and industrial modernization, nor as simple rational traders with fewer and inferior *endowments* in the agricultural means of production, but as *inheritors of ecological squalor*, caused by the uneven development and ecosystem degradation/transformation brought about by their initial inducement into the global capitalist orbit.

Degradation of the resource base, particularly in the case of soil fertility, *creates and perpetuates* the dependency on extra-local sources of fertility renewal. Unequal exchange is therefore a symptom, not a cause of agricultural intensification. Once having established the initial separation of producers from the land, and of the renewal of the means of production from land-based processes, as well as the renewal of soil fertility from cultivation *in situ*, and the husbanding of animals from cropping systems, the separation of nature provided the basis for the monopolization of these requirements of agricultural sustainability. Moreover, the demand for the cheapest and fastest yields with the highest turn over, in order to maximize market share, drives producers, now recombined with the land under the capitalist mode of production, producing commodities for exchange, to maximize the capital intensiveness of their agriculture through the purchasing of industrial means applied to cultivation. As Clark and Foster (2009) note,

> Ecological imperialism allows imperial countries to carry out an 'environmental overdraft' that draws on the natural resources of periphery countries. As the material conditions of development are destroyed, Third World countries are more and more caught in the debt trap that characterizes extractive economies. The principles of conservation that were imposed partly by business in the developed countries, in order to rationalize their resource use up to a point, were never applied to the same extent in the Third World, where imperialism applied an 'after me the deluge' philosophy. (Clark and Foster 2009:330)

Thus, the movement begins with changing/degrading the material conditions of production, ensnaring with the debt trap in order to purchase as commodities what were once on-site renewable resources in order to compete, and frontier style activity with little concern for future sustainability. Even if local producers are sensitive to sustainability needs, entering into cycles nevertheless links them, and their livelihoods, to the global circuit of capital.

Explication of world historical capitalist development is one thing, but in keeping with the overall agenda of empirical research it is necessary to establish the specific and proximate causal processes that test the predictions of each theory. In the chapter that follows, I review existing quantitative research on trade and export liberalization, foreign direct investment, and structural adjustment in order to prepare the way for the analytical component of the research project.

CHAPTER III

LITERATURE REVIEW

Research on Global Inequality and the Environment

This chapter reviews the research literature that has attempted to explain and empirically assessed the negative ecological effects of agricultural export dependence, foreign investment dependence, and structural adjustment on ecological sustainability. While many of these studies and the theories used imply one another, and there may be considerable overlap in the ways their identified mechanisms operate, the analytical necessity of operationally defining such mechanisms has led to the practice of isolating one or the other phenomenon as independent and therefore of analytical interest. Following suit, after the review I isolate the key predictions that can be derived from the theoretical statements, and which have proven to be of predictive value in previous cross-national research. The review covers some discussion of case studies but mainly is limited to those quantitative analyses that have focused on the environmental impacts from agriculture in particular, and which have employed independent variables of interest that relate directly to the theory above.

Environmental Kuznets Curve

The evidence of an EKC in the overall trajectory of environmental impacts associated with modernization is mixed. Most evidence is limited to countries that are already well capitalized, or to the study of limited, short-term, local impacts from specific, point-source pollutants posing high risks to human health, such as sulfur dioxide (Dinda 2004). In contrast, globally diffuse yet disruptive outputs of CO_2, energy consumption, waste disposal, and traffic volume increase monotonically. Citing a "pollution haven" effect Dinda notes the thesis that "the changes in the structure of production in developed economies are not accompanied by equivalent changes in the structure of consumption, therefore, EKC actually records displacement of dirty industries to less developed economies" (Dinda 2004:436). Failure to generate the equivalent change in composition translates, for the Third World, into a predominance of the agricultural, livestock, forestry, and mining sector industries. Foreign direct investment and other mechanisms of liberalization can also contribute to an environmental race to the bottom: as capital flees environmentally restrictive countries for less restrictive countries, poorer countries compete for capital by reducing such restrictions, fighting to provide the cheapest place for the dirtiest capital to operate. Rather than the diffusion of high-tech and efficient technologies, outmoded technologies (and pesticides) are transferred to the periphery (Jorgenson 2006).[10] This last point is particularly important when considering the effects of agricultural modernization on the

[10] There is the question as to what level of development is necessary for an environmental Kuznets curve to occur, and whether or not that such a level of affluence is even attainable for the majority of the world, or if it were, whether or not the world's ecosystems could bear it. The turning point in the EKC is of course a function of the specific impact in question. Yet the higher the turning point the more worldwide emissions continue to grow as countries try and top the curve (Selden and Song 1994) and passing the turning point is nevertheless very likely to exceed ecological thresholds beyond which environmental change and deterioration is irreversible (Arrow et al. 1995).

resource base of countries.

However, there is also reason to believe that an EKC in fertilizer intensity, and overall energy use in agriculture, is a real possibility. For fertilizer, diminishing marginal returns in yield for the amount used is influenced by the fact that the high-yield varieties are showing evidence of maxing out their yield potential (Brown 1996). With regard to energy intensity, the necessity to remain efficient with production in the face of increasing costs is an issue and may influence energy use *in agriculture* such that some Kuznets curve may be evident although there is very little, if any evidence that such a curve exists for energy overall.

Export Concentration

Export concentration, as it relates to ecological consequences, is theorized as a mechanism by which less-developed nations develop their economies around exports of raw materials and agricultural goods, typically to more powerful nations, in turn depleting their own resources and polluting domestic land and water from the highly intensified agricultural and resource extraction sectors that are used to supply their more powerful trading partners. According to proponents of the theory of unequal ecological exchange, agricultural export concentration, especially in the primary sector, simultaneously facilitates the consumption of resources in the center while externalizing the environmental impacts from source activities to the geographical locations of production, even though consumption in those areas is disproportionately low relative to the environmental impacts being generated. Using the percentage of GDP represented by exports, (Jorgenson 2006, 2007a) found that export dependence was inversely related to the size and growth of the per capita footprint of nations. However, because the measure included environmental impacts overall, the manufacturing and services sectors proved to be the net significant driver. In Jorgenson's (2007a) study, agricultural intensity was found to be non-significant. This makes sense due to the dependent being used. Thus, the globalization of manufacturing turns out to involve the export of the environmental impacts of that sector, while benefits via consumption of those products goes disproportionately to the more powerful countries.

Two other recent studies examined the effects of export concentration on one of the specific outcomes of interest here: fertilizer use. In a cross-national study of total fertilizer consumption Longo and York (2008) found that agrochemical consumption, including fertilizers and pesticides, increased with an increase in a nation's export agriculture, measured as agricultural exports as a percent of gross domestic product. Net other significant factors, including the per capita gross domestic product, population size, availability of arable land per person, and the proportion of irrigated land, export agriculture exerted a positive and significant increase in fertilizer consumption. Examining the related but distinct phenomenon of export concentration, and using a random effects panel model for three time periods, Jorgenson and Kuykendall (2008) found that fertilizer intensity was not significantly influenced by export concentration (measured in their study as the percent of merchandise exports from agricultural commodities). Instead, the independent variable of interest in that study, foreign direct investment in the primary sector, proved to have a positive effect on fertilizer intensity.

Foreign Investment Dependence

The theory of foreign investment dependence (Kentor and Boswell 2003; Kentor and Grimes 2006), argues that foreign capital invests in developing nations when there is an opportunity to gain, and that usually means lower costs of labor, fewer regulations and restrictions, and high potential for profit repatriation. However, these same conditions make developing countries targets for the capital export of polluting industries, older and less efficient technology, and products that are banned or politically untenable in the developed world. The theory is one of foreign investment *dependence* because the economy of the developing country is tied to these industries, yet the majority of the benefits of such economic activity go to the investor nation, with a disproportionate amount of impacts borne by the host country. As foreign investors gain a greater share in and control of a host country's economy, production tends to be organized around export to the core nations, as this orientation represents the more profitable outlet for investment. Explaining the role of FDI on the environment, investors and TNCs are attracted to countries with lower environmental standards, poorly paid labor, coercive states willing to keep labor under control, and rich natural resources (Jorgensen and Kick 2006). This is especially true when it comes to outsourcing highly polluting and labor intensive industries, as political organization in the advanced capitalist nations and the higher average costs of labor make doing business there more expensive.

Corporate controlled value-added commodity chains require the sourcing of low cost agricultural and other primary sector raw materials in order to produce value-added items for consumption in more affluent markets. Partnerships between domestic merchants, state elites, large-scale land owners, input producers, and output processors facilitate an emphasis on export commodity concentration, especially in areas where natural conditions facilitate high end crops destined for luxury consumption. The overall effect of this constellation of forces is to pressure producers, through economic rationality, to increase the capital and resource intensiveness of cultivation. This involves increasing the proportion of fertilizer consumed and increasing the use of agricultural technologies that require more energy, such as tractors and irrigation.

Jorgenson and Kuykendall (2008) connect foreign direct investment to the heavy indebtedness of developing nations and the austerity programs such as IMF/World Bank structural adjustment, which helped to open the economies of less-developed countries to foreign capital investment. The concessions and exemptions associated with making a country more attractive to investors also make it a more likely place for activity associated with intensive environmental impacts, such as the agrochemical industries. In turn, the local markets for the products of these industries—pesticides and fertilizers—generate a supply driven increase in their intensive use. Unequal and disproportionate trade is evidenced by the unequal growth in the developing world of impacts relative to benefits, such as calories per capita in exchange for agrochemical consumption (Jorgenson and Kuykendall 2008).

In their study of primary sector foreign direct investment, Jorgenson and Kuykendall (2008) found that foreign capital penetration in the primary sector was indicative of larger trends in the global organization of agricultural manufacturing. In a cross national analysis of less-developed countries, fertilizer and pesticide intensity were directly and significantly influenced by foreign direct investment, net other factors (Jorgensen and Kuykendall 2008). Using accumulated primary sector foreign investment stocks as a percent of GDP as the measure for foreign investment dependence, they found that increases in FDI, domestic investment, and level of development were all implicated in the rise of fertilizer and pesticide intensity (Jorgenson and Kuykendall 2008). Elsewhere, Jorgenson (2007b) found while controlling for the scale of agriculture and intensity of agricultural machinery use, foreign direct investment in the primary sector in 35 less-developed countries registered a net overall increase in carbon dioxide associated with agriculture. Grimes and Kentor (2003), using world system position as a control, found similar results. Thus, like studies showing negative social consequences of FDI, research to date on environmental consequences also reveals a pattern of increasing impact associated with agricultural modernization, but little benefit for the developing societies open to foreign capital penetration.

Trade and Unequal Ecological Exchange

The theory of Unequal Ecological Exchange locates the structural mechanisms for the unequal consumption and distribution of environmental costs related to that consumption in the uneven flow of energy and natural resources between those countries whose economies are mainly centered around extractive industries and those countries where productive economies dominate. Core nations engage in environmental cost shifting and space appropriation because of their historically conferred structural position, giving them disproportionate access to natural resources. When examining the theorized operational measures that capture UEE, it is clear that the theory is simply a refinement of the oversimplified export intensity model. Using unequal ecological exchange as a framework, Jorgenson (2006) found in a cross-national study that weighted export flows between structurally unequal nations attributed to an unequal ecological consumption pattern that benefits core nations at the expense of the natural resource base of peripheral regions, as the higher the proportion of exports sent from developing countries to developed countries increased alongside the rate of deforestation in the former. Likewise, Shandra et al. (2009) examined the expectations of UEE with respect to organic water pollution, finding in a cross-national regression analysis that the greater the magnitude in exports from poor to wealthy nations, the higher the water pollution in those poor countries. Despite these early attempts at examining the relationship between investment dependence and the environment, the field on UEE is nevertheless nascent and the studies to date represent only initial attempts to flesh out the dynamics of exchange on developing societies. Combining foreign direct investment in a larger analytic framework should help to tease out its role relative to other social forces.

Structural Adjustment

According to dependency theory in general, agricultural production in the developed world is organized in less-sustainable ways due to a confluence of state policy and capital penetration, which contribute to the growth of export oriented production having fewer environmental controls. However, sourcing core consumption while outsourcing core wastes presupposes that the host country's conditions are amenable to such foreign capital penetration and control in the first place. Many scholars have pointed to structural adjustment as a crucial factor in creating these conditions.

Consequences of Structural Adjustment: Evidence from Case Studies

Babb (2005) summarizes the social consequences of structural adjustment, including changes in the governance of national economies, transformation of class structures, and the emergence of international networks. "The era of structural adjustment has been associated with a number of fundamental and seemingly irreversible social transformations" (Babb 2005:216). In place of "strong governmental involvement in promoting economic development, the new conventional wisdom demanded a dramatic downsizing of many government interventions . . . that it was only through thus liberating market forces that poor countries could grow and catch up to the developed world" (Babb 2005:200).

Macroeconomic reform sponsored by the Bank and the Fund varied somewhat from country to country, but a general pattern was nevertheless evident: reductions in the role of the state to reduce government expenditures being paramount, along with promotion of export earnings. Decreasing employment in agriculture, through technological intensification, was a major goal. Focusing on foreign exchange and balance of payments problems, structural adjustment dictates the movement out of traditional and relatively sustainable agricultural practices into non-traditional production for export, luxury, and feed crops, systems requiring greater foreign capital investment, enticed by governments willing to offer incentives such as control of labor, tax holidays, and suspension or absence of environmental restrictions. Currency devaluation is supposed to make a nation's products more competitive on the world market, leading to demand for those products (Babb 2005; Peet 1999; Redclift and Goodman 1991).

The social and ecological consequences of SAPs are intertwined. Kessler and Van Dorp (1998) summarize the negative ecological impacts, such as increasing poverty and the overexploitation of marginal lands, stimulus of cash-cropping for export, and its attendant land-base consequences, an increase in extractive and heavy industries, forestry and agriculture, the dismantling of domestic regulation of natural resource use, and an acceleration of a frontier style of development (Kessler and Van Dorp 1998:268). Stable subsistence production that depends on close human interaction between plant, cropping system, landscape, and climate is replaced with capital- and energy-intensive systems. Domestic production declines, increasing dependency on foreign imports of staples, even as luxury crops are exported.

