THE PARADOX OF GREEN COMMODITES

by

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DISSERTATION ABSTRACT

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In this dissertation, I establish a theoretical and empirical critique of modern forms of environmentally sustainable technology. Theoretically, I critique the application of environmentally sustainable technologies in modern capitalist economies using the treadmill of production theory and metabolic rift theory. I also expand on these theories by developing an analytical concept – the displacement paradox. The displacement paradox refers to a counterintuitive phenomenon, where green technologies expand rather displace traditional production processes. Empirically, I assess the assumptions of the displacement paradox by analyzing the relationship between organic farming and agrochemical application, organic farming and greenhouse gas emissions, organic farming and water pollution, and alternatively fueled vehicles and total fuel consumption per vehicle. In each of these cases, I find that green technology (in the form of organic farming and alternatively fueled vehicles) is not displacing traditional production processes, and instead expanding alongside them. I argue that these findings are a result of the broader socioeconomic structure that green technology is produced under. Specifically, I contend that because current socioeconomic systems are established around traditional production processes, to substantially reduce environmental degradation, green technologies must operate as a social and technological counterforce to traditional production processes. Currently, the green technologies explored in this dissertation act as a technological alternatives to traditional production processes, making them commodities that sustain the current structure of social relations, as opposed to social and technological counterforces to environmentally hazardous forms of production. I conclude that in order for green technologies to successfully reduce environmental degradation, they must be established under social conditions that support their use over traditional production processes.

This dissertation contains previously published and unpublished co-authored material.

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I dedicate this to the memory of Julia Audrey Whitten McGee

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CHAPTER I

INTRODUCTION: THE PROBLEM WITH GREEN REVOLUTIONS

Recently, in a course I was teaching on environmental sociology, I opened up a lecture by asking the class what they knew about the green revolution. The topic of this particular lecture pertained to the environmental impacts of agricultural production. The point of the question was to get a good sense of the students' prior knowledge of the technology developed during the green revolution. Like most questions I asked at the start of lecture, I gazed around at blank faces for about thirty seconds, before finally one student raised their hand to break the silence. The student who had raised their hand confidently proclaimed that the green revolution referred to the recent rise in environmentally sustainable laws, products, and technologies around the world. Admittedly, I was somewhat baffled by this response, but it was not because the student was incorrect. On the contrary, I was astonished by the student's interpretation of the current era in which we live. The student not only saw this era as a revolution, but more importantly, defined this revolution using the term "green".

Contrary to my first impression, the development and promise of what my student had acknowledged as today's green revolution was strikingly similar to the development and promise of the actual green revolution. The green revolution generally refers to the period between 1940 and 1970, where innovations in agricultural technology, such as the creation of "dwarf crops" and synthetic fertilizers, significantly increased the amount of calories produced per hectare of agricultural land. The origins of the green revolution begin with Norman Borlaug, an American forest pathologist interested in agriculture, who created a disease resistant high-yielding variety of wheat that transformed the Mexican wheat market into a large global exporter (Manning 2004). Borlaug eventually brought his innovations to the United States, where he was funded by the Rockefeller and Ford Foundations to increase research on dwarf cropping (Shiva 1991). His research and innovation not only increased wheat production in North America, but also throughout the developing world (Manning 2004).

The promise of the green revolution and the story that is often told, is that industrial agriculture can feed the world and increase the quality of life of billions living in poverty. On the surface this appears to be true. From 1975 to 1986 rice and wheat production increased thirty-two percent and fifty-one percent, respectively. Additionally, the massive famine that had plagued India prior to this period was reduced dramatically (Shiva 1991). This is all attributed to Borlaug's innovations, and he was eventually awarded a Nobel Peace Prize in 1970 for the success of the green revolution. There is no doubt that the technology of the green revolution increased agricultural output dramatically, excluding China, the green revolution increased food per capita by 11%. However, due to the massive restructuring of agribusiness during the green revolution, the number of hungry people also increased by 11% (Lappé 1998). This is because hunger is mostly linked to poverty, which also increased due to the corporate consolidation of agribusiness and consistent economic growth in the agricultural industry.

The often unacknowledged story of the green revolution is that it increased the power of fertilizer, pesticide, and seed manufactures in the agribusiness industry. Borlaug's dwarf crops required massive application of agrochemicals to be maintained, forcing farmers to be heavily reliant on agrochemicals (Manning 2004). For example, within twenty years the green revolution completely deteriorated the soil fertility that had lasted for generations with "phosphorus and potash generated from geological deposits and nitrogen derived from petroleum" (Shiva 1991: 101). Additionally, new seeds that were heavy consumers of fertilizers were required to maintain production, and pesticides were increasingly needed to allow mono-cropping techniques to flourish. The increased reliance on external agro-inputs helped to vertically and horizontally integrate the agribusiness industry and expand the agricultural market (Magdoff et al. 2000). This is the true promise of the green revolution — the increased commodification of agriculture, as the organic compounds necessary for agricultural production, became commodities themselves.

The promise of the original green revolution, mirrors the promise of what my student and many others see as today's green revolution – the promise that economic growth can address the very problems it creates. However, similar to how the original green revolution increased poverty and hunger by further commodifying the resources necessary to combat it, the new green revolution has increased environmental degradation by further commodifying the technology necessary to combat it. In this dissertation, I argue that the production of green technologies produces paradoxical dependencies between green development and environmental degradation, where green technologies, rather than displacing environmental degradation, work to expand markets and increase environmental impacts. Throughout this dissertation I will empirically assess the paradoxical relationship between various forms of green development and environmental degradation to demonstrate how green technology is limited due to the socioeconomic context that it operates under. The thesis of this dissertation is that capitalist economies have commodified green technologies in a way that makes them conducive to modern socioeconomic processes that perpetuate environmental degradation.

What is Green?

Before discussing this thesis further, it necessary to understand what green technology means in capitalist economies. A global definition of green can be found in the United Nations Environment Program's (UNEP 2011) annual report on the green economy, which is a compilation of publications from international organizations and national governments regarding environmentally sustainable development. These publications proclaim to be a continuation of the World Commission on Environment and Development (WCED 1987) efforts to promote an environmentally sustainable economy. The WCED was a gathering of twenty-two nations in 1987 that sought to lay the foundations for what they considered to be environmentally sustainable development, defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED 1987). It marked not only the first time multiple nations assembled to address the escalating possibility of an environmental catastrophe, but also the first time sustainable development became an economic concept. The broad definition of sustainable development defined during the WCED was later translated by economists to mean production that does not depreciate per capita well-being over time (Pezzey 1990). Although in the preceding decades many definitions of sustainability have been developed (Pearce[1] and Walrath. No date), this particular definition became the template used by many nations to address environmental degradation (see Confederation of Indian Industry 2008; Republic of Korea 2009; Statistics Netherlands. 2009; APCO 2010; Republic of Rwanda. 2011; UNEP 2011; UNEP 2012a; Climate Works Australia 2011; Ministry of Environment and Sustainable Development 2011; Ministry of Environment and Sustainable Development 2011; Jamet 2012; World Bank 2012; CIF 2012; United States Department of Energy 2013).

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[1] Pearce and Walrath (no date accessed May , 2015) found over 200 definitions of the term

In this definition of environmental sustainability, well-being is a synonym for capital accumulation. This logic is evident in the UNs assessments of successful forms of green growth, which argue that:

> …moving towards a green development path is almost certainly a means for attaining welfare improvements across a society, but it is also often a means for attaining future growth improvement. This is because a shift away from basic production modes of development based on extraction and consumption and towards more complex modes of development can be a good long-term strategy for growth. (UNEP 2011: p. 22)

This logic is also evident in multiple nations' attempts to promote green economic growth, which have been highlighted in various reports by the UN (see UNEP et al. 2008 UNEP 2010; UNEP 2012). In all of these reports, green development is discussed as a technology and/or practices that reduces environmental impacts and promotes economic growth. What is considered to be green is technology that either increases the efficiency of resource use to limit the emission of environmental impacts, or a technology that is void of specific environmentally hazardous resources that can act as a substitute for an environmentally hazardous technology. While there has been considerable research conducted on the former these processes, (See Alcott 2005; York and McGee 2015, on the Jevons Paradox), my dissertation focuses on the latter.

Technologies commonly perceived to be void of specific environmentally hazardous resources that can act as substitutes for traditional forms of production are renewable energy sources and organic agricultural practices (FAO 2012; IEA 2009a; 2009b; 2010; UNEP 2010; 2011). In discussions of these two forms of green production, it is clear that the goal of producing these types of green technology is to substitute what the UN defines as brown technology[2]. Below is an example of how each type of technology is discussed.

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[2] The United Nations defines brown technologies as processes that produce substantial environmental degradation, such as fossil fuels and conventional agriculture (See UNEP 2011).

> The other key to balancing different forms of capital recognises that substitutability is a characteristic of current technologies. Investing in changing and substituting these technologies can lead to new complementarities. Most renewable energy sources, such as wind turbines or solar panels, considerably reduce the amount of natural capital that is sacrificed in their construction and the lifetime of their operation, compared to fossil fuel burning technologies. Both of these types of solutions – setting thresholds and altering technologies – are important for achieving a green economy. (UNEP 2011: 19)
>
> FAO promotes organic agriculture as an alternative approach that maximizes the performance of renewable resources and optimizes nutrient and energy flows in agroecosystems. Life cycle assessments show that emissions in conventional production systems are always higher than those of organic systems, based on production area. Soil emissions of nitrous oxides and methane from arable or pasture use of dried peat lands can be avoided by organic management practices." (FAO 2012)

Each of these processes are put forth as alternatives to existing forms of production. Moreover, the goal of each form of production is to reduce a specific environmental impact by substituting out an existing, more environmentally hazardous type of manufacturing. In this context, green refers to any type of technology that produces little to no environmental impact. Green growth refers to the ability of green technology to act as a substitute for a traditional technology in a way that allows capitalist economies to grow and expand without producing pollution or degrading the environment. This interpretation of environmental sustainability is very similar to the interpretation of economic sustainability in neoclassical economics, which identifies sustainability as sustained economic growth.

The Problem with Green Growth

Attempts to produce green technologies as substitutes that sustain economic growth is nothing new to capitalism. For example, growth theory in neoclassical economics, developed by Solow (1956) and Swan (1956), is a way of understanding long term growth trends through technological innovations and resource substitution. The Solow-Swan growth theory model grew out of a critique of a long-standing classical theory on economic growth, which originated from the likes of Smith, Ricardo, and Keynes (for an overview of the classical origins to growth theory, see Sardadvar 2011). Solow was critical of what became to be known as the Harrod-Domar model of economic growth, which he claimed “boils down to a comparison between the natural rate of growth which depends, in the absence of technological change, on the increase of the labor force, and the warranted rate of growth which depends on the saving and investing habits of households and firms” (Solow 1956:1). The key to Solow and Swan’s growth theory models is the influence of technological change on economic development. Thus their models emphasized the determinants of economic growth as a function of increases in inputs, such as labor and capital, and technological progress. Their theoretical framework purported that old capital would be pushed out and substituted by new capital that is produced from new constantly improving technology.

The logic of growth theory parallels the logic applied by various nations and international organizations to implement green technologies. For instance, both are predicated on the ideology that technological progress and resource substitution can sustain economic growth. In this sense, the production of green technologies as discussed by governments and international organizations is an extension of growth theory, where the notion of sustained economic growth is slightly altered to encompass environmental sustainability. However, this logic if flawed in that green technologies can be used to sustain economic growth without substituting traditional technologies. This is because green technologies are currently produced under a socioeconomic context that is not conducive for their widespread use. Instead of acting as direct substitutes for traditional technologies, green technologies function as extensions of existing markets in a way that perpetuates economic growth. As a result, green technologies that are produced as alternative forms of production, are often commodified versions of environmental sustainability, and as such act as a continuation of the unique feature of capitalism that Immanuel Wallerstein and Karl Polanyi famously referred to as “the commodification of everything”. Radical scholars, and in particular those in the historical materialist tradition, have long been critical of this process. In their book titled *The Tragedy of the Commodity* Longo, Clausen, and Clark explain this process very thoroughly.

> Central to this process [capitalism] is the necessity for accumulation of capital, of which the commodity is the central vehicle. Capitalism is a system predicated on constant expansion. Capital is invested and reinvested to accelerate economic growth, which continually propels and sustains the system. The generalized production of commodities in the capitalist economy is made so immensely transformative by the endless pursuit of economic growth and the institutional mechanisms by which it socially transpires. (Longo, Clausen, and Clark 2015: 148)

This is to say that the current production of green technologies is a way of incorporating environmental sustainability into the growth imperative of capitalism. By marrying the two concepts of sustainability (economic and environmental), capitalist economies can now measure the success of green technologies by their sheer volume, and fail to recognize how they operate as tools of economic growth.

For example, in January of 2016, United States President Barak Obama delivered his final State of the Union speech, highlighting the many accomplishments of his seven years as president. Among the accomplishments highlighted, was his legacy as the “green” president of the United States. He touted the success of clean energy programs, particularly the growth in solar and wind energy markets around the United States, proclaiming that not only had these markets expanded due to policies implemented during his tenure as president, but clean energy was beginning to compete with fossil fuel markets. All this expansion, however, occurred under a presidential regime that lifted the United States’ ban on oil exports (allowing the United States to soon outpace Saudi Arabia in oil production), signed a bill on transportation expediting pipeline permits for oil and natural gas companies, and expanded exports of coal and natural gas.

President Obama’s emphasis on the accomplishments of sustainable technology and lack of acknowledgement of the consistent expansion of fossil fuel production during his final State of the Union, demonstrates the problematic narrative surrounding the production of green technology. There is a general assumption that anthropogenic environmental degradation is purely a technological problem. This narrative ignores the socioeconomic context that has developed around the production of traditional technology that has led to massive anthropogenic environmental degradation. This narrative has also been taken up in academia, specifically within the social sciences, in the theory of ecological modernization.

The theory of ecological modernization is an academic argument supporting capitalist economies’ efforts to promote a green economy. A key theme within ecological modernization theory is the notion that environmental reform and sustainable development can be reached within the current structure of modern society (Spaargaren 2009; Spaargaren and Cohen 2009). This is often understood to occur through the development of environmentally-conscious technology. Huber (2009, pp. 334–35) argues that economic progress and the emergence of “green technologies” (e.g., “clean-burn hydrogen”, photovoltaics) help to reduce the overall volume and intensity of resource consumption. Thus as a theory in sociology ecological modernization emphasizes instances of environmental reform as examples environmental change (see York and Rosa 2003), similar to the way President Obama did in his latest state of the union, without providing any comprehensive analysis of environmental reform and unsustainable production. It relies on the same neoclassical economic framework discussed above to emphasize purely on the volume green technological development, and not green technology’s relationship to traditional forms of production or environmental degradation. In environmental sociology, there are several theoretical frameworks that are critical of the socioeconomic context that technology is produced under, and have specifically been critical of ecological modernization theory. In this dissertation, I will be employing two of these theories – treadmill of production theory and metabolic rift theory – to structure a critical argument of the socioeconomic context that green technologies are currently produced under.

Treadmill of Production

Treadmill of production theory was first introduced by Allan Schnaiberg (1980) to explain the massive rise in environmental degradation since World War II. The name was meant to convey an image of a society running in place without moving forward. It also represented the decrease in social efficiency of the productive system. Schnaiberg's main argument was (1), that environmental degradation was intrinsic to capitalist society, such that social inequalities were interwoven with each environmental concern, and (2) that social and political responses to these production processes were "variable and volatile" (Schnaiberg et al. 2002). For these reasons, treadmill of production theory argues that capitalist efforts to ecologically modernize are simply perpetuations of the treadmill, and offer no solutions to the systemic rift between capitalism and nature.

For treadmill of production, the problem with creating new green markets is that they do not necessarily alter the production of existing markets. Furthermore, the success of green markets occur at the level of consumption, which does not imply an overall change in production. Schnaiberg (1980) noted that, consumer preferences are predicated on a culture of individualism, where consumers see themselves as acting alone in consumption, as opposed to collectively. This makes the outcome of consumer preferences within capitalist economies contingent upon market constraints. So much so that the ability of green consumption patterns to generate positive environmental outcomes is dependent upon the allocation of profits earned from green markets. If for example, the consumption of green goods continued to rise at a rapid pace and the profits earned from their consumption was used to increase the production of environmentally hazardous technologies, then there would be no reason to believe the prevalence of green technologies has any positive outcome on overall environmental quality.

Some treadmill of production theorists have offered critiques of sustainable efforts within modern society through directly addressing the construction of green markets. For example, York (2004) argues that instances of environmental reform cited by ecological modernization theorists are a result of “confusing a trend in variability with a trend in central tendency” (384). He contends that most environmentally conscious products are profitable only as market niches, where they provide specialized services and goods to consumers willing to pay a premium price. In this sense, environmentally conscious products offer no changes to the general trend of markets. York concludes that treadmill of production theory emphasizes the overall environmental outcome of capitalist modernization, and that processes of ecological modernization should be assessed on this same standard.

Ecological Marxism

Ecological Marxism stems from the historical materialist tradition in political economy; where capitalism is understood as a system that facilitates the relationships between humans and nature. Similar to the treadmill of production, it takes on a critical view of industrial capitalism. Specifically, it argues that the contradictions of capitalism extend beyond how Marxists have traditionally perceived them. For example, O’Connor (1973) argues that in addition to undermining the labor processes that sustain it, capitalism also presents contradictions to the natural environment, which maintain its growth. O’Connor claims that the contradiction between capitalism and the environment is the “second contradiction” of capitalism (the first being the contradictions between capitalism and labor). He asserts that both capital and labor are dependent upon the exploitation of nature. Thus, capitalism as an arena of material relations is inherently contradictive to nature.

