Does the Biofuel Industry, With the Aid of Certification Programs, Contribute to Sustainable Development?

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DOES THE BIOFUEL INDUSTRY, WITH THE AID OF CERTIFICATION PROGRAMS, CONTRIBUTE TO SUSTAINABLE DEVELOPMENT?

by

James Michael Kierulff

Abstract of a Dissertation
Submitted to the Graduate School
of The University of Southern Mississippi
in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy

August 2011
ABSTRACT

DOES THE BIOFUEL INDUSTRY, WITH THE AID OF CERTIFICATION PROGRAMS, CONTRIBUTE TO SUSTAINABLE DEVELOPMENT?

by James Michael Kierulff

August 2011

Despite being a source of alternative energy and an avenue for broad economic development, a number of biofuel producers have demonstrated that the biofuel industry has significant potential for unleashing social, environmental and economic harm. To largely avoid such perils, the industry must demonstrate that it is operating in a sustainable manner, contributing to the sustainable development of all stakeholders who rely upon the industry’s responsible operation. Recently minted, internationally developed certification programs have been developed to move the industry into sustainable compliance and to offer a means by which stakeholders can incentivize the industry toward greater levels of sustainability practice.

Using OLS regression analysis, this dissertation estimates that the industry is currently operating within the bounds of sustainable development as measured through the World Bank’s sustainability model. This conclusion, however, is made with some caution. Many biofuel industry certification programs, despite covering a number of sustainable issues, have created loopholes within their criteria that must be resolved to avert greater long term damage to sustainable development. This work will conclude with methods and additional criteria that can be used to help move the biofuel industry toward more stable and sustainable development activity.
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2011
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Approved:

Edward Sayre
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Brian Richard

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Dean of the Graduate School

August 2011
DEDICATION

I dedicate this work to my family and friends, particularly my wife and my Dad. Sheri, your unwavering support, love and thoughtfulness throughout this process made it possible. We knew the vocations we chose would be challenging. We accomplished this together. To Dad, whose wisdom, love and support also made this work possible.

Thanks for always believing in me. To the rest of my family and friends, I thank you for your encouragement throughout this process. I also wish to thank my fellow IDV colleagues for their friendship. I will miss our group gatherings.
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CHAPTER I
INTRODUCTION

Despite hype, disappointing performance, questionable sustainability practices and a host of other challenges, biofuels are still being looked upon as a source of alternative energy that can help meet growing world energy needs. Cadres of some of the best minds in energy, environment and agriculture are looking into the failed human component of this opportunity, building certification programs as a means to incentivize sustainability throughout all stages of production. Ignoring the potential of biofuels and discarding them summarily as degradation to the values of sustainability without detailed analysis is akin to potentially throwing the baby out with the bathwater. If it is the human element of biofuel production that has failed, then what is at risk by hindering responsible biofuel industry growth (as explained below) is the very viable opportunity for expanded energy stocks world wide and a strong means to lift an enormous number of struggling agrarian communities from impoverishment.

Research Questions and Hypotheses

Research questions for this work, given the above concerns, are as follows: a) Does the production of biofuels provide a sustainable source of alternative energy? b) Can certification programs align existing biofuel operations with more sustainable practices? This dissertation will contribute an answer to the questions above. It will estimate biofuel sustainability using currently available data, examine certification program contributions with respect to moving biofuel enterprises toward sustainable operations and determine what data needs to be collected to more precisely reflect the biofuel industry’s contribution to sustainable development on a country-by-country and
aggregate, worldwide scale. This introductory chapter reviews the basics of what biofuels are, provides a brief definition of sustainability and summarizes the opportunities and threats biofuel production has on sustainable development. The end of this chapter summarizes the organization and content of the chapters that follow. The hypotheses of this dissertation are as follows:

HA1: There is a positive relationship between country level biofuel industry production and sustainable development as measured by the World Bank sustainable development model.

H01: There is no relationship between country level biofuel industry production and sustainable development as measured by the World Bank sustainable development model.

HA2: There is a positive relationship between certified biofuel industry production and sustainable development as measured by the World Bank sustainable development model.

H02: There is no relationship between certified biofuel industry production and sustainable development as measured by the World Bank sustainable development model.

Background: What are Biofuels?

Biofuels are liquid fuels developed from biological sources such as plant material, waste fats (such as cooking grease), and other organic material refined into a volatile substance. (For biofuels that are agriculturally produced the literature often uses the term “agrofuels”. For the sake of simplicity the term “biofuels” will be used when referring to the liquid form of organically derived fuels.) Not all biofuel sources are equal in value
for the production of energy. Some organic material is more suitable for conversion into sources of power, and is more economically feasible, than others given varying combustion, cultivation yields and conversion characteristics. Optimal organic material is being sought out by the energy production industry in the current race to help shore up dwindling energy resources in the face of ever growing, worldwide energy demands.

Biofuels are gaining momentum as an answer for transportation combustion engine needs. Bio-ethanol, blended with gasoline, is used to reduce fossil gasoline consumption. Bio-ethanol is derived from sugar and starch crops; cellulosic biomass; and agricultural and forest residues (M. Punia 2007). First generation biodiesel is primarily obtained from vegetable oils, both edible and non-edible which, upon a simple refining technique called transesterification (and other, minor processes), produce bio-diesel. Refined biodiesel resembles common fossil diesel in energy properties and can be used in many different engines which run on diesel (Punia 2007) but, as will be illustrated in the Environmental Contribution sub-section below, is a far cleaner burning fuel than fossil diesel.

The illustration at the top of the following page depicts the biofuel lifecycle process. Feedstocks are the plant material that many biofuels are obtained from. Such feedstocks are agriculturally derived, not drilled for or mined as with fossil fuels. Feedstocks are transported after harvest to refining operations which process raw plant material into combustible fuel. This fuel is primarily distributed to the transportation energy sector.
Sustainability

Sustainability, and more specifically sustainable development, has a wide variety of definitions in the literature (see John Pezzey 1992, 55-62). A discussion of what sustainability is will be left to the next chapter. For purposes of this introduction (contextually) sustainability is, simplistically stated, a term that refers to a measure of the maintenance of the quality of economic, social and environmental life over a given period of time. The lack of sustainability refers to the decline of quality along these three domains, over time. The growth of sustainability refers to the increase in quality along the same three domains, also over time. Quality is often understood as meaning “quality of life” (Pezzey 1992, ix). Quality of life, taken from the economic perspective, is often described in the sustainability literature as the lack of declining utility (Kirk Hamilton et
al. 2006, 15). What distinguishes sustainable development from sustainability is that sustainable development looks at any given effort (or efforts) to build economic, social and environmental assets within a people group and determines holistic, directional impact on utility or quality of life. The biofuel industry has an impact on all three domains of sustainability. If the biofuel industry contributes positively to sustainability its value to development can be demonstrated. The reverse is also true. Measuring and explaining biofuel industry impact on sustainable development is a goal of this work. (The link between sustainability and economic growth is presented in Chapter II.)

Biofuel Industry Importance

Fossil fuel sources are dwindling, becoming more expensive and much of it is controlled by unstable nations. Debates are still intense with respect to how to resolve the Earth's dwindling fossil fuel reserves. Alternative energy sources abound such as wind, solar, hydrologic, tidal, geothermal and many others. Each of these alternative energy options are receiving significant research and development focus the world over. This work chooses to focus on biofuels given biofuels have the potential to positively impact not only energy supply concerns but also have unique contributions to economic development in impoverished communities around the world and can contribute to energy independence goals of a country. The negative influences biofuel operations can have are of urgent importance. These urgent issues, currently receiving consistent attention in current events around the globe, are primarily concerned with food shortages, social problems and environmental degradation. The challenge faced by the biofuel industry worldwide is to resolve negative hazards of production and investment while maximizing positive outcomes. Positive biofuel industry contributions to sustainability are briefly
described below. Negative impacts are described in the Current Challenges subsection that follows.

_Economic Development_

The biofuel industry has shown enormous growth potential within both the developing and developed world (Jane Early and Alice McKeown 2009; Roben Farzad 2007; Worldwatch 2006) and has proven itself as a tool for economic growth (Valeria Costantini and Chiara Martini 2010; Ywe Franken 2006, 2007; Anelia Milbrandt and Ralph Overend 2008; Michael Renner, Sean Sweeney and Jill Kubit 2008). Of particular advantage to economic growth in the developing world is that the tropical and subtropical climates many developing nations are located in are optimal regions for premier (high yielding) biomass crop cultivation (R.E.E. Jongschaap et al. 2007, 1).

A country that can build its own biofuel production capacity has the potential of utilizing the resultant industry toward its economic growth and development. The importance of resolving issues that will unlock economic development potential can be seen in the extent of development the biofuel industry has to offer. Measurement of potential economic development at the national level is readily conducted through the following brief illustration, utilizing national income accounting.