To highlight just two three out of numerous case studies on SAPs, in Mexico a report from the mid 1990's, "The Crippling Effect of Structural Adjustment in Mexico" concluded that structural adjustment "increased poverty, a further concentration of income, depressed wages, and the undermining of rural livelihoods" (Development Gap 1995a). In the agricultural sector, the influx of cheap, foreign-produced commodities was supposed to improve the economies of the target nation by bringing down the cost of basic consumables, making labor power cheaper and thus productivity higher, freeing up labor for more industrial and specialized economic sectors with higher surplus potential, and generating more foreign exchange. However, the flooding of Mexican markets with US maize has had the reverse effect. Farmer's cannot compete with conglomerates and competition is replaced with monopolistic control of what value-added production of domestic foodstuffs there is—such as tortillas—which have quadrupled in price. Local varieties of maize adapted for the region and growing climate are going extinct, economic growth is not enough to absorb the influx of former subsistence producers, and economic stability has been undermined rather than ensured (Kempf 2007). Meanwhile, in Costa Rica, "drastic reductions in the availability of credit and technical assistance to small farmers" resulted "in the nation moving from near self-sufficiency in food production in the early 1980s to importing more than one half of all basic food grains consumed today" (Development Gap 1995b:2). The debt of Costa Rica has doubled since the initiation of structural adjustment reform. Poverty continues, as resource extraction occurs at rates above regeneration, continuing to plague the endogenous development potential of that country. In Benin there has been some evidence for the economic and environmental benefits of SAP on the agricultural sector. In their case study, Senahoun, Heidhues, and Deybe (2001) found on three farms over three years that structural adjustment increased farmer's use of fertilizer in cotton planting, which controlled the erosive effects of this primary cash crop. However, the study did not assess the effect on "other sustainability indicators such as the soil nutrient or organic matter balance" (Senahoun et al. 2001:131).

Structural Adjustment: A Need for Rigorous Analysis

Overall, these and other case studies provide compelling detail of the on the ground experience with structural adjustment in different countries and they therefore represent an important contribution to our understanding of the effects of structural adjustment. However, there are two drawbacks to the existing research. First, it is difficult to assess the overall effect that SAPs have on sustainable development in general without comparing the outcomes of receiving nations with the same outcomes for those countries that are not under structural adjustment. Second, the historical linkage of structural adjustment with debt, export orientation, and foreign direct investment make it difficult to assess the relative and independent effects of SAPs on nations. This second point is particularly important considering that structural adjustment represents a qualitatively different phenomenon than the simple flows of capital and resources. It is the trigger, so to speak, of events that may or may not contribute to changes in these flows.

Perhaps the greatest challenge to research on structural adjustment that has found negative environmental consequences comes form the World Bank. In 2003, Gueorguieva and Bort argued that

> Despite the controversy surrounding structural adjustment and the environment, the debate has been largely based on anecdotal evidence and country case studies. Most of the case studies reviewed are not quantitative and have not applied rigorous statistical methods. …The infrequency of high-caliber studies is due to data scarcity and statistical limitations (Gueorguieva and Bort 2003:v).

The authors accept that structural adjustment will inevitably have some “impact on the environment” due to economic growth and the consequent resource exploitation and pollution (Gueorguieva and Bort 2003:v). However, in the view of the Bank the “net effect of SAPs on the environment has been varied: sometimes positive and sometimes negative" and that there is difficulty in "generalizing about the direction and magnitude of these environmental impacts, as the linkages are complex and case specific" (Gueorguieva and Bort 2003:v).

To meet this challenge, the present research includes a more comprehensive and rigorous investigation of the effects of structural adjustment, including the use of cross-national time series data in a panel regression analysis. Central to this collection of research is a concern with policy effects on the social equity and ecological sustainability of endogenous producers within nations. Between the case studies and existing quantitative analyses there is evidence of serious problems with structural adjustment and dependency on developing nations. But when trying to capture within one analytic framework the processes endemic to capitalism that directly affect the social nexus of a population and its relationship to the material world, and thereby understanding the dynamics by which capitalist integration works, the case study method falls short. Not only do we need a better historical understanding of these dynamics, as mentioned at the outset a combined review including all nations and their trajectories might reveal patterns unnoticed with only a small sample.

Quantitative research on the effects of structural adjustment on the environment is quite rare. This is probably due in part to difficulties in operationally defining SAPs and then obtaining reliable data on implementation. To address this issue, Shandra et al. (2008) employed ordinary least squares regression analysis using Walton and Ragin's (1990) "conditionality index," which combines the number of external debt renegotiations and debt restructurings experienced by a country with the number of times a country utilized the IMF and the percentage of allowable IMF loans used, all transformed to their *z* scores and summed. Comparing this indicator with a debt service to multilateral institutions dependence indicator, measured as publicly guaranteed debt as a percentage of exports, the authors found support for dependency type theories in that both debt and structural adjustment models positively increased deforestation. The persistence of external debt and accumulated effects of structural adjustment over the years 1990 to 2005 were major drivers of environmental degradation in least-developed countries (Shandra et al. 2008).

While a positive step in the right direction, the use of the Walton and Ragin (1990) conditionality index to assess impacts on the environment is nonetheless limited because it only measures conditional arrangements with the IMF. There is considerable case study evidence that World Bank conditional lending also contributes overall to environmental degradation with little net benefits of economic return (Ambrose 2001). To this point, and in order to assess the contribution of both the Bank and the Fund in a quantitative, cross-national, and longitudinal study, Abouharb and Cingranelli (2007) constructed a composite measure of structural adjustment that included Structural Adjustment Agreements (SAAs) with both entities. While their outcome of interest was the relationship between human rights and structural adjustment, I have adopted their measure for use here because it is theoretically sound and is amenable to panel analysis.

Conducting a global, comparative analysis using cross-national time series data for the time period 1981 to 2003 in order to estimate effects of structural adjustment conditionality on human rights, Abouharb and Cingranelli (2007) improved existing research on SAPs by constructing an index that combines the implementation of World Bank and IMF programs into one measure. Previous analyses typically focused solely a country's agreements with the IMF. However, as Abouharb and Cingranell (2007) argued, such a procedure underestimates the overall influence of multilateral loan conditionality, in *either* beneficial or detrimental directions.

Abouharb and Cingranelli (2007) constructed the combined measure in three steps. To operationally define "being under structural adjustment," the authors built a dichotomous measure in longitudinal form indicating whether a country made an SAA with either the IMF or the World Bank in a given year, designated as "joint structural adjustment receipt," and they then dummy coded that variable with a *zero* equal to no agreement and a *one* equal to agreement (Abouharb and Cingranelli 2007:91). Then, distinguishing between receipt of the loan and the onset of the effects of implementation they coded a second dichotomous variable indicating the beginning of implementation of a SAP, with a value of 1 registering in the second variable one year following the original year of agreement registered in the first. This time lag was justified from the observation in existing literature on structural adjustment that SAPs "often do not have an effect on the economies of loan-recipient countries until about eighteen months after loan receipt" (Abouharb and Cingranelli 2007:91). The new variable, "joint implementation," designated the status of "being under conditionality" for a duration "beginning the year after receipt and lasting for three years" (Abouharb and Cingranelli 2007:92). Thus, to register the onset and limited duration of SAP implementation, the joint implementation variable codes a 1 for year of implementation and the two years following, and then, in the absence of renewed agreements, returns to zero on the fourth year.

Finally, the authors tabulated a third variable, a "running count of the number of years under structural adjustment for each country year," effectively providing a way to test the hypothesis that "the more years a country had been under structural adjustment the worse its government's respect for most human rights" (Abouharb and Cingranelli 2007:81). Under the assumption that a country might renew structural adjustment agreements with either the World Bank or the IMF on a continuous basis, then the maximum number of years of implementation would be 21 years, the number of years covered by the study minus the first possible year of agreement. Therefore, the cumulative 'running count' measure of the effects of structural adjustment ranges from a possible value of 0 to the maximum score of 21.

Another important feature of Abouharb and Cingranelli's work is that they control for factors of selection. On the question concerning the influence of structural adjustment on human rights, it is conceivable that an observed relationship between SAPs and political deterioration is actually the result of the poor economic conditions that preceded and led to debt, and therefore the consequent conditionality associated with multilateral loans, and not the adjustment program itself. Thus it is also possible that without such policy changes as part of the SAA, matters in the respective country could have gotten worse. Anticipating this potential criticism, the authors controlled for "selection-effects" that could assess "World Bank and IMF selection criteria concerning which types of countries were more likely to receive such loans" (Abouharb and Cingranelli 2007:27).

Using a two-stage modeling process that took into account preexisting issues that were likely to spur the need for multilateral loan agreements, such as shortfalls of foreign currency reserves, balance of payments issues, inflation, skyrocketing publicly guaranteed debt service, and general industrial and infrastructural underdevelopment, they predicted the characteristics of nations that increased the probability of being selected for structural adjustment agreements in the first place. Of the variables they examined, including debt as a proportion of GNP, GDP per capita, exchange rate value, average foreign currency reserves, extent of international trade, and change in GDP per capita, only low integration into international trade, high levels of debt relative to the size of the economy, and large population size (to a lesser extent than the other two) showed any significant influence on selection.

The results of their second stage model estimation indicated that, in addition to making questionable progress on economic growth, most human rights, including physical integrity and worker rights, deteriorated under structural adjustment. However, one potential benefit they found was a positive effect on procedural democracy and rights of private property. Structural adjustment was found to be a positive influence on free elections and freedom of association, speech, and press (Abouharb and Cingranelli 2007:5). The authors also noted that while such factors may be important for understanding what contributes to procedural and nominal freedom, the linkage between environmental impacts from structural adjustment and geopolitical strategy need not be congruent or concurrent with changes in governmental respect for human rights.

Summary of Propositions

From the review of the literature and theoretical expectations, specific causal processes of agricultural modernization can be identified, and the predicted outcomes for each theory empirically tested using a common analytic framework. Here we identify the predicted outcomes associated with each theory. The presentation parallels the order in which the respective theories were discussed. Propositions outlined below are laid out with respect to the cross-national processes that can best capture the expected outcomes of each theory.

Three general theoretical perspectives were discussed above including operative theoretical positions within each perspective that can be used in explanatory causal models predicting the relative influence of key sociological variables on the pollution and energy impacts related to agricultural modernization. From the human ecology tradition (Mazoyer and Roudart 2006; York et al. 2003a, York, Rosa and Dietz 2003b), the interaction of the level of affluence of a society, defined as its per capita gross domestic product, and the size of its population is theorized to have an interactive effect on the overall impact of a society. Here I follow their conceptual approach, extending it to panel regression, with a crucial difference: since the outcome of interest in the original analysis below uses fertilizer intensity and energy intensity, both land-scaled dependent variables, I use population scaled to land size. Combined with per capita production, this basic specification allows for the estimation of how the relative size of a nation's economy interacts with its population density and affects the intensity of agricultural impacts.

Within the mainstream theoretical approaches discussed above I identified trade liberalization and ecological modernization theory, both having positive expectations about the institutions of modernity: free trade in the framework of international agreements and restructured production in the framework of international governance, respectively. Ecological modernization predicts that as institutions modernize their production and increase their material wealth, the scientific knowledge of the risks generated by early (industrial) modernity, along with a change in social priorities from a concern with scarcity to a concern with such risks, motivates the restructuring of the production process according to an ecological rationality. The feedback between knowledge and production is channeled through market mechanisms and social mobilization within the context of centralized and strong democratic states, but also increasingly through multilateral global institutions of governance. The overall and general expectation is that economic growth can be de-linked from environmental impacts. Ecological modernization theory can therefore be used to predict the outcome of per capita production (wealth) on the overall intensity of production, but in the opposite direction (a non-monotonic trajectory) than that expected by human ecology.

For trade liberal theorists structural adjustment represents an opportunity for nations to improve their economic capacity, which decreases the rural workforce on agricultural land, protecting fragile habitat. In addition, the use of mineral fertilizers decreases the demand on marginal lands. Export agriculture concentration, foreign direct investment and structural adjustment should all ameliorate the negative effects of the methods of soil fertility management based on inorganic inputs, as with decreased land extensivity, farmers will improve the efficiency of their use in order to rationalize production costs. Structural adjustment also enhances the ability of a nation to implement through market mechanisms a system of valuation of productive resources. Thus, trade liberalization theory, would predict a neutral or declining rate of resource use intensity as the duration of structural adjustment increases.

World systems theory is premised on a hierarchical division of nations unevenly combined into global markets, with structural stability between positions and relative mobility within that structure. Vertical flows of trade facilitate the unequal exchange of economic values and the use-value of natural resources, benefiting countries that dominate the trade relationship with their advantageous position. From the theory of unequal ecological exchange we would then expect that not only the flow of resources, but also that of wastes is asymmetrical. Wealthier nations can outsource their less-efficient and higher impact production, particularly in the primary sector, displacing the negative consequences of such production to poorer nations, who, through unequal ecological exchange degrade their eco-productive resource base, losing vital raw materials which go to support the consumption of the advanced capitalist world.

The specific mechanisms by which such unequal ecological exchange is carried out are agricultural export dependence, agricultural export composition, and foreign investment dependence. The higher the proportion of a country's GDP coming from agricultural exports, the more that country is dependent on export agriculture. The higher the proportion of a country's total exports that come from agriculture, the more that country export sector is concentrated in agriculture. If either variable is significantly positive on fertilizer and energy intensity, then the country is engaged in unequal ecological exchange by virtue of the theory that the greater the raw materials and raw agricultural commodity exports, as a proportion of total exports, the more resource use-value flows away from the nation.