John Bellamy Foster further elaborates upon these contradictions with the notion of “metabolic rift”, which refers to Marx’s expression of the “irreparable rift in the interdependent process of social metabolism.” (Marx 1981: 949) Foster’s use of metabolic rift is based on Marx’s writings regarding metabolism and the development of soil chemistry and the use of chemical fertilizer (Foster 1999; 2000). Foster argues that Marx acknowledged the growing contradictions between capitalism and nature in his observation of Liebig’s work and the British agricultural revolution. Marx accuses capitalism of breaking the natural laws of sustainability in its use of synthetic fertilizers to restore nutrients to the soil that were lost during large scale agricultural production. This is facilitated and perpetuated by industrialization, which “reduces the agricultural population to an ever decreasing minimum” and “results in a squandering of the vitality of the soil, which is carried by trade far beyond the bounds of a single country” (Marx 1981: 949).

Metabolic rift theory has been used by social scientists to further contextualize environmentally hazardous outcomes of various forms of social organization. For example, Mancus (2007) examined the metabolic rift in global agriculture markets. He argues that the structure of industrial agriculture, which is defined by the overuse and dependence of inorganic nitrogen fertilizer, has breached the social metabolism between society and the nitrogen cycle, creating massive environmental pollution in natural waterways and soil erosion. In a similar vein, Gunderson (2011) applies metabolic rift theory to analyze large-scale livestock production, showing how the environmental impacts of industrial livestock production increase greenhouse gas emissions, and pollute natural water systems. Clausen and Clark (2005) apply metabolic rift theory to marine systems, demonstrating how intensified production of aquaculture systems and overfishing practices pollute natural water systems and reduce aquatic biodiversity.

Ecological Marxists' views on green markets follows the logic of the second contradiction and metabolic rift. The (second) contradiction that capitalism creates with nature generates a metabolic rift that is perpetuated by capitalism's "blind desire for profit" (Marx 1981). This prevents any true rational application of green technologies within capitalism, as they are implemented similarly to the guano based fertilizers that Marx observed in England. In this way, green capitalism uses resources to maintain and perpetuate the rifts generated between natural sustainability and capitalism. This notion was best exemplified by Clark and York (2008) who expand on the theory of metabolic rift using the notion of rifts and shifts, which applies to the processes "whereby metabolic rifts are continually created and addressed (typically only after reaching crisis proportions) by shifting the type of rift generated" (p. 17). They argue that "to the myopic observer, capitalism may appear at any one moment to be addressing some environmental problems, since it does on occasion mitigate a crisis. However, a more far-sighted observer will recognize that new crises spring up where old ones are supposedly cut down" (2008 p. 17).

The Displacement Paradox

In this dissertation, I will use treadmill of production theory and metabolic rift theory to critically assess the application of green technology in capitalist economies. My overarching argument is that the specific attempt to substitute traditional technologies with green technologies produces a displacement paradox, where green commodities do not completely displace environmental degradation produced by traditional technologies. The displacement paradox was first identified and discussed by York (2008; 2012) to refer specifically to the inability of one type of technology to fully substitute another group technologies (e.g. one kilowatt of renewable electricity not completely substituting one kilowatt of renewable energy), I expand this concept here to additionally refer to the inability of green commodities to reduce the environmental degradation produced by traditional technologies. While it is useful to understand the paradoxical relationship between green technology and traditional technology based on green technology's inability to substitute traditional forms of production, in some instances, it is not always the most useful way of conceptualizing the paradoxical relationship between green technology and traditional processes. For example, the ability of organic farming to operate as a counterforce to conventional agriculture is not simply based on its ability to act as a substitute for conventional agricultural land or agricultural products, in that organic agricultural practices at times rely indirectly on conventional practices (e.g. the use of manure produced on conventional land) to produce goods. Thus it may be the case that organic farming is substituting conventional agriculture in terms of land use and product use, while still increasing the application of conventional agricultural practices in a way that increases environmental degradation from conventional farming.

Expanding the displacement paradox in this way allows me to empirically and theoretically capture the broader counterintuitive phenomenon associated with the production of specific types green technologies. Green technologies that produce displacement paradoxes are technologies designed with little to no environmental output, produced specifically as substitutes for traditional technologies. This includes technologies such as renewable energy, organic farming practices, and non-petroleum based vehicles, which are all void of specific elements (e.g. fossil fuels or synthetic fertilizers) that produce environmental impacts. I argue that these types of technologies in capitalist economies represent a commodification of environmental sustainability in a way that allows green processes to support social structures that perpetuate environmental degradation.

Empirically, the displacement paradox is represented by a counterintuitive association between green technology and traditional forms of production. The inability of green technology to substitute traditional technology and/or displace environmental degradation from existing processes, can be understood as a counterintuitive association that is caused by a multitude of factors that vary based on the social and/or biophysical context in which green technology is introduced. Thus throughout this dissertation, I will be empirically be assessing what I call displacement associations, which refers to the counterintuitive association between green technologies and traditional forms of production, using statistical models. These association apply to two instances – (1) an outcome where green commodities do not substitute traditional commodities or (2) when green commodities are associated with increases in total environmental degradation. I will draw from various environmental sociological theories as well natural scientific findings to explore the causal link of these displacement paradoxes, however, the empirical associations by themselves are simply correlations. My goal is to demonstrate how each association is connected to larger socioeconomic processes that can be more generally theorized on.

In this dissertation I will be exploring the displacement paradox of two forms of green production – organic agriculture and alternative fueled vehicles. I chose to assess these forms of production because of the unique socioeconomic circumstances that each has developed under, which will be discussed in the proceeding chapters, and the widely available data on each form of production. In chapter two, I will connect the unique history of organic farming to the theory of metabolic rift, and demonstrate how they rely on similar criticism of capitalist agriculture. Additionally, I will argue that the structure of organic farming has changed in such a way that it may no longer address the metabolic rift between modern agriculture and the environment. I conclude that development of organic farming within the context of capitalism limits its ability to reduce the application of agrochemicals, such as synthetic fertilizers and pesticides. I build upon this argument in chapter three, demonstrating that an additional consequence of organic agricultural production, which is its inability to reduce greenhouse gas emissions and water pollution. In chapter four, I explore the potential reason and consequences of the displacement paradox between alternatively fueled vehicles and traditionally fueled vehicles, arguing that the larger structure of the vehicle industry limits the ability alternatively fueled vehicles to substitute traditionally fueled vehicles. In the final chapter, I explore potential solutions to the displacement paradoxes analyzed in chapters 2 through 4, arguing for alternative socioeconomic solutions that allow green technologies to flourish. The larger argument being constructed in the next few chapters is that the production and use of green commodities produces a paradox, where green commodities fail to displace environmental degradation and/or environmentally hazardous forms of production.

CHAPTER II

THE HISTORY OF ORGANIC FARMING AND THE DISPLACEMENT PARADOX OF CERTIFIED ORGANIC AGRICULTURE

Perhaps the most widely-ignored factor in assessing the ecological merits of organic farming is its socioeconomic context. Numerous national policies and international organization recommendations (FAO 2014), discuss the merits of organic farming almost exclusively in biophysical terms. For example, national certified organic programs, such as the USDA (2016), the European Commission (2016), and the Organic Federation of Australia (2016), rely on life cycle assessments that weigh the ecological benefits of specific organic practices against conventional farming techniques, claiming that certified organic farming offers a more naturally based form of agricultural production that works to reserve natural ecosystems by preserving natural resources and biodiversity, and supports animal health and welfare. However, these assessments ignore the broader socioeconomic factors that contribute to the development of organic farming, such as the standards most often employed on organic farms, and the interconnectivity between organic and conventional farming. In order to understand the socioeconomic factors influencing the application of organic farming practices, it is essential to understand the historical development of organic farming.

Early in its history, organic farming was discussed as a socioeconomic alternative to conventional agriculture, arguing for a reorganization of society around a self-sustaining, non-synthetically dependent, agricultural system that connects urban and rural landscapes. Over time however, it became seen more as a technological alternative to conventional agriculture, defining itself by its use of naturally occurring inputs over synthetically derived inputs. This can be seen explicitly in national organic certification programs, which define organic farming solely as a biophysical alternative conventional agriculture. This has led organic farming has become less of a counterforce to conventional agriculture and more of an extension of it, relying on off-farm inputs such as organic pesticides and manure based fertilizers that indirectly support conventional agricultural practices. In this chapter, I will empirically explore the relationship between organic agricultural land and the application of agrochemicals. I argue that the socioeconomic context that organic farming currently operates under produces a displacement paradox between organic farmland and agrochemical application, where organic farming increases the application of synthetic fertilizers and pesticides rather than reducing them.

The History of Organic farming

Environmental scientists and agricultural philosopher John Paull (2009; 2011a; 20011b; 2014) has argued that organic farming's origins can be traced back to the mid-nineteenth century and the work Justus von Liebig. In his book *Organic Chemistry in its Application to Agriculture and Physiology* (1840), Liebig laid the ground work for what he considered to be a rational transformation of agriculture, which was the fusion of scientific knowledge and agriculture. In his assessment of the necessity of nitrogen in plant growth, Liebig became convinced that chemistry could develop a synthetic substitute for fertilizers that would stimulate plant development and lower the cost of agriculture. Liebig would later go on to criticize the unsustainability of agriculture. However even in his criticisms, he provided precognitions of the future of agricultural development. In one of Liebig's later criticisms of agriculture he notes that "Population has reached such a level that it can only be sustained with present techniques of husbandry under two conditions. One, if a Divine miracle intervenes to restore the fields to the degree of productivity stripped from them by folly and ignorance; and two, if deposits of manure or guano are discovered in volumes approximating to those of the English coalfields" (Liebig quoted in Kautsky 1988 p. 53).

Eventually, the German chemists Haber and Bosch would discover a way to make nitrogen as abundant as the British coal fields when converting nitrogen and hydrogen to liquid ammonia (Bosch 1922), sparking a new agricultural revolution and with it a new critique of the unsustainable nature of capitalist agriculture. Haber and Bosch's discovery transformed modern agriculture, resulting in a proliferation of chemical farming. The success of Haber and Bosch's research not only influenced the agricultural industry, but it also supported the German war effort in World Wat I. Ammonia became an essential ingredient for ammunition and fueled the demand for explosives during the Great War (Bosch 1922; Paull 2009).

As a response to the proliferation of chemical agriculture, in the summer of 1924 in Poland, Austrian philosopher and social activists Rudolf Steiner delivered an eight-lecture series on the development of modern agriculture (Paull 2011a). In the course, Steiner responded specifically to the rise of synthetic fertilizers, claiming that

"Nowadays people simply think that a certain amount of nitrogen is needed for plant growth, and they imagine it makes no difference how it's prepared or where it comes from… In the course of this materialistic age of ours, we've lost the knowledge of what it takes to continue to care for the natural world" (Steiner, 1924b, pp.9-10; cited by Paull, 2011a p. 64).

This was the first known negative commentary on industrial agriculture that called for an alternative system. It was here that Steiner promoted the idea of agriculture as an organism, which focused on a holistic approach to agricultural development that blended with earth's natural ecology and was self-sustaining (Paull 2011b).

Steiner's arguments would further developed after his passing by his student Ehrenfried Pfeiffer. Pfeiffer eventually coined the term "biodynamic farming" in the book *Bio-Dynamic Farming and Gardening* (1938), to refer to Steiner's vision of an organismic agricultural system. Biodynamic farming specifically rejected the use synthetic chemicals and non-farm inputs, and promoted ecological, social, and economic sustainability (Ehrenfried 1938). In 1939, Ehrenfried was invited to a conference on biodynamic farming in Switzerland, where he met Oxford lecturer Lord Northbourne.

A year later Northbourne, inspired by the ideas of biodynamic farming, published the book *Look to the Land* (1940), where he coined the term organic farming. Northbourne's view of organic farming was closely related to Steiner and Ehrenfried's biodynamic farming. Both emphasizing agricultural practices that allowed farming to operate as an organism. He notes that "the farm itself must have a biological completeness; it must be a living entity, it must be a unit which has within itself a balanced organic life" (Northbourne 1940 p.81, cited by Paull 2014 p. 34). He also makes specific claims regarding imported fertility, contending that it "cannot be self-sufficient nor an organic whole" (p.96). The rejection of imported fertility, and advocacy of a self-sustaining agricultural system, are essential features of both Ehrenfried and Steiner's view of biodynamic farming and Northbourne vision of organic farming. These features stress the need for a sustainable agricultural system that operates like an organism embedded within the natural environment.

In many ways, this conception of the farm as an organism is analogous to Marx's use of metabolism when explaining the irreparable rift between society and the environment (see Foster 1999; Foster 2000). Marx's notion of metabolic rift deals specifically with the dialectal relationship of humans and the environment, identifying the rift caused by agricultural production when it fails to replenish the nutrients taken by humans in cities.

“Large landed property reduces the agricultural population to an ever decreasing minimum and confronts it with an ever growing industrial population crammed together in large towns; in this way it produces conditions that provoke an irreparable rift in the interdependent process of the social metabolism, a metabolism prescribed by the natural laws of life itself. The result of this is a squandering of the vitality of the soil, which is carried by trade far beyond the bounds of a single country” (Marx 1981,p. 949–50. Cited by Foster 1999: 379)

This recognizes the rift caused by humans to the environment due to social organization. Northbourne’s critique of chemical farming mirrors this sentiment, arguing that farms that rely on external inputs, such as chemical fertilizers, cheap labor, and large-scale mechanization, are imbalanced and must be restored as a whole. He calls for an agricultural system that uses mixed crop-livestock farming, green manure, crop rotations to restore the imbalance of industrial farming. Thus, Northbourne’s organic farming is a statement on the sociobiological relationships, arguing for a social reconstruction of agriculture to address the environmental consequences of industrial farming. . This is somewhat different from what became the popular perception of organic farming in the United States that was conceived by Jerome Rodale.

Jerome Rodale was an American publicist, who is often given credit for starting the organic movement (see Pollan 2006; Silver 2006), although, some have criticized him as simply being a promoter, popularizer, and rebrander of ideas from Britain to the American public (Jackson, 1974; Paull 2014). On the day of Rodale’s death in 1971, he appeared on “The Dick Cavett Show”, where he boasted about the merits of the organic diet. Rodale discussed how he felt as though he could live to be one hundred years due to his strict organic diet. Unfortunately, it was during this televised appearance, when Cavett was interviewing his second guest that Rodale was later pronounced dead from a heart-attack that he suffered on-set (Cavett 2007). Prior to his death, Rodale had become the champion of the organic movement in the United Sates. He began writing about organic gardening in 1942 in his magazine *Organic Gardening and Farming*, which in 1971 sold over 720,000 copies (McGrath 2014). Throughout his life, in numerous interviews and various publications, Rodale consistently promoted a vision of organic farming that lacked of many of Northbourne's original ideas. Specifically, even though he did advocate for environmentally sustainable farming, Rodale emphasized the health benefits of natural inputs to the complete exclusion of organic farming's ability to address the metabolism between society and nature. In this way, Rodale's version of organic farming is distinct from its predecessors, in that it ignored the broader implications of a sustainable agricultural system, such as mending the divide between agricultural production and social sustainability.

This distinction is important, since even though the original concept of organic farming lie with Northbourne's writings in 1940, Rodale's influence on organic farming was much greater. This is evident in the way that Northbourne is continually ignored in historical writing about organic farming, such as Lockeretz's 2007 book *Organic Farming, An International History* and Pollan's *The Omnivore's Dilemma: The Search for a Perfect Meal in a Fast-Food World* (2006), which are two prominently read sources on sustainable agriculture. Northbourne did however, have a substantial influence on the development of The Soil Association, which is one of the first certifying entities of organic standards. He was cited liberally by founder Eve Balfour in her book *The Living Soil*, which is commonly acknowledged as the book that started The Soil Association. Unsurprisingly, The Soil Association to this day has some of the strictest standards on organic farming.

The difference between Rodale’s version of organic farming and Northbourne’s demonstrates a broader ideological divide amongst proponents of organic farming. For instance, social scientists, have discussed the ideological split between those who support the development of national organic standards and the integration of organic farming and agribusiness, and those who see organic farming as an opponent to the larger social context that modern agriculture operates under. Below is a discussion of the social factors that have influenced the development of the modern organic market and the current divide within the organic industry.

The Current Social Context of Organic Farming

The modern interpretation of organic agriculture can be seen in national organic certification programs, which create unified definitions of organic farming that farmers must abide by. The rise of certified organic farming has been met with many criticism by social scientists. The most prevalent criticisms have been brought forth by scholars developing the conventionalization thesis, which hypothesizes that as certified organic farming grows, it begins to mimic conventional agricultural practices. The term conventionalization was first proposed by Buck et al. (1997) to describe the changes occurring within organic agriculture in California. The authors utilized the concept to convey the transition of organic farming from an idealistically driven counter cultural movement, to a slight variant of conventional agriculture. Buck et al. (1997) and Guthman (2004a), found that organic farming was increasingly becoming industrialized, relying on non-farm inputs, such as machinery, fertilizers, feed, agrochemicals, and resource substitutions, to stimulate production. This has resulted in a bifurcation of the organic market, creating of two organic systems—one more in line with the original ideals of the movement that emphasized local small scale farming, direct consumer sales, and prohibited the use of non-farm inputs, and another economically driven market that helped to integrate organic agriculture into the agribusiness industry.