Gross Domestic Product (GDP) is a common measure of the output of a nation. National income accounting, revealing the overall output of an economy as reflected by GDP, is expressed in the following formula:

\[ Y = C + I + G + (X-M) \]

“\( Y \)” represents the total value of all goods and services produced by a nation. “\( C \)” is the private consumption of goods and services. “\( I \)” represents business and residential
investment. “G” is the goods and services purchased by government. Finally, “X-M” is a measure of net exports (exports minus imports).

Gross National Income (GNI) is the most commonly used measurement of a country's economic activity, wealth and well being (Michael Todaro and Stephen Smith 2006, 50). The national income accounting formula can be slightly modified to reflect GNI as follows:

\[ Y = C + I + G + (X-M) + (F_I-F_P) \]

Y, in this case, represents GNI. \( F_I \) represents income citizens receive from other countries “in exchange for factor services (labor and capital)” (Todaro and Smith 2006, 50). \( F_P \) represents payments to other countries for the same services.

With the above formula a general visualization of the potential effect a domestic biofuel industry can have on national income can be realized. Imports (such as for oil) represents leakages of income from an economy (Charles Sawyer and Richard Sprinkle 2006, 263). Solely from the standpoint of economic growth, leakages have the effect of reducing the GNI and thus the wealth of a country. However, energy is crucial for the growth of an economy (Costantini and Martini 2010, 591-592). Oil imports can have a significant contribution to the energy stocks of a country and thus help enable a country's ability to produce goods and services. As such, the net effect of oil imports can be greater, positive GNI growth.

Should a nation become the producer of its own oil the import leakage will be transformed into an injection as illustrated below. The portion of “M” - imports – that are composed of imported oil are moved to investment, consumption and government spending enabled by this new domestic industry. The resources of a nation originally
spent on oil imports will remain inside of the nation, fostering additional GNI growth impacts through investment in the new industry and related multiplier (see Jochen Hartwig 2003; John Keynes 1973) effects.

\[ Y = C + I + G + (X-M) + (F-I-FP) \]

If a small business produces a replacement for a product originally imported it can be expected that the economy surrounding that small business will benefit in some way, thus causing a multiplier effect thanks to the effects of the original substitution. For example, small holder, entrepreneurial farm establishments can have such an effect in the biofuel industry on a micro economic scale. These micro scale economic activities aggregate into macro level economic impact.

On a macro scale, a specific case will help illustrate the above points. The United States (U.S.) Department of Energy's Energy Information Administration records the Philippines as having net oil imports of 315,700 barrels per day in 2006 (Energy Information Administration 2010a). On an annual basis, this amounts to approximately 115,230,500 barrels. Multiply this by the cost of crude oil per barrel and one obtains a perspective on how much national income is leaving the country due to oil imports. If a single barrel of oil costs the Philippines $100 USD (United States Dollars) the 2006 demand equivalent costs the Philippine economy around $11.5 billion USD, approximately 4% of their estimated 2007 GDP (World Bank 2008). Applying an economic multiplier of a yearly $11.5 billion USD injection into that developing economy is an order of magnitude many times over the effects of official foreign assistance. According to the Organization for Economic Development and Cooperation
(OECD), total gross disbursements of official developmental assistance from all donors to the Philippines was a little more than $1 billion USD in 2007 (Organization for Economic Cooperation 2009). The market initially appears to be a larger source of development funding. However, the stronger question to be addressed is whether these economic benefits will work their way down to the poorest that need it most, allowing for real Gini coefficient and Human Development Index type gains over time.

The basic economic question at this point is: could a microeconomic element, such as the biofuel industry, have a measurable macroeconomic impact? A similar “windfall” impact on national welfare as noted above has been described by Martin Weitzman (1976, 161-2). The production possibilities frontier of a nation expands outward creating a rise in net national product. Regarded as “unanticipated technological change,” the net effect, as argued by Weitzman, will “result in less consumption and more investment” (1976, 162). Further economic stimulus can result.

Taiwan, South Korea and other "Asian Economic Tigers" brought themselves out of the grasp of third world impoverishment, in part, thanks to one of the biggest economic breaks in recent history: the electronics revolution. Taiwan had its start when its relatively gifted and educated people had the chance to focus on manufacturing for export (Alice Amsden 2004, 136-7, 153). Countries such as Taiwan began as primarily agrarian societies, building upon strengths and opportunities to the point where strong standards of living are made possible. Effective government policies and foreign investments launched their path of industrialization through manufacturing and exports (Alice Amsden and Wan-Wen Chu 2003, 14-16, 152, 168-9). History witnessed successful nations starting to add services (banking and insurance for example) into the
mix of growing economic offerings as such nations matured into modernization (Amsden and Chu 2003, 133-140). With respect to a break for developing “remainder” (Amsden 2004, 292) nations, they do not necessarily need highly technical backgrounds as exemplified by Taiwan. Many have the background they need within their agrarian sectors - skills that have been developed over generations. Biofuel cultivation is one mass economic opportunity made possible through the talents of those in the agricultural sector.

*Environmental Contribution*

Biofuels have significant pollution abatement potential. For example, the chart below provides findings from a U.S. Environmental Protection Agency study of biodiesel emissions. The graph depicts engine emissions with ever increasing proportions of biodiesel blends with common fossil diesel. Emission levels from pure biodiesel (not blended with any fossil diesel) are shown as the lines representing specific pollution elements reach the far right border of the graph. As biodiesel blend percentages increase, three primary toxic emissions decrease. Pure biodiesel emits nearly 50% less carbon monoxide and particulate matter, and nearly 70% less hydrocarbons than fossil diesel. Comparative life cycle emissions (calculated from fuel source production through engine combustion) is a broader indicator of environmental impact as is indirect impacts of biofuel production. Comparative results of such measurements are still being debated in the literature due to measurement difficulties but major research is still underway (United States Congress 2009).
The NOx (Nitric Oxide) figures above have been contested. Tests conducted by the National Renewable Energy Laboratory of the U.S. Department of Energy have found only negligible increases in NOx (McCormick et al. 2006, 29).

According to the U.S. Department of Energy's website, biodiesel has significant advantages over common road diesel. The use of biodiesel

… substantially reduces emissions of unburned hydrocarbons (HC), carbon monoxide (CO), sulfates, polycyclic aromatic hydrocarbons, nitrated polycyclic aromatic hydrocarbons, and particulate matter (PM). The reductions increase as the amount of biodiesel blended into diesel fuel increases. B100 [pure biodiesel] provides the best emission reductions, but lower-level blends also provide benefits. B20 has been shown to reduce PM emissions 10%, CO 11%, and unburned HC 21%. Using biodiesel also reduces greenhouse gas emissions because carbon dioxide released from biodiesel combustion is offset by the carbon dioxide sequestered while growing [the biodiesel feed stock]. B100 use reduces carbon dioxide emissions by more than 75% compared with petroleum diesel. Using B20 reduces carbon dioxide emissions by 15%. (United States Department of Energy 2010)
Biodiesel is safer to handle and store than conventional diesel. According to the U.S. Department of Energy, biodiesel will not be as damaging to the environment if it is spilled compared to petroleum based diesel. Biodiesel is also less volatile than petroleum diesel given its flash point is at 150°C. By comparison, the flashpoint of road diesel is approximately 52°C (United States Department of Energy 2010). “Biodiesel is safe to handle, store, and transport” (United States Department of Energy 2010). Of environmental as well as economic note is biodiesels efficiency in production compared to the ever increasing difficulty in drilling for remaining fossil fuel reserves (United States Department of Energy 2010). "It also has an excellent energy balance: biodiesel contains 3.2 times the amount of energy it takes to produce it” (United States Department of Energy 2010).

Social Welfare Improvements

Without basic material needs, human beings suffer. In many cases the world’s impoverished suffer nightmarishly. The biofuel industry presents a potential source of poverty relief (Farzad 2007; Franken 2006). As stated above, biofuel production does not involve drilling and mining as with fossil fuels. Instead, biofuels (such as biodiesel and ethanol) are derived from agriculture. The majority of the world's poor are made up of agrarian communities (Todaro and Smith 2006, 67-8, 422) existing on subsistence farming or are employed as plantation workers. Those in rural areas can face fewer opportunities to earn a living; decreased levels of health care and education, as well as vulnerabilities to environmental extremes (Dwight Perkins, Steven Radelet and David Lindauer 2006, 218). Premier biofuel crops grow in tropical and sub-tropical regions (Jongschaap et al. 2007, 1) where much of the world’s poorest reside. Biofuel cultivation
presents a longer term economic benefit horizon given energy shortages and vast
domestic (and world wide) energy demand. However, it can not be overemphasized that
if these opportunities are to be realized, such development must be sustainable.
Otherwise, as will be described in the Current Challenges section below, the poor will
suffer (and have suffered) all the more as could the entire planet.