Likewise, foreign direct investment represents in this view an opportunity for external investors to control production in a host company, leading to greater impacts, especially in the primary sector. The associated mechanisms center on the leading imperative of transnational corporations to secure outlets for investment, maximizing return by cheapening the costs of production, increasing the likelihood that they will choose host countries with lower environmental and living standards, lower costs of living, and labor organization repression coupled with state repression. TNCs are also more likely to displace production that would otherwise be prevented by regulations in their home nation. Pollution management is not the only factor, however. Partnerships between domestic merchants, state elites, large-scale land owners, and TNCs facilitate an emphasis on export commodity concentration especially in areas where natural conditions are amenable to the production of high-end crops destined for luxury consumption. Where such opportunity is not available, corporate controlled commodity chains nonetheless require the sourcing of low cost agricultural and other primary sector raw materials in order to produce value-added items for consumption in more affluent markets and corporations will seek out the lowest costs anywhere they can find. The overall effect of this constellation of forces is to pressure producers, through economic rationality, to either cut costs through hyper-exploitation, or to pool investments to increase the capital and resource intensiveness of cultivation. Regardless of machine intensification, however, due to the rate of demand and previous historical conditions, fertilizer use is not optional. Where FDI is strong it facilitates other aspects of the seed-chemical-machinery package of the Green Revolution and can drive both greater fertilizer intensiveness and energy consumption in the primary sector (Ross 1998).

In addition to theories of international exploitation based on exchange, the theory of ecological imperialism brings to the foreground the ongoing relationship between primary accumulation and commodification in the expansion of the global capitalist system. One of the central processes of capitalist expansion in the current era is the establishment of new markets for the absorption of a growing surplus. This can include markets for final products, or for already monopoly-controlled means of production, such as the socially necessary means of soil fertility renewal in the form of industrial inputs.

Just as important, and perhaps more so, is the secondary and related process of converting subsistence production into commodity production, increasing the marginalization of peasant agriculture, or their inclusion into commodity circuits along with the conversion of lands and production units to serve world agriculture. In contrast to the early history of the development of capitalist Europe, which drew upon the soil resources of the conquered world once its own soils had reached relative exhaustion, the ascendancy of monopoly capital's control of the energy- and capital-intensive process of fertilizer production, especially ammonia synthesis, resulted in a reversal of fertility management flows, now from the industrial centers to the periphery. Instead of importing soil nutrients to the core, as in the colonial period, present accumulation means controlling global fertility through the export of inorganic nutrients—as means of production turned commodities—to the periphery, which facilitates the return cycle of qualitatively useful items that cannot be sourced as cheaply and which contain in their own tissue micronutrients, water and solar energy appropriated from the periphery. Investment surplus in this view seeks out profitable outlets, and the consolidation of global agriculture subsuming more of labor and nature into the capitalist orbit.

From this theory, it was expected that multilateral imposition of conditional loans and the accompanying austere 'rationalization' policies required of debtor nations—especially policies affecting the agricultural sector—represent a form of primary accumulation. The longer the period of time under structural adjustment, the greater time there is for this transition to take place, the more unsustainable agricultural production will become. This outcome should result net the other factors related to unequal ecological exchange such as agricultural export dependence, agricultural export intensity, and foreign direct investment. Therefore, SAPs should increase fertilizer intensity and energy intensity while decreasing value appropriation within the domestic commodity agricultural sphere.

CHAPTER IV

METHOD

Research Design

Panel Regression Analysis

As a statistical method of data analysis, panel regression facilitates the testing of causal propositions using observations on a cross-section of multiple units over multiple points in time. In addition, by estimating fixed effects models, panel regression can be used to control for "the omitted variables problem" (Wooldridge 2002:247). Omitted unobserved variables that are specific to an individual unit (nations, in this analysis) and constant over time are interpreted using the unique y-intercept estimated for each unit. This allows for a closer approach to experimental conditions than in cross-sectional analysis, providing greater insight into the causal outcomes that are the result of the persistent influence of time variant explanatory variables. In the models that follow, the fixed effects estimation is used unless otherwise specified. This follows the general form

$$y_{it} = x_{it}\beta + c_i + u_{it}$$

where, for each *i*th case at time *t*, *y* is the outcome of interest, *x* is the explanatory variable for (x_1, x_2, x_3, … x_n), *c* is the time-invariant disturbance unique to each unit, *u* is the specific unit-time error term and β is the coefficient of estimation (Wooldridge 2002).

Data and Measurements

Data

The secondary data analysis conducted here utilizes cross-sectional time series data from the World Development Indicators (WDI) statistical database covering over 200 series for all United Nations member countries over a forty-year period (International Bank for Reconstruction and Development 2007). Many of the agricultural statistics provided by the Bank are compiled from the United Nations Food and Agriculture Organization (UNFAO). In addition, energy consumption data for the years 1990 and 2002 were obtained through the EarthTrends online statistical database of the World Resources Institute (2006), originally collected by the International Energy Agency (IEA) in concert with the Organization for Economic Cooperation and Development (OECD) detailing the Total Final Consumption (TFC) of energy in the agriculture sector for 135 countries.

Measurement

Four dependent variables make up the outcome of interest used to test the validity of the comparative theoretical predictions outlined in Chapter III: total fertilizer consumption, fertilizer intensity, agricultural energy intensity and agricultural value efficiency. The first two are employed in order to examine more closely earlier analyses of cross-national fertilizer use, but with the advantage of using a larger dataset (Jorgenson and Kuykendall 2008; Longo and York 2008). Previous analyses of fertilizer consumption and fertilizer intensity in comparative international context have the shortcoming that their findings are not generalizable to the full time period of available data, or to the entirety of nations. Longo and York (2008) focus solely on cross-sectional data in their analysis of fertilizer consumption. Jorgenson and Kuykendall (2008) limit their sample to developing nations (also see Chase-Dunn 1975). To extend these original analyses, I first examine total fertilizer consumption using variables employed by Longo and York, but conducted using cross-sectional time series data in panel analysis format. Following up on Jorgenson and Kuykendall (2008), I reconstruct a partial replication of the model which they used to examine the fertilizer intensity of developing societies, but with I expand the sample of interest to the entirety of nations (limited only by data availability in the WDI database). The results of these replications are discussed at the beginning of Chapter IV. Then, I examine fertilizer intensity with my own original model specification that includes a population variable scaled to land, and the independent variable of interest, structural adjustment, both of which are omitted in the Jorgenson and Kuykendall (2008) study. Included are measures of capital dependence and structural adjustment, examined to assess net effect on fertilizer intensity.[11]

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[11] Given the ubiquitous and concomitant usage of pesticides and fertilizers worldwide, it may surprise the reader that pesticide intensity is not included in the analysis. This omission is made for both conceptual and practical reasons. Conceptually, a distinction can be made between pesticide and fertilizer usage. While pest management is a problem for agriculture, pesticide use is not a requirement for meeting this need. Thus, pesticide management can take place through strictly on-farm methods endogenous to the farm unit, such as biological management, therefore precluding the necessity of importing material for pest control. However, as far as nutrient use is concerned, farming cannot forgo nutrient replenishment in at least some form of importation outside of the cultivated area and plant nutrients are an intrinsic part of the make up of plant structure and metabolism. Nutrients play a central role as a limiting factor in the renewal of agriculture and agricultural sustainability generally, and this role represents a central theoretical focus of the present analysis. Therefore, the decision was made to isolate for study cross-

Next I present a unique contribution to the quantitative cross-national study of the environment, using the energy intensity of agriculture as a dependent variable. Energy consumption in the agricultural sector has not been used before as a dependent variable in a longitudinal study of the social drivers of environment impacts. Once again, I use a fixed effects cross-national time series panel design inclusive of the entirety of nations (limited, once again, only by data availability). The energy variable, scaled to land, gives a better assessment of the resource intensity of agricultural modernization and gauges more closely the problem of soil fertility renewal in the modern era. Dependent variable four, the value output of the agricultural sector of a country relative to the fertilizer consumed, is included here to investigate two claims, one by advocates of liberalization and one by its critics.[12] First, mainstream approaches, especially trade liberalization, claim that although negative consequences of agricultural intensification may occur, they are offset by gains in the economy. Thus, one would expect value in the agricultural sector to increase relative to fertilizer consumed. Second, it is expected from the logic of dependency theory that FDI and export agriculture negatively affect value efficiency because value extraction occurs through the mechanism of unequal ecological exchange. Core nations appropriate value and food through the commodity chain, while externalizing their fertilizer pollution effects onto the dependent nations.

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national fertilizer usage and the energy involved in such use over time. Practically, pesticide data in cross-section time series form is severely limited, which hampers the potential for using fixed effects models, reaffirming the decision to forgo pesticide intensity as a dependent variable.

[12] Unlike the Kuznets curve, which estimates declining rates of impacts relative to production, using value efficiency as a dependent variable allows for estimation of the benefits of production relative to impacts.

The construction of these two original dependent variables develops from the discussion of the research on the first two. Combined, all four variables give a fairly comprehensive view of sustainable production issues pertaining to the soil fertility replenishment of industrialized commodity agriculture and should be interpreted as a whole. From the total volume of global nutrient pollution, to the intensity of fertilizer use, to overall agricultural energy per unit land, to the value produced for the amount of fertilizer consumed, the estimation of key theoretically derived variables on these outcomes will give some insight into the processes that drive the negative consequences of agriculture intensification.

Definitions: Dependent Variables

- Total Fertilizer Consumption

Fertilizer Consumption refers to the volume, in metric tons (t),[13] of the mineral nutrients nitrogen (N), potash (K_2O), and phosphate (P_2O_5) used in agriculture. Traditional sources of nutrients—animal and plant manures—are not included. This variable is included to extend Longo and York's (2008) study of social-structural influences on fertilizer consumption.

- Fertilizer Intensity

Fertilizer intensity is measured by scaling total fertilizer consumption to the amount of arable land in a nation. Arable land includes land used for temporary crops,

[13] Only metric units are used in the present research. Therefore, "ton" or "t" refers to metric tons, despite standard use referring to 2000 pounds.

temporary pastures and meadows, gardens, and fallow grazing and non-grazing lands, but excludes abandoned land from shifting cultivation. The measurement is in 100 *grams* per hectare. One hectare equals $1/100^{th}$ of a square kilometer. The variable is examined using panel regression to engage and extend previous work done by Jorgenson and Kuykendall (2008). Fertilizer intensity constitutes the premier dependent variable of the present research, as exemplified in the specification for Model C, where all relevant independent variables found to be or theorized to be of importance are compared in a common analytical framework.

- Energy Intensity of Agriculture

Energy use in agriculture is a composite measure constructed by combining Total Final Consumption in the agricultural sector with a weighted estimate of the energy equivalent for total fertilizer consumed (See Appendix for details on the construction of this measure). The variable is meant to capture energy per land area to sustain national commodity agriculture, both that directly consumed within national boundaries and indirectly through the importation of fertilizer that required energy for its production elsewhere.

TFC of energy in agriculture includes the sum of all end-uses in cultivation within a country regardless of the source. It also includes non-energy uses of oil products such as lubricants, waxes and spirits, but excludes (crucially) petrochemical feedstock (which is vital to ammonia synthesis). In compiling agricultural TFC the IEA accounts for end-use activities using the International Standard Industry Code (ISIC, Version 3.1) (World

Resources Institute 2006). Agriculture includes activities classified as agriculture, hunting, and forestry, including energy used in cropping, market gardening, horticulture, farming of animals, mixed farming (animals and croplands combined), agricultural and animal husbandry services (excluding veterinary activities), and hunting, trapping, and game propagation (including related services) as defined by the ISIC. Agricultural end use consumes natural gas, liquid propane, gasoline, diesel fuel and electricity for *on farm* cultivation, including activities such as motorized draft, transport, sowing, harvesting, threshing, irrigation, heating, and refrigeration. The definition excludes processing other than that required to bring the raw product to market, with some exceptions (wineries with their own vineyards on site) and also excludes landform preparation such as terracing, drainage, paddy construction, and irrigation infrastructure (energy used to power irrigation is included). Forestry includes timber production as well as wild harvest, but excludes milling.

The energy equivalent relies on estimates for the energy requirements of fertilizer production relative to the actual amount of fertilizer produced. Total fertilizer consumption for each country is then converted to a common energy metric shared with agricultural TFC (thousand metric tons of oil equivalent) and the two quantities are summed (see Appendix). The variable is then scaled to productive land on a per square kilometer basis. Productive land is comprised of all arable land, agricultural land, and forests. Agricultural land includes the total of permanent crop and pastureland. Permanent cropland includes fruit and nut-producing trees, shrubs and vines, but excludes timber and fiber, hence the addition of forestland to the denominator.

Pastureland is defined as long-term cropping and natural forage area for dedicated use as silage and fodder. Forest area is land under natural or planted stands of trees for use as timber and fiber, whether economically productive or not.

- Economic Efficiency of Fertilizer Consumed

This variable measures the ratio of economic value-added in agriculture (in Year 2000 *U.S.* Dollars) per unit ton of fertilizer consumed, and is used to assess whether or not the consumption of fertilizer has a positive effect on the economic gain of agricultural modernization, *despite* the persistence of nutrient pollution as an environmental problem. The logic is that part of the bargain of using fertilizer intensive practices and risking decline of the soil-resource base in order to meet the demands of export agriculture is offset by the potential of increasing domestic income.

Thus, the higher the value of this ratio, the better national production is doing with respect to fertilizer intensity. The lower the ratio, the less efficient agricultural production is, and therefore the less available economic value produced in the domestic economy relative to fertilizer outlays. The outcome can also be conceived to indirectly capture the proportion of fertilizer to the means of production in use, since the better the machinery, seed, and technical know how, all other things being equal, the greater the expected efficiency of fertilizer use.