It has been argued that the certification of organic farming helps facilitate “regulatory capture” and corporate co-optation of organic goods by watering down specific organic standards (e.g. Howard 2009). Jaffee and Howard (2010) argue that within the United States, the United States Department of Agriculture (USDA) has watered down standards to allow specific inputs and limit regulatory oversight. For example, organic certification in the United States does not require specific organic agricultural practices, such as crop rotations for pest control and manure-based fertilizers produced on farm, which in turn allows these methods to increase the amount of external agricultural inputs used on organic farms (USDA 2015). Guthman (2004b) argues that this allows post-production activities to capture a higher proportion of the total value of organic goods, as agribusiness is able to penetrate the organic industry through the production of agricultural inputs. This process increases the presence of pesticide and fertilizer manufacturing companies in the organic industry, and helps to facilitate the horizontal and vertical integration of the organic market similar to the conventional market (see Magdoff, Foster, and Buttel 2000). Ultimately, increasing the input of external agricultural products in organic farming, such as pesticides, has been found to intensify the have negative environmental impacts associated with agriculture (see Bahlai et al. 2010).

Some have found evidence of conventionalization in other regions, specifically in Europe, as well as a variety of organic sectors (Langer and Frederiksen, 2005; Flaten et al. 2006; De Wit and Verhoog 2007; Best 2008). For example, Best (2008) found that newer organic farms in Germany show signs of conventionalization, noting that newer organic farmers tended to use slightly larger farms and had more specialized operations. Additionally the author found that recent adopters did not share the same “pro-environmental” values as earlier farmers. Flaten et al. (2006) similarly found that newer organic dairy farmers in Norway used more concentrates and had higher milk production yields, highlighting that while all organic farmers shared favorable views toward the environment, older farmers had much stronger views and placed more emphasis on soil fertility, fertilizers, and pollution. Läpple and Van Rensburg (2007) in Ireland, also found that late adopters of organic farming expressed lower environmental values and were much more profit driven than early or medium adopters. In the Netherlands, DeWit and Verhoog (2007) found that conventional agro-food commodity chains were increasing and the use of non-farm inputs in organic farming.

Obach (2015), has expanded on this narrative, noting that historically there has never been a true consensus on what organic farming means. While exploring the development of the organic movement in United States, he uses the term “spreaders” to refer to those who welcome the wider market for organic food and work with national governments and agribusiness, and “tillers” to refer to those who see organic farming as part of a larger social movement that encompasses massive social change. His narrative expands the bifurcation concept used by (Buck et al. 1997) and Guthman (2004a), demonstrating the true boundaries between the split groups in organic farming. For Obach, “spreaders” are more or less those who accept the conventionalization of the organic market, and assume that even watered-down organic practices are better than chemical intensive agriculture. Obach also notes that “spreaders” argue that they are responding to the majority of consumer demands for organic goods, and reaching more people by making organic goods more accessible. While the “spreaders” place emphasis on the individual health benefits of organic farming, as did Rodale, the “tillers” on the other hand, have stayed as close as possible to the ideas of organic farming promoted by Northbourne and the early developers of biodynamic farming. The assumptions made by "spreaders", however, is void of any understanding of the broader social implications of organic agriculture. Furthermore, the arguments made by "spreaders", mirrors the rhetoric used by those advocating for a green capitalism, in that they assume the environmental merits of organic farming stem from what is done on the organic farm, and that organic farming can eventually operate as a substitute for conventional agriculture.

While the studies discussed above pertain to practices utilized on specific farms, they offer a broader conceptualization of how organic farming operates in relation to conventional farming. As is found in multiple studies, organic farming at times relies on techniques that are common in conventional agriculture, such as the use of off-farm inputs. This fact is telling in and of itself, as it demonstrates how organic farming is increasingly playing by the rules set forth by the conventional agriculture. It also demonstrates how organic farming is influenced by the monopolistic structure of the larger agricultural industry, as organic farming is forced to operate as a response to the dominant structure of conventional agriculture but not a counterforce to the social relations that support it.

The agricultural industry is largely structured around the needs of an urban population. As discussed previously, the use of inputs to replenish soil fertility, the mechanization of agriculture, and the increasing size of farms, are all responses to the town-country divide. Capitalism's response to this divide has been to further decrease rural populations and commodify agricultural processes. Since Liebig's early writings regarding agricultural chemistry, soil nutrients have been an essential commodity in the agricultural industry. During the second agricultural revolution, farmers' have had to purchase nutrients, such as bird guano, in order to maintain or increase farm productivity (Foster 1999; 2000). This process has only heightened after the proliferation of Haber-Bosch's chemical fertilizer, which, coupled with the developments that occurred during the green revolution, made farmers increasingly reliant on off-farm chemical inputs (Hefferman 1998) Additionally, over the past half-century, meat, grain and seed production has gradually become consolidated vertically and horizontally (see Hefferman 1998; Hendrickson et al. 2014 Howard 2009). While these processes have not been directly mirrored by organic farming, they have been very influential, particularly in the United States, on the practices used on organic farms. For example, in the United States, the United States Department of Agriculture's (USDA) National Organic Program (NOPP) allows organic farms to apply manure to land from conventional farms (NOP 2011). This is problematic for a multitude of reasons, but what is perhaps most troubling about this process, is that it represents organic farming's direct and indirect reliance on the monopolistic structure of conventional agriculture. A large amount of the production of synthetic fertilizers and genetically modified seeds are used to produce grain feed for conventional livestock, such as poultry, dairy, beef, hogs, and sheep. When organic farms use the waste produced by conventional livestock to replenish soil nutrients, such as nitrates, they are using nutrients produced synthetically that are absorbed by livestock when consuming conventional feed. Thus, organic farms that use conventional manures are partially relying on synthetic chemicals to restore soil nutrients. While the use of livestock manures to replenish soil nutrients is an essential component of organic farming, in Northbourne's (1940) original vision of organic farming, the use of manure is understood as part of the cyclical nature of organic farming that allows it to operate as an organism. For Northbourne, the use of livestock manures to restore soil nutrients are essential because they are cycled through organisms and back to the land. Using livestock manures that are produced on organic farms are qualitatively different than using livestock manures that derive from off-farm, chemical-intensive practices. While the extent to which manure from conventional farms is used in organic farming is unknown, the fact that conventional manures are allowed on organic farms demonstrates how organic farming is being shaped by the structure of agribusiness.

The structure of conventional agriculture, which is dictated by various monopolies at different stages of agricultural production, determines the pathways that organic farming can take as an alternative market/movement. In many respects, organic farming can be understood as reacting to the pressures of monopolized agribusiness in a way that falls in line with the theory of monopoly capitalism, where. For example, as Baron and Sweezy note, small businesses in the stage of monopoly capitalism are constantly “reacting to the pressures of Big Business” (Baran and Sweezy: p. 52), making them qualitatively different than corporations. Each end of the bifurcated organic market—both the “tillers” and the “spreaders”—are reacting to the pressures of conventional agriculture. While on the one hand “tillers” have maintained a strict stance against conventional agriculture, operating exclusively in alternative markets, such as community supported agricultural programs and farmers markets, they have increasingly become more peripheral over time. Currently, in the United States more than ninety percent of all organic sales occur in grocery stores (USDA 2015). “Spreaders” have reacted to the pressures of conventional agriculture by conforming to the structure of agribusiness, relying off-farm inputs to increase productivity and indirectly relying on conventional processes to obtain these inputs. For example, it has been demonstrated in research pertaining to the conventionalization thesis that newer entrants in organic farming, whom Obach would identify as “spreaders”, are more concerned with economic prosperity than environmental quality. Additionally, as Obach notes, those considered to be “spreaders” in the organic movement are more concerned with the growth of the organic industry than the broader values of social activism and/or specific aspects of environmental quality.

The problem with the conventionalization of organic farming and the viewpoints of “spreaders” is that they limit the ability of organic farming to operate in opposition to conventional agricultural practices, and act as a true alternative to conventional farming. While conventionalized organic farming does not make up all of organic farming, their existence does raise the question of whether or not organic farming is displacing conventional agricultural processes. One potential outcome of the integration of organic farming with conventional agriculture is the inability of organic farming to displace the application of agrochemicals. Another somewhat ignored feature of organic farming is its reliance on organic-based pesticides, of which proponents of the conventionalization thesis have been very critical. If the trends of conventionalization continue to grow and organic farming becomes more reliant on off-farm inputs, such as livestock manures and pesticides, there may be a displacement paradox between organic farming and agrochemicals. Below I develop hypotheses regarding these possibility and use the best available data on organic farming and agrochemicals to explore the relationship between organic farming and agrochemical application.

Methods:

The hypotheses tested here assess the degree to which organic farming reduces the application of agrochemicals:

H1: Increases in the proportion of certified organic farming increases the total amount of agrochemicals applied to agricultural land.

H2: Increases in the proportion of certified organic farming increases the intensity of agrochemicals applied to land.

To test my hypotheses I use a fixed-effects panel regression with robust standard errors adjusted for clustering by nation where data is available (124 for fertilizer application and 69 for pesticide application), from 2003-2010. This approach differs from previous analyses that have studied the relationship between socioeconomic development and hazardous agricultural practices (Longo and York 2008), as well as those that have looked at organic farming's relationship to hazardous agricultural practices (Knight and Newman 2013) in that it is longitudinal. A fixed-effects panel model controls for any unobserved, time-constant features between nations, as well as events that occurred in each year that have affected nations simultaneously. Additionally, I included time dummy variables to account for general period effects (see Jorgenson and Clark 2012; York and Rosa 2012). I chose to focus on all nations where data is available in order to obtain the most accurate description of global organic agricultural practices.

The logic of my modeling approach derives from the STIRPAT framework (See Cole and Neumayer 2004; Cramer 1998; Rosa et al., 2004; Shandra et al. 2004; Shi 2003; York 2008; York and Rosa 2012; York et al. 2003a, 2003b, 2003c). STIRPAT was first developed by Dietz and Rosa (1997) as a reformulation of the popular IPAT equation. IPAT and STIRPAT both assume that environmental impacts are a multiplicative function of population, affluence, and technology, however as a stochastic model, STIRPAT allows for hypothesis testing. My models assume that chemical fertilizer and/or pesticide application (I) are a multiplicative function of population (P), affluence (A), and technology (T). Similar to other STIRPAT analyses, I have converted each variable to natural logarithms to obtain their elastic relationship (see York et al.

2003a; 2003c; York and Rosa 2012). This makes the variables relationship multiplicative, resulting ecological elasticity coefficients (York et al. 2003c).

$\ln y_{it} = \beta_1 \ln(x_{it}) + \beta_2 \ln(x_{it}) \ldots \beta_k \ln(x_{itk}) + \mu_i + w_t + e_{it}$

Here the subscript i represents each unit of analysis (nation) and the subscript t the time period, y_{it} is the dependent variable in original units for each nation at each point in time, x_{itk} represent the independent variables in original units for each nation at each point in time, β_k represents the elasticity coefficient for each independent variable, u_i is a nation specific disturbance term that is constant overtime (i.e., the nation specific y-intercept), wt is a period specific disturbance term constant across nations, and e_{it} is the stochastic disturbance e term specific to each nation at each point in time.

Model A total chemical fertilizer applied$_{it}$ = βpopulation$_{it}$ + βGDP per capita$_{it}$ + βpercent organic hectares of total agricultural land$_{it}$+ $\mu_i + w_t + e_{it}$

Model B chemical fertilizer applied per hectare of agricultural land$_{it}$ = βpopulation$_{it}$ + βGDP per capita$_{it}$ + βpercent organic hectares of total agricultural land$_{it}$ + $\mu_i + w_t + e_{it}$

Model C total chemical pesticide applied$_{it}$ = βpopulation + βGDP per capita + βpercent organic hectares of total agricultural land+ $\mu_i + w_t + e_{it}$

Model D chemical pesticide applied per hectare of agricultural $\text{land}_{it} = \beta \text{population}_{it} + \beta \text{GDP per capita}_{it} + \beta \text{percent organic hectares of total agricultural land}_{it} + \mu_i + w_t + e_{it}$

Dependent variables:

The data for the dependent variable in model A and B was obtained from the World Bank's Development Indicators index (2014). Chemical fertilizer refers to the total amount of chemical nitrogen, phosphate, and potash applied per hectare of land (the original form of the data obtained) measured in kilograms. I chose fertilizer applied per hectare of land to demonstrate the relationship between changes in my indicator variables and the intensity of fertilizers applied.

The data for my dependent variable in models C and D were obtained from the United Nations Food and Agriculture Organization (FAO) statistic. Chemical pesticide applied per hectare of agricultural land measures the average kilogram of insecticides, herbicides, fungicides and others (such as growth regulators) applied per hectare of land (the original form of the data). Similar to models A and B, the variable pesticides applied per hectare of agricultural land allows me to estimate the relationship between changes in my indicator variables and the intensity of pesticide applied. The dependent variables in all models measures the application in kilograms.

Table 1 Descriptive statistics of dependent variables.

Dependent Variables	Total chemical fertilizer (Kilograms)	Chemical fertilizer per hectare of land (Kilograms)	Total pesticide application (Kilograms)	Pesticide application per hectare of land (Kilograms)
Mean	1.94e+07	245.543	2.50e+08	4.713
Standard deviation	1.06e+08	1079.268	1.14e+09	8.419
Maximum	1.15e+09	16532.31	9.24e+09	85.27
Minimum	17.37465	.005	1748	.01

Independent variables:

To operationalize P, A, and T within my models model, I use the independent variables population (P) GDP per capita (A), and percent organic land (T). The variables chosen to measure P and A are analogous to other studies that have researched drivers of fertilizer and pesticide consumption (see Knight and Newman 2013; Longo and York 2008), with the exception of models A and B where P is operationalized as population per hectare of agricultural land in order to standardize the specification of population based on the dependent variable. This was done by dividing population by hectares of farmland. The data for population, GDP per capita, and agricultural land was obtained from the World Bank's development indicators index. The data on population represents total number of people living in each country in each year. The data for GDP per capita represents the gross domestic product per capita within each nation measured in US dollars adjusted for 2005 inflation. I also include a quadratic term for GDP per capita (GDP per capita squared) to test for a potential EKC (Dinda 2004), which would indicate a non-linear relationship. The data for agricultural land represents the total amount of agricultural land in use in a given year and is measured in hectares.

The data for organic agricultural land was obtained from Organic World Statistics. Data on certified organic agriculture is obtained from the SOEL/FiBL/IFOAM survey. Certified organic farming refers to both the certified in conversion areas and the certified fully converted areas. A major drawback of this data is that definitions of organic may vary across countries and data are gathered using various methods (e.g., surveys, secondary data, experts, etc.). However despite these drawbacks, all data on organic farming adheres to the definition "that it is a system that relies on ecosystem management rather than external agricultural inputs" (FAO 2015). Furthermore, the point of this analysis is to explore the extent to which global organic farming promotes specific farming practices, thus the variability in farming practices is part of what is being assessed. Nonetheless, it is still very important to interpret the results presented here cautiously.

The independent variable percent organic farmland is a proportion of organic land to total agricultural land. This was obtained by dividing the amount of certified organic farmland by the total amount of agricultural land used in a specific year. Additionally, I included a quadratic term for percent organic farmland (percent organic farmland squared) to test for a potential non-linear relationship. I chose to include a quadratic term based upon the assumptions within the conventionalization thesis, which argue that over time certification is used as a tool to water down standards and promote the economic vitality of organic farming (Buck et al, 1997; Guthman 2004a). The assumption specifically within my models is that over time certified organic farming starts to directly or indirectly support the use agrochemicals.

Table 2 Descriptive statistics of independent variables

Independent variables	Population	Population per hectare of land	GDP per capita	Percent organic land
Mean	3.58e+07	13.547	12550.92	.600
Standard deviation	1.47e+08	162.612	20316.97	.310
Maximum	1.35e+09	2870.266	193892.30	14.5
Minimum	9530	.007	108.01	8.13e-06

Results:

The fixed-effects models presented below control for omitted factors that vary cross-nationally but are temporally invariant, such as geographic, climatic, and geological factors, as well as the effects of the historical legacy preceding the periods examined here (e.g., the era during which a nation began to industrialize agriculture). The models, therefore, control for characteristics unique to each nation. Additionally, the models control (via the time dummies) for cross-sectional invariant factors that change over time, such as prices of organic goods. Thus, these models focus on change overtime within nations, not on cross-sectional differences or on general average global trends, which has been the focus of previous analyses assessing chemical fertilizer and pesticide application (Knight and Newman 2013; Longo and York 2008). I present the "within R^2" indicating the proportion of variance within nations overtime that is explained.

Table 3 Fixed-effects panel regression coefficients predicting total and per hectare agrochemical application

Independent Variables (logged)	**Model A** Total chemical Fertilizer application (SE)	**Model B** Chemical fertilizer application per hectare of agricultural land (SE)	**Model C** Total Pesticide application (SE)	**Model D** Pesticide application per hectare of agricultural land (SE)
Population	-.186 (.563)		.715 (.807)	
Population per hectare of land		. 515 (.281)		-.277 (.412)
GDP per capita	.493*** (.100)	.489*** (.100)	.289* (.126)	.242* (.132)
Percent Organic land	-.023 (.013)	-.024 (.013)	-.012 (.015)	-.007 (.015)
Constant	13.110 (9.388	-.045 (.871)	1.971 (13.376)	-1.540 (1.070)
R^2 Within	.035	.036	.189	.115
Highest VIF[3]	1.51	1.30	1.51	1.30

* p < .05** p < .01*** p < .001(two-tailed tests)

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[3] Note VIF estimates do not include values for the quadratic terms.