Biofuel farming does not necessarily mean, and should discourage, mono-
cropping applications. Multi-cropping biofuel crops with compatible food crops is an
acceptable agricultural practice within the industry. If abandoned, marginalized land is
identified and effectively utilized for cultivation of both crops, food stocks stand to
increase (J. Ogunwole et al. 2007).

Economic thinkers from Aristotle to de Tocqueville to modern economists reveal
that the success of a civilization is due in large part to the size, strength and persistence of
its middle class. Lack of development is linked to conflict as reported in the literature
(Terry Boswell and William Dixon 1990, 542; Chester Crocker 2003, 33; Robin Williams
1994, 66). Entrepreneurial enabling models, such as small-holder agricultural businesses,
help build a country's middle class. As demonstrated by Daron Acemoglu and James
Robinson (2005, 273-278) a strong, sizable middle class reduces the threat of repression
(rich repression of the poor) making conflict less likely. However, agro-industrial firms
appear to dominate the biofuel industry in the literature (Melinda Kimble, Marie-
Vincente Pasdeloup and Clifford Spencer 2008, 80), bringing more affluence to the
wealthy. The challenge will be finding out “... how to engage the poor” (Kimble,
Pasdeloup and Spencer 2008, 72) and “… how to best integrate all biomass resources in a
win-win relationship benefiting the poorest of the poor” (Kimble, Pasdeloup and Spencer
As stated by the U.S. Department of Energy, "The United States imports more than 60% of its petroleum, two-thirds of which is used to fuel vehicles in the form of gasoline and diesel. The demand for petroleum imports is increasing. With much of the worldwide petroleum reserves located in politically volatile countries, the United States is vulnerable to supply disruptions" (United States Department of Energy 2010, n.p.). Biofuels can be grown throughout much of the world, decreasing or eliminating the need to obtain energy from rogue nations. With many nations able to produce biofuel, the U.S. can exercise greater choice in what nations it will be able to purchase energy from.

Market Failure

A market failure within an economy is defined as a misallocation of resources that are not in the best interests of a given society (Todaro and Smith, 2006, 520). Biofuel's capability to reduce pollution, improve health, build energy stocks, provide economic development, and a host of other benefits all at potentially competitive prices to fossil sources is widely documented (United States Environmental Protection Agency 2002; McCormick et al. 2006, 29; National Biodiesel Board 2009; U.S. Congress 2009, 6; United States Department of Energy 2010). Given fossil fuel use and its dependency causes environmental damage, negative health impacts, and has a history of sending economies into shocks; biofuels have a clear societal advantage to fossil based fuels if the biofuel industry can produce in a sustainable manner. With these differences in mind, impediments to sustainable biofuel implementation in an economy provide the less initiated with the strong sense of a market failure. However, the reality of a handful of urgent challenges faced by the biofuels industry leaves biofuel implementing societies
with an entirely different impression which needs pragmatic resolution.

Resolving industry challenges and the market failure is not necessarily a matter of government action alone. Rather, the market can help be a corrective through consumer and industrial action working in partnership. Certification mandates can help make this a reality.

Current Challenges within the Biofuels Industry

The biofuel industry appears to have much to offer, yet it can be fraught with significant problems. Concerns and controversies surrounding this industry can be summarized as economic hardship on vulnerable populations and significant environmental damage. Environmental groups have uncovered strong cases of such controversial activities, at times concluding biofuel production is an ecological disaster. The findings of such groups are valuable in that they raise warnings with respect to serious problems that can become universal, disturbing trends. Unfortunately, in the rush for economic gain, the biofuel industry in most countries has taken the promise of biofuels down the path of social, economic, and environmental peril. Such perils are exemplified through the industry's track record as described below.

Economic

Aside from concerns over food shortages from using food agricultural biomass for biofuel production (the food versus fuel debates), there are concerns that enough food biomass could not be grown to fulfill demand for both food and energy production. For example, according to the World Bank, studies of the U.S. domestic biofuel industry reveal food crops are not likely to satisfy energy demands alone. These studies reveal that even if thirty percent of U.S. maize production could be used for ethanol it would
account for less than eight percent of U.S. gasoline consumption (World Bank 2007a, 71). Consideration of biofuel crop yields becomes a crucial matter if biofuels are to overcome economic barriers. The current focus on low yielding food crops for biofuels appears unsustainable.

Environment

Destroying pristine, biologically diverse landscapes to make way for cultivation of high demand biofuel crops with little concern for environmental consequences has occurred (Renner, Sweeney and Kubit 2008, 18, 123-4). A specific case was recently uncovered by the Rainforest Action Network (Rainforest Action Network 2010) involving mass rainforest destruction in Asia. Deforestation to develop land for biofuel cultivation is a concern that is addressed by certification program guidelines. The need for strong incentive is crucial for compliance with environmental expectations. Just having a certification program is no guarantee of the needed environmental conscientiousness.

The most concerning issue with respect to biofuel production drawbacks relates to byproducts. The primary byproduct of biodiesel production, for example, is glycerin. World demand for glycerin is currently a small fraction of what the biofuel industry has the potential of producing. In the worst case, if lack of comparable demand for glycerin becomes a reality, biofuel refiners will need to determine how to store or dispose of glycerin stocks in an environmentally friendly way. Calls for increasing research into more products that can use glycerin are already circling throughout industry and new glycerin uses and glycerin enhanced products have been discovered (Thijs Adriaans 2006; M.S. Punia 2007). With glycerin's nature being low toxicity, concerns are typically
with respect to the quantities developed. To be clear, however, environmental loss is assured with the dumping of quantities as small as those encountered through irresponsible home based refining efforts (see William Kemp 2006).

Social

Supplanting food production, compounding food shortage problems and rising food prices around the world (Derek Heady and Shenggen Fan 2008, 8; Mark Rosegrant 2008) continue to be a concern. Frustration abounds throughout the world regarding elevated food prices. Food riots in many developing countries have been a consequence of food shortages (see for example Saeed Shabazz 2008). The concern is to the point where the World Bank has called on developed nations of the world to lend a hand with feeding programs in the face of mounting unrest within impoverished nations. The president of the World Bank, Robert Zoellick, requested developed nations step up on their commitments for food aid to meet crises stemming from an estimated doubling of food prices (Harry Dunphy 2008). Price increases in food have been directly linked to the alignment of food crops to growing biofuel needs. According to the World Bank's World Development Report 2008 increases in food prices are directly related to corn's use for biofuels (World Bank 2007a, 70-1).

“Green, but not decent” wage type jobs for “exploited biofuels plantation day laborers” (Renner, Sweeney and Kubit 2008, 40) has been noted in the literature. Such ventures have worked to the effect of a net reduction in livelihoods. In extreme cases vulnerable small-holder farms have been expropriated by governments seeking to meet national biofuel production goals (Oxfam 2007, 1-3). Focusing on industrial development models that, despite a given country's commitment (or lack thereof) to labor
rights, leaves vast room for Pareto improvements for the very poorest citizens upon which the biofuel industry depends (see Kimble, Pasdeloup and Spencer 2008; Rachel Smolker et al. 2008).

The primary issue for policy is that if these and other challenges are resolved, biofuels will solidify its position as a strong supplement to fossil energy sources. Market failure is apparent should energy, economic, and social policy not focus support on maximizing the potential of this industry while the industry delivers on its promises for social welfare and environmental benefit.

Certification Programs Incentivizing Industry Sustainability

A way to tame the perils, helping ensure responsible activity in the industry, and maximizing the industry's benefits to all concerned is a focus of international political bodies, national governments, non-governmental organizations (NGOs) and the biofuel industry itself. A primary means to accomplish such ends is by setting sustainable production standards through certification programs. Certification programs seek to determine at what point actors within the biofuel industry are operating in an economically, environmentally and socially responsible (or deleterious) manner. A key to creation of such standards is to determine what responsible activity is within the industry and provide a way participants in the industry can be measured along that standard. Another key to the success of certification programs is to provide a mechanism whereby program adherents can demonstrate “sustainability”; particularly that the impact the biofuel industry is having must prove itself to be able to achieve “sustainable development.” Proper incentivization fosters adherence.