Independent Variables

- Per Capita Gross Domestic Product (GDP)

Gross domestic product is the total annual output to a country's economy, the market value of all final goods and services, measured in year 2000 US dollars. The variable is scaled to total population and then logged according to the model specification described below. GDP per capita is a commonly used indicator of a country's overall affluence, a pivotal component in the human ecological formulation of environmental change (York et al. 2003a). The relative size of the economy is conceived as proportionate to the level of material and energetic throughput. Throughput refers to "the flow of raw materials and energy from the global ecosystem, through the economy, and back to the global ecosystem as waste" (Daly & Farley 2004:6). Within the human ecology framework, a rise in per capita GDP is expected to increase the amount of fertilizer consumed, the relative fertilizer intensity, the overall energy a country uses in agriculture, and the value-added efficiency.

- Per Capita GDP, squared

In order to test for a possible environmental kuznets curve in the relationship between economic growth and fertilizer and energy use, logged per capita GDP is centered (to control for collinearity with the baseline term) and squared. The predictions of ecological modernization and trade liberalization theory expect that the rate of rise in the dependent variables registering material and energy use will slow down and eventually change direction, becoming negative at some point in a nation's domestic growth (the Environmental Kuznets Curve). A negative and significant coefficient of the squared term (referred to here as the "Kuznets variable") indicates the existence of such a relationship.

- Total Population

Total population is the midyear absolute number of people in a country. It is a count of all residents regardless of legal status or citizenship, except documented refugees. Its use is limited to the replication of Longo and York (2008).

- Population Density and Urban Population

Population density is the total population of a country divided by the amount of land area within its territorial boundaries. Urban Population is the percent of the population living in urban areas. In the human ecology paradigm, the theorized effect of population is that the total size of a population will have a slightly higher than unit elastic effect on environmental impacts relative to affluence, although there is some indication that the effect is actually higher in longitudinal analyses (York et al. 2003b; York, personal communication).

Scaling the population to land size allows for a balanced model specification when using land-scaled dependent variables. Furthermore, human ecology theorizes that the greater a nation's population density the more productive its agriculture will have to be in order to feed itself. This productivity should, ceteris paribus, come either through extensification (appropriating the output of foreign production) or intensification (increased fertilizer consumption), or some combination thereof. Population density should therefore have an independent and direct effect on fertilizer and energy use.

- Arable Land Per Capita

Used by Longo and York (2008) to scale fertilizer consumption to potential national production. It has a similar causal specification to population density but is more restrictive due to the use of arable land. Arable land is an important factor in the possibility for food production, and it primarily refers to land that is used for annual and non-permanent cropping.

- Arable Land Per Agricultural Worker

This measurement includes all arable land divided by the number in the work force employed in agriculture. It is used in Model D to examine value-added efficiency when combined with the measure for food production (discussed below).

- Food Production Index Per Unit Arable Land

Food production includes food crops that are considered edible and contain nutrients. The variable is measured as an index relative to the economic valuation of food production, with the scale set equal to 100 for the year 2000. Scaling to arable land, the variable measures the potential food yield of a country, and is specified in Model D to interact with arable land per worker yielding a regression equation that can estimate value-added in agriculture.

- Irrigation Intensity

Irrigation intensity is the percent of cropland purposely provided with water, including controlled flooding. Depending on land use and climatic factors, irrigation can be supplied mechanically, or it can involve the massive use of energy for pumping and distribution of water. Irrigated land is thought to play a similar role as tractor use, increasing energy directly, and indirectly affecting fertilizer use through the seed-chemical-technology agricultural intensification package. Irrigation intensity is therefore expected from a human ecology standpoint to have a positive influence on all four dependent variables.

- Livestock Production

Livestock production includes meat, milk, dairy products, eggs, honey, silk, wool, hides, and skins. The variable is measured as an index relative to the economic valuation of meat production, with the scale set equal to 100 for the year 2000. Extensive livestock production (grazing) is implicated in land use degradation. Intensive livestock production (CAFOs) is implicated in numerous problems, including energy consumption and concentrated wastes. The link between fertilizer and livestock is the use of the former to produce grains, pulses, roots and tubers, and silage and fodder as feed. From basic human ecological expectations, livestock production should have a demand driven influence on the amount of fertilizer and energy consumed while positively influencing value efficiency.

- Tractor Intensity

Used as a control variable for capital-intensive means of production, tractor intensity is measured as the number of tractors per 100 hectares.

- Agriculture as a Percentage of GDP

Value added in agriculture measures the output of the agricultural sector, which includes value added from forestry, hunting and fishing, cropping and livestock. This measure is used to control the degree to which agriculture makes up a country's economy and therefore, how much total fertilizer it might be expected to use. Thus, the measure is included here and used in the models that replicate Longo and York's (2008) findings on total fertilizer consumption.

- Agricultural *Exports* as a Percentage of GDP

Agricultural raw materials include all crude materials except fuels, such as untreated hides, cork, wood, pulp and waste paper, and crude animal and vegetable products, and is defined using Standard International Trade Classification (SITC, Section 2), which excludes crude fertilizers, minerals, and ores and scrap. This measure is obtained by taking the percentage of the value of raw agricultural commodities exported from a country relative to that country's GDP and is used as a statistical control in the partial replication of Jorgenson and Kuykendall (2008). This is the measure for agricultural export dependency. Proportion rather than percentage is used in the replication of Longo and York (2008). Otherwise, percentage is used.

- Agricultural Exports as a Percentage of Total Merchandise Exports

This measure also uses raw agricultural commodities in the numerator. Merchandise exports, used for the denominator, represent the total value of all merchandise going abroad (all goods exported). The measure approximates the degree to which an economy's exports are dominated by agricultural raw materials, and is intended to measure agricultural export concentration.

Both trade liberalization and unequal ecological exchange theories expect developing countries to have a greater proportion of their exports in agriculture because the wide-spread adoption of the comparative advantage model and the lower levels of industrial development in those countries. Liberalization theory suggests emphasizing export agriculture will raise domestic income and diminish fertilizer intensity while increasing value efficiency. UEE theory suggests that agricultural export composition is actually the key mechanism by which developing nations remain in a structurally disadvantaged trading position, relative to richer nations, and expects that as the percentage increases, so should impacts from primary sector activity.

This variable has been used in previous research because "trade measures, such as agricultural exports, partly controls for the extent to which a country is integrated into the world economic trading system. This variable is also a measure of agriculture export intensity" (Jorgenson and Kuykendall 2008:538-539).

Table 1 reveals the high correlation between agricultural export composition (the degree to which agriculture dominates exports) and the percentage of a country's gross domestic product from agriculture. The r^2 of 0.764 (in bold) indicates that the use of agricultural exports as a percentage of total exports can safely substitute for the variable that scales agricultural exports to GDP.

Table 1. Correlation Matrix of Independent Variables Associated with Progressive Underdevelopment.

	Debt Service	Agriculture as % GDP	Export Intensiveness	Export Concentration	FDI	SAPs
Debt Service	1.000					
Agriculture as % GDP	0.320	1.000				
Export Intensiveness	0.080	0.329	1.000			
Export Concentration	0.168	0.407	**0.764**	1.000		
FDI	-0.074	0.210	0.021	0.124	1.000	
SAPs	0.296	0.120	0.063	0.031	0.033	1.000

With this in mind, agricultural export composition is potentially at least as good an indicator of a dependency relationship as the measure for agricultural exports scaled to GDP. There is reason to believe that it is a better measure as well. This is because agricultural exports as a percentage of GDP gives the degree to which domestic value production is based in agriculture but not the degree to which export activity is dependent on agriculture, which is the relationship of interest.

- Gross Domestic Investment

Gross domestic investment is defined as total capital formation as a percentage of GDP. The variable is used in the partial replication of Jorgenson and Kuykendall (2008). Capital formation includes land improvements, plant, machinery and equipment, infrastructure, and residential, commercial and industrial construction.

- External Government Debt as a Percentage of GDP

This measure of debt service controls of the amount of public and publicly guaranteed debt registered in financial balance of payments accounts of individual countries. Controlling for this factor allows for a comparison of the extent to which environmental impacts are a consequence of debt service per se and thereby gives a better picture of the independent effects of structural adjustment. Using external government debt measures inclusively funds loaned both from private and from international financial institutions.

- Foreign Direct Investment, Net Stock as a Percentage of GDP

Foreign Direct Investment is defined as "investment to acquire a lasting management interest (10 percent or more of voting stock) in an enterprise operating in an economy other than that of the investor" (International Bank for Reconstruction and Development 2007). Foreign direct investment stocks measure the total stocks *accumulated* in a country in a year. This measure is similar to the key theoretical variable in Jorgenson and Kuykendall (2008) –where they use accumulated stocks in the primary sector—and is used in a partial replication of their model of fertilizer intensity. It is the closest measure to net accumulated stocks of primary sector foreign direct investment obtainable from the WDI series and is intended to capture the cumulative effects of capital penetration—i.e., foreign ownership—relative to the size of the economy.

- Foreign Direct Investment, Net Inflows as a Percentage of GDP

This measure is similar to net accumulated stocks but instead gives a measure of net FDI inflows relative to GDP. According to the theory of unequal ecological exchange, increased foreign capital penetration should increase the fertilizer intensity and energy use intensity in agriculture. Alternately, liberalization-based theories and ecological modernization theory predict potential decreases in fertilizer intensity resulting from an increase in foreign direct investment flows.

- Cumulative Years Under Structural Adjustment

The variable used here is a running count reflecting the number of years under structural adjustment programs implemented by joint agreement between a country and either the World Bank or the IMF. Since the implementation of one structural adjustment program is estimated to begin one year after agreement, and the duration of implementation is estimated as an average of 3 years, then if no other agreements ensued, the total number of years under structural adjustment would register as a score of 3 and would stay at that value for the remaining number of years in the data. With each new agreement, the duration of implementation is once again lagged one year and lasts for three years, meaning that each new round of implementation adds to the running total. Therefore, the more new SALs a country receives, given the evidence that each phase of implementation builds upon earlier ones, the greater the expected magnitude effect that SAPs have on that country.

In the discussion on the construction of this variable, I pointed out that Abouharb and Cingranelli (2007) found that low integration into international trade, high levels of debt relative to the size of the economy, and large population size were weak predictors of being selected for a SAA, which would be expected given the nature of the IMF and World Bank's agenda during that time period. Would it not be unreasonable for critics to question whether or not agricultural conditions prior to SAA contributed to the selection of that country and therefore that changes in fertilizer intensity reflect dynamics that were already in place before the SAP began? After all, Abouharb and Cingranell (2007) did not use environmental variables in their first stage estimation of selection criteria. Table 2 displays the correlation matrix for the variables fertilizer intensity, total population, and external debt as a percentage of GDP, for the year 1980, the beginning of the decade when the Third World debt crisis accelerated and SAPs became more common. Only a weak and negative relationship between fertilizer intensity and external debt is registered in the correlation coefficient while there is almost zero product moment correlation between population and fertilizer intensity. Thus, it is probably safe to assume that fertilizer intensity—and hence fertilizer dependency—was not a defining feature of selection for structural adjustment. This variable also works in tandem with fixed effects specification to control for existing soil fertility baseline.

Table 2. Correlation Matrix of Variables with Potential Selection Effects for Structural Adjustment Agreement for the Year 1980.

	Fertilizer Intensity	Population	External Debt as a % of GDP
Fertilizer Intensity	1.000		
Population	-0.025	1.000	
External Debt	-0.248	-0.170	1.000

Returning to the discussion of the structural adjustment measure, for trade liberalization theorists, structural adjustment represents an opportunity for nations to improve their economic capacity, which decreases the rural, decreasing pressure on marginal lands, and therefore protecting the resource base and critical habitat. Also, farmers should be expected to improve the efficiency of their use in order to rationalize production costs. Structural adjustment is expected to enhance the ability of a nation to increase the value efficiency of their primary sector production. Thus, trade liberalization theory would predict a declining rate of resource use intensity relative to increased production *and* structural adjustment.

If ecological modernization theory is correct, an increase in the duration of structural adjustment represents time to implement sectoral reorganization and would make agriculture more efficient. Hence, the more time under structural adjustment, the greater the likelihood that sectoral restructuring could succeed. There should therefore be an EKC in the relationship between per capita affluence and fertilizer and energy intensity.

In contrast, from the theoretical expectations of ecological imperialism, if debt is the mechanism that places pressure on a country, and liberalization is the channel toward increased export concentration and foreign capital penetration—i.e., increased integration into the global capitalist orbit—then structural adjustment represents the opening of the floodgates. An increase in the duration means an increase in the opportunity for capital, that is, *multilateral institutions*, to restructure agriculture in such a way as to secure new labor and resources in the drive to prop up the system. Thus, given that the specific effects of structural adjustment are somewhat delayed due to the nature of implementation, and following from the expectation that SAPs exert a long term, cumulative, and lasting change in national development, we would expect to see an increase in the agricultural intensity of nations the longer they are under structural adjustment, net other factors.

Model Specification

Early work in environmental social science conceptualized the interaction of social factors and the environment using models that were mainly heuristic in nature. Duncan's (1961) construct of "Population Organization Environment Technology" (POET) and Norgaard's (1994) coevolutionary model are prominent examples. The advance of inferential statistical techniques led to the capacity to specifying directional interactions, for example in the way Ehrlich and Holdren's (1972) IPAT formulation was developed into the STIRPAT analytic framework by Dietz and Rosa (1994) and York et al. (2003b). The central project of cross-national research on the drivers of ecological change is to tease apart the various social components thought to be implicated in ecological impacts.

The present research draws upon and replicates in a broader sampling context than previous research on fertilizer consumption and intensity. In a cross-national study Longo and York (2008) found evidence that trade liberalization increased national dependence upon agrochemical inputs, showing a "significant relationship between export-focused agricultural production and the consumption of fertilizers and pesticides, which suggest that increasing energy- and capital-intensive practices in agricultural production are related to the growing global trade in agricultural commodities" (Longo and York 2008:101). Further evidence that export dependence, as well as foreign investment dependence, is related to increasing the impacts from agriculture comes from Jorgensen (2006, 2007a, 2007b) and Jorgenson and Kuykendall (2008). They found that pesticide and fertilizer use intensity in the developing world was positively associated with foreign investment dependence in the primary sector (agriculture, extraction, and associated industries). Using a random effects and static score panel analysis for the years 1990, 1995, and 2000, they found that accumulated stocks of foreign investment coming from foreign capital in the primary sector of developing nations significantly increased pesticide and fertilizer intensity in those countries, an influence that increased during the 1990s (Jorgenson and Kuykendall 2008).