Table 4 Fixed-effects panel regression coefficients predicting total and per hectare agrochemical application

Independent Variables (logged)	**Model A** Total chemical Fertilizer application (non-linear) (SE)	**Model B** Chemical fertilizer application per hectare of agricultural land (non-linear) (SE)	**Model C** Total pesticide application (non-linear) (SE)	**Model D** Pesticide application per hectare of agricultural land (non-linear) (SE)
Population	-.945 (.654)		.537 (.915)	
Population per hectare of land		.460 (.283)		-.143 (.411)
GDP per capita	1.648*** (.381)	1.231*** (.348)	2.237*** (.478)	2.279*** (.437)
GDP per capita^2	-.075*** (.024)	-.048*** (.022)	-.123*** (.030)	-.129*** (.027)
Percent Organic land	.061 (055)	.084 (.054)	.318** (064)	.303*** (.062)
Percent Organic land^2	.005 (.003)	.006** (.003)	.020*** (.004)	.019*** (.004)
Constant	2.763* (10.317)	-2.437 (1.491)	-1.434 (14.580)	-8.166*** (1.819)
R^2 Within	.047	.044	.190	.195
Highest VIF[4]	1.51	1.30	1.51	1.30

* p < .05** p < .01*** p < .001 (two-tailed tests)

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[4] Note VIF estimates do not include values for the quadratic terms.

Table 3 presents the basic linear STIRPAT model, which assumes a linear relationship between GDP per capita, population, and percent organic land. Here I find that affluence measured as GDP per capita is positively correlated and significant at a two-tailed test for both the total application of agricultural chemicals and the intensity of agricultural chemical application. Interestingly, population is found to be non-significant in all the models. This differs from cross-sectional analyses that have found population to be an essential driver of environmental impacts within the STIRPAT framework (see Shandra et al. 2004; Shi 2003; York 2008; York and Rosa 2012). This is possibly a result of the expanding reliance on agricultural exports having little impact on agricultural production in nations. Thus, this finding does not contradict other STIRPAT analyses, but instead shows that rises in population size overtime within nations does not substantially alter agrochemical application. This is similar to Mazur's (1994) finding in regards to energy consumption, where the author found that year to year fluctuations in population were an "unimportant contributor" to the year based fluctuations in energy consumption The coefficient percent organic farmland is also not significant in models A, B, C, and D of table 3.

Table 4 presents the non-linear STIRPAT models and includes a quadratic term for GDP per capita. Likewise, table 4 includes a quadratic term for percent organic farmland to account for the assumptions within critics of organic farming who argue that organic farming over time – begins to support the application of off-farm inputs (Flaten et al. 2006; Best 2008). Similar to table 3, population found not to be significantly correlated in any of the models.

Similar to table 3, GDP per capita is found to be positive and significant in all four models, however each model has a quadratic that is negative and significant. For models A and B, the point at which GDP per capita is associated with declines in fertilizer application (total and per hectare) is 26,000. Approximately 15 of the 124 countries sampled (listed below) have a GDP per capita above 26,000, meaning in these countries the total amount of chemical fertilizers applied to farmland and the intensity of chemical fertilizers applied to farmland declines as GDP increases. For models C and D, the point at which GDP per capita is associated with declines in pesticide application (total and per hectare) is 8,000. Approximately 26 of the 69 countries sampled in models C and D reach this tipping point, where GDP becomes associated with declines in total and per hectare application of chemical pesticides. This implies that there is not only a tipping point where GDP begins to be associated with reduction in agrochemical application cross-nationally (see Longo and York 2008), but a point within nations over time where GDP is correlated with declines in agrochemical application as well. Percent organic farmland is not significant in model A and B, but positive and significant in models C and D. The quadratic term for percent organic land is positive and significant in models B, C, and D. This demonstrates that per hectare fertilizer and pesticide application grows exponentially with proportional increases in organic farmland, as well as total pesticide consumption. This suggests that organic farming is increasing the per hectare application of chemical fertilizers and pesticides over time and the total application of chemical pesticides, which differs from what others have found, for instance Knight and Newman's (2013), who discover that nations with a higher percentages of organic farmland use lower amounts chemical fertilizers. My finding provides evidence that while countries with higher proportions of organic farmland use less chemical fertilizer than countries with lower proportions of organic farmland, increases in organic farmland within nations over time increases the intensity of fertilizer use.

Discussion

My argument here is that although historically organic farming was developed as a socioeconomic counterforce to conventional agriculture, its current application in nations through certification programs limits its ability to reduce conventional agricultural practices. I find support for this argument in that organic farming is associated with increases and not decreases in agrochemical application. This outcome is evidence of the displacement paradox, as it demonstrates that organic farming has not displaced processes associated with conventional agriculture. The association at the very least establishes that there is a counterintuitive relationship between organic farming and agrochemical application. The positive correlation between organic farming and agrochemical application may be a result of organic farming supporting conventional agriculture by responding to the diverse needs of some consumers, rather than operating as a true counterforce to conventional agricultural practices. This would be an example of organic farming acting as an additional facet of the treadmill of production, where it works to expand production by diversifying supply in reaction to the practices in conventional farming. As mentioned previously, this is a unique characteristic of small businesses within the monopoly stage of capitalism. The fact that organic farming positions itself as an alternative agricultural initiative, makes it a small business in comparison to the much larger conventional agricultural industry. Indeed the fact that organic farming makes up such a small amount of total agricultural land makes it unlikely that it would have a measurable impact on conventional farming practices. Despite this, I find that organic farming is actually associated with increases in conventional agricultural. While it would be an ecological fallacy to assume that is a result of organic farms being able to use conventional manure in a significant number of countries or that this is a result of organic farms using more conventional practices, such as off-farm inputs, it would also be inappropriate to assume that these has no effect on the relationship between organic farming and agrochemical application at the national level.

Furthermore, treadmill of production theory argues that any declines over time seen between economic growth and environmental degradation is a result of the widening global production of ecologically hazardous processes, which suppresses the intensity of hazardous production in developed economies. This is observed in the positive nonlinear correlation found between organic farmland and agrochemical application and the negative nonlinear correlation between agrichemical application and economic growth. These findings suggests that even though the relationship between agrochemical application and economic growth are attenuating over time organic farming is not the culprit behind the observed decline. This positive correlation between organic farming and the application of agrochemicals, begs the question of whether organic farming is displacing environmental impacts associated with agricultural production. This relationship will be explored in the processing chapter.

CHAPTER III:

THE BIOPHYSICAL CONTEXT AND METABOLIC RIFT OF CERTIFIED ORGANIC FARMING

Organic farming is often put forth as a sustainable alternative to conventional agriculture, claiming to rely on ecologically sustainable practices that are more in line with earth's natural ecology (USDA 2014; FAO 2015). This has helped to increase the popularity of organic goods around the world, as sales on organic farms have risen five-fold over the past decade and a half (FiBL 2015). The recent success of organic farming is also partially due to the rise in organic certification, a process whereby external entities, usually government organizations, create a unified definition of organic farming to regulate the practices used by farmers and help consumers identify organic goods (USDA 2014; ECPA 2015; Soil Association 2015).

While there are clear merits to having a cohesive definition of organic farming, some have argued that certification is being used to integrate the organic industry into to the agribusiness industry by regulating standards in a way that increases the economic viability of organic agriculture. Specifically, some researchers have suggested that organic certification leads to a "conventionalization" of the organic market, by watering down standards and increasing the use of inputs produced off farm, such as non-synthetic fertilizers and pesticides, to reduce the risk of direct farm investments (Buck et al. 1997; Guthman 2004a; 2004b). If tilling methods and fertilizer management practices are being refashioned on organic farms to serve economic interests over ecological interests, then the ability of nations to reduce specific environmental hazards caused during agricultural production by shifting toward organic practices may be weakened. In particular, it has been noted that even though organic goods have clear environmental benefits in terms of biodiversity protection and human health (Shepard et al. 2003

Stolze et al. 2002), they can have similar, and in some instances higher levels of greenhouse gas emissions and nitrate leaching as their conventional counterparts if certain practices (e.g. seasonal crop rotations and manure management) are not implemented properly (Syväsalo 2006; Torstensson 2006; Aronsson 2007; Tuomisto 2013;). In this chapter I will explore the agricultural processes that contribute to both water pollution and greenhouse gas emissions. I also present several models aimed at demonstrating the displacement paradox between organic farming and pollution and greenhouse gas emissions.

Agriculture and water pollution

Agriculture is one of the largest contributors to global water pollution. It increases the amount of organic contaminants found in natural water systems and produces chemical imbalances through the extensive use of pesticides and fertilizers (Torstensson 2006). Pesticide runoff is known to increase bioconcentration, which is the accumulation of chemicals on or in organisms, and biomagnification, where chemicals become more concentrated as they move up the food chain in ecosystems and may induce biodiversity loss (Ongley 1996). While a lot of organic farms do use pesticides (USDA 2014;ECPA 2015; Soil Association 2015), organic pesticides have not been linked to water pollution, and there are currently no studies finding a clear relationship between organic pesticides and water pollution. Thus at this time, there is no reason to believe use of organic pesticides increases water pollution.

Organic fertilizers that contain nitrogen and phosphate on the other hand, can leach into soil and create algal blooms in surface water, causing overall oxygen levels in water to decline, which also can result in biodiversity loss in natural water systems (EPA 2009). This process often occurs when water drains through soil, taking with it the nitrates contained in the soil. Organic fertilizers, such as animal manures that contain nitrogen, have been linked to nitrate leaching when nitrate is added to soil while drainage is occurring, when more nitrate is supplied than needed for a crop to grow, and when there is a lack of synchrony between nitrogen supply and crop uptake (Shepard et al. 2003). Shepard et al. (2003) also notes that “if soils are left bare during fall or crops are poorly developed, there will not be an effective rooting system to utilize the soil N that is mineralized after harvest and this will be at risk of leaching over the winter” (p. 37).

Some studies that observe levels of nitrate leaching between organic and conventional farms argue that organic farms have lower levels of nitrate leaching due to overall lower inputs of nitrogen (Edwards et al. 1990; Eltun 1995; Younie and Watson 1992 Shepard et al. 2003), however, the bulk of these studies relies on data from specific organic and conventional farms and were conducted prior to what recent research that is seen as the conventionalization period of organic practices. Furthermore, studies conducted during this same period noted that in some instances organic agriculture had similar or higher leaching rates than conventional farms. For instance, Hettige et al. (2000) showed that the average nitrate content in soils between conventional and organic farms that used manure-based fertilizers in fall was slightly higher in organic farms, and far higher in organic farms *versus* conventional farms that did not use manure-based-fertilizers. Condron et al. (2000) found in simulations that nitrate losses were similar between conventional and organic farms during rotations in New Zealand. Stopes et al (2002), also found that during rotations nitrate leaching was similar for conventional and organic farms that used under 200 kilograms per hectare of fertilizer, but were greater for organic farms receiving more than 200 kilograms per hectare of fertilizer. More recent studies have also concluded that nitrate leaching is similar and in some instances slightly higher on organic farms (Syväsalo 2006; Aronsson 2007). For example, Tuomisto et al. (2013) in a systematic study of research observing the environmental impacts between organic and conventional farms, concluded that nitrate leaching per unit of area was 31% lower on organic farms, but 49% higher per unit of product on organic farms.

Comprehensively, these studies demonstrate the degree to which water pollution derived from nitrate leaching is induced by conventional and organic farming. Furthermore, they reveal that in order for organic farms to have lower levels of nitrate leaching than conventional farms, they must use specific management practices, which include seasonally conscious crop rotations as well as careful and limited inputs of nitrate-based fertilizers. While organic farming is often promoted as an agricultural method more in line with Earth's natural ecology, the requisites for this are diverse and complex, and may be limited based on the social context in which organic farms are developed. For instance, scholars using the conventionalization thesis have revealed that over time organic farmers have become less concerned with the environment, less strict about farming practices, and more economically motivated (Buck et al. 1997; Flaten et al. 2006; Läpple 2011). These trends produce an organic agricultural system that is less cognizant of the practices necessary to reduce bio oxygen demand in water, due to decreasing concern about and application of methods necessary to combat nitrate leaching. Additionally, the processes of conventionalization work to increase the size of organic farms, and the concentration of inputs used on organic farms. Based on criticisms of proponents of the conventionalization thesis and the analyses of natural scientists regarding the practices necessary to reduce nitrate leaching, I hypothesize that organic farming may not function as a counter-force to all forms of water pollution derived from agricultural production, and in fact perpetuate specific types of water contamination.

Organic Farming and Greenhouse Gas Emissions

Organic farming practices are known to be more effective at mitigating climate change. Methods commonly used in organic agriculture as opposed to conventional agriculture, such as conservative tilling and crop rotations, have been found to lead to carbon sequestration (Soil Association 2009; Govaerts 2009), a process by which atmospheric carbon dioxide is absorbed by plants through photosynthesis and stored as carbon in biomass and soils (FOA 2012). Additionally, organic agriculture has been found to have larger sinks for carbon dioxide in soil compared to conventional agriculture due to its higher rates of biomass levels and lower rates of soil respiration (OECD 2003). Despite these benefits, organic farming does still contribute to climate change through the emission of nitrous oxide (N_2O), methane (CH_4), and carbon dioxide CO_2.

N_2O emissions from agricultural production occur both aerobically during the nitrification of ammonium ions and anaerobically during the denitrification of nitrate ions (Hutchinson & Davidson, 1993). The largest source of these emissions derive from the application mineral fertilizers and storage and application of livestock manures. (Chadwick *et al*., 1999). Since the application of mineral fertilizers is prohibited in organic farming, organic agriculture emits N_2O mostly through the management and application of livestock manures and from waterlogging of soils where there is a legume crop, which are often used as nitrate sources in soils (Shepard et al. 2003). Additionally, organic farming manages both dry manures, which contribute aerobically to greenhouse gas emissions and slurry manures, which can contribute anaerobically. According to Kirchmann et al. (2014), using animal manure instead of nitrogen fixing crops increases the yields of organic farming proportionally to the amount of nitrogen minerals the manure contains. Kirchmann et al. (2014) also mentions that because animal manure releases nitrous oxide when added to the soil and since livestock produces methane gases, manure will have higher emissions of GHGs than inorganic nitrogen fertilizers when calculating per unit product.

The main agricultural methane sources globally are enteric fermentation of ruminant livestock, stored manures, rice grown under flooded conditions, and land use change (US-EPA 2006). Organic farming contributes to methane emissions based on the type of feed used. Carbon emissions from agricultural production occur through the use of fossil fuels on farms (Shepard et al. 2003). Organic matter, can also act as a CO_2 sink in agriculture and temporarily store atmospheric carbon. However it is important to note that the data used in this analysis does not measure the amount of carbon sequestered on agricultural land.

Recent analyses have also looked comparatively at organic and conventional agricultures' relationship to climate change through life cycle analysis. In these studies, organic farming is implemented on the scale of conventional agricultural production in an effort to determine which farming practices emit the most greenhouse gases. Williams (2006) analyzed the life cycle impacts of conventional and organic wheat, oilseed rape, potatoes, and tomatoes, and found that while organic used less energy than conventional agriculture on average, due to organic avoidance of synthetic nitrogen, it was offset by lower organic yields and higher energy requirements for field work. Additionally, Williams found that organic tomatoes emitted 30% more greenhouse gases than conventional agriculture mainly as a result of lower yields.

In a review of life cycle assessments comparing organic and conventional land, Tuomisto et al. (2006) found that organic olive, beef and some crops had lower GHG emissions whereas organic milk, cereals and pork had higher GHG emissions compared to conventional products. Additionally, In the Netherlands Thomassen et al. (2008) found that most of cases organic milk production had higher GHG emissions compared with conventional systems. Higher GHG emissions in organic systems were due to higher methane and nitrous oxide emissions and lower milk production per animal.

Similarly, Pelletier and Rasmussen (2008) studied a hypothetical national transition from conventional to organic production of canola, corn, soy, and wheat in Canada. They found that organic production would generate 23% lower greenhouse gas emissions than conventional production, without considering soil carbon sequestration. This difference was almost entirely related to the production of synthetic nitrogen fertilizers for conventional farming. The models in this analysis assumed that organic yields produce at the rate of at least 90% of conventional yields, that on-farm energy use is similar to conventional farms, and that all organic nitrogen inputs are derived from intercrops or cover crops.

Leifeld and Fuhrer (2010) investigated the ability of organic farming to sequestrate carbon from the atmosphere compared to conventional farming. In an analysis of 68 case studies that dealt with carbon sequestration and conventional and organic agriculture, the authors concluded it was premature to assert that organic agriculture yielded higher benefits in this specific area. Furthermore, the authors found that the advantages of organic agriculture were largely determined by disproportional application of organic fertilizer compared to conventional farming.

In an analysis of the life cycle patterns of 12 conventional and organic crops in California Venkat (2012) found that greenhouse gas emissions from organic production were on average 10.6% higher (excluding walnuts as an outlier) than conventional production. Venkat cited lower yields and higher on-farm energy use in organic farming, the production and delivery of large quantities of compost in some organic systems, and the fact that emissions from the manufacture of synthetic fertilizers and pesticides used in conventional farming are not large enough to offset the additional emissions in organic farming as reasons for this phenomenon.

In a comprehensive review of literature comparing the effects of organic agriculture to conventional agriculture, Shepard (et al.) 2003 found that there was no definitive difference between N_2O emissions on organic versus conventional farms, that methane emissions were lower per hectare of land on organic farms but higher per yield, and that carbon emissions were slightly higher on organic farms due to increased machinery use.