Sustainability analysis, although still in its infancy, provides a method to start
quantifying certification program contribution to responsible activity in the biofuel industry. Yet, it is important to note that no certification program can be created that is without weak points. Vigilance in the industry is essential to prevent widespread social and environmental catastrophe. Certification programs such as the Council on Sustainable Biofuel Production (CSBP) and the Roundtable on Sustainable Biofuels (RSB) provides the biofuel industry with a significant, positive start in guidance for responsible action. Given continued biofuel industry growth, however, existing certification guidelines can hinder sustainability by limiting economic development and opening loopholes to widespread environmental damage. RSB’s and CSBP’s programs are a focus of this work. Potential weak areas in these guides are presented in chapters six and eight.

Certification criteria can be evaluated to determine objectively whether criteria can contribute to sustainability and to what extent. The provision of quantitative sustainability measures will enable an objective element into sustainability evaluation. In the end, the goal of all stakeholders is to develop guidelines that can be reliably depended upon to provide valid measurements of responsible, sustainable activity within the biofuel industry.

Contribution

What is missing from the literature is a quantitative analysis of the potential impact the biofuel industry has on country level sustainable development, either with or without the influence of certification programs. There is currently (at the time of this writing) no sustainable measurement tool, or model, used by the industry to determine aggregate, quantitative impacts of biofuel production on country level sustainable
development. This study seeks to provide an initial approach by which sustainable development in the biofuel industry can be quantitatively evaluated using the World Bank sustainable development model as a theoretical base.

Current sustainability analysis is conducted at a macro and broad industrial sector level. Specific industrial sectors within a country can have significant impact on macro level sustainability performance. Macro level analysis can average out sustainable influences of individual industries if analyzed as a whole. By applying sustainability analysis to large industries it is possible to determine their contribution to a country's specific sustainability goals, allowing for policy development, industry self-regulation and informed consumer involvement.

The biofuel industry, in particular, has far reaching sustainability implications for countries choosing to proceed toward a measure of energy independence. The industry has strong implications for economic development among impoverished developing world citizens. It also has demonstrated strong potential for social, environmental and economic harm. As such this industry is ripe for sustainability evaluation in order to harness its benefits within a framework of objective evaluation that can alert policymakers and industry stakeholders to possible abuses.

Dissertation Components

The following chapter will examine the impact of sustainability on economic growth. Chapters III and IV will provide a detailed look at sustainability theory as well as a closer look at the World Bank model. The literature will be consulted to determine what sustainability is and how it is measured. How biofuel production, using the World Bank’s sustainability model as a guide, impacts country level sustainability will be the
subject of Chapter V. Chapter VI will describe current certification programs revealing their commonalities and compatibilities with World Bank sustainability indicators. Not all certification principles have measurable criteria that can be directly linked to World Bank model variables. Given the further work being conducted on certification criteria and the lack of certification performance data, estimations will need to be conducted in order to determine the biofuel industry’s contribution to sustainability at the country level. These estimations will primarily use World Bank data and data from the Energy Information Agency of the U.S. Department of Energy to determine if country level biofuel production is contributing to sustainable development. Chapter VII will also propose an initial model for assessing biofuel sustainability in a more precise manner, discussing what data is needed from certification programs. Chapter VIII discusses sustainability implications for development and initial quantitative results of biofuel industry sustainability measurement. Chapter IX concludes the work with biofuel policy, measurement and certification improvement recommendations.
CHAPTER II
SUSTAINABILITY AND ECONOMIC DEVELOPMENT

Sustainable development has been defined in this work through the Brundtland Commission as development that meets current needs without compromising the needs of future generations (United Nations 1987, 54). Sustainability has three primary domains: economic, environment and social. Should an entity be considered “sustainable” the value for the individual domains can begin to be understood. What this chapter seeks to investigate is sustainability’s link to economic development. If an entity is sustainable, what does that mean in terms of economic growth?

Terminology

A distinction needs to be made between economic development and economic growth as the two terms, although often used together, are not the same. Economic growth refers to increasing output or income of a given economy. Economic development has more to do with growth in the standard of living (Daphne Greenwood and Richard Holt 2010, 3). What makes sustainability an important concern for the human experience is that it does not simply look at output or income. Should the standard of living of stakeholders be subtracted from growth (impacting that same group of stakeholders) yielding a net negative result, the growth becomes unsustainable development. Growth can make a positive or a negative impact on the human condition. The important process for policymakers is to balance both. Increasing income is important for consumption of those goods that are required for a given standard of living. Economic development that comes with troubling social or environmental outcomes, however, is not responsible growth (Greenwood and Holt 2010, 3, 10).
Declining Sustainability Hinders Economic Growth

Illustrations help describe the previously noted points. Todaro and Smith (2006) in a case focused on the Philippines stated that the outcomes of that nation’s industrialization, movement toward urbanization and economic development lead to, “such problems as air and water pollution; depletion and losses in flora and fauna species; greenhouse gas emissions; and biodiversity imbalances” (Todaro and Smith 2006, 504). The resolution of these drawbacks to development has been the focus of much policy effort in that country. Further, the authors provide a table of several environmental problems drawn from a World Bank study published in 1992. The table reveals that environmental problems, often triggered by economic activity, have direct and negative consequences on growth (Todaro and Smith 2006, 477). Through these examples the link to unsustainable economic activity and damage to growth is well illustrated. Water pollution and water scarcity resulting from economic activity, for example, is linked to health problems resulting in illness and death. A resultant loss of productivity is well understood. The same pollution results in declining fisheries, and economic activity is hampered that depends on adequate water sources (Todaro and Smith 2006, 477).

Such concerns lead to the need for corrective policy. Economic policies that promote sustainable development practice include, as pointed out by Joseph Stiglitz and Carl Walsh, “elimination of energy subsidies and agricultural subsidies that encourage farmers to use excessive amounts of fertilizers and pesticides” (Stiglitz and Walsh 2006, 601). Policy, however, must not be construed as only existing at the highest levels of government. Rather, local governments have tremendous impact on issues that can affect stakeholders from a local to a global scale. Greenwood and Holt remind their readers that
broad scale destructive events may have their source in localized action. The necessary sustainable practices to prevent quality of life or sustainability loss may see greater influence when connected to results that are at the local levels (Greenwood and Holt 2010, 5).

Increasing Sustainability Impact on Economic Growth

It is apparent that economic growth can bring about social, environmental and economic harm. For all its benefits, can sustainable development bring about economic growth? This question has been asked by numerous authors in the literature. This work briefly reviews two. Giedrė Lapinskienė and Kęstutis Peleckis (2009) examined the link between environmental indicators and GDP in three developing Baltic countries and six developed European countries. The authors discover a positive correlation between environmental indicators that suggest increasing pollution and GDP growth in developing countries. The opposite is found in the developed countries (Lapinskienė and Peleckis 2009, 110-1). This suggests an environmental Kuznets effect. The authors conclude that the findings suggest environmental policy is being implemented more effectively in developed countries than in developing countries (Lapinskienė and Peleckis 2009, 113).

In another study by the same first author a limited number of sustainable development indicators were used to determine that a strong and significant impact can be found between these indicators and real GDP. Similar to the first study, the authors find a division between developed and developing economies. “Only the increasing economic power allows the states to invest in social and environmental development” (Giedrė Lapinskienė and Manuela Tvaronavičienė 2009, 210). Conclusions of these two studies point to policy and economic strength as being intervening variables in the
The Importance of Policy and Indicators

Policy needs to be supported by indicators. Alexandria Frawleya and Ronald Gunderson (2009) discuss the need for indicators to track effective policy for development. Also focusing at the local level, their case study examined sustainable development policy and indicators at the city of Flagstaff, Arizona and its surrounding county. The authors expressed their concern about local development projects in the past relying solely on a limited form of cost-benefit analysis before making a go or no-go decision. Such narrow analyses ignore pressing social and environmental need in the face of growing environmental decay and social welfare concerns (Frawleya and Gunderson 2009, 203). Progress toward sustainability goals can be measured and applied to policy analysis as revealed by the authors’ case. Indicators are used, quantitatively and qualitatively measured, to evaluate project performance to sustainability goals within all three domains of sustainability: social, environmental and economic (Frawleya and Gunderson 2009, 197). Development of specific indicators is up to local needs, reflective of local values (Frawleya and Gunderson 2009, 198). Specific policies were linked up to measures that reflected the outcomes of programs. Affordable housing is one such policy touching the domain of socio-economic sustainability. Indicators of local median wage ability to pay for housing are used to evaluate policy and socio-economic sustainability (Frawleya and Gunderson 2009, 198).

Viable indicators for development are suggested in Greenwood and Holt (2010). The authors describe the indicators as having impact on the quality of life or sustainability of some category of capital stocks. The indicators are separated into
categories that expand on the three domains of sustainability namely economic; environmental and land use quality; health and public safety; civic and social participation; cultural and education; and transportation and mobility (Greenwood and Holt 2010, 152-5). Indicators such as these are used to measure the variation in the (locally relevant) capital stocks they represent. Measurement should reveal depletion or enhancement of these stocks in order to determine if the income or quality of life these stocks provide will be available for future generations to enjoy (Greenwood and Holt 2010, 146).