However, both the Longo and York (2008) study and the Jorgenson and Kuykendall (2008) study have some significant limitations. Longo and York (2008) studied only cross-national variation in total fertilizer consumption, which gives only a snapshot of what are arguably ongoing dynamics. Also, total fertilizer consumption, while showing the contribution of agriculture to global reactive nitrogen accumulation, makes it more difficult to isolate processes that are related to the scale of resource consumption. Jorgenson and Kuykendall's (2008) study represents an improvement over these limitations by conducting a longitudinal analysis and examining national fertilizer consumption relative to land size. Still, a weakness of Jorgenson and Kuykendall's (2008) analysis was their limited sample of developing nations. A standard practice in world-systems influenced quantitative cross-national research on the environment, this limitation poses a problem for generalization. The patterns of agrochemical intensity found in the developing nations may reflect patterns that are true across all nations, but without information from the developed world, one cannot tell. Hence, determining that foreign direct investment has the theorized effect may indeed be a spurious conclusion. Moreover, their model has no population variable, which is strange considering the clear connection between population, resource consumption, and pollution effects found in previous cross-national research on the environment.

Table 3 gives a summary of the models, which are described in the discussion immediately following. An "X" in each column marks the independent variables included in that model [For instance, Model C shows the revised, saturated fertilizer intensity model proposed here.] Models shown only include those constructed by me for either the replication or the original contribution.

To advance the field and improve our understanding of the drivers of fertilizer intensity, I use panel analysis to follow up on the Longo and York (2008) study in order to test their findings over time. Likewise, I partially replicate the Jorgenson and Kuykendall (2008) study to verify if the patterns they found for developing nations are consistent across the entirety of nations. In my own contribution, I use fixed effects panel analysis to test for the effects of structural adjustment on fertilizer intensity, agricultural energy intensity and the value efficiency of fertilizer use.

Table 3. Summary Matrix of Model Specification.

Independent Variables Used	Model A	Model B	Model C	Model D	Model E
Per Capita GDP	X	X	X	X	
Per Capita GDP, squared	X	X	X	X	
Total Population	X		X		
Population Density			X	X	
Urban Population as a Percent of Total Population			X		
Arable land per capita	X		X		
Arable Land per Agricultural Worker			X		X
Food Production Index By Agricultural Land			X		X
Irrigation Intensity	X		X	X	
Livestock Production			X	X	X
Tractors per Hectare			X		
Agriculture as a Proportion of Gross Domestic Product		X	X		
Agricultural *Exports* as a % of Gross Domestic Product	X	X	X		
Agricultural Exports as a % of Total Exports		X	X	X	X
Gross Domestic Investment		X	X		
Government Debt as Percent of External Debt			X		
Foreign Direct Investment Net Stock as % of GDP		X	X		
Foreign Direct Investment Net Inflows as % GDP			X	X	X
Cumulative Years Under Structural Adjustment			X	X	X

Replication and Extension of Previous Research

Model A

Model A replicates in longitudinal format the previous research of Longo and York (2008). In that paper they expressed the increase in national fertilizer consumption as a linear function of size of the economy, scale of agricultural productivity (with a control variable for the EKC), size of the population, availability of arable land, irrigated land, and the main variable of interest, export agriculture, using a log-log model. I replicate this study for longitudinal analysis using fixed effects panel regression.

Model B

Model B is a partial replication of Jorgenson and Kuykendall's (2008) study of developing nations, where the primary variable of interest is primary sector foreign direct investment. Examining the theory that foreign investment dependence has an effect on developing countries' fertilizer intensity (and a related measure on pesticide intensity, not used here) they used primary sector FDI, but were limited in that the data were available for only 3 time periods. I use FDI inflows as a percent of GDP as a close approximate. I also use per capita GDP rather than the measure for per capita Gross National Income (GNI) as used by Jorgenson and Kuykendall (2008).[14] GDP is more straightforward to interpret since it represents value gained in domestic production, in contrast to GNI, which includes receipts from activity abroad. Other than these changes my model partially replicates theirs, first using their restricted sample of 34 developing countries

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[14] Results of bivariate correlation between the two variables yields an $r^2 = 0.91$.

and then the full sample. This is done in order to cross-validate my use of the partially replicated model for the panel that includes all countries. [15]

Original Models

Models C and D build off of the basic specification of the STIRPAT equation developed by Dietz and Rosa (1994) and York et al. (2003b). First, I begin with a functional form similar to that which yields the STIRPAT equation

$$I_{it} = aA_{it}^{b}P_{it}^{c}e_{it}$$

where *I* is the impact of question, equal to the multiplicative (interaction) effect of Affluence (*A*) and Population (*P*), and any unobserved technological factors (*e*), for each cross sectional unit (*i*) over multiple points in time (*t*). This initial functional form is then specified to adjust for the land-scaled basis of the dependent variable, such that *I* equals fertilizer consumption per unit arable land, *A* remains gross domestic product per person, and *P* is transformed to total population divided by total land area, shown here as

$$\frac{fertilizer}{arable\_land} = \frac{gross\_domestic\_product}{population} \times \frac{population}{total\_land}$$

This formula specifies equality between fertilizer intensity and land-scaled gross domestic production (the product of the interaction shown on the right side of the equation). However, following the STIRPAT research team, I wish to estimate the

[15] Anticipating the chapter on results, I noted by inspection that my partial replication model using the restricted sample produced coefficients and standard errors fairly consistent with Jorgenson and Kuykendall's (2008). I then ran the regression using all countries for which there are data.

effects of GDP per capita and population density on fertilizer intensity. Taking the natural log of each component gives the transformed equation

$$I_{it} = a_{it} + b[\ln(A_{it})] + c[\ln(P_{it})] + e$$

where $b = \beta_1$ and $c = \beta_2$, the coefficients of Affluence and Population density, respectively. This functional form specifies the interaction of level of economic development and population density in an analytic framework that can be combined with other observed variables and used to estimate the net effect of each component on the dependent variable using ordinary least squares regression.

Model C

Model C regresses fertilizer intensity on the basic human ecology components of this framework (*Gross Domestic Product per Capita*, *Total Population*) and in addition includes other independent variables of theoretical interest, including domestic investment (*Gross Domestic Investment as a Percentage of GDP*), population density (*Population Density, Urban Population*), agricultural technology (*Irrigation Intensity, Tractor Intensity*) including meat production (*Livestock Production*), importance of agriculture to the economy (*Agriculture as a Percent of GDP*), agricultural export dependency (*Agricultural Exports as a Percentage of GDP*), agricultural export concentration (*Agricultural Exports as a Percentage of Total Merchandise Exports*), government debt (*External Government Debt as a Percentage of GDP*), capital penetration (*Foreign Direct Investment Net Inflows as a Percentage of GDP*), and the main independent variable of interest in this original research: *Cumulative Years Under*

Structural Adjustment. I argue that this model specification is an improvement over that used by Jorgenson and Kuykendall (2008) as an estimate of fertilizer intensity because (1)) it is based on a baseline functional form that has demonstrated considerable and consistent predictive power for the estimation of both resource consumption and waste pollution impacts, (2) uses a population density variable to scale the model to the dependent variable, and (3) compares the effects of structural adjustment programs with that of foreign direct investment, agricultural export dependency, and agricultural export concentration. By building from the simplified to the saturated model, as is done here and reported in the results below, one can identify the net influence of structural adjustment while controlling for other variables in the literature theorized and/or found to be relevant for predicting fertilizer intensity.

Model D

Model D uses the same basic analytic framework as Model C but substitutes the energy intensity measure for the dependent variable. This model can be conceptually understood as an estimation of the factors that drive over time the replacement of systems of nutrient management derived from extensive land-based resources to one of intensive means (drawdown). National agricultures draw upon finite global fossil reserves in two distinct but interdependent pathways: direct energy use and (indirectly) through fertilizer consumption. The dependent variable is consequently a combined measure of direct energy use and the energy equivalence of fertilizer use (see Appendix).[16] Present day commodity agriculture exceeds the solar budget for the regeneration of non-renewable resources, which are consumed via industrial manufacture. The model is therefore indirectly an estimation of the relationship between the social drivers of agricultural modernization and the development of the productive forces that facilitates temporary emancipation from, and oftentimes degradation of, the land-based conditions of production.[17]

Model E

In contrast to Models A through D, which follow along the lines of previous cross-national research on the environment—where size of the economy and population are found to be the major drivers of overall environmental impacts—Model E focuses specifically on the agricultural benefits yielded to a nation for their investment in agricultural modernization, the consumption of fertilizer in particular. Agricultural benefits are conceptualized in terms of the agricultural value-added per unit of fertilizer consumed. The validity of this measure is twofold. First, a crucial issue for comparative international research on the environment is the extent to which developing countries are enmeshed in a larger trading matrix that structures their trade relations with other nations in ways that unsustainably and unequally draws on their own resources. The resources in

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[16] This omits energy used in the production of biocides, machinery, equipment, and seed, which makes for a conservative estimate of overall agricultural energy intensiveness.

[17] In the analysis of Model 4, I also used pooled regression due to the fact that the panels were unbalanced, determined by the lack of consistent data for TFC. I discuss the results of that analysis with the rest in Chapter V.

question are the land's productivity (which is not just limited to mineral content but includes soil organic matter, soil structure and ecology, water etc.) and labor. Given that commodity agriculture combines the commodified means of production with commodified land and labor, then in the proletarianization of farming the circulation of fertilizer for food represents the vehicle for the extraction of surplus labor and the bioproductive use-values that derived from labor's activity on the eco-historical conditions given. Using the framework of UEE, since the measure of gain from being integrated into the global trading system is economic value, then the return on investment for participating in the agricultural modernization complex is an important consideration of the equality of trade. Value-added in agriculture represents a generous approximation of labor's remuneration.[18]

Second, the combination of the means of production (the seed-chemical-machinery package) with land and labor to produce raw agricultural output represents from the point of view of examining the monopoly capital system in its entirety the moment at which capital can exploit labor, and therefore the proportion of the composition of this recombination attributed to capital gives us a relevant base for measuring the amount of capital invested. Consequently, the dependent variable is an inverse of the ratio of what Marx (1976) in Capital called the "technical composition of capital" (Marx 1976:762).[19]

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[18] Generous, indeed, as much of it may not go to labor at all.

[19] "The composition of capital is to be understood in a twofold sense. As value, it is determined by the proportion in which it is divided into constant capital, or the value of the means of production, and variable capital, or the value of labour-power, the sum of

Model E is a unique analytical structural framework concerning the drivers of agricultural efficiency, derived from the theory of agrarian systems. As discussed in Chapter II, Mazoyer and Roudart (2006) define the capacity of an agrarian system to sustain a maximum population density as a function of the potential output of the agrarian system itself (the crop/land complex) combined with the extent of land in that system that one worker can cultivate (the land/labor complex), which mutually condition one another. Holding time and agrarian system constant, the "gross productivity of a system is the result of the *output per hectare multiplied by the cultivated area per worker*, an area that depends on the effectiveness of the tools and the power of the energy sources (human, animal, moto-mechanical) that this worker uses" (Mazoyer and Roudart 2005:69, emphasis added). From this one can derive the equation

$$Gross\_productivity(V) = \frac{output}{hectare} \times \frac{hectare}{labor}$$

where *Output Potential (O)* equals the yield per land area of a given agrarian system, measured here as the food production index divided by the amount of agricultural land in each nation, and *Labor Potential* (*L*) equals the land area that can be cultivated by one person in that agrarian system, measured as the arable land divided by the number of

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total wages. As material, as it functions in the process of production, all capital is divided into means of production and living labour-power. *This latter composition is determined by the relation between the mass of the means of production employed on the one hand, and the mass of labour necessary for their employment on the other.* I call the former the value-composition, the latter the technical composition of capital. *There is a close correlation between the two.* To express this, I call the value composition of capital, in so far as it is determined by its technical composition and mirrors the changes in the latter, the organic composition of capital" (Marx 1976:762, emphasis added).

agricultural workers.[20] This is written nominally as $V = O \times L$. Cross multiplying the right hand side of the equation and we get

$$Gross\_productivity = \frac{output}{labor}$$

At this juncture I make a critical assumption. In the industrial agrarian era, the agricultural means of production are not only monopolized, representing an increase in the value composition of capital, but also are industrially intensive, representing an increase in the technical composition of capital. Therefore, this fact must be registered at some point in the model. In Mazoyer and Roudart's (2006) scheme, soil fertility renewal is assumed as part of the agrarian system (the extensiveness of land includes not only the cultivable area but also includes land beyond the cropping location, an extension in space for pre-fossil systems and an appropriation in time for the present era (drawdown). Because drawdown, that is, the time dimension beyond the cultivation space, dominates in the present era, its inclusion in the general scheme of land per worker (the means of production/productivity component) is also assumed, and any influence would be absorbed into that component. This frees up the fertilizer measurement as part of the dependent variable. In that case, where output per labor represents the consequent yield of the technical composition of capital, value per fertilizer 'mirrors' the consequent yield of the value composition of capital. Hence, substituting valued-added in agriculture per

[20] Recall that the amount of cultivable land is smaller than, but dependent upon the extension of agricultural land generally. This explains why the two components are made up of two different land areas, the first being the yield of the national 'system' and the second being the workable area of cultivable land per 'agrarian.'

unit of fertilizer consumed for the gross productivity term (*V*), one obtains the following formula

$$\frac{Agricultural\_value\_added}{fertilizer} = \frac{Food\_production}{agricultural\_land} \times \frac{Arable\_land}{farmer}$$

which is the baseline specification used for Model E.[21]

Other benefits of using this model include the fact that yield is scaled constant to a per unit hectare basis and thus the area of agricultural land for each nation is controlled for in the measure. Also, the initial baseline fertility of a country's soil is difficult to measure (and a somewhat arbitrary starting point anyway, considering the history of ecological imperialism and the fact that industrialized agriculture has been in full force in many regions of the world for dozens of years now). Using the per unit yield of value as an input efficiency is yet another way to control for variations in natural soil conditions, as they are subsumed into one measure that can then be used to compare across cases. That is, the model controls for uneven technological development in agriculture assuming native fertility specific to each unit.