These studies demonstrate the ways in which organic farming contributes to climate change through the emission of greenhouse gas. Similar to organic farming's relationship with water pollution, it is found that organic farming can limit greenhouse gas emissions when relying on on-farm methods over off-farm inputs. It is also demonstrated through these studies that organic farming can emit similar level of greenhouse gas as conventional agriculture when it tries to match the productivity of conventional agriculture. Based on these findings I hypothesize that similar to the case with water pollution, organic farming may be contributing to greenhouse gas emissions from agricultural production rather than reducing it.

The Metabolic Rift of Organic Farming

The studies highlighted above demonstrate the types of organic farming practices that contribute to climate change and water pollution. They also demonstrate the extent to which organic farming has higher environmental benefits than conventional farming and show the abundant literature aimed at assessing the environmental sustainability of organic farming. My argument here is that a flaw in discussions pertaining to the green economy is their over reliance on biophysical analysis, such as the ones discussed above, to reach conclusions regarding organic farming's ability to reduce environmental impacts. It is equally important to understand the socioeconomic dynamics influencing the application organic farming practices, and how these dynamics affect ecological benefits of organic farming. While the socioeconomic context influencing the application of organic practices was discussed in detail in the previous chapter, here I intend to expand this discussion by emphasizing how these processes further limit the environmental merits of organic farming in regards to water pollution and greenhouse gas emissions.

Metabolic rift was developed by John Bellamy Foster (1999) to refer to Marx's expression of the "irreparable rift in the interdependent process of social metabolism" (p. 949). The term is based on Marx's writings regarding metabolism and the development of soil chemistry and the use of fertilizer in agricultural production. Foster argues that Marx acknowledged the growing contradictions between capitalism and nature in his observation of Liebig's work and the British agricultural revolution. There, Marx proposes that capitalism is breaking the natural laws of sustainability in its use of fertilizers to restore nutrients to the soil that were lost during large scale agricultural production. Marx also accuses "large landed property" of "reducing the agricultural population to an ever decreasing minimum" and as a result, the concentration of populations in cities, leads to "a squandering of the vitality of the soil" (because all soil nutrients end up in city sewers rather than the land) (Foster 2000 p. 949). He further contends that "The way that the cultivation of particular crops depends on fluctuations in market prices and the constant change in cultivation with these prices—the entire spirit of capitalist production, which is oriented towards the most immediate monetary profits—stands in contradiction to agriculture, which has to concern itself with the whole gamut of permanent conditions of life required by the chain of successive generations" (Foster 2000 p. 754). In essence, as Foster (1999) notes, Marx argues that the application of market values to agricultural production contradicts the ecological forces that sustain farm systems. This involves the ever-increasing size and scale of farms as well as enhanced reliance on non-farm inputs, such as nitrates, phosphates, and potassium derived from manure and guano that are added to soil to maintain and increase fertility.

While Marx's concern with the application of fertilizers was on soil sustainability rather than water pollution produced from nitrate leaching, the notion of metabolic rift has also been further developed to explore capitalism's inherent contradiction with sustainability. Clark and York (2008) apply the term rifts and shifts to the process "whereby metabolic rifts are continually created and addressed (typically only after reaching crisis proportions) by shifting the type of rift generated" (p. 17). They argue that "To the myopic observer, capitalism may appear at any one moment to be addressing some environmental problems, since it does on occasion mitigate a crisis. However, a more far-sighted observer will recognize that new crises spring up where old ones are supposedly cut down" (Clark and York 2008 p. 17).

I expand on this argument, and contend that the socioeconomic conditions influencing organic agriculture mirror those influencing conventional agriculture, as a result, the environmental degradation developed by organic agriculture is similar to the environmental degradation of conventional agriculture. For instance, just as the metabolic rift observed by Marx was a result of the town-country divide, which was addressed by increasing the amount of non-farm inputs used in agriculture, I argue that conventional organic farming is a refashioning of this metabolic rift, relying on natural rather than synthetic inputs. This is to say that the production of industrial organic farming (the conventionalized cousin of the original organic movement) is simply a change in the technology used in agriculture's previous metabolic rift, shifting to the use of natural inputs (ironically the inputs observed in Marx's original analysis) instead of synthetic inputs. However, agriculture's metabolic rift was never about the inputs, but the structural processes necessary to maintain society's destructive relationship with nature. Thus in order to address industrial agriculture's rift with nature, nations must address the economic as well as technological context of agriculture. Before discussing how I model and test these assumptions, I will briefly review previous research using metabolic rift theory and discuss how our research builds on this tradition.

Metabolic rift theory has been used by social scientists to contextualize the environmentally hazardous outcomes of various forms of social organization. For example, Mancus (2007) examined the metabolic rift in global agriculture markets. He argues that structure of industrial agriculture, which is defined by the overuse and dependence of inorganic nitrogen fertilizer, has breached the social metabolism between society and the nitrogen cycle, creating massive environmental pollution in natural water ways and soil erosion. In a similar vein, Gunderson (2011) applies metabolic rift theory to analyze large-scale livestock production, showing how the environmental impacts of industrial livestock production increase greenhouse gas emissions, and pollute natural water systems. Clausen and Clark (2005) apply metabolic rift theory to marine systems, demonstrating how intensified production of aquaculture systems and overfishing practices pollute natural water systems and reduce aquatic biodiversity.

Others have expanded metabolic rift theory by focusing on the historical development of science and technology. For instance, Clark and York (2005) focus on the historical development of science and technology to explain the metabolic rift between industrial civilization and the carbon cycle. Moore (2003) provides a historical examination of environmental history using metabolic rift theory to explain the rise of global capitalism and the development of the world system.

In a fashion similar to these works, I apply metabolic rift theory to further explore the rift between modern social organizations and the natural environment. I expand the theory of metabolic rift by examining how it offers critical insights into mechanisms of sustainability, specifically, organic agriculture. Additionally, I adopt the conceptual framework of rifts and shifts to explain how organic farming is a result of shifting industrial agriculture's rift from synthetic agrochemicals to organic practices. I argue that the process of conventionalization, specifically, the vertical and horizontal integration of the organic market, mirrors the structure of the conventional agricultural industry by increasing organic farms' reliance on non-farm inputs. In turn, these inputs help to increase the economic viability of the organic market by increasing the financial gains of organic pesticide and fertilizer manufacturers (Buck et al. 1997). I argue that this shift in the organic market may limit its ability to reduce water pollution and greenhouse gas emissions. Below I assess the relationship between global organic agricultural production and water pollution, as well as organic farming relationship to greenhouse gas emissions globally and nationally within the United States.

Hypotheses

Based on the theory discussed above I hypothesize that as the proportion of organic farming increases over time, it will not reduce the greenhouse gas emissions and water pollution. To this end, I ask if there is a positive correlation between organic farming and water pollution within nations as well as whether or not there is a positive correlation between organic farming and greenhouse gas emissions within states in the US and within nations overall.

Methods

To test my hypotheses I use a series of fixed-effects panel regressions (for nations and states where sufficient data is available) and include time dummies with robust standard errors adjusted for clustering by nation from 2002 to 2007 for my analysis assessing organic farming's relationship to water pollution, and from 2002 to 2010 for my analysis assessing organic farming's relationship to greenhouse gas emissions. For my national-level analysis, I use state level data on both organic agricultural land and agricultural greenhouse gas emissions, which was obtained for 49 states from the years 2000-2008 creating an N of 439[5].

A fixed-effects panel model with time dummies controls for any unobserved, time-constant features particular to each nation, as well as events factors that change over time but that do not vary across nations, such as international commodity prices.

The logic of my modeling approach is based on the STIRPAT framework (Dietz and Rosa 1994; Cramer 1994; Cole 2004; Shi 2003; Shandra 2004; York et al. 2003a; York et al. 2003b; York 2008; York and Rosa 2012). STIRPAT was first developed by Dietz and Rosa (1994) as a reformulation of the popular IPAT equation to gauge how population (P), economic growth or affluence (A), and technology (T) affect the scale of environmental impacts (I). STIRPAT is a stochastic model that assumes environmental impacts are a multiplicative function of population, affluence, and technology, but does not assume that each factor has a proportional effect, STIRPAT thereby allows for hypothesis testing. In STIRPAT analyses each variable is

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[5] The models exclude Alaska in the years of 2000 and 2001, and Louisiana due to absent data in the NASS, resulting in an N of 439.

converted to natural logarithmic form, since an additive model with logarithms is equivalent to a multiplicative model with variables in original units. STIRPAT is therefore an elasticity where beta coefficients represent a proportional rate in the dependent variable (here environmental impact) for every one-percent change in the independent variable corresponding to the beta coefficient (York 2003). The fixed-effects model specification is therefore:

$$\ln y_{it} = \beta_1 \ln(x_{it}) + \beta_2 \ln(x_{it}) \ldots \beta_k \ln(x_{itk}) + \mu_i + w_t + e_{it}$$

Here the subscript i represents each unit of analysis (nations/states) and the subscript t the time period, y_{it} is the dependent variable in original units for each nation at each point in time, x_{itk} represent the independent variables in original units for each nation at each point in time, β_k represents the elasticity coefficient for each independent variable, u_i is a nation specific disturbance term that is constant overtime (*i.e.*, the nation specific y-intercept), wt is a period specific disturbance term constant across nations, and e_{it} is the stochastic disturbance e term specific to each nation at each point in time. Our model is specified below:

Dependent Variables

The dependent variable water pollution measures water pollution via biochemical oxygen demand (BOD) (in thousands of kilograms per day) which is the amount of oxygen microorganisms in water need to break down waste in natural water systems. Organic material in water comes from a variety of sources, such as plant, animal, and/or human waste and industrial activities. While the organic materials are in the water, metabolic processes of bacteria break down the waste over time (Penn 2003). During these processes, a certain amount of dissolved oxygen is consumed. BOD measures the amount of oxygen consumed by microorganisms to decompose waste. Waters with high amounts of waste correspond to a high BOD because a large number of microorganisms are necessary to breakdown the waste. High BOD rates put other aquatic life at risk due to reduced oxygen availability. Nitrates and phosphates are important elements that contribute to the amount of BOD found in natural water systems (Penn 2003). BOD measurements are one of the most reliable pollution indicators because it is relatively inexpensive to measure. In addition, BOD measurements are traditional starters for industrial pollution control within nations and are widely used in across nations (Hettige et al. 2000). Our data for BOD comes from the World Bank's environmental indicators website (2010). The World Bank's data on BOD started as continuation of Hettige et al. (2000) attempts to measure the amount of industrial pollutants found in natural water systems globally. To achieve this, the authors gather data on BOD levels in natural water systems from multiple nations, when/where data was available. The World Bank continued this aggregation through 2007.

The dependent variable agricultural greenhouse gas emissions, measures the total amount of greenhouse gas emissions from agricultural production in metric tons. In my national-level analysis, this data was gathered from the most recent report of the World Resource Institute (2010) (WRI). WRI obtains sector-based data on greenhouse emissions from the United States Environmental Protection Agency's (EPA) Inventory Improvement Program. The Inventory Improvement Program uses standard methods to obtain annual sector-based data on greenhouse gas emissions for each state and the District of Columbia annually. The data is gathered through assessing three major types of agricultural practices that are known drivers of greenhouse gas emissions, and several smaller practices. The three major types include; soil management (the most influential factor), which consists of fertilizer application and tillage practices, emissions from livestock production, and manure management. The smaller sources of emissions include rice cultivation and burning crop residue.

The data for greenhouse gas emissions in my cross-national analysis comes from the United Nations Food and Agriculture Organization (FAO 2015). The main agricultural processes that the data measures are enteric fermentation, manure management, rice cultivation, synthetic fertilizers, manure applied to soils, manure left on pasture, crop residues, cultivation of organic soils, burning – savanna, burning – crop residues, energy use in agriculture. Note that similar to my national level data, global data on greenhouse gas emissions is aggregated in accordance with the IPCC (1997; 2000; 2003; 2006) guidelines for each nation. The major difference between these data and my national-level data is that they includes carbon dioxide emissions from energy use on farms. This allows me to hypothesize about one of the key differences acknowledged by natural scientists regarding the differences between organic agricultural production and conventional agricultural production, which is energy use (see above section).

Key Independent Variables

The independent variable in each global analysis is the proportion of organic farmland, which estimates the amount of the organic hectares divided by the total farming hectares. The data for organic agricultural land was obtained from Organic World Statistics (2014). Data on certified organic agriculture is obtained from the SOEL/FiBL/IFOAM survey. Certified organic farming refers to both the certified in conversion areas and the certified fully converted areas. A major drawback of this data is that definitions of organic may vary across countries and data are gathered using various methods (e.g., surveys, secondary data, experts, *etc.*) thus I interpret the results presented here cautiously.

The data for organic agricultural land in the United Sates was obtained from the United States Department of Agriculture's (USDA) National Agricultural Statistics Service (NASS) (2012). The NASS measures the total amount of certified and exempt organic farmland in acreage per state[6]. A major draw- back to the data used in each of these analysis on organic agriculture is that they excludes informal organic practices, which may lead to underestimation of organic farming. Furthermore, definitions of organic vary within what is considered certified organic by both the USDA and IFOAM (i.e. some organic farms use much stricter practices than what is required), which may result in the data not reflecting the mitigating effects of stricter organic practices. Additionally, while certified organic farms account for a large portion of the organic products developed and used within the United States, they do not capture organic farming practices utilized for non-traditional consumer outlets, such as community gardens, farmers markets, and community supported agricultural programs. Therefore, I interpret my results cautiously and approach this study as a preliminary understanding of organic agricultural production's relationship to greenhouse gas emissions in the United States.

Cross-national independent variables

GDP per capita is a control variable to account for a country's economic standing and was gathered from the World Bank (2010). The variable was measured in constant 2005 US dollars. GDP per capita is a standard control variable for most environmental impacts analyses. Environmental sociological theories of the treadmill of production and world-systems suggest economic development to be a major structural driver of environmental degradation (York et al. 2003b). Previous research on water pollution, ecological footprints, carbon dioxide emission, and energy consumption find GDP per capita to be a positive predictor (Shandra 2004; York et al. 2003a; York et al. 2003b; Jorgenson 2007) (Earlier models not shown here were estimated with a

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[6] In order to be truly exempt from organic certification, NOP policy states that an organic farm cannot sell more than $5,000 worth of organic agricultural products annually. That $5,000 is total gross sales, not net sales.

quadratic term for GDP per capita and urbanization, however neither was found significant in a two-tailed test).

Population and urbanization are additional control variables representing important national demographic factors and were collected via the World Bank. Previous research on nature/society have found population to be a significant factor (York et al. 2003a; York et al. 2003b; Jorgenson 2007). Urbanization is included as a control variable to evaluate the level of a country's urbanization. Number of persons living in urban areas is estimated as the total persons living in urban areas divided by the total population. Additionally, we included urbanization as a control variable to serve as a proxy for the number of sewage systems and industrial processes that contribute to BOD (Penn 2003). Prior research has shown urbanization to be a significant predictor for environmental impacts.

National independent variables

The data for organic agricultural land was obtained from the United States Department of Agriculture's (USDA) National Agricultural Statistics Service (NASS) (2012). The NASS measures the total amount of certified and exempt organic farmland in acreage per state.[7] A major draw-back to USDA data on organic agriculture is that it excludes informal organic practices, which may lead to underestimation of organic farming. Furthermore, definitions of organic vary within what is considered certified organic by the USDA (i.e. some organic farms use much stricter practices than what is required by the USDA), which may result in the data not

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[7] In order to be truly exempt from organic certification, NOP policy states that an organic farm cannot sell more than $5,000 worth of organic agricultural products annually. That $5,000 is total gross sales, not net sales.

reflecting the mitigating effects of stricter organic practices. Additionally, while certified organic farms account for a large portion of the organic products developed and used within the United States, they do not capture organic farming practices utilized for non-traditional consumer outlets, such as community gardens, farmers markets, and community supported agricultural programs.

In order for my data to accurately determine the correlation between greenhouse gas emissions from agricultural production and USDA certified organic farming, I included three indicator variables—total agricultural land, gross domestic product, and population—to control for other drivers of greenhouse gas emissions from agricultural production. Total agricultural farmland, my first indicator variable, measures the amount of agricultural land within each state in acres. By using total agricultural land as an indicator variable, I am able to control for the amount of greenhouse gas emitted by agriculture, allowing the model to show the effect of organic farmland on greenhouse gases. Data on total agricultural land was acquired from the NASS (2012). My second indicator variable, gross domestic product (GDP), measures the average gross domestic product within each state, allowing the model to control for the variations in economic size and economic growth in the years measured within each state. The data on GDP was acquired from the United States Economic Research Service (ERS) (2012). My last indicator variable, population, was acquired from the United States Census Bureau (2012). This allows me to control for the amount of people in each state, which potentially affects the amount of food and other agricultural products produced in each state and therefore the amount of agricultural greenhouse gas emissions.

Results

As noted above, the fixed-effects models presented below control for omitted factors that vary cross-nationally but are temporally invariant, such as geographic, climatic, and geological factors, as well as the effects of the historical legacy preceding the periods examined here (e.g., the era during which a nation began to industrialize agriculture). The models, therefore, control for temporally invariant characteristics unique to each nation. Additionally, the models control (via the time dummies) for cross-sectional invariant factors that change over time, such as international prices of resources. Thus, these models focus on change over time within nations, not on cross-sectional differences. All variables (except dummy variables) are in natural logarithmic form, which makes this an elasticity model.