Again, local indicator “projects,” as termed by Greenwood and Holt (2010), are important given different communities have different characteristics and needs. Making indicator projects work is a challenge requiring the choice of indicators that a given community can agree to, being able to collect relevant data and having the strength to build and enforce policy based on the outcomes of indicator measurement (Greenwood and Holt 2010, 159-60). These challenges are similarly faced on a national and international scale. Sustainability indicator development, implementation and policy creation does not need to be limited to localized application, only. It can be utilized on a country level given some indicators of quality of life are certainly universal across borders (such as air and water pollution). Utilization can also be focused at the industry level. Relevant to this work, the biofuel industry can develop a set of indicators of sustainability that will allow it to be measured on a macro country-by-country and micro enterprise-to-enterprise level. For example, the food versus fuel debate has strong implications for social sustainability. The use of an indicator that tracks the impact of biofuel production on food production is very relevant in determining the sustainability of
development that the industry can bring. Consistent measurement will allow for comparisons on a macro and a micro level. Biofuel entities can also be evaluated at the local level for the same reasons as suggested by Greenwood and Holt. Sustainability analysis at one level is no substitute for another level. Both are critical.

Conclusion

In this brief chapter a closer look at sustainability’s impact on economic growth and development is presented. With an understanding of this broader context the importance, place and influence the biofuel industry has within sustainability and economic growth can be understood. As the case is made throughout the rest of this text, biofuel production has the opportunity to positively impact all three domains of sustainability which, in and of themselves, can further add to economic growth and development opportunity. The question is if biofuel entities will embrace good sustainability practice to ensure all domains of sustainability and economic growth can be positively accounted for.
CHAPTER III
SUSTAINABILITY THEORY

The notion of sustainability has existed for millennia in different forms and within different cultures. The normative, philosophical foundations of sustainability, in the sense of sustainability's focus on inter-generational well-being, have roots in ancient thinking. These roots stretch at least as far back as Aristotelian philosophy of citizenship (John O’Neill 2006, 159) twenty-three centuries ago. Early Native American philosophy, many centuries prior to Aristotle (Barry Pritzker 2000, 52), reflected the necessity of care for Earth and kin to the benefit of all living entities (Trudy Griffin-Pierce 1992, 26-7). In more recent centuries economists and other scientists living as far back as the Industrial Revolution (if not further) warned about the limited nature of natural resources and challenges societies will face if these resources are not managed well (William Nordhaus and James Tobin 1972, 522). Foundational elements of modern, empirical treatment of sustainability and its theories have roots in the early part of the twentieth century. As a practical limitation, this chapter will limit review of the evolution of modern empirical sustainability to the last several decades. Sustainability concepts are presented first, prior to describing the development of modern sustainability thinking, in order to serve as context for explanations of the theories that follow.

Sustainability Concepts

Sustainability, specifically sustainable development as a term and a concept, made its first widely published appearance in 1980 as part of an International Union for the Conservation of Nature and Natural Resources study on natural resource conservation and development (Pezzey 1992, 1). Preceding this report is the often quoted, normative
definition of sustainability developed by the Brundtland Commission of the United Nations: “... development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (United Nations 1987, 54). In keeping with this definition and expanding on it from a measurable standpoint, “most models of sustainability have at their core the notion that there must be intergenerational equality within the distribution of resources and consumption and that utility, taken to mean quality of life, should not decline” (Pezzey 1992, 48). Although many definitions of sustainability exist, the above definitions will be used in this dissertation.

Deepening the Brundtland definition from the economic perspective, sustainable development is non-declining utility (Kirk Hamilton and Michael Clemens 1999, 334). This allows a reformation of the above Brundtland definition to consider that the utility experienced by one generation should not compromise the ability of future generations to enjoy similar, if not at least the same, levels of utility. To enable sustainability, an economy needs a stock of resources (wealth) that produces material to meet human needs (consumption) and a means to maintain stocks of those resources (through investment or “genuine savings”) in a non-declining manner (taking into account population variations and technological progress). To the extent an economy accomplishes this provides evidence of sustainability. In a sense, sustainable development is seen as a form of portfolio management of a given economy's assets (Hamilton et al. 2006, xvi, 14, 56). This expanded description of sustainability helps frame the analysis that follows this chapter.

The goal of sustainability may not reasonably be the maintenance of a particular level of per capita consumption or utility (Pezzey 1992, 45). Rather, its increase, by
some measure, may well become the goal of a given population group, particularly with respect to impoverished regions. On the other hand, declining consumption may be required in more developed economies where a constant, high level of consumption cannot be sustained in the long run. Conservation, and the setting of a new standard of utility and consumption levels, may be required (at a minimum) to reduce waste.

As is evident in the literature review to follow, sustainability has three primary domains: economic, environmental and social. Each domain must be addressed relative to the context whereby sustainability is applied. The lack of sustainability in any one domain may render the greater context under scrutiny to be “unsustainable.”

Development and Origins of Sustainability Analysis

Literature reviews covering the evolution of sustainability analysis point to different combinations of published works in order to explain the path sustainability analysis took in its development. It is beyond the scope of this work to examine each path described in the literature. As a practical limitation, the more common, well recognized works will be examined in this brief summary of sustainability theory development. The history of modern sustainability analysis is frequently acknowledged in the literature as starting in the early portion of the twentieth century. Although most early quantifiable measurements of economic development begin with familiar economic variables, sustainability literature frequently points to its birth with the first widely recognized analysis of non-renewable resource optimization. Sustainability theory builds on economic development analysis and neoclassical resource optimization through the inclusion of ecological and human welfare variables, constructing the empirical forms sustainability analysis has today.
Early Contributions toward Sustainability Analysis

Within the literature some (Geoffrey Heal 2007, 8) believe the beginnings of empirical sustainability analysis rest with Harold Hotelling's 1931 work on the economics of non-renewable resources. Hotelling's own work, however, references earlier works that discuss policy measures needed to restrict the usage of scarce natural resources as a means to improve social welfare (Hotelling 1991, 281). Emanating from Hotelling's original 1931 work is the widely recognized “Hotelling Rule.” This rule states that, in contexts of free competition, absent of complicating factors such as production waste, a given non-renewable resource's discount rate should be set at the market interest rate in order to maximize the present value of the resource over the life of its extraction. The market interest rate functioned as a discount rate in optimality models used to determine the length of time a set quantity of a given resource can be extracted to maximize social welfare (Hotelling 1991, 285-7). Although a helpful start to sustainability considerations, this rule does not tackle issues of substitutions for the given natural resource or potential effects on society from the mounting loss of the given resource. It was, however, a way to quantify the economic value of a resource under free market conditions while calculating the maximum utility obtained from such an approach. Mathematical formulas to quantify sustainability build upon integrals present in works such as Hotelling's.

With the world's attentions turned to economic depression and warfare, further substantial contributions to sustainability analysis would arguably need to wait until the 1950s. During this time period changes to national income accounting were suggested. The intent of these changes was to bring country level economic outlooks into account
for the impacts of environmental damage and natural resource depletion. Karl-Göran Mäler confirmed that such “green accounting,” which was the subtraction of pollution damage and natural resource depletion from national income, has been around since the 1960s (2007, 63). A “concerted effort” to green national accounting at the World Bank began in the 1980s (Susmita Dasgupta et al. 2008, 6). The effort to include natural capital (resource) considerations was a departure from common economic growth models which considered national income variables to be primarily composed of man made capital and labor as influenced by savings (as needed) and technological advancement (Pezzey 1992, 3, 6).

Within that same decade the foundational element of measure used to determine sustainable income (or growth) of an economy came under scrutiny. Mäler (2007, 64-5) notes Paul Samuelson's 1961 article (“The Evaluation of 'Social Income': Capital Formation and Wealth”) that first brought wide attention to Net National Product's (NNP) limitations as a consistent measurement of national income due to changing intertemporal prices. Samuelson called for a more “wealth-like” measure to be used instead when measuring national welfare. It was not until Martin Weitzman's 1976 article “On the Welfare Significance of National Product in a Dynamic Economy” that such a wealth measure was proposed in the form of the present value of discounted future consumption (Mäler 2007, 66; Weitzman 1976, 156). Weitzman described a nation's capital beyond “the usual equipment, structures, and inventories. Strictly speaking, pools of exhaustible natural resources ought to qualify as capital, and so should states of knowledge resulting from learning or research activities” (Weitzman 1976, 157), calculated on a per capita basis.
In 1972, William Nordhaus and James Tobin also discussed the need for a better national welfare measurement. They pointed out that sustainable consumption, as opposed to GDP (a production measurement), should be used as a gauge for the welfare of a population (Nordhaus and Tobin 1972, 512). Nordhaus and Tobin also noted that even with consumption being measured other externalities, “socially productive assets” (under which they include the environment), exhaustible resources, and “ecological disturbances” need to be accounted for in order to provide a full measure of a population's welfare (Nordhaus and Tobin 1972, 521, 524-5).