Lastly, the model can also potentially capture dynamics occurring at the scale of the world market. The measure for agricultural value added is made in United States year 2000 dollars, and hence the figure for each country reflects that nation's share of the total agricultural value produced. As the volume of output increases, the supply of agricultural commodities on the world market can potentially increase, driving down the price and

[21] While it may seem that the actual causal direction is interactive, it is very likely that it is instead *iterative*: the output becomes the new driver for the next stage's input. Such an analysis will have to be saved for a later date.

hence the overall exchange value of those commodities. When this happens, the value of the fertilizer also diminishes. This would be assumed as a period effect and would wash out of the measurement altogether, reflected in the fact that greater value gained for fertilizer consumed reveals that nation's position vis-à-vis the others in the world trading system. Consequently, as the social variables of interest are added to the model, such as FDI and SAPs, the overall effect of these factors on the national benefits for consuming commodity mineral fertilizers can be assessed.

Similar to the discussion on Models C and D, transforming the identity to a functional form that can be used in linear regression allows for the estimation of each component on the outcome of interest, rather than designation of this relationship *a priori*. Measuring each variable separately allows for their estimation using panel regression. The transformation is identical to that for the baseline framework for Models C and D. Logging each exogenous component gives a functional form whereby their multiplicative interaction is expressed as an additive linear equation, such as in the STIRPAT reformulation discussed above. In the model used here

$$V_{it} = aP_{it}^{b}L_{it}^{c}e_{it}$$

is reformulated to become

$$V_{it} = a_{it} + b[\ln(P_{it})] + c[\ln(O_{it})] + e_{it}$$

and to this baseline model the theoretical variables of interests are added in linear fashion, including those specifying the agriculture/meat complex (*Livestock Production*), agricultural export dependency (*Agricultural Exports as a Percentage of GDP*), agricultural export concentration (*Agricultural Exports as a Percentage of Total*

Exports), capital penetration (*Foreign Direct Investment Net Inflows as Percentage of GDP*) and economic restructuring (*Cumulative Years Under Structural Adjustment*).

Last but not least, time indicators are included in all fixed effects models to control for possible period effects, although the output for these is not reported. Also, in each table the form of the variables used in the models (such as logarithmic transformation) is noted. The Hausman test was run for Models C, D and E (the original models of the present research) rejecting the null hypothesis that there was no significant difference between fixed and random effects estimation for the models, restricting the specification to fixed effects. Results of the panel analyses are discussed in the next chapter.

CHAPTER V

RESULTS AND DISCUSSION

In this chapter I go over the results of the models specified in Chapter IV, first by presenting the results of previous research originally reported elsewhere and used here as a starting point for the analyses that follow. The results are summarized and discussed, below, but first, a brief overview. Table 4 gives the results reported by Longo and York (2008) and Table 5 reports the results for Model A, which extends their analysis. Table 6 shows the results reported by Jorgenson and Kuykendall (2008) and, in an extension of their work, Table 7 reports the results for Model B using the restricted sample while Table 8 reports the results for the same model using the unrestricted sample. The results of the analysis for Model C are given in Table 9, for Model D in Table 10, and for Model E in Table 11. Taken together as a whole, these models construct an emerging picture of the effects of the international division of labor and nature and reveal how the global structure of the food system impacts the agricultural sustainability of unevenly combined nations.

Replication

The replication of Longo and York (Table 5) confirms their original analysis. All of the independent variables used by Longo and York (2008) are significant. In support

Table 4. Robust Regression of National Fertilizer Consumption Using Cross-Sectional Data for the Year 2000. Results reported by Longo and York (2008).

Independent Variables	Coef.	Std. Err.	
Per Capita GDP (ln)	0.831	0.069	**
Per Capita GDP (ln), centered and squared	-0.235	0.037	**
Total Population (ln)	1.28	0.056	**
Arable Land Per Capita (ln)	0.343	0.120	**
Irrigated Land as a Proportion of Cropland (ln)	0.143	0.064	**
Agricultural Exports as a Proportion of GDP (ln)	0.478	0.090	**
Constant	-9.27	0.974	**
N = 147			
$R^2 = 0.846$			

$+ p < 0.10$; $* p < 0.05$; $** p < 0.01$; $*** p < 0.001$

Table 5. Fixed Effects Panel Regression of National Fertilizer Consumption (ln) for the Years 1962–2002. Replication of Longo and York (2008).

Independent Variables	Coef.	Std. Err.	
Per Capita GDP (ln)	0.514	0.050	***
Per Capita GDP (ln), centered and squared	-0.197	0.016	***
Total Population (ln)	2.381	0.108	***
Arable Land Per Capita (ln)	0.422	0.070	***
Irrigated Land as a Proportion of Cropland (ln)	0.120	0.031	***
Agricultural Exports as a Proportion of GDP (ln)	0.028	0.012	*
Constant	-29.252	1.926	***
Observations = 3490			
Groups = 147			
R^2: within = 0.563			
between = 0.726			
overall = 0.723			

$+ p < 0.10$; $* p < 0.05$; $** p < 0.01$; $*** p < 0.001$

of the findings of International Political Economy, an increase in the percentage of GDP from export agriculture shows an increase in the amount of fertilizer consumed for the period covered in the analysis 1962-2002. Since the model is log-log, we can interpret the results as they did, as an elasticity coefficient (York, Rosa and Dietz 2002).

Noting the first variable, per capita GDP, for every one percent increase in the independent variable fertilizer consumption increases by 0.5 percent, slightly weaker than the independent variable's effect in the cross-sectional model. Skipping the squared term momentarily, the population coefficient is of interest because of its interaction with affluence, and it shows a 2% rise in fertilizer consumed with just a one percent rise in population over time. This is more than a unit elastic increase and has implications for the role of population growth in the sustainability of the consumption of fertilizer. Changes in population over time have more of an impact on fertilizer consumption than changes in affluence.

Arable land per capita has a moderate and significant influence on fertilizer consumption, indicating that the sheer availability of farmland affects the amount of fertilizer consumed. This finding contradicts the idea that the greater availability of land might lessen the need for fertilizer consumption and suggests that countries with land exploit it for agricultural production to the maximum that they are able. Irrigated land also causes a mild and significant increase on fertilizer use, which could be interpreted as a consequence of the technology package associated with agricultural modernization, or, because the irrigation measure includes free flowing water storage and diversion and not just mechanical pumping, this could also reflect the high use of urea in paddy agriculture, ubiquitous throughout Southeast Asia and China (Smil 2001, 2008). The variable used to test export agriculture dependency, export agriculture as a proportion of total agriculture, shows a weak and slightly significant influence on fertilizer consumption, lending some support for the hypothesis that the more a country relies on agricultural exports, the more likely it is to increase the impacts of agricultural modernization.

Returning to the Kuznets variable, the squared term of per capita GDP is both negative and highly significant suggesting the presence of a Kuznets curve in total fertilizer consumption. Longo and York's (2008) original analysis also detected the presence of such a phenomenon, but the predicted level of affluence required to reach such a turning point was found to be at the extreme end of the range of observed values for that variable (Longo and York 2008:96). In the panel analysis conducted here, the predicted turning point in fertilizer consumption is at approximately $8,000 per person. At first blush, there does indeed seem to be Kuznets curve with respect to fertilizer consumption. However, considering that the mean per capita GDP for the sample was $5,590 and the median was $1,990, it seems clear that the turning point is far off for the majority of countries.

Moving on to Table 6 we can see the results reported by Jorgenson and Kuykendall (2008), where they used a random effects panel analysis of fertilizer per hectare (fertilizer intensity) regressed on key independent variables for the years 1990, 1995, and 2000, as discussed in the literature review. Only unstandardized coefficients are shown here. In Jorgenson and Kuykendall (2008) their variable of interest was primary sector foreign direct investment and they used data limited to point estimates for three separate years.

Table 6. Random Effects Panel Regression of Fertilizer Intensity (ln) Using Point Estimates 1990, 1995, and 2000. Results reported by Jorgenson and Kuykendall (2008).

Independent Variables	Coef.	Std. Err.	
GNP per capita (ln) -- 1995 US$	0.416	0.199	*
Gross Domestic Investment	0.029	0.012	**
Agriculture as a Percentage of GDP	0.008	0.015	
Agriculture Exports Concentration (ln)	-0.113	0.152	
Primary Sector FDI Stocks, Percent of GDP	0.096	0.031	***
Primary Sector FDI Rate (ln)	0.282	0.425	
Latin America (Indicator Variable)	0.020	0.448	
Constant	-0.177	1.765	

Observations = 105
Countries = 35
R^2: within = 0.302
between = 0.202
overall = 0.210

+ $p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Since they also included an indicator variable for the region of Latin America they estimated a random effects model. Examining the theory that foreign investment dependence has an effect on developing country fertilizer intensity (and a related measure on pesticide intensity, not investigated here) they found that primary sector FDI as well as the rate of FDI growth in the primary sector relative to existing stocks exerted a positive influence on the dependent variable. This finding supported the theoretical expectations of foreign investment dependence.

Table 7 shows the results of the fixed effects panel regression of fertilizer intensity on those independent variables similar to Jorgenson and Kuykendall, using the same sample of 34 countries (one country they included, French Guiana, is incorporated into the unit for France in the WDI database and hence not available). Overall, the

Table 7. Fixed Effects Panel Regression of Fertilizer Intensity (ln), 1966–2002. Partial replication with Jorgenson and Kuykendall's (2008) sample of developing nations.

Independent Variable	Coef.	Std. Err.	
GDP per capita (ln)	1.002	0.107	***
Gross Domestic Investment	0.002	0.003	
Agricultural as a Percentage of GDP	0.007	0.004	*
Agriculture as a Percentage of Exports (ln)	0.073	0.026	**
Net stock of FDI as a Percentage of GDP	2.278	1.053	*
Constant	5.433	0.418	***

Observations = 741
Countries = 34
R^2: within = 0.428
between = 0.117
overall = 0.124

+ $p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

outcome supports the general results of Jorgenson and Kuykendall. Like primary sector FDI, aggregate foreign direct investment stocks relative to GDP shows significant and positive effects on fertilizer intensity. Even with slight differences between the two models, the within-unit estimation comes close to corroborating completely the general form of the model overall, finding significant and positive effects not only for FDI as a percent of GDP, but also per capita GDP. However, in the place of domestic investment, agriculture as a percentage of GDP becomes significant. This would mean that for fertilizer intensity, using only overall foreign direct investment as the measure for the independent variable of interest, the proportionate size of the agricultural sector is more important than the actual domestic investment. In addition (and supporting the expectations of agricultural export composition) the results show a positive and significant effect from agricultural exports as a percent of total merchandise exports, giving support to expectations derived from export composition and dependency theory generally.[22]

Comparing Table 7 and Table 8 it is clear that the fixed effects partial replication with the unlimited sample shows all variables significant and in the same direction as the limited sample. Also compare Table 8 with the previously shown Table 5 (the Longo and York replication) and note that the GDP per capita variables have coefficients and standard errors that are fairly close to one another. In contrast, comparing Tables 7 and 8, the log of GDP per capita has a stronger effect on the fertilizer intensity for the sample of developing countries when compared to the sample consisting of all countries, (1.002 compared with 0.465). The fact that the coefficient is fairly consistent when comparing the two models that include all countries and a difference when compared with the developing countries panel would indicate that a rise in GDP has a much stronger effect

[22] Because these last two variables are not logged and the dependent variable is it becomes difficult to interpret the associated magnitude change.

on fertilizer intensity for the developing world than across the entire gamut. This makes sense from a basic human ecology point of view in that as per capita wealth increases farmers are compelled to buy more fertilizer, but at some point there is a diminishing margin of return for further investment. But it can also be interpreted as the result of lower income countries using more intensified fertilizer cultivation.

Table 8. Fixed Effects Panel Regression of Fertilizer Intensity (ln), 1966–2002. Partial replication of Jorgenson and Kuykendall (2008) with an unrestricted population.

Independent Variables	Coef.	Std. Err.	
Per GDP (ln)	0.465	0.073	***
Gross Domestic Investment	0.004	0.002	*
Agriculture as a Percentage of GDP	0.005	0.003	*
Agriculture as a Percentage of Exports (ln)	0.072	0.017	***
Net stocks of FDI as Percentage of GDP	0.407	0.187	***
Constant	5.336	0.440	***

Observations = 1985
Groups = 116
R-sq: within = 0.190
between = 0.340
overall = 0.297

+ $p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

The variable for gross domestic investment, initially used by Jorgenson and Kuykendall as a control to ascertain the effects of primary sector FDI, appears as significant with the unrestricted sample but not with the restricted. However, the coefficients and their confidence intervals from each sample overlap to such an extent that making an interpretation about the comparative influence between the samples of GDI on fertilizer intensity is not straightforward. In one analysis, the first, gross domestic investment is not significant. In the second analysis with the full sample it is. However, the comparative findings are not statistically significantly different. Across the entire gamut of nations, gross domestic investment plays a role in fertilizer intensity. In the developing nations sample, it does not.

However, as discussed in Chapter IV, the Jorgenson and Kuykendall model does not have a population variable and may therefore incorrectly estimate the net effects of foreign direct investment on fertilizer intensity. I turn next to the results of Models C and 4 to correct for this omission as well as to test for the influence of structural adjustment on fertilizer intensity. What follows is my original contribution to the QCN research.