The results from my analysis are reported in Tables 4, 5, 6, and 7. I present R-squared within and the highest variance inflation factor (VIF) for each model. Within R-squared measures the variation of the dependent variable within countries explained by the independent variables. In fixed-effect panel analyses, R-squared within is a better measurement than R-squared overall because fixed-effects disregards between-unit variation (York 2008). The variance inflation factor measures the amount of multi-collinearity, note that none of the independent variables in the models presented below reach a VIF of 10 or higher. This means that my coefficients are not substantially affected by a collinear relationships (Beasly et al. 1980; O'Brian 2007).

Results for organic farming and water pollution

My results in Table 1 provides evidence that the global conventionalization of organic farming is increasing, and not reducing agriculture's metabolic rift with respect to water ecosystems. Specifically the model demonstrates that as a country's organic land increases there is a corresponding increase in BOD while holding constant population, urbanization, and GDP per capita, indicating that the rift of water pollution in the water cycle is enhanced through organic farming. It is important to note that the coefficient for proportion organic farmland is close to zero, meaning that organic farming may have a significant but negligible effect on BOD. Of course, the coefficient is not negative, clearly ruling out the hypothesis that organic farming is reducing BOD. While these results support my theoretical assumptions, they must be understood with caution as they do not assess the specific types of practices conducted on organic farms.

Population, GDP per capita, and urban population were also found to be significant predictors of BOD, which is consistent with the findings of previous STIRPAT analyses (Dietz and Rosa 1994; Cramer 1994; Cole 2004; Shi 2003; Shandra 2004; York et al. 2003a; York et al. 2003b; York 2008; York and Rosa 2012). Specifically, I find that a one percent increase in GDP per capita corresponds with a .169 percent increase in BOD. We also find that a one percent increase in population results in a more than 1.3 percent increase in BOD, indicating that there an elastic relationship between BOD and population. Similarly, we find that a one unit increase in the percent of urban population corresponds to a one percent increase in BOD, meaning that not only is population a powerful contributor to BOD but specifically urban population. Previous research on BOD found similar results from control variables (Jorgenson 2007).

My results support the findings of soil scientists that specific organic management practices lead organic farms to have higher or similar levels of nitrate leaching as conventional farms (Stolze et al. 2002; Stopes et al. 2002; Shepard et al. 2003; Syväsalo 2006). Additionally our results support the findings of social scientists who argue that organic farming is becoming increasingly reliant on non-farm inputs such as organic fertilizers (Buck et al. 1997; Guthman 2004a; 2004b; Flaten et al. 2006; Best 2008). However, these results may also suggests that shifts toward organic farming are correlated with BOD but have not increased enough to counteract the amount nitrate leaching that occurs from conventional farming.

Table 1 Fixed-effects panel regression coefficients predicting Biochemical Oxygen Demand.

Independent Variables Logged	**Coefficients (SE)**
Population	1.308 *** (0.467)
Percent urban population	1.032 * (0.438)
GDP per capita squared	0.169 ** (0.054)
Proportion organic land	0.018 *** (0.003)
R-squared within	0.266
Highest VIF	1.003
N	277

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$ (two-tailed tests).

Results for organic and greenhouse gas emissions at the national level

The logic of my model in table 2 is to control for any potential drivers of greenhouse gas emissions from agricultural production (e.g., the economic output of a state, the amount of people in a state, and the total amount of agricultural land producing crops in a state), and assess specifically the correlation between rises in organic agricultural land and the average output of greenhouse gas from agricultural production in states between the years 2000–2008. Keep in mind that because my data is interpreted using fixed effects, my models explicitly focus on how change in organic farming within states relates to greenhouse emissions. In model 1 the variables, total farm acreage, population, and GDP, are found to be insignificant in relation to greenhouse gas emissions from agriculture. However, organic agriculture is positively associated with greenhouse gas emissions from agricultural production, indicating that changes in the amount of certified organic farmland were associated positively with changes in the amount of greenhouse gases released from agricultural production.

The logic of my model in table 3 is a slightly nuanced version of model 1, in that it demonstrates how the proportion of organic land to conventional land affects the intensity of greenhouse gases emitted from agricultural production while holding constant other potential driver of agricultural greenhouse gas emissions (e.g., GDP and population). This is accomplished by having the dependent variable in model 2 illustrate the average amount of greenhouse gases emitted per acre of agricultural land. Unlike model 1, model 2 is also aimed at addressing the social problems associated with organic farming, such as corporate co-optation and conventionalization. Just as in model 1, the variables total agricultural land, population, and GDP are all insignificant. However, similar to model 1 the independent variable organic farmland (here presented as a proportion of total farm land) is positive and significant. The subtle distinction here is that rises in organic land are correlated with rises in the intensity of agricultural greenhouse gases emitted per acre of agricultural land. Therefore, models 1 and 2 understood together demonstrate that organic agricultural land is correlated positively with greenhouse gas emissions from agricultural production, as well as the intensity of greenhouse gas emitted per acre of agricultural land. Additionally, I estimated the variance inflation factors (VIF) of each of my independent variables to test for potential multi-collinearity and found that none of my independent variables reached a VIF of 10 or higher. This means that coefficients in each of my models are not affected by a collinear relationship between my independent variables[8] (see Belsley et al. 1980).

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[8] VIFs for independent variables in model 1: GDP per capita .7, Organic farmland .9, total agricultural land 1, population .9. VIFs for independent variables in model 2: GDP per capita 1, percent organic farmland 1, total agricultural land .9, population .9

Table 2 Agricultural greenhouse gas coefficients for fixed effects panel regression, measured in metric tons

Independent variables	**Coefficients (standard errors)**
Organic farm acreage	0 .014*** (0.003)
Total farm acreage	-0.0001 (1.65 X 10^{-7})
GDP (In billions of dollars)	3.500** (0.002)
Population	-0.273 X10^{-7} (2.69 X 10^{-7})
R^2 within	0.205
R^2 between	0.202
R^2 overall	0.155
Highest VIF	1
N	439

*P <.05 **P <.01 ***P <.001

Table 3 Greenhouse gas emitted per acre coefficients for fixed effects panel regression, measured in metric tons

Independent variables	**Coefficients (standard errors)**
Percent organic farm acreage	2.260×10^{-6}* (1.020×10^{-6})
GDP (In billions of dollars)	0 .027*** (0.006)
Population density	-4.570×10^{-9} (4.900×10^{-9})
R^2 within	0.116
R^2 between	0.0001
R^2 overall	0.000
Highest VIF	0.9
N	439

*P <.05 **P <.01 ***P <.001

Results for organic and greenhouse gas emissions at the global level

The model used to produce the results in table 4 applies the same logic as table 3. The key difference being that this model observes the effect at the global level. Additionally, it controls for the same independent variables. Similar to the previous tables, table 4 also controls for general period effects via time dummies, which are not reported. The main indicator variable in table 4 (hectares of organic land) has a positive and significant coefficient, meaning that a one unit increase in organic agricultural land is associated with an increase in agricultural greenhouse gas emissions. My additional control variables (total agricultural land, population, and GDP) are also all found to be drivers of agricultural greenhouse gas emissions. This means that organic farming increases agricultural greenhouse gas emissions independent of rises in total agricultural land, population, and economic development.

Table 4 Fixed-effects panel regression coefficients predicting agricultural greenhouse gas emissions

Independent variables	**Coefficients** **(SE)**
Organic hectares	1.541*** (.398)
Total agricultural land (hectares)	.098*** (.0218)
Population	.7420*** (.000)
Gross domestic product in thousands of dollars (adjusted for 2005 inflation)	.005*** (.001)
R-squared within	.514
Highest VIF	1.508
N/nations	795/128

Discussion

The results found in each of these models demonstrates that organic farming is associated with the expansion rather than reduction of environmental degradation. This phenomenon represents one type of displacement paradox that I argue occurs during the production of green commodities in capitalist economies. Specifically, growth of organic agricultural land in capitalist economies represents a continuation of the socioeconomic processes that produce the environmental impacts derived traditional agricultural production. This is evident in the conventionalization of organic farming, which has helped integrate organic agriculture into the larger structure of agribusiness by mirroring practices common in conventional farming, such as the use of off-farm fertilizers to increase the nitrogen content in soil (Buck et al. 1997; Guthman 2004a; Best 2008). Agricultural scientists argue that when organic farming increases yield productivity to match the output of conventional agriculture, it can have similar levels of nitrate leaching and greenhouse gas emissions as conventional farming (Stopes et al. 2002; Shepard et al. 2003). Additionally, it is argued in multiple studies that the growing use of and mishandling of animal manures increases both greenhouse gas emissions and nitrate leaching on organic farms (Kristensen *et al*; Kirchmann et al. 2014). Thus the positive association in these models between organic farming and environmental impacts could potentially be result of organic farming mirroring conventional agriculture practices. Metabolic rift theory and the concept of rifts and shifts is useful in for understanding this phenomenon, as they indicate that organic farming can shift conventional farming's metabolic rift toward away from synthetic inputs and toward organic inputs.

While the models themselves only imply an association between and water pollution/ greenhouse gas emissions and organic farmland, there are a multitude of scenarios that would explain why this correlation might occur. For instance, this association could be a result of organic farming and conventional agriculture growing simultaneously, and organic farmland not completely substituting conventional farmland. Additionally, as I discussed in the previous chapter, organic farming frequently relies on inputs that are developed on conventional farms, such as livestock manures. A likely scenario contributing to the association discovered here is the use of livestock manures in organic farming that are produced using conventional farming techniques, which could intensify greenhouse gas emissions derived from livestock and increase BOD in water. Specifically, the utilization of conventional manures on organic land would add on top of the water pollution and greenhouse gas emissions that are produced to developing these manures, as the application of manure is associated with additional nitrate leaching and greenhouse gas emissions. These models ultimately demonstrate that organic farming has not substantially reduced environmental impacts, which is evidence of a displacement paradox.

CHAPTER IV

THE DISPLACEMENT PARADOX OF ALTERNATIVELY FUELED VEHICLES

Nations and international organizations often assume that alternative resources directly substitute their fossil fueled-based counterparts (UNEP 2011; United States Department of Energy 2013). Whether or not this is the case has been a key concern for social scientists, as it is often noted that due to the many complexities embedded within modern socioeconomic processes, new resources aimed at substituting conventional goods do not necessarily result in their expected outcome (York 2006; McGee 2014). For example, York (2012) found that alternative forms of energy have an unexpected impact on fossil fuel sources of energy. Specifically, in contrast to the assumption that a one unit of alternative energy displaces a proportional unit of fossil fuel, York found alternative sources of energy only minutely displace fossil fuel sources. In an effort to elaborate upon the potential consequences of displacement paradoxes, here I explore the relationship between alternatively fueled vehicles (AFVs) and total fuel consumption per vehicle in the United States.

I estimate time-series cross-sectional Prais-Winsten regression model with panel-corrected standard errors (PCSE) to explore (1) how increases in the percentage of AFVs in states from 2003-2010 affect the fuel consumption rates of all vehicles, and (2) how increases in the proportion of AFVs affect the travel rates of vehicles. This chapter, will further examine how the treadmill of production theory (Schnaiberg 1980; Gould 2004) can be used to explain the phenomenon of the displacement paradox. Specifically, I will argue that the displacement paradox of AFVs is a product of the treadmill of diversifying production (York 2004), where green commodities help to increase total consumption within specific industries.

Previous Discussions on AFVs

Previous studies on AFVs have predominantly focused on two phenomenon – the potential of integrating AFVs into the vehicle market, and the environmental impacts associated with AFVs. The first of these studies offers insights into the manner in which AFVs work as a counterforce to climate change, by emphasizing AFVs' ability to displace traditional vehicles. For example, Tran et al. (2013) quantify the conditions that may trigger widespread adoption of AFVs, and identified the barriers that exist for early and mass adoption of AFVs. The authors note that for early adoption, a major barrier, is price premiums and the lack of available charging facilities particularly for battery electric vehicles. They find that the integration of AFVs is largely dependent upon a vehicle market that values carbon reduction, which they note is currently not the main motivation behind early adopters, as most consumers are influenced by the financial rather than environmental benefits of AFVs. In a similar vein, Zhang et al. (2011) explore factors that could "speed the diffusion of AFVs", finding that market pull factors such as "word-of-mouth" marketing have a positive impact on the potential diffusion of AFVs. However, the authors also find that government mandates on fuel economy standards decrease the diffusion of AFVs, due to the market share of fuel efficient gasoline vehicles increasing. Achtnicht et al. (2012) find alternative fuel availability to be an additional barrier to further integration of AFVs, specifically in Germany. They argue that expanding accessibility to alternative fuel stations will have a positive effect on consumers' choosing AFVs, indicating once again that availability is a crucial component in the integration of AFVs into the vehicle industry. While these studies demonstrate how AFVs can eventually displace traditional vehicles, they fail to acknowledge the additional environmental impacts that would undoubtedly come from diversifying the vehicle market.

Scholars have discussed the environmental outcomes of AFVs for decades, often in comparison to gasoline vehicles. For example, Moriarty (1994) assesses the extent to which electric cars reduced greenhouse gas emissions in Australia, finding that if the electric grid could be made up of at least fifteen percent wind energy, replacing traditionally fueled vehicles with electric cars would reduce greenhouse gas emissions relative to their petroleum based counterparts. Additionally, Moriarty argued that ethanol from sugar cane had high costs per ton of CO_2 reduction, and when other trace gases were considered, it shows no definite improvement over petroleum. More recently, Lapola et al. (2010) found that carbon emissions derived from land use change perpetuated by the growing demand for biofuels in Brazil, would be low due to their replacement of rangeland. However, Lapola also argues that indirect land-use changes, especially those pushing the rangeland frontier into the Amazonian forests, could offset the carbon savings from biofuels, illustrating that growth in biofuel production can potentially yield little to no reductions in overall environmental degradation.

Other studies have used lifecycle analysis to explore the varying environmental impacts of AFVs (e.g. Segal, 1995; Hill et al., 2009). For example, Ogden (et al. 2004) preformed a lifecycle analysis of numerous categories of AFVs to assess the impacts of each fuel type, and found that hydrogen based fuel had the lowest externality cost of all types of fuel. This was cited as a result of the life cycle cost of hydrogen-based vehicles as compared to newer gasoline-based vehicles, which does not include the cost of extraction. Other research has also found that there may be additional individual health risks associated with AFVs. Specifically, Lapin et al. (2002), who found that the currently employed natural gas fueled heavy duty trucks have particulate exhaust emissions that possess mutagenic activity, which is known to cause serious human health risks.

It is clear based on these analyses that there are present barriers preventing expanded use of AFVs, and that there are environmental risks associated with the use AFVs. My interest here is on the ecological implications of the current barriers preventing further application of AFVs. To this end, I propose that it is important to understand the current use of AFVs within a larger political economic context that takes into the consideration the broader implications of the automobile industry and society's relationship to nature. If for example AFVs are working to expand the vehicle industry, the environmental impacts produced from AFVs may be adding to the total environmental impact of vehicle use in the United States What follows is a brief overview of the political economic legacy of automobiles and broader socio-environmental implications of AFVs.

The Environmental Political Economy of Automobiles

The automobile is a unique commodity that continues to have a large impact on the development of the cities, consumer culture, and human-environmental relationships. Paul Baran and Paul Sweezy (1966) identified the automobile as an "epoch-making innovation" in capitalist economies, matched only by the invention of steam engines and railroads. Paterson (2007) argues that cars not only embody capitalism, but produce a unique culture and form of capitalism. This is because cars have shaped the pattern of economic development over the past century, creating massive investment opportunities for a variety of markets. The invention of the automobile has been accompanied with the rise of oil corporations, as well as construction and insurance companies that all profit greatly from the continual growth of individual car use (Sweezy 1973; Paterson 2007). The sustained use of cars as a primary form of transportation in cities is a result of multiple governmental and economic efforts to continually shape cities around the car use (Paterson 2007). Additionally, the rise of the automobile has coincided with the development of monopoly capitalism (Sweezy 1973), a stage of capitalism that is defined by large corporations that accumulate massive amounts of surplus to continually increase consumption and counteract diminishing investment opportunities. I argue here that due to these unique aspects of the automobile industry, increases in the number of AFVs within the vehicle fleet helps to further expand the use of vehicles in the United States rather than operate as a counterforce to the environmental degradation produced by the use of vehicles. Below I further develop this argument using the treadmill of production theory.

Schnaiberg (1980) points out that the car industry is a clear of example of the "consumer sovereignty model", where consumer preferences are contingent upon the social circumstances that are manipulated by capitalists' interest. He notes that

> Nowhere is this clearer than in the transportation field. A mixture of public and private U.S. enterprises provided urban mass transportation in the first third of this century. Over the next three decades, government policy shifted dramatically toward expanded provision of public highways, stimulating and expanding suburbanization and private automobile usage. (Schnaiberg 1980: 181-182).

For Schnaiberg this is an example of the treadmill of production, which is a theory of human-environmental relationships in post-World War II society. Treadmill of production theory (ToP), argues that the inherent tendency of modern economies is to expand development by increasing resource extraction, which in turn increases environmental impacts (Schnaiberg, 1980; Schnaiberg & Gould, 1994; Schnaiberg, 2002). It was first developed Schnaiberg in 1980, as a response to the massive increases in resource extraction and environmental destruction that occurred after World War II. In assessing modern society's relationship to nature, Schnaiberg concluded that environmental degradation is intrinsic to capitalist society such that social inequalities are interwoven with each environmental concern, and that social and political responses to these production processes are ultimately futile and unpredictable (Schnaiberg et al., 2002). Furthermore, the environmentally destructive characteristics of capitalist production are unhindered by consumer and regulatory action aimed at reducing environmental impacts, as these attempts are contingent upon capital investments (Schnaiberg, 1980; Schnaiberg & Gould, 1994; Schnaiberg, 2002).