The Beginnings of Comprehensive Sustainability Analysis

In 1983, a call was made through the UN General Assembly to build country scale strategies for achieving long-term sustainable development. This call was made out of concern for the world environment's growing deterioration and the consequences such deterioration could bring. The desired outcome of the investigation started by this call was

… to recommend ways concern for the environment may be translated into greater co-operation among developing countries and between countries at different stages of economical and social development and lead to the achievement of common and mutually supportive objectives that take account of the interrelationships between people, resources, environment and development.

(United Nations 1987, 11)

A report regarding sustainable development strategies for the new millennium was developed by the Commission (initially known as the Brundtland Commission after Gro Harlem Brundtland who chaired the efforts to produce the report), given the title of “Our Common Future” and was released in the year 1987 (United Nations 1987, 1). From this report, a widely recognized definition of sustainability was presented: “... development that meets the needs of the present without compromising the ability of future generations
to meet their own needs” (United Nations 1987, 54). This definition of sustainability and the report's linking of development with the environment became one of the foundational and leading elements toward the creation and direction of today's United Nations Environment Programme (UNEP 2009, 10).

Robert Solow expands and clarifies the Brundtland definition of sustainability stating that:

The duty imposed by sustainability is to bequeath to posterity not any particular thing - with the sort of rare exception I have mentioned - but rather to endow them with whatever it takes to achieve a standard of living at least as good as our own and to look after their next generation similarly. A sustainable path for the economy is thus not necessarily one that conserves every single thing or any single thing. It is one that replaces whatever it takes from its inherited natural and produced endowment, its material and intellectual endowment. What matters is not the particular form that the replacement takes, but only its capacity to produce the things that posterity will enjoy. Those depletion and investment decisions are the proper focus. (Solow 1993, 168)

Solow's statement leaves it up to future generations to determine what endowment substitutions (“replacements”) take place, focusing instead on current efforts to maintain a volume of assets in the hopes that such volumes will allow the capacity to produce at least as good of a standard of living for future generations. Solow (1993, 167) credits the findings of the Brundtland Commission as the start of the literature's current focus on sustainability analysis.

John Pezzey (1992, iii) stated that the mutually exclusive treatment of the environment and of economic development by governments and development agencies came to an end in the 1980s. As an outcome of debates up to that time it became very clear that environmental issues have a strong place in considering whether development can even succeed at all in the long term. In 1992, environmental economics became a primary area of study at the World Bank (Dasgupta et al. 2008, 4). The multi-domain
nature of sustainability began taking shape.

*John Pezzey and Neoclassical Economic Contributions to Sustainability Modeling*

With respect to sustainability analysis, the application of a number of tools and theoretical elements of neoclassical economics made a contribution to the measurement of sustainability. Refinement of those measurements produced a method whereby quantitative analysis of sustainability was enabled in its current state. Details of the early formulaic elements of these sustainability measures follow in the next subsection. Although many contributors are present in the literature, John Pezzey’s work is of focus due to his thorough approach to sustainability modeling at the time (early 1990s).

Pezzey (1992, xi-xii) examined sustainability within a neoclassical economics framework, approaching sustainability as a question of how to optimize resource use across generations. As such, Pezzey investigated optimal growth models as a way to describe and measure sustainability within an economy and point toward relevant policy development. Optimality, used in this case, is the sustainable path that provides the highest present discount value of consumption (or utility). Sustainability, however, functions as a constraint as well as an optimizer (Pezzey 1992, xi, 18), placing a limit on current asset consumption in favor of the needs of future generations. Weaving both elements together, current and future consumption is optimized within a set of existing constraints. Optimal control theory was utilized by Pezzey to demonstrate that a steady growth in consumption can be made possible when the rate of technological advancement exceeds the discounted utility rate (Pezzey 1992, xii). With respect to renewable resources, Pezzey's work demonstrates that renewable resources, adjusted for population growth and utility discount, can achieve optimality if initial resource stocks are sufficient
to meet the needs of the initial population (Pezzey 1992, xii-xiii).

Pezzey acknowledges that neoclassical economics alone does not provide realistic models of sustainability due to oversimplification, limited generalizability, lack of numeric data that can quantifiability determine a state of sustainability in any given economy, difficulty in accounting for changes in perceptions of utility (such as changes to culture and the effects of “social disruption” over time), and the realization that substitutions (freely conducted such as depleting ecologically sensitive resources, substituting them with produced capital) can draw moral consequences, not to mention that such substitutions may not be physically possible to begin with. Commonly accepted optimality formulas used in neoclassical economics encounter problems with assumptions, primarily those that consider intergenerational preference as static (Pezzey 1992, 2, 9, 11, 49). Despite these limitations Pezzey's findings did provide an initial way to analyze sustainability in a manner that began to inform policy development (Pezzey 1992, 49).

After demonstrating that free markets may not always attain sustainability Pezzey comes to the following conclusions, stating policy action is required. Unsustainable activity may be caused by slow technical progression and open, unconstrained access to environmental resources. Poverty itself can be further perpetuated by environmental decline. The opposite is also possible. The solution Pezzey proposed to these concerns is policy that helps regulate environmental use, slows the pace of degradation and ensures natural assets remain available for future generations. Pezzey noted that effective policy tools toward such goals include subsidies for conservation, clearly defined environmental property rights, the enforcement of such rights and creation of depletion taxes. With
respect to policy that endeavors to affect intergenerational equality, conservation of resources is required. To meet consumption requirements of future generations, output needs to be constrained through initiating policies that increase prices (Pezzey 1992, ix, xii).

Building a Wealth Estimate for Sustainability

The wealth of a people group is the sum total of the resources and assets which can be used to produce goods for consumption. If a people group is running down such assets, production of consumables will decline. In the case of population decline, such a circumstance of reduced consumption may be a critical concern where a reduction in population is less than the reduction in production of consumption goods. Such asset declines signal that an economy may be on an unsustainable path (Hamilton et al. 2006, 19). Changes to an economy’s wealth (given population variation, technical progress and potential over or under consumption patterns) become the foundation by which its existing practices can be discernible as sustainable or unsustainable.

In order to make wealth a measurable, tangible tool for an economy's evaluation, a new way of calculating wealth was needed. David Pearce has been credited by Mäler (2007, 67) as the first to describe a wealth measurement (suggested earlier by Samuelson) as he and his colleagues worked to develop an index of sustainable development which closely followed the Brudtland Commission's widely acknowledged definition of sustainability. Pearce suggested that each successive generation of a people group should inherit no less a stock of man made and environmental assets than the previous generation. In a sense their definition did not treat environmental and man made assets separately, thus suggesting substitutability between these assets (Mäler 2007, 71). (The
issue of substitutability of these assets is controversial, warranting separate consideration of this topic in the next subsection.) In 1993, Pearce and his colleagues added that a country’s wealth estimation required per capita measurements so that wealth dynamics can take population changes into account. Pearce and his group also stated that educational expenditures belong in the capital (asset) account instead of being considered a consumption item given education’s contribution to human capital (Mäler 2007, 70-1).

In the early 1990s studies were beginning to appear that numerically examined the price society and economic progress could pay as a result of environmental decay and natural resource depletion. Pearce was noted by Giles Atkinson and Kirk Hamilton (2007, 44) as suggesting these initial studies were helpful but “ambiguous” in that the measurements used did not provide a clear indication if development was sustainable or not. According to Solow, most sustainability discussions in the literature up to the early 1990s had been normative in nature with comparative little pragmatic application to policy (Solow 1993, 167).

Solow (1993, 162) introduced a train of thought leading to an understanding of how sustainability measurement came into form in the late twentieth century as well as the overall need for such analysis. Solow starts to build the case for sustainability analysis by discussing the limitations of using GDP as an insight into the health of an economy. Solow notes GDP provides insights into employment changes and demand but it does not reveal how efficiently a country uses the assets at its disposal for the well being of its people. A nation that wastes resources or places considerable, undo wear on its assets accelerates depreciation compared to a country that is careful with their resources. The greater the depreciation, the sooner the given assets will no longer be
productive. In order to grasp the impact of such misuse on national welfare, measurements such as net national product were put in place (Solow 1993, 162-3).