Original Analysis

Moving from the preliminary analysis to the main research question of concern here, the following results are derived from the analysis seeking to ascertain whether or not economic restructuring is a factor in the fertilizer intensity and energy intensity of agriculture and to what extent these environmental 'costs' are offset by benefits to each country. The results for Model C are shown in Table 9.

Beginning with the basic human ecology variables, which act both as indicators and controls, the results of the first run of the simplified form of Model C (left column) show a mild effect from per capita GDP, a significant Kuznets term, and the influence of arable land over time on fertilizer intensity. One interesting observation is that per capita

Table 9. Fixed Effects Panel Regression of Fertilizer Intensity (ln), 1980–2004. Original model specification.

Ind. Variables	Coef.	Std. Err.		Coef.	Std. Err.		Coef.	Std. Err.		Coef.	Std. Err.	
Per Capita GDP (ln)	0.410	0.039	***	0.145	0.046	**	0.764	0.062	***	1.314	0.432	**
Per Capita GDP (ln), squared	-0.150	0.012	***	-0.185	0.013	***	-0.216	0.019	***	0.015	0.106	
Total Population (ln)	2.312	5.686		-8.342	5.856		3.927	6.245		94.108	48.635	+
Population Density (ln)	-0.769	5.692		9.571	5.865		-2.349	6.254		-93.122	48.689	+
Percent Urban	-0.004	0.002		-0.003	0.002		-0.007	0.003	*	0.010	0.020	
Per Capita Arable Land	-0.767	0.104	***	-0.870	0.106	***	-1.357	0.121	***	-0.302	0.828	
Irrigation Intensity				0.025	0.002	***	0.022	0.002	***	0.034	0.022	
Livestock Production				0.004	0.001	***	-0.001	0.001		-0.001	0.003	
Tractors Intensity				0.000	0.000	***	0.000	0.000	***	0.000	0.000	
Percent of GDP from Agriculture							0.006	0.002	**	0.015	0.007	*
Agriculture Exports as Percent of GDP							1.211	1.040		-1.827	8.174	
Agriculture as a Percentage of Exports							0.013	0.002	***	-0.005	0.019	
Gross Domestic Investment										0.000	0.007	
Government Debt as Percent of External Debt										-0.002	0.001	
Foreign Direct Investment										0.015	0.011	
Cumulative Years Under Structural Adjustment										0.040	0.021	+
Constant	-30.295	68.361		101.66	71.298		-53.973	77.424		-1180.351	604.908	+
Observations	5230			4798			3100			330		
Groups	165			151			141			60		
R2 within	0.469			0.494			0.532			0.203		
between	0.004			0.134			0.003			0.010		
overall	0.000			0.100			0.000			0.070		

+ $p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

arable land decreases fertilizer intensity. Thus, the argument made here that controlling for population was an omission that may have led to spurious conclusions in previous analyses proves valid. The second run shows the variables associated with capital-intensive production. All are significant and exhibit positive influences on fertilizer intensity, which is to be expected given the nature of the seed-chemical-technology package of agricultural modernization. In the next run, the inclusion of variables that control for the economic importance of agriculture and the degree of export orientation shows a net significant influence on fertilizer intensity, but in subsequent runs only agriculture as a percent of GDP remains significant. In the last run, government debt and foreign direct investment do not show a significant influence on fertilizer intensity—as theorized by unequal ecological exchange—whereas cumulative years under structural adjustment shows a net, positive effect on fertilizer intensity, as expected from the theory of ecological imperialism. In the fully saturated model, structural adjustment, affluence, population size, population density, and economic importance of agriculture remain the important predictors of fertilizer intensity.

It is important to note that once domestic investment, debt, and foreign investment variables are included in the analysis the Kuznets variable washes out and remains insignificant for the rest of the analysis. We can interpret this to mean that when controlling for dependency factors, any potential turning point in fertilizer intensity that may result from ecological modernization is limited to those nations already in a dominant position in the world economy. Any EKC that may have existed across the spectrum of countries masks that for countries undergoing economic restructuring such a phenomenon either does not exist or is so out of reach as to be practically nonexistent.

Instead, increases over time in population size, population density, and affluence all combine with the cumulative effect of being under structural adjustment to cause fertilizer intensity to increase monotonically over time. Thus, the longer a country is under structural adjustment, giving more time for an imposed radical reorganization of that nation's agricultural and development priorities administered by the wealthy nations of the world, the more intense its agricultural impact becomes. This trend is independent of the size of the nation's economy, population pressure, level of urbanization, capitalization of production, the size of agriculture in the domestic economy, agricultural export orientation, the government's debt load, and flows of foreign direct investment. In the final analysis, structural adjustment has an effect in the theorized direction derived from ecological imperialism, while human ecology is also supported.

Moving on, the results from Model D, which uses as the dependent variable the combined metric that estimates energy consumption in agriculture per hectare, are shown in Table 10. The results show that when the fixed effects estimation is specified, the only significant (and quite positive) influence on energy intensity is population density. From the results, a cautious interpretation here would be that population density has a significant effect on energy intensity in agriculture. However, Model D is primarily a preliminary and exploratory analysis, and it is clear that improved data will be required for future research.

Table 10. Fixed Effects Panel Regression, Agricultural Energy Intensity, 1990 and 2001.

Independent Variables	Coef.	Std. Err.	
Per capita GDP (ln)	0.568	0.549	
Per capital GDP (ln), centered and squared	0.066	0.141	
Population Density (ln)	3.928	1.085	**
Irrigated Land as a Percentage of Cropland	0.002	0.014	
Livestock Production	-0.006	0.005	
Percent of Total Exports from Agriculture	0.015	0.017	
FDI Net Inflows as Percentage of GDP	0.007	0.018	
Cumulative Years under Structural Adjustment	-0.001	0.022	
Constant	-19.205	7.189	*

Observations = 172
Groups = 106
Countries With Two Observations = 66
R^2: within = 0.374
between = 0.418
overall = 0.518

+ $p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Finally, the results for Model E, estimating the predictors of value-efficiency for fertilizer consumed, are shown in Table 11. The specified model is based on the gross productivity function from agrarian systems theory. The causal relationship is theorized that, at a bare minimum, the output per labor (or a labor substitute) will be a multiplicative function of the land that a farmer can work times the potential yield for a given cropping system. The dependent variable is expressed as a ratio of economic value produced in agriculture to fertilizer consumed (a capital-intensive substitute for labor).

Both arable land per worker and food production per agricultural land, the basic components in the agrarian systems specification, are significant predictors of agricultural value efficiency. This lends qualified support to the reformulated expression

Table 11. Fixed Effects Panel Regression of Fertilizer Economic Efficiency (ln), 1980–2002.

Independent Variables	Coef.	Std. Err.	
Food Production of Agricultural Land (ln)	-0.261	0.127	*
Arable Land per Worker (ln)	0.226	0.029	***
Livestock Production Index	0.003	0.001	
Agricultural Exports as a Percentage of Total Exports	6.522	1.377	***
Foreign Direct Investment Net Inflows	0.003	0.003	
Cumulative Years Under Structural Adjustment	-0.018	0.005	***
Constant	7.239	0.953	***

Observations = 1188
Countries = 99
R^2: within = 0.231
between = 0.014
overall = 0.019

$+ p < 0.10$; $* p < 0.05$; $** p < 0.01$; $*** p < 0.001$

of Mazoyer and Roudart's (2006) production function and makes sense in that the more land per agricultural worker, the greater value efficiency of the means of production. The direction of the coefficient for food production is negative, however, indicating that the greater the per unit hectare productivity of national agriculture, the less value added per unit of fertilizer consumed. One potential explanation for this, what might seem counterintuitive at first, derives from the fact that measure for food production includes more stages in the commodity chain than value-added in agriculture. This is because the measure of value-added in agriculture is limited to that gained from the sales of farming output alone. The negative direction of the coefficient suggests that the more food a country produces, the less efficient its raw commodity output. It may be that such countries use much more fertilizer than they need or it could mean that the countries where value from food production tends to be added in stages higher up on the commodity chain do not tend to be the same as those where raw commodity value is most efficient. In this exploratory analysis it is difficult to tell without further research.

Taking into consideration the other variables in the model, several trends can be noted. Neither livestock production nor FDI are significant predictors of value efficiency.[23] Given that the livestock complex is only indirectly connected to fertilizer consumption, and that regional production is known to span borders in ways that crops simply cannot, the production of livestock is exogenous to value efficiency relative to fertilizer consumption. Also, the fact that FDI net inflows show no significant influence indicates that foreign investment dependence is not a major driver of agricultural energy use.

Last of all, the export concentration measure and the structural adjustment measure are highly significant, but in opposite directions. The higher the percentage of total exports comprised of agricultural products, the greater the value-to-fertilizer ratio, which indicates, other factors being equal, that export concentration is not a mechanism

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[23] As means of production, irrigation and tractor intensity are subsumed into Arable Land per Worker variable, discussed in Chapter IV, and hence not included separately in the model.

of a forced trade off between economic gain and environmental damage. Rather, export concentration clearly improves the potential to gain value from agriculture relative to the amount of fertilizer consumed. In contrast, the number of years a country endures a structural adjustment program diminish over time the potential value that can be gained from the amount fertilizer consumed. These observations once again lend support to the theory of ecological imperialism and against the theory of trade liberalization.

Capital penetration and economic restructuring have been shown here to play a consistent role in agricultural degradation, along side the typical outcomes expected by the scale of production and population size. Structural adjustment was shown to contribute to a decline in the value efficiency for fertilizer used, which suggests that structural adjustment acts in a dual fashion, increasing the impacts of agricultural modernization while at the same time diminishing its benefits. In the period studied here, when where capital restructuring contributed to the emergence of a global food system, structural adjustment proved to be a crucial mechanism by which the sustainable development potential of Third World societies actually declined. The results from previous research were validated, with qualifications. Model C, the showcase of this section, demonstrated that structural adjustment had a clear influence on the potential for agricultural *over*-intensification, a consequence that is independent of the size of the economy and population, common factors attributed to environmental degradation in the popular literature. Unequal ecological exchange and ecological imperialism were consistently supported by the findings across the several models. In contrast, liberalization and ecological modernization theories had very little, if any confirmation.

CHAPTER VI

CONCLUSION

The immediate goal of this research was to determine the extent to which structural adjustment affected the negative impacts of agricultural modernization. The findings above indicate that structural adjustment programs do indeed exert a significant increase in fertilizer intensity the longer a nation is under its domain. At the same time, SAPs have a negative effect on the economic gain that can potentially come from the use of fertilizers.

Regarding the predictions of human ecologists, their less than sanguine outlook on the role of affluence and population pressure in generating environmental impacts once again proves to have an overall and general relevance. In fact, per capita GDP and population density were *the* consistent predictors of all the outcomes tested with those variables as part of the specification. Although there was some indication of an Environmental Kuznets Curve in fertilizer consumption, the threshold for a declining rate of consumption is well beyond those nations that as a group have undergone structural adjustment, and there was no EKC shown in the intensity models. Thus, modernization may appear to offer the possibility of some degree of rational management of soil fertility, at least for those nations having the per capita GDP large enough to implement such systems, but judicious nutrient management of industrially sourced inputs still poses a resource intensity issue plaguing developing nations. Considering that value decreases and impacts increase for the amount of fertilizer consumed in the third world, as revealed in the analysis, the unequal outcomes for the center and periphery are most likely mutually conditioning. Ecological modernization proves once again to be mainly a theory about the amelioration of point source pollution in the developed world rather than about the overall ecological restructuring of the production/consumption trajectories of the modernization process in general. Moreover, the absolute increase in impacts worldwide continues to rise, suggesting that even as countries may be able to displace their impacts, or trade off one for another, the overall scale of production continues to drain the planet's finite resources while at the same time undermining the land-basis for bioregeneration. So far the institutions of modernity have not led the way out of the crisis.

Trade liberalization theory has been the main rationale for the implementation of structural adjustment. While the greater ecological good of a nation was never the main goal of SAPs, concerns over population, environment, and famine nevertheless comprised part of the overall rhetoric of liberalization theory. In addition, as the second phase of SAPs came on line in the 1990s, advocates of liberalization and of ecological modernization emphasized the necessity for integration into global economy as *the* means toward sustainable development of the Third World. The twin problems of poverty and environmental degradation were seen as solvable through this pathway alone.

Given the actual history of structural adjustment and trade liberalization, coupled with the findings here, the roles of the IMF and World Bank are revealed to be contradictory. Positioned between human needs and private capital, their persistant emphasis on economic rationalization belies their supposed status as neutral development institutions. In the context of late twentieth century global economic restructuring, SAPs served as a critical tool for meeting the economic needs of more powerful nations and their investors. Structural adjustment therefore is more accurately viewed as a means for the coercion of the poorer nations of the world to adopt the development strategy of *hyper*-dependency (what is comparative advantage, after all, when carried out to its logical extreme).

These findings are particularly noteworthy, since in order to qualify for structural adjustment loans a country would have to have already been impoverished or heavily indebted to begin with. This means that the very programs that were championed as opportunities for improvement did not do what they intended, and in fact contributed to the very opposite. In light of all the case studies examining the effects of economic restructuring under the auspice of IFIs, and now with the results of this project, it is hard not to conclude that integration into the global economy in this particular way maintains rather than alleviates the conditions that prevent Third World sustainable development.

A more comprehensive and abstract goal of the research was to find a way to differentiate between processes that are attributable to the system properties of the global capitalist food system and the immediate processes that are attributable to unequal trade. While previous research in the area of the uneven environmental consequences of globalization has focused on export agriculture and foreign direct investment as drivers of nutrient pollution, the results here contextualize such conclusions by bringing into focus the historical period during which export orientation and capital penetration were amplified. Unequal ecological exchange can only make sense insofar as exchange is between unevenly matched trading partners. Yet, the existence of that unevenness is a phenomenon to be explained rather than assumed, especially so that we can avoid repeating the mistakes of the past.