Gould et al. (2004) notes that each round of investment in capitalist markets perpetually increases levels of demand for natural resources for a given level of social welfare, work to weaken employment circumstances for production workers, and degrade the environment. This process is accomplished by creating a consistent need for investments to employ workers, and continually extracting variety of natural resources to produce new goods. ToP theorists argue that this level of dependency reduces consumers and politicians' ability to work in their best environmental interest (Schnaiberg 1980). For example, strong environmental regulations from the political sphere are seen as antagonistic to workers, and therefore voters, as it often reduces the expansion of jobs by decreasing levels of extraction. This hinders politicians' ability to take regulatory action against environmental degradation.

Workers'/consumers', ability to reduce environmental impacts is weakened by their lack of influence in resource extraction and production. For instance, if a consumer refrains from participating in an environmentally hazardous market, and there is no environmentally sustainable alternative commodities within said market, they risk acquiring additional socioeconomic burdens that using a environmentally hazardous commodity may relieve. Participating in alternative markets or purchasing alternative products aimed at counteracting the social and environmental impacts of traditional markets can also be limited, due to the monopolistic structure of modern capitalist economies (see Baran & Sweezy, 1966).

> One must be careful not to fall into the trap of assuming that Big Business and smaller businesses are qualitatively equal or of coordinate importance for the *modus operandi* of the system… Smaller business, is on the receiving end, reacting to the pressures of Big Business, to a certain extent shaping and channeling them, but without effective power to them and still less to exercise an independent initiative of its own. From the view of a theory of monopoly capitalism, smaller business should be properly treated as part of the environment within which big business operates rather than as an actor on the stage. (Baran and Sweezy 1960: p. 52)

In this context, the presence of smaller businesses that sell AFVs and/or big corporations that sell AFVs should be understood as reactions to the larger structure of the vehicle industry, which is the selling of cars that run of traditional fuel. This concept is explored by York (2004) in his notion of the "treadmill of diversifying production". York (2004) argues that introducing sustainable alternatives to environmentally hazardous markets simply diversifies production, and ultimately expands markets by meeting diversified consumer interests. This process renders ecologically sustainable resources more a reaction to unsustainable processes, rather than a counterforce or substitution for them. In a more recent article, York (2006) further explores this phenomenon along with the more widely-known Jevons Paradox, which is a phenomenon where improved resource efficiency escalates the consumption of that resource, to question whether technological advancements alone lead to conservation of natural resources. Here he contends that in addition to the Jevons Paradox, there is a paradox of substitution (referred to here as the displacement paradox), where new resources fail to reduce existing ones.

York (2012) empirically tests the displacement paradox by exploring the extent to which alternative sources of energy displace fossil fuel sources of energy. He finds that the increased presence of alternative sources of energy, such as hydroelectric and nuclear energy, only minutely displace the production of fossil fuel energy sources, and argues that this goes against traditional assumptions regarding energy expansion. Based on his findings, York concludes that the reduction from fossil-fuel energy use does not occur inevitably with the expansion of alternative sources. York's (2012) findings regarding the paradox of substitution fits the theoretical assumptions of ToP, as it demonstrates that the diversification of resources used in particular industries produce a "treadmill of diversified production" (York 2004).

To this end, I examine the extent to which the increasing proportion of AFVs affects the fuel consumption rates per vehicle. While York's (2012) analysis does not specifically engage with ToP, it offers insights into how scholars can further empirically test the assumptions of ToP.

Hypothesis:

I ask whether increasing the proportion of alternative fueled vehicles within the vehicle fleet increases or decreases total fuel consumption rates per vehicle. This question is articulated in the hypotheses below.

H1: Increasing the proportion of AFVs within the vehicle fleet reduces the total amount of fuel consumed by vehicles within states.

H2: Increasing the proportion of AFVs within the vehicle fleet increases the total amount of fuel consumed by vehicles within states.

H1 assumes that AFVs are operating as a counterforce to the treadmill of production and reducing the amount of fuel that is consumed by vehicles annually at the state level. This outcome could be a result of multiple factors, such as AFVs having higher fuel efficiency or AFVs being associated with lower rates of travel. In contrast to the H1, H2 assumes that AFVs are exacerbating production and increasing the amount of fuel consumed by vehicles at the state level. Similarly to H1, H2 could be a result of multiple factors, such as higher fuel efficiency amongst AFVs, the number of AFVs adding to the total number of vehicles in the vehicle fleet, or AFVs increasing travel.

To further understand the extent to which AFVs act as a facet of the treadmill of production, I pose the additional of question of whether rises in the proportion of AFVs increases or decreases the amount of miles travelled by vehicles at the state level. This question is articulated in the hypothesis below:

H3: Increasing the proportion of AFVs within the vehicle fleet decreases the amount of miles traveled per vehicles in the United States.

H4: Increasing the proportion of AFVs within the vehicle fleet increases the amount of miles traveled per vehicles in the United States.

H3 assumes that one way AFVs operate as a counterforce to the treadmill of production is by reducing the amount of miles traveled by vehicles at the state level. Conversely, H4 assumes that one of the ways in which AFVs act as a facet of the treadmill of production is by increasing the amount of miles traveled by vehicles at the state level. Although H1 and H3 both assume that AFVs operate as a counterforce to the treadmill of production, H1 one can be confirmed while H3 is rejected and vice versa. For example, it may be the case that AFVs are on average more fuel efficient than gasoline and diesel vehicles requiring less fuel consumption per vehicle but increasing travel due to their increased fuel efficiency. This argument is similar to the rebound effect (see Greening et al., 2000; Small & Van Dender, 2005; Small & Van Dender, 2007; Sorrell, 2007), which argues that consumption rates for gasoline grow due to lower cost from increased fuel efficiency and behavioral shifts in consumers. Likewise, although H2 and H4 both assume AFVs are acting as a facet of the treadmill of production, H2 can be confirmed while H4 is rejected and vice versa for the same reasons noted above.

Data and Methods

In order to test my hypotheses, I estimate three elasticity models, which were created by taking the natural log of my dependent and independent variables. Elasticity models assume that a dependent variable is determined by a multiplicative combination of the independent variables. Multiplicative models intrinsically take into account one type of interaction among factors, by recognizing that a change in one independent variable does not simply add to the dependent variable directly, but rather scales it relative to the values of the other factors. Additionally, each coefficient for my independent variables is interpreted as the proportional effect of a one percent change of the independent variable on the dependent variable.

Both models are estimated using a time-series cross-sectional Prais-Winsten regression model with panel-corrected standard errors (PCSE), allowing for disturbances that are heteroskedastic and contemporaneously correlated across panels (see Beck and Katz 1995). Each model estimates the relationship from 2003-2010 across U.S states (including the District of Colombia)[9]. I include state-specific and year-specific intercepts, making the model equivalent to a two-way fixed effects model. As with a fixed effects model, this method estimates effects within states, rather than between states, over time and controls for variation between states. Finally, I correct for AR(1) disturbances within panels, treating the AR(1) process as common to all panels because there is no theoretical reason to assume the process is panel specific (see Beck and Katz 1995). The model I estimate is:

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[9] Note that the 357 N in Models 3 and 4 is a result of missing data for Alaska in the EIA database.

$y_{it} = B_1(x_{1it}) + B_2(x_{2it}) \dots B_k(x_{kit}) + u_i + w_t + e_{it}$

Here the subscript $_i$ represents each unit of analysis (states) and the subscript t the time period, y_{it} is the dependent variable for each state at each point in time, x_{kit} represents the independent variables for each state at each point in time, u_i is a state specific disturbance term that is constant over time (i.e., the state specific y-intercept), w_t is a period specific disturbance term constant across states, and e_{it} is the stochastic disturbance term specific to each state at each time point.

The logic of my modeling approach is to observe how change in the number of AFVs effects change in the dependent variables. I chose to use a PCSE model year and state specific intercepts because it allows me to specifically assess the effect of change from year to year within states as oppose to differences across states.

Dependent Variables

The data for the dependent variable in Table 3 was obtained from the United States Office of Highway Policy Information (OHPI, 2014). The data includes annual motor fuel consumption rates for all civilian vehicles and the total number of vehicles. The data on motor fuel consists of gasoline, gasohol, diesel, ethanol (85% or higher), compressed natural gas, electricity, hydrogen, liquefied natural gas, and liquefied petroleum all measured in gasoline equivalent gallons. The dependent variable in Table 3 was calculated by dividing the total amount of fuel consumed by civilian vehicles by the total number of civilian vehicles, which includes all mid-sized automobiles, compact automobiles, full-size automobiles, sub-compact automobiles, low-speed vehicles, motorcycles, SUVs, pickup trucks, full-size trucks, light-weight vans, mid-size vans, and mini vans. The dependent variable in Table 4 was also obtained from OHPI (2014) and measures the total amount of miles traveled per vehicle. This variable was created by dividing the total amount of miles traveled by the total number of vehicles. The data for motor fuel consumption, total number of vehicles, and miles traveled per vehicle relies on annual state reports, where each state follows established federal guidelines to maintain consistency across regions. The OHPI notes that "These estimates may not be comparable to data for prior years due to revised estimation procedures." However, the most recent revised estimation procedure occurred in 2002 when automated data submittal process was implemented by a web-based application, which was intended to ease the reporting burden and improve the data accuracy. Thus the data used in this analysis is not subject to this particular inaccuracy.

Table 1 Summary statistics of dependent variables (unlogged)

Variable	Mean	Minimum	Maximum	Standard deviation
Miles traveled per vehicle	12,823	1,968	32,340	3,051
Fuel consumption per vehicle (in gallons)	774.968	505.969	1834.413	173.015

Independent Variables

In order to accurately test the relationship between AFVs, fuel consumption, and miles travel per vehicle I employed a number of independent variables to control for the potential influence of related time-variant factors. In Tables 3 and 4, I control for the effect of change in percentage of the license drivers. The data for this variable also comes from OHPI (2014), and helps to control for the impact of changes in the driving pool from year to year. I also control for the effect of changes in real GDP per capita in Tables 3 and 4 to account for the influence of changes in economic size. The data for GDP per capita was obtained from the Bureau of Economic Analysis (BEA 2014). While it seems appropriate in an analysis like this to control for the year to year fluctuations in fuel prices, unfortunately, data at the state level for year to year fluctuation in fuel price is not available. To address the potential influence of fuel prices, I control for the impact tax rates on gasoline, which coupled with my time dummies that control for general period fluctuation in my dependent variables, captures the effect of changes such as price over time. In Table 3, I control for miles traveled per vehicle to assess how changes in the amount of travel by individuals over time affects gasoline consumption. The main independent variable in Tables 3 and 4 is percent AFVs, which accounts for the percentage of mid-sized automobiles, compact automobiles, full-size automobiles, sub-compact automobiles, low-speed vehicles, motorcycles, SUVs, pickup trucks, full-size trucks, light-weight vans, mid-size vans, and mini vans that do not use gasoline relative to the entire civilian vehicle fleet. Data on AFVs were obtained from the EIA (2014) and includes the following fuel sources: ethanol (85% or higher), compressed natural gas, electricity, hydrogen, liquefied natural gas, and liquefied petroleum measured in gasoline equivalent gallons. It is important to note that according to the EIA (2014) the vast majority of AFVs owned by individuals use gasoline and diesel, due to the limited availability and economic viability of E85 fuel. Additionally, the EIA’s estimates on AFVs do not include gasoline or diesel hybrids since their primary fuel sources are traditional fuels.

Table 2 Summary statistics of independent variables (unlogged)

Variable	Mean	Minimum	Maximum	Standard deviation
Percent alternative fuel vehicle	.350	.004	5.694	.446
Miles traveled per person	10,388	1,679	18,295	1,947
GDP per capita (in dollars)	48,628	30,333	177,934	18,937
Percent of population with driver license	.702	.428	.907	.056
Gasoline tax rate (in cents)	21.256	7.5	37.5	5.465

Results

The PCSE models control for omitted factors that vary across states but are temporally invariant, such as the effects of the historical legacy preceding the periods examined here (e.g., the era during which a state introduced AFVs). The models, therefore, control for characteristics unique to each state. Additionally, the models control (via the time dummies) for cross-sectional invariant factors that change over time, such as fluctuations in international energy prices. Thus these results specifically show the effects of within unit change in the independent variables on the dependent variable.

Table 3 presents the PCSE model that regresses total fuel consumption on percent AFVs, GDP per capita, percent population with a driver's license, tax on gasoline, and miles traveled per vehicle. These models test my hypothesis that increases in the percent of AFVs will increase total fuel consumption against the null hypothesis, which is that there is no relationship between AFVs and total fuel consumption for vehicles, and the alternative hypothesis, which supports the conventional view that AFVs are working as a counterforce to traditional vehicles. Model A in Table 3 omits miles traveled per vehicle to assess the combination of both the potential direct effect of percent AFVs and an indirect effect of AFVs via its influence on miles travelled. Here I find the variable percent AFVs is associated positively with gasoline consumption per vehicle at the .001 level with a two-tailed test. This indicates that the rise in percent of AFVs proportionally increases the amount of gasoline consumption per vehicle. GDP per capita is also positive and significant in Model A at a .001 with a two-tailed test, which demonstrates that change in economic size through time within states increases total fuel consumption per vehicle. Thus Model A in Table 3 demonstrates that rises in the number of AFVs in the vehicle fleet over time within states increases total fuel consumption per vehicle, while holding constant changes in economic size, percentage of the population that has a driver's license, gasoline tax rate, and the general period fluctuation in total fuel consumption. This finding supports my proposed hypothesis that AFVs are adding to the consumption rates of total fuel consumption.

Model B in Table 3 is meant to further test my hypothesis, by controlling for miles traveled per vehicle in addition to the independent variables used in Model A. Here I find that percent AFVs is still significantly correlated with fuel consumption per vehicle, however the effect of a one unit increase in the percent of AFVs is much smaller. Additionally, the variable percent driving population becomes significant and is negative, indicating that increases over time in the percentage of licensed drivers decreases fuel consumption per vehicle. Similar to Model A GDP per capita is also positive and significant in Model B at a .001 with a two-tailed test. The independent variable miles traveled per vehicle in Model B is positively correlated with total fuel consumption per vehicle and significant so at a .001 two-tailed test. This means that, unsurprisingly, increases in travel per vehicle enhance the amount of fuel consumed per vehicle. The change in the overall effect in percent AFVs when adding miles traveled per vehicle as an independent variable in Model B implies that the influence of AFVs on fuel is most likely heavily tied to AFVs relationship to vehicle travel.

Table 3 Prais-Winsten regression model with panel-corrected standard errors coefficients predicting gallons of fuel consumption per vehicle[10]

Independent variables (logged)	Model A Coefficients (Standard errors)	Model B Coefficients (Standard errors)
Percent AFV	.122*** (.031)	.089*** (.022)
Miles traveled per vehicle (in thousands of miles)		.238*** (.071)
Real GDP per capita (in thousands of dollars)	.396*** (.102)	.397*** (.076)
Percent of population with driver license	-.172 (.089)	-.145* (.074)
Gasoline tax rate (in cents)	-.028 (.059)	-.047 (.1048)
R^2	.886	.917
Highest VIF	4.42	4.41
N	357	357

* $p < .05$ (2-tailed test) ** $p < .01$ (2-tailed test) *** $p < .001$ (2-tailed test)

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[10] Note that the 357 N is a result of missing data for Alaska in the EIA database

Table 4 Prais-Winsten regression model with panel-corrected standard errors coefficients predicting miles traveled per vehicle[11]

Independent variables (logged)	Coefficients (standard errors)
Percent alternative fueled vehicles	.187*** (.035)
GDP per capita (in thousands of dollars)	-.441*** (.074)
Gasoline tax rate (in cents)	.001 (.095)
Percent of population with driver license	-.067 (.097)
R^2	.098
Highest VIF	4.34
N	357

* $p < .05$ (2-tailed test) ** $p < .01$ (2-tailed test) *** $p < .001$ (2-tailed test)

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[11] Note that the 357 N is a result of missing data for Alaska in the EIA database

Table 4 presents the PCSE coefficients for miles traveled per vehicle and is meant to explore my hypothesis that increasing the proportion of AFVs increases travel per vehicle. Here percent AFVs is found to be positive and significant at the .001 level with a two-tailed test. Specially, a unit increase in the percent of AFVs is corresponds with a proportional increase in miles traveled per vehicle. This confirms my initial hypothesis by demonstrating that AFVs are increasing the average travel per vehicle in the United Stated. Table 4 also shows that increases in economic development significantly decreases the amount of miles traveled per vehicle within states, demonstrating that further economic development within states reduces the average amount of travel per vehicle.

Discussion and Conclusion

My analysis finds that AFVs are associated with increases in total fuel consumption per vehicle, as well as increases in travel rates per vehicle. These findings suggest that AFVs are expanding vehicle use in the United States rather than shifting fuel consumption away from traditional sources (e.g. gasoline and diesel). Consequently, this means that AFVs may be increasing overall environmental impacts produced from the vehicle industry. One lesson to be learned from this analysis is that the assumption that AFVs work to reduce the use of fossil fuels at this point is not true at the state level. While this is not to say that there are no environmental merits to AFVs, it does demonstrate that the social and economic barriers at this point prevent AFVs from completely offsetting the environmental impacts of mass transportation.