For similar reasons, the misuse of natural assets required for production and national welfare should also be accounted for. Wear and tear on the environment also needs to be accounted for as initially demonstrated by Pearce in the early 1990s (Atkinson and Hamilton 2007, 52; Pearce and Atkinson 1993, 105-6). Pollution, for example, not only causes wear on productive assets, it also harms the well being of people (Hamilton et al. 2006, 38). “Stock pollutants” that damage assets and can accumulate in the environment and “flow pollutants” which cause damage as long as an asset is exposed to the pollutant (such as the impact of noise on social welfare) are considered in the literature (Atkinson and Hamilton 2007, 55). Negative impacts to productive asset values are made by estimating emission costs based on the present value of the pollutants' net future impacts. These deductions are known in the literature as “marginal willingness to pay” for each unit of pollution, correcting for transboundary pollutants (Atkinson and Hamilton 2007, 52, 54, 58).

At this time two measures of wealth were beginning to take hold. One calculated wealth through the inclusion of environmental, human and produced assets. The other determined the wealth needed for future generations through discounting future consumption. Assessing the two will determine the sufficiency of wealth. The building of wealth stocks to meet future needs, through the formalized term “genuine savings,” would be another breakthrough (described after the next section) in sustainability thinking. After developing initial methods to calculate wealth, issues of natural asset depletion needed attention. Natural assets can be depleted at alarming rates to make
room for human consumption and produced capital. The next puzzle to solve, inclusive of Hottelling's and Hartwick's rules (explained below), was if and to what extent natural and man made assets could be substituted for one another.

**The Substitutability of Natural and Human Made Assets**

Substitution of man made capital for environmental resources is not easily conducted. Successful application of economic valuation to natural resources, despite the best possible intentions of substitution, is the source of much debate. Hamilton (2006, 101) exemplifies this debate by considering ecosystems. If the entire ecosystem is destroyed what can be substituted for it? The substitution of some form of physical capital is not possible if the very basis for it, ecosystems, no longer exists. In another example offered by Solow (1993, 171) some forms of our natural surroundings can be argued to have intrinsic value and are not readily open to substitution such as the major national parks of the United States. Geoffrey Heal indirectly makes a similar case using the example of biodiversity. “Every time a species is driven to extinction, this stock falls in an irreversible way. We are depleting that stock and do not fully understand the consequences” (Heal 2007, 10). Lacking an understanding of consequences limits our ability to assign accurate economic value. Without an understanding of economic value, substitution of natural assets remains a debatable concept.

As Atkinson and Hamilton (2007, 46) point out, the past efforts of “greening” the national accounting system is neutral toward substitution. Such neutrality does not resolve concerns surrounding harm to critical natural assets or potential catastrophes associated with their depletion by unfettered substitution for man made assets. Assigning precise economic value to critical natural assets is quite complex and has remained hotly
contested and unresolved in the literature for decades. Although future breakthroughs are required to form precise valuations a group of environmental and economic professionals began to weave an approach to the dilemma two decades ago in an attempt to place a framework around the more contentious portions of the debate.

Mäler (2007, 65) notes that ecosystems have no market value requiring different approaches to assigning value and price. By the early 1990s general approaches to that challenge were beginning to be worked out. Pearce and Atkinson (1993, 103) begin to put forward an answer by introducing the concepts of “weak” and “strong” sustainability. With respect to “weak sustainability” assets, the substitution of some environmental assets (“degradation”) for the production of man made assets is acceptable as long as “the overall capital stock should be non-decreasing”. Other environmental assets are categorized as “strong,” or “critical natural capital,” which are assets who's degradation in any amount would be considered unsustainable (Pearce and Atkinson 1993, 106).

Pezzey (1992, 13) brings up the similar notion of “deep ecology ethic” which also factors into considerations for environmental asset preservation. This ethic states that living organisms have an existential right to a sustained existence outside of any apparent economic value. In addition, Pezzey's substitution model comes up with further constraints within the context of substitution. At a point, natural resource depletion has a boundary at which damage is “irreversible and possibly catastrophic” (Pezzey 1992, 49). In such a case a natural asset that may have been known as “weak” may then prove to be “strong.” According to Atkinson and Hamilton (2007, 46), if a portion of a given natural asset must be maintained in order to preserve utility the criteria of strong sustainability applies. Mäler (2007, 72) points out the necessity for future research to adequately define
such “critical” assets and determine the disposition of potential substitutability of critical natural capital. Pezzey (1992, ix) offers a different categorization, noting that natural capital should be categorized as “significant, essential or substitutable.” Such categories are helpful in concept, suggesting that some assets need to remain outside the bounds of substitutability. What is lacking, however, is adequate valuation and measurement of what can be substitutable.

There is another consideration for substitutability as pointed out by Mäler. Mäler reminds his readers that myopic exchanges of environment for production hinder responsible resolution to the above debates. Mäler states that if there is no substitute for a given resource that creates a particular consumption good the conclusion that there is no substitute for the resulting utility is not valid. Expanding this thought, the utility obtained from a good produced by a strong (or even weak) asset could very well be substitutable in some alternative manner (Mäler 2007, 72).

Statistically, substitutability between natural and produced resources have been demonstrated by Hamilton (2006, xviii, 104) and Anil Markandya and Suzette Pedroso (2005, 9) in a purely mathematical sense. Nested elasticity of substitution production functions are used by both authors with resulting elasticities of one or greater for land resources (crop land, pasture land, and, to a limited extent, protected areas) demonstrating substitutability can be obtained in a limited formulaic sense. Another result of their analysis, as stated by the authors, is that natural endowments are not necessarily critical for development (a finding somewhat different from that of Pezzey, 1992).

**Intergenerational Equality and Genuine Savings**

Sustainability, as defined above, needs to account for production of, and thus
consumption by future generations. The use of non-renewable assets, for example, can build consumption for the current generation while ignoring the needs (or well being) of future generations. As such, future well being could be placed in doubt. This issue is addressed by sustainability considerations.

After using a portion of non-renewable asset endowments to produce goods for current consumption what is not consumed can be reinvested in assets that will be utilized in future production. This is the essence of the Hartwick principle of resource rent reinvestment for the benefit of future generations (John Hartwick 1977, 972). Rents received from natural resource harvesting can be invested into renewable assets that can provide a minimum level of consumption per capita for future generations. If natural resources are consumed and not invested, future generations will lose out once the natural resources are completely consumed. Reinvestment, or savings, has been demonstrated as having a positive effect on future economic performance (Hamilton et al. 2006, 71). As such, this savings should “equal the change in future well-being, specifically the present value of future changes in consumption” (Hamilton et al. 2006, xvii). Accounting needs to be made, within national accounts, which “properly charges the economy for the consumption of its resource endowment” (Solow 1993, 163-4). Such charges will give a more accurate picture of well being. With respect to policy, changing genuine savings rates and productive asset portfolio management will help policy makers set appropriate depletion rates of non-renewable assets (Atkins 2007, 46), keeping the Hartwick rule noted above firmly in mind. Non-renewable resources can be accounted for by measuring each asset’s discounted value in terms of economic profits over the asset’s lifetime (Hamilton et al. 2006, 147). Depletion, or reductions in the overall value of a
given asset, is the measure of the cost of resource extraction (Atkins 2007, 46-7).

Important assumptions are evident and detailed by Hamilton and Solow. Ideally, nothing is wasted in production. Efficiency, and at least equal sharing of resources for future generations, is to be realized (Solow 1993, 165). Important to maximizing production over the long term is to efficiently manage all resources (assets - including the renewable and non-renewable) necessary for production, and ultimately, consumption. Investment, non-renewable resource depletion and environmental use (impact) decisions are to be made such as to maximize production over time. Given wealth producing assets of a country can be discounted over time the result of such discounting is a total wealth measurement that estimates the present value of future consumption (Hamilton et al. 2006, xiv, 25; Solow 1993, 165).

Work continues with respect to accounting practices that gather environment and natural resource asset valuation and pricing. Mäler (2007, 71) notes several international efforts are still ongoing to accomplish such a task. Accounting processes that provide empirical data used to demonstrate lack of substitutability are also waiting to be fully developed (Mäler 2007, 73).

With the construction of a better measure of economic well being, policies for sustainability can also improve. Successful application of sustainability requires policy. As Hamilton (2006, xix) warns, policy makers that help forge the direction of environmental standards and resources must be aware of their economic consequences. In addition, economic policy makers must weigh the sustainability of their decisions in light of impacts to the environment given environmental links to production and overall well-being (Hamilton et al. 2006, xix). With respect to replenishment of productive asset
stocks:

We know the rough magnitude of this requirement. The appropriate policy is to generate an economically equivalent amount of net investment, enough to maintain society’s broadly defined stock of capital intact. Of course, there may be other reasons for adding to (or subtracting from) this level of investment. The point is only that a commitment to sustainability is translated into a commitment to a specifiable amount of productive investment. (Solow 1993, 171)

In 1999 and 2006, Kirk Hamilton et al. began to demonstrate how to measure, on a country level, changes to wealth over periods of time. The term for this calculation, “genuine savings,” was brought to the literature by Pearce and Atkinson in 1993 as well as Hamilton in 1994 (Hamilton et al. 2006, 35). Policy implications for genuine savings calculations reveal that maintaining genuine savings rates that are both positive and growing slower than interest rates will lead to increased consumption (Atkinson and Hamilton 2007, 44, 46) and thus enhanced utility and social welfare. The calculations used, however, are not a complete measurement of genuine savings but are a good start, demonstrating enough significance and robustness to motivate the World Bank to regularly compile these numbers (World Bank 2010). Genuine savings, along with its respective wealth calculation, are utilized in this work. The most recent of these calculations are detailed in the fourth chapter.

Measurements of Sustainability

Kenneth Arrow et al. (2004, 148) notes, as does Hamilton et al. (2006, 15), that recent measurements of sustainability often use utility of consumption as a base measurement rather than asset based wealth. Such a measurement is considered social welfare related, specifically “intertemporal social welfare.” Others use measurements that determine if an economy is able to maintain living standards. This work uses asset based wealth, affected by genuine savings, following after the World Bank model to
determine sustainability. A comparison of these approaches will be discussed in Chapter IV where the World Bank model will be explained in detail. Early sustainability measurements are as follows.

Pezzey (1992, 5, 6, 14) starts with a production function of:

\[ Q = Q(K,L,T,R,S,P) \]

where \( Q \) is production, \( K \) is produced capital (equal to new capital minus depreciation), \( L \) is labor productivity (affected by a function of consumption, natural resource stock and the negative impacts of pollution), \( T \) is technology (equal to new technology minus depreciation), \( R \) is aggregate resource flow (renewable and non-renewable resources), \( S \) is aggregate natural resource stock and \( P \) is the growth of pollution stock (as measured by calculating the rate of waste disposal subtracted by natural absorption of pollution and human clean up expenditures). All functions are continuously differential and population is set to be a constant (Pezzey 1992, 5, 19). The formula is altered to reflect production by reducing the last two variables to environmental aggregate effects on production \( E_1 \), finishing with the following production function (Pezzey 1992, 5):

\[ Q = Q(K,L,T,R,E_1) \]

Pezzey also examines the status of utility or social welfare:

\[ U = U(C,S,P) \]

where \( U \) is utility, \( C \) is consumption, with \( S \) and \( P \) measured as it is in the formula above. This utility function reduces to the following function:

\[ U = U(C,E_2) \]

with \( S \) and \( P \) also replaced to reflect environmental aggregate effects, but in this case welfare, or what the literature refers to as “environmental amenity” \( (E_2) \), is used (Pezzey
1992, 6, 14). Focusing on the neoclassical perspective, substitutability is next formulized.

Pezzey points to the use of a Cobb-Douglas production function to begin demonstrating substitution in a formulaic manner (Pezzey 1992, 15):

\[ Q = Q(K^{a}R_{n}^{b}e^{mt}) \]

Maintaining a continuous amount of consumption requires the preservation of capital (K) and non-renewable natural resource stock (R_{n}) through investment derived from Q-C (Pezzey 1992, 15). The above formula ignores renewable resources and natural resource stocks. The function states that as non-renewable resource stocks are depleted produced capital must be substituted to some degree. Pezzey adds natural resources stocks, resource flows, labor and technical progress to extend the above Cobb-Douglas formula as follows (Pezzey 1992, 33):

\[ Q = Q(AK^{a}L^{b}R^{c}S^{d}e^{mt}) \]

According to Pezzey, what the above formulas do not account for are degrees of substitution and what resources are substitutable.

Pearce and Atkinson (1993, 106) discusses sustainable development in terms of an economy being able to save more than the total depreciation of produced and natural capital. Atkinson and Hamilton (2007, 45) explains how such sustainability is measured as built from the following formulas. First, the authors define genuine savings, in a basic way, as follows:

\[ G = \sum_{i=1}^{N} p_{i}K_{i} \]

G represents genuine savings, K_{i} represents the stock of all assets in a given economy, and p_{i} is the shadow prices of these stocks which are numbered one through “N.”
Genuine savings must account for all possible assets in order to provide a more accurate picture of an economy's wealth. As Atkinson and Hamilton point out, this includes assets that have negative shadow prices such as pollution stocks. Including such negative assets allows for a "green accounting" of assets, netting out productive assets from those that cause wealth degradation. Shadow prices, in the case of the above formula, are measured in units of utility. The shadow price measures the present value of future utility ascribed to a one unit increase in a given stock (Fabrizio Bulckaen and Marco Stampini 2009, 1198).

Using genuine savings as a function of utility Atkinson and Hamilton (2007, 45-6) continues, describing the insight of Kirk Hamilton and Michael Clemens (1999) linking social welfare with genuine savings as follows:

$$ G = \lambda^{-1} \frac{dV}{dt} $$

In this above case, the formula for $G$ (genuine savings) is modified to reveal its equality to the immediate change in social welfare ($V$), measured monetarily. The lambda symbol represents marginal utility of consumption. The social welfare component is derived as follows:

$$ V = \int_{t}^{\infty} U (C, \ldots) \cdot e^{-\rho(s-t)} \, ds $$

The above formula states that social welfare is equal to the present value (obtained through the utilization of integral calculus) of utility whereby the utility function is composed of consumption and any other goods or bads that can be valued in an economy (Atkinson and Hamilton 2007, 46). Along with these formulas came the insight that negative genuine savings reveals that utility levels over a period of time will be lower.
than current utility levels. If genuine savings for a given economy is negative, unsustainability is realized. Atkinson and Hamilton also note that strong and weak sustainability asset considerations are missing from the above formulas. Shadow prices respective of such assets must be incorporated into the genuine savings formulas in the form of a constraint in order to begin accounting for the impacts of such assets (Atkinson and Hamilton 2007, 45-6).

The “e” is a continuous component in the formula, allowing for continuous discounting at a given pure rate of time preference (“p”) applied between the current time and the selected future time period. Pure rate of time preference is a ratio that describes a society’s willingness, in this case, to consume now as opposed to the future. The larger the pure rate of time preference, the more a society wishes to consume now (Pearce 1999, 4). Pure rate of time preference is a component of the social discount rate which is simplified for use in sustainability formulas. The assumptions used in the formula utilized in this dissertation are that consumption increases at a constant rate and elasticity of utility regarding consumption over time has a value of one (Hamilton et al. 2006, 144). These assumptions, and the use of a social discount rate, will be explained further in chapter four.

The pure rate of time preference chosen is a point of debate in the literature but generally falls in the range of one to two percent (David Pearce and David Ulph 1995, 7) with a rate of 1.5 being accepted in the literature reviewed (Samih Azar 2009, 204; Hamilton et al. 2006, 145; Pearce and Ulph 1995, 10). The debate centers on what ethical foundation one is to use with respect to the rate chosen. The Hartwick rule focuses on constant, unchanging consumption in consideration of setting the pure rate of
time preference with respect to achieving intergenerational equality. Rents from non-renewable resources are reinvested into produced capital, acting in substitution for natural resources (Pezzey 1992, 13-4). A utilitarian viewpoint suggests impartiality in considering equality with future generations. David Pearce and David Ulph (1995, 7-9) argue that utilitarianism is acceptable unless people have varying productive capabilities. In such cases, Pezzey states, utilitarianism will meet the needs of the most productive, leading to inequality. Future generations can be more productive than the current generation with the help of capital accumulation and technological improvement made possible, in part, by building assets today (keeping the rate low). Pearce and Ulph conclude that, due to an inability to see into the future to determine if future generations will or will not be better off, there is no consensus in the literature about what the rate should be (1995, 7-9). This rate can be set to reflect the needs of a given country as they analyze their sustainability position.

Pezzey (1992, 10) defines optimal in terms of resource use as the integral of utility over a given period of time with application of a social discount rate (\( \delta \)):

\[
\int_0^\infty U(t) \cdot e^{-\delta t} \, dt
\]

Sustainability, according to Pezzey (1992, 10), of a single resource is also measured by an integral with respect to time, applying a given social discount rate:

\[
\int_t^{t+T} X(\tau)e^{-\delta \tau} \, d\tau
\]

In this case "X" is the asset (or group of assets) of focus which one cares to measure the sustainability of. "\( \tau \)" is the technical progress rate, "t" is current the time of interest and "T" is the relevant time frame extending into the future.
Sustainability measurements used by the World Bank's method (Hamilton et al. 2006; Lange et