One framework for thinking about SAPs is that they are part of the ongoing process of primary accumulation and commodification. In the most invasive examples of primary accumulation, the resources of vulnerable societies are pillaged. Yet, any theory that depends on imperialism as an explanatory device must be able to differentiate between kinds and phases of imperialism. The hallmark of capitalist imperialism is the supplanting of previous economic modes with capitalist productive relations, and in doing so actually changing the natural resource base and methods of production of the conquered land. Once these changes are in place, the capitalist core is able to continue to draw upon the labor and resources of peripheral regions by virtue of the fact that such changes in the conditions and relations of production undermine the endogenous development potential of those societies.

After the resource rich periphery was exhausted of use-value during the colonial phase, the post-colonial phase brought about a reversal of the flow of agricultural raw material inputs. Nutrients returned to the periphery, now as capital-intensive mineral concentrations to be recombined with the newly restructured and 'modernizing' farms of the mid to late twentieth century. These historical developments established path dependencies that by virtue of the need for economic survival mandated competitive (and hence capital intensive) production practices and, through the use of these practices, progressively degraded the soil (or continued the ongoing degradation of previously exhausted soil), thereby requiring intensive fertilizer use for soil fertility renewal.

The progressive underdevelopment of the periphery has been linked to the dependence on extractive economies and to the history of continued land use degradation of ecosystem productivity in those regions. However, the degradation of the soil combined with dependency on core industry remains a distinct process and may better explain unsustainable underdevelopment. With the onslaught of intensified agriculture, the productivity per acre of entire regions increase, if only under the auspices of the command and control system of mechanized, capitalized, and commodified production. Moreover, in contrast to extractive industries like mining, agricultural commodities go directly toward the reproduction of labor power. Under the international division of nature, the origin of the mode of fertility renewal lies in the industrial production process under the control of capital. Fertilizer then circulates through agricultural fields to combine with farming labor power and return in the form of cultivated raw materials, which feeds labor in the core. These observations flesh out the ways in which food production is a unique (and perhaps the oldest) method by which labor and nature is appropriated without direct coercion. Due to the centrality of cheap foodstuffs for labor power's reproduction, it is also makes sense why ensuring this dependency continues to be an imperative policy agenda of the capitalist core even today.

Consider how unequal ecological exchange works with respect to the food system. First, the use values of agricultural raw materials are traded on the global market, where they are both food and feedstock for downstream processing. Their usefulness comprises their qualitative value as food while also contributing to the potential to cheapen the costs of labor in the core and thereby facilitate the extraction of quantitative value from the production process. The appropriation of exchange value in the core contributes to internal articulations, to capital formation, and to capital accumulation generally. The reinvestment in this productive surplus is then divided into value that contributes to the development of the center, and value that can be used to further augment the process of capital accumulation. Reinvestment requires not only markets for surplus investment, but also a qualitative form in which the commodities can secure continuation of market access and control, and thereby the continued appropriation of use-values from the periphery having intrinsic qualities necessary for continued core consumption. This global enclosure of natural productivity is closely linked to labor's appropriation, not only in facilitating the cheapening of labor power in the core (and hence increasing the potential for relative surplus value appropriation) but also controlling labor power in the periphery, appropriating absolute surplus value as peasant farmers and to some extent petty farmers (including especially day laborers) work under conditions of intensified self-exploitation.

Hence, inequality and degradation are both structured *via* the intensification/commodification dialectic. Using the theory of ecological imperialism we can then reframe the problem of fertilizer intensity in a particularly important way, pointing toward the larger forces at work in shaping the global political economy. Rooted in a Marxist analysis of capitalist development, and in particular the observation that capitalism divides and recombines in order to conquer, ecological imperialism calls attention to the ways in which farming is but one aspect of the larger division of labor and nature in the global food system. The seed-chemical-machinery package seen in this light is a crucial tool for maintaining the continued extraction of surplus labor and renewed accumulation.

But what are the implications for the way forward? How are the productive forces to be developed and under what historical circumstances? Why these are questions to be answered in praxis from the ground up by those directly involved, it still remains important to elucidate what the history of agricultural development, both under capitalism and universally, informs us on how to proceed. From the modernization point of view, devastating extant ecological bases is not a problem so long as there can be an adequate (read: efficiently profitable) substitute put in its place. However, the research here brings to bear a reasoning process that questions this logic.

It may very well be that the supposedly neutral status of existing technology needs to be radically called into question. This is not to hearken back to a critique of science or instrumental activity in and of itself. Rather, we must radically re-envision what it means to be instrumental. That requires, in the Marxist analysis, an examination of how human relationship, societal metabolism, and mediation with and within the biosphere involve an interplay and dialectic between social labor and the dynamic constellation of bioproductive forces, networks, and process we are only just now beginning to comprehend. It is not only our reliance on these processes which calls for their protection but the pervasive unintended and non-linear consequences that result from attempts to manage them for profit maximization.

We do not need to give up the human propensity to transform our relation to the world. Rather we need to give more attention to the way the biophysical world contributes to and informs our propensity to transform. Bridging a Marxist conceptual framework with ecology improves our understanding of the overall impacts of societies on the environment and conversely, the potential for sustainable agriculture. The complex of cultivated ecosystem and agricultural labor is the central locus of societal metabolism and forms the base of all subsequent societal development. The locus is not one sided, but includes the coevolutionary influence of the nature side of the dialectic.

Under structural adjustment, or capitalist development generally, development of the productive forces, and hence of the social system, undermines both the management of and the integrity of the ecosystem. The way that farm labor carries out cultivation, the way it puts means of production to use, is determined by the social relations on-farm, by access to land, and by the way the means of production are reproduced. Previous researchers have identified social labor and land tenure as key elements determining farmer viability. However, less noticed, but perhaps more important under present historical circumstances is the way in which farm means of production themselves become commodities. In the demand to control and appropriate labor and nature, commodity agriculture translates into agricultural intensification, which directly affects the socio-technical aspects of farm unit reproduction, including labor and means of production, but also the potential continuity of the socio-ecological aspects of the resource base: the cultivated ecosystem.

Structural adjustment programs perform not only the extra-economic function of primary accumulation they also facilitate commodification. The recombination of international farming labor with monopoly capital contributes to accumulation on a world scale, connecting various agrarian systems with the specific strategies of scientific-technical management through the simplification and control of farm labor. Thus the effects of SAPs dovetail neatly with a theory of capitalist exploitation, which posits at the heart of capitalist society the appropriation of surplus labor and value. This involves turning land and labor—in this case, farm labor—into a commodity. While the technology and implements of a production system determine to some extent the methods of cultivation and fertility renewal, the types of tools and energy used are themselves conditioned by the division of labor and of nature.

The cultivated ecosystem is influenced by the social productive system and in turn the social productive system is influenced by the way in which farm unit reproduction is carried out. Farm unit reproduction is accomplished by either self-supply or exchange, including financial obligations. Net outflows can be used to either contribute to the ongoing renewal and development of the productive system (and within it, potentially the farm unit as well) or to development elsewhere. However, a third possibility, the development of the system of societal metabolism (and farming reproduction)—that is, the capitalist agro-food complex—can be supported by net farm payments, which supports the possibility for future farm production and renewal, but only in a conditional and contradictory way. Conditionally, future farm production and renewal is locked-up in the social relationship with the monopoly control of farm means of production. Contradictorily, this relationship facilitates these same monopoly agribusinesses to enjoy the majority of value appropriation, and hence it is capital accumulation rather than the socio-ecological needs of the production system that is renewed.

Given the findings here, which contribute to a growing body of evidence that SAPs, as but example of global economic integration, are not sustainable, the issue how the future relationships between nations of the world can be mutually advantageous remains problematic. Ecological imperialism offers a theory of integration that focuses on the capitalist division of labor, and of nature, throughout the global economy. In this view integration means assimilation into an economic system that is already structured unequally and for the benefit of capital accumulation in general and specifically for the handful of nations that dominate global trade. This implies that alternative pathways to development require genuine, rather than nominal integration. Future research might focus on the various actors both within and across nation states, while also getting a better picture of geographical differences worldwide. A network analysis of agribusiness firms and their clients seems called for in that it might highlight the hidden relations and flows of values that structure the global economy in ways that use and abuse the state.

APPENDIX

CONSTRUCTING THE ENERGY USE INTENSITY VARIABLE

The construction of the composite measure used as the third dependent variable requires some explanation. The weighted estimate of energy equivalent for fertilizer consumed is derived by using average energy requirements for the production of each plant macronutrient in its soluble form, multiplied by the proportion of global fertilizer production represented by each individual macronutrient, and then summed. For illustration and comparison, Table 12 gives estimates of the world average energy requirements by nutrient type and lifecycle stage for inorganic fertilizers.

Table 12. Global Energy Requirements for the Production of Agricultural Nutrients, 2003 [BTU/lb (kJ/kg)].

	Nitrogen	Phosphate	Potash
Production	29,899 (69,530)	3,313 (7,700)	2,753 (6,400)
Packaging	1,119 (2,600)	1,119 (2,600)	774 (1,800)
Transport	1,936 (4,500)	2,452 (5,700)	1,979 (4,600)
Application	688 (1,600)	645 (1,500)	430 (1,000)
Total	33,642 (78,230)	7529 (17,500)	5,936 (13,800)
Metric Eq.	78.23 GJ/t	17.5 GJ/t	13.8 GJ/t

Source: Gellings and Parmenter (2007)

The table shows the relatively large energy requirements of nitrogenous fertilizer production when compared to phosphate and potash. Ammonia synthesis itself used roughly 70,000 kilojoules (kJ) per kilogram (kg) of nutrient (30,000 BTUs per pound), almost 90% of nitrogen fertilizer's total energy requirement that year. In contrast, the production of phosphate and potash accounted for only about 45% of the total energy requirement for these nutrients. When including transport and application, the energy requirement for nitrogen fertilizer is 4.5 times that of phosphate fertilizer, and 5.7 times that of potash fertilizer. Considering that fertilizer energy amounts to approximately 40% of energy use in agriculture (Giampietro and Pimentel 1994), it is clear that capturing the energy requirements for its production is an important consideration in attempting to gauge the degree of metabolic rift across nations.

Smil (2008) puts average worldwide energy efficiency of synthesis of ammonia at 40 to 45 gigajoules/tonne (GJ/t), rock phosphate-complex production at 15 to 30 GJ/t, and approximately 10 GJ/t for potash production. Phosphate and potash figures include mining and processing. However, when considering conversion of each *element* to useful form, the relative amounts change to 50 GJ/t N, 20 GJ/t P and 10 GJ/t K (Smil 2008:310).

Actual quantities of global fertilizer consumption for crop year 2002/2003 are listed in Table 13. Once again, the dominance of nitrogenous fertilizers is clearly

Table 13. Global Quantities of Fertilizer Consumed by Type, 2002–3 [million tons].

	Nitrogen	Phosphate	Potash
World	85.11	34.08	24.69

Source: International Fertilizer Industry Association (2004) demonstrated, as the volume of nitrogen fertilizer surpasses the other nutrients by factors of at least two. Fertilizer consumed by nation is given in aggregate form in the World Bank data package. Using the data on global production, in conjunction with Smil's (2008) average energy requirements for each macronutrient in elemental form, we can estimate a *weighted* energy equivalent of fertilizer consumption using the production figures and energy costs. Since only the energy equivalent for production (and not transport, packaging, application, etc.) is used, the value is a more conservative estimate of the total energy requirements of agriculture than would be otherwise. Table 14 displays the weighted factor (bottom row, fourth column) derived from the equation

$$F_{ee} = [(N_t*N_e)+(P_t*P_e)+(K_t*K_e)] / N_t+P_t+K_t$$

where F_{ee} is the energy equivalent of fertilizer consumed, N = nitrogen, P = phosphorous, and K = potassium, symbols designated with the subscript X_t represent the respective amount of that element produced, and X_e is the energy requirements per unit production. The factor F_{ee} (bottom row, column four) gives a *weighted* average estimate of the energy required to produce the fertilizer consumed in agriculture, approximately 39 GJ per metric ton of fertilizer. Its usefulness depends on the assumption that fertilizer consumption at the national level reflects the proportions of production at a global scale. Given the available data on global production and the proportion of each nutrient required for typical cultivation, this makes for a fair approximation of the non-renewable energy consumed to support industrial fertility management.[24]

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[24] Of course, fertilizer can be produced using renewable means. However, the high-temperature and pressure conditions of ammonia synthesis, using latest available technology, surpass in volume available renewable sources, while the mining of

Table 14. Deriving the Factor for Converting Fertilizer Consumed to Energy Equivalent

	2002/3 Global Production (Mt)	Global Average Energy Costs (GJ/t)†	GJ Energy per Nutrient	Energy Costs of Fertilizer (GJ/t)
N	85.11	55	4.681×10^9	
P	34.08	20	6.816×10^8	
K	25.69	10	2.569×10^8	
Sum	144.08		5.620×10^9	$F_{ee} = 39.003$

† Source: Smil (2008:287)

Multiplying total fertilizer consumed by F_{ee} and then dividing it by .004193 GJ/ktoe (GJ = gigajoules, or one billion joules; ktoe = thousand tons of oil equivalent) gives the energy equivalent, in terms of oil equivalent, that can be combined with the total final use figures. Using this common metric facilitates a greater approximation of the total amount of energy consumed in national commodity agriculture than figures for total final consumption in the agricultural sector and registers the energy use at the site of consumption rather than the site of production.[25]

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phosphate and potash typically uses heavy equipment. Both technologies require considerable pools of energy to supply necessary thermal and motor power.

[25] This approach is similar to the Ecological Footprint (EF). However, unlike the EF the current measure does not take into consideration land requirements for given levels of consumption, nor does it estimate an ecological surplus/deficit. The advantage of the approach, however, is its specificity to agricultural production, allowing the comparison of production units on a national scale.

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