Perhaps the most important implication of these results is that for now, the poor economic viability of most alternative fuel sources prevents the displacement of fossil fuel consumption. The IEA (2015) notes that the limited availability and economic viability of some fuel sources, such as E85 fuel, results in the vast majority of AFVs owned by individuals using traditional fuels. Additionally others have found similar barriers leading to limited use of AFVs (see Achtnicht et al. 2012; Tran et al. 2013; Zhang et al. 2011 discussed above).

Automobiles represent a unique epoch in technological innovation that is tied to a diversity of industries that profit from traditional automobiles. This influences the social context that AFVs function under. Baran and Sweezy (1966; 1973) and Schnaiberg (1980) have noted that the larger goal of the automobile-industrial complex is to expand production by incentivizing consumption. Under this agenda, AFVs are limited in their ability to displace the consumption of traditional fuel in that they may be used to expand total fuel consumption. My results support these possibilities, as I find that diversifying the types of vehicles within the automobile industry increase total fuel consumption over time. There are many scenarios that would explain this phenomenon. For example, individuals who traditionally refrain from using personal vehicles for travel due to their negative environmental outcomes may use AFVs due to their perceived environmental merits. Additionally, people who use traditional vehicles may also use AFVs to expand their travel via personal vehicles. In these scenarios AFVs adhere to York's (2004) notion of the "treadmill of diversifying production", where AFVs function as a reaction to the environmental impacts of traditional fuel consumption, and not a counterforce. Similar to York's (2012), my findings here demonstrate a displacement paradox in capitalist production, and suggest that AFVs do not displace consumption of traditional fuel. While this relationship may change over time, it is worth noting that if the present barriers that prevent further integration of AFV into the vehicle fleet persists, then the expansion AFVs may continue to increase total vehicle use in the United States.

AFVs may also increase fuel consumption for vehicles similarly to the rebound effect (see Greening et al., 2000; Small & Van Dender, 2005; Small & Van Dender, 2007; Sorrell, 2007), where consumption rates for gasoline grow due to lower cost from increased fuel efficiency. It is likely that rises in the number AFVs is correlated with increases in fuel efficient vehicles, such as electric-hybrid vehicles, which could intensify consumption of gasoline by reducing its cost. Furthermore, it is argued that the rebound effect is a result of increased travel, the findings here demonstrate a strong correlation between travel and AFVs, suggesting that increased travel perpetuates both phenomenon.

In conclusion, these results coupled with the findings of Moriarty (1994), Segal (1995), Lapin (2002), Ogden et al. (2004), Hill et al. (2009), Lapola (2010) suggest that the environmental impacts associated with AFV production are at this point additions to the vehicle industry's hazardous environmental output. Future research into this area could directly explore how AFVs influence environmental degradation from vehicles, as well as the travel behaviors of drivers. This finding also warrants further investigation into other displacement paradoxes within environmentally sustainable production.

CHAPTER V

CONCLUSION

It is fitting to offer some sort of solution to these problems in the conclusion of a dissertation that discusses environmental problems, which is ultimately what I intend to do in this chapter. However, one thing that makes this dissertation somewhat unique is that it is engaging critically with existing solutions that have been put forth to environmental problems, making my discussion of solutions to environmental problems a bit difficult, as the solutions I offer must be solutions to solutions (this sentence is meant to be confusing). In many ways, this puts me in the position of “Liza” in the song “There is Hole in the Bucket”, as my solutions to solutions may have their own problems that Henry can’t fix. Fortunately, the statistical models I have used in my dissertation have also allowed me play Henry in this analogy, as I have pointed out problems to multiple solutions that have been offered. This juxtaposition gives me insights that Liza never had, as I am able to identify the root of the problems that are connected to the failed solutions that have been offered.

I hope that this dissertation has at least clarified that the paradox of green commodities is that growth cannot simultaneously be a problem and a solution. Just like Henry in the children’s song “There is Hole in the Bucket” must realize that he cannot fix the hole in his bucket with the tools he has because they all require him to use the bucket, which has a hole in it. Modern society must realize that we cannot fix our current environmental problems that stem from growth using tools that lead to growth, because growth has a hole in it. The hole in this case is the many contradictions that exists between economic growth and the environment. In this dissertation, the one specifically discussed is the displacement paradox, which is defined by the inability of green commodities to displace traditional commodities and/or the environmental impacts from the production of those commodities. To this end, I would like to discuss solutions that address the inherent problems embedded in modern economies' that produce displacement paradoxes.

In the first chapter of this dissertation, I noted two distinct types of displacement paradoxes. The first was discussed heavily by York (2006; 2012) and described the inability of alternative commodities to completely displace traditional commodities (e.g. the inability of one kilowatt hour of alternatively sourced electricity to displace one kilowatt hour of fossil fuel energy). The second, referred to inability of an alternative commodity to reduce environmental degradation associated with a traditional commodity. Together, these two outcomes demonstrate a unique paradox in the production of green commodities, which is their inability to act as true counterforces to environmental degradation. This paradox is distinct from other paradoxes that have been identified in capitalist economies, such as the Jevons paradox and the green paradox, in that it does not refer to inadequacies of efficiency increases or sustainable policies, instead, it deals with the problem of introducing environmentally sustainable technology into capitalist economies. Similar to other paradoxes however, it can be defined as simply a counterintuitive association. For example, York (2012) and Sellen and Harper (2002) establish that there are counterintuitive associations between alternative energies and fossil fuel energies, and digital upgrades to computers and paper usage respectively, however, they do not establish causal links to their findings. What makes this dissertation unique from these previous inquiries is that each chapter attempts to establish a causal link that is tied to abstract political economic conditions that influence societies' relationship to the environment.

I identify these political economic contradictions utilizing treadmill of production and ecological Marxists theories. This dissertation in many respects is a continuation of the efforts of treadmill of production theorists and ecological Marxists to understand the inherent contradiction between capitalism and nature. Treadmill of production theorists have abstractly criticized these efforts by claiming that the production of sustainable commodities within capitalist economies helps to diversify the resources utilized in specific markets to increase growth, rather than substituting non-sustainable resources with sustainable resources (York 2004). Ecological Marxists have also criticized environmentally sustainable efforts within capitalist economies by claiming that environmentally sustainable technology shifts the inherent metabolic rift between capitalism and nature to other ecological processes (Clark and York 2008). I argue that one empirical outcome of these contradictions is counterintuitive association between green technologies and processes associated with traditional technologies. In this dissertation, I have empirically assessed the theoretical assumptions of treadmill of production and ecological Marxists theorists, and have found evidence to support their claims in multiple instances by finding a displacement paradox between green production and traditional production.

In chapter 2 of this dissertation, I explored the connection between organic farming and Marx's theory of metabolic rift, arguing that both metabolic rift and early notions of organic farming criticized modern agriculture's inability to return nutrients that were lost during agricultural production back to the soil. Additionally, I argued that although organic farming initially relied on agricultural practices that addressed the metabolic rift produced by capitalist agriculture, over time, organic farming began to be practiced in a variety of ways that mirrored conventional agriculture. Specifically, a "conventionalized" variant of organic farming, which relied more on mono-cropping and off-farm inputs, developed and helped integrate organic agriculture into the agribusiness industry. The certification of organic goods helped expand the conventionalization of organic farming by creating a ceiling and floor for the practices necessary to be considered organic. For example, most national certified organic programs do not require organic based fertilizers, such as livestock manure, to be developed on organic farms or from organic farming, and can instead, allow the application of manures obtained from conventional farms. Additionally, organic farms are allowed to apply organic-based pesticides. As a result, I argued that there may be a displacement paradox between certified organic agriculture and agrochemical application. My findings demonstrate that as the proportion of organic agricultural land grows within countries, agrochemical application grows as well. While my findings are not a definitive causal link between organic farming and agrochemical application, they do demonstrate a potential pattern of conventionalization of organic farming at the national level.

A potential solution to this particular displacement paradox is to eliminate the application of manure-based fertilizers derived from conventional farming on organic farms and/or limit the amount of pesticides organic farms can emit. Though, this solution would most likely reduce the economic viability of organic farming, which would in turn decrease the pace at which organic farming currently grows. The larger problem behind this phenomenon is the economic context under which organic farming has become prominent. Organic farming's ability to displace conventional agricultural techniques has become determined by its economic viability as an alternative to conventional farming. However, organic farming has been forced to compete with conventional agriculture in outlets that are conducive to conventional farming practices, such as grocery stores and supermarkets, which rely on large shipments of goods to centralized locations. In the United States, over 90% of certified organic goods are sold in grocery stores and supermarkets (USDA 2016). This not only limits organic farming's ability to employ agricultural techniques, conservative tilling, on-farm composting, and on-farm manures, which can reduce environmental degradation, it also forces organic farming to employ techniques that have similar environmental consequences as conventional agriculture. In this way, organic farming is a reaction to the structure of conventional agriculture, helping agribusiness expand consumption by increasing prices and capture a larger consumer base.

Though speculative, it would be easy to imagine a scenario in which organic farming increases the profits made in the conventional farming industry by establishing a market for manure-based fertilizers. This allows conventional farms to sell what was traditionally waste to organic farms and increasing their overall profits, which can in turn be used to expand conventional agricultural production. Furthermore, it has been noted by other scholars that there is an increasing presence of corporate conventional manufacturers in the organic market, which increases the likelihood of profits made on organic farms being used to expand conventional agricultural production.

To this end, the best potential solution to the displacement paradox between organic farming and agrochemical application is to change the major outlets in which organic goods are sold. Fortunately, a different outlet already exists in the form of community-supported agricultural programs (CSAs). CSAs are conducive to locally-sourced organic agriculture and produce a variety of goods using strict environmentally sustainable farming practices. The logic of CSAs is to develop a community-oriented agricultural system, whereby consumers invest in shares of a farm by paying an upfront fee (usually annually) that collectively covers the cost of maintaining the farm. The consumers then obtain a proportion of the goods that are produced on the farm (mostly weekly) throughout the harvest season. Since payments are usually made prior to harvest, consumers often share the investment risks as well. CSAs are also often locally-based and mostly rely on organic/biodynamic agricultural practices (Lass et al. 2003). Furthermore, many CSA farmers utilize practices that are stricter than organic certification standards and even at times avoid organic certification in lieu of more environmentally/economically sustainable practices (Obach 2015).

Although it is not required that CSAs only use environmentally sustainable practices, their relatively small size and consumer base allow farmers to more easily implement practices that are more in line with the original ideals of organic/biodynamic farming (see chapter 2) and mend the metabolic rift produced by modern agriculture. For instance, since CSAs for the most part operate in close proximity to the communities they supply to, they limit the environmental contradictions that develop out of long distance trade of agricultural goods. This feature allows CSAs to address the metabolic rift developed through the town country divide, which Marx argued squanders "the vitality of the soil, which is carried by trade far beyond the bounds of a single country (Marx 1981,p. 949–50. Cited by Foster 1999: 379). Additionally, the way in which consumers participate in CSAs through directly sharing in farm investments, allows farmers to use economically risky practices from which conventionalized organic farmers have now strayed, such as crop rotations and grazing livestock (see Buck et al. 1998; Guthman 2004). These practices have the potential to accomplish what early advocates of organic/biodynamic farming called for by tying communities closer to their environments both socially and economically.

CSAs also have the potential to address the displacement paradoxes found in chapter 3 of this dissertation. The statistical models in chapter three find that at both the national and international level, organic farming has not reduced greenhouse gas emissions from agricultural production, and at the international level it has not reduced water pollution. In chapter 3 I argue that these findings are potentially a result of conventionalized organic farming reproducing the metabolic rift of conventional farming. It is worth noting here that the models used in this chapter as well as in chapter 2 could be expanded to assess the temporal affect of organic farming on agrochemical application, greenhouse gas emissions, and water pollution over time. The economic structure of CSAs also allows them to operate more easily as a counterforce to conventional agriculture, since they are not directly participating in the agribusiness industry. As I suggested previously, the largest limitation certified conventional organic farming has is that it participates in markets structured around conventional agricultural practices. CSAs free farmers from the necessity to generate a constant surplus, as they participate in economic system.

However, I would offer caution in assuming that most CSAs operate in ways that address concerns raised in metabolic rift theory and/or by early organic farmers. Here I am simply arguing that CSAs have the potential to address the socioeconomic contradictions embedded in capitalism. Furthermore, the outcomes of the widespread use of CSAs have yet to be fully realized. Future research could incorporate the theories to explore the overall viability of CSAs, and specifically assess their current limitations and whether or not they can be implemented without being heavily influenced by external capitalistic forces.

In chapter 4 of this dissertation I assess the environmental and socioeconomic implication of alternative fueled vehicles (AFVs). I review literature that argues that AFVs are not necessarily a more sustainable alternative to gasoline-based vehicles. Nonetheless, they are still put forth by the United States government as route toward displacing gasoline and diesel consumption:

> The resulting demand for different types of transportation fuels in 2050… have significantly decreased fuel demand due to less demand for motorized transportation services and greater fuel economy of vehicles. As indicated, conventional gasoline is nearly completely displaced and use of conventional diesel is reduced dramatically.

(United States Department of Energy 2013: 3)

My findings in chapter 4 demonstrate that there is a paradoxical relationship between the production of AFVs and fuel consumption rates per vehicle, where increasing the amount of AFVs within the vehicle fleet tends to increase total fuel consumption per vehicle. I contend that this finding is most likely a result of a displacement paradox occurring between the production of AFVs and gasoline and diesel-based vehicles. I further explore the casual mechanisms behind this counterintuitive relationship in a subsequent model in chapter 4, where I assess the relationship between AFVs and the amount of miles traveled per vehicle in states. In this model, I find that AFVs are correlated positively with increases in miles travelled per vehicle, suggesting that one reason AFVs increase fuel consumption rates per vehicle at the state level is because they increase they increase the amount of miles traveled per vehicle at the state level. The findings from my statistical models in chapter 4 support the hypothesis posed by Schnaiberg (1980) and York (2004) that there is a treadmill of diversifying production, where commodities that are perceived to be environmentally sustainable simply operate as facets of the treadmill of production and increase total resource extraction/consumption. Additionally, in chapter 4, I argue that the monopolistic structure of the automobile industry limits the ability of AFVs to act as counterforces to the treadmill of production.

While placing AFVs as a counterforce to environmental impacts derived from gasoline and diesel based vehicles is a worthy endeavor, I believe AFVs must be part of a larger challenge to the automobile industrial complex. AFVs in their current application seem to only challenge one facet of the automobile industrial complex, the gasoline and diesel industry. As a result, they fall victim to an additional part of the automobile industrial complex—the construction industry or more specifically the road construction industry. Sweezy (2000) and Schnaiberg (1980) each acknowledged the interconnectivity between the automobile industry and the United States government, which led to the United States' current reliance on the automobile for travel. Each note that road reconstruction was a way of subsidizing the automobile industry. Reducing the vehicle fleet in the United States' reliance on gasoline would require a restructuring of roads that are more conducive travel by AFVs. As was noted in chapter 4, a consistent factor that limited the use of AFVs by individuals was the lack of infrastructure supporting AFVs. Furthermore, a restructuring of the road infrastructure in the United States must also deemphasize the need for travel by vehicle. This could mean incentivizing more communal forms of travel or reducing the need for excessive travel in specific communities. Thus, a solution to the paradox found between AFVs and total fuel consumption rates per vehicle in chapter 4 is a restructuring the means of travel within the United States. Obviously, this is no small feat, however if the findings in chapter 4 are any indication of the future, further attempts to introduce AFVs will continue help increase vehicle travel and fuel consumption.

Perhaps the overarching solution to the paradox of green commodities is altering social relations to incentivize the widespread use of green technologies. The counterintuitive relationships found in this dissertation between green technology and traditional production processes are a result of green technologies functioning as commodities that serve the interest of existing markets. While the findings in this dissertation are in no way natural laws of capitalism, they can be understood as stochastic outcomes of structural tendencies in capitalist economies. For example, most nations and international organizations apply the logic of growth theory to the production of green technology. Growth theory is a neoclassical economic theory that argues that long term economic growth trends in capitalist economies can reached by perpetual technological innovations, and the substitution of old technology by new technology. In the context of green technology, it is argued that old environmentally hazardous technology can be substituted by new environmentally conscious technology to reduce environmental degradation and sustain economic growth. This logic does not account for the use of green technology in capitalist economies to expand existing markets by diversifying production procedures, and the application of traditional socioeconomic processes to green technologies. It is found in this dissertation that green technology can support traditional production processes by directly/indirectly expanding the use of traditional technologies and/or the absolute use of a particular type technology. While this is not the intended outcome of producing green technologies, it is a result of green technologies being used as technological alternatives under socioeconomic conditions that are conducive to traditional technologies. For example, organic farming's direct and indirect support of conventional farming practices (e.g. the use of off-farm inputs and the use of conventional manures in crop production) is as an unintended consequence of the continual restructuring of certified organic farming standards to increase the economic viability of organic goods. The intentions of most national certified organic programs is to increase the economic viability of organic farming procedures by making organic farming more accessible to farmers, and in turn the environmental merits produced through organic farming. What I find in this dissertation is that organic farming is supporting some conventional agricultural practices and as a result increasing some environmental impacts produced by agricultural production. In this way, the paradox between organic farming and conventional farming an unintended consequence of applying growth theory to the production of green technology. While it is not an intentional outcome of national organic certification programs, it is a product of a structural tendency in capitalist economies. These types of structural tendencies have been discussed extensively by environmental sociologists, particularly those theorizing about treadmill of production and metabolic rift theory, my findings support several assumptions of these theories. This, at the very least, suggests that environmental sociologists should continue to find ways to test these assumptions, and at the most, suggests that environmental sociologists can contribute greatly to political discussions pertaining to environmental sustainability.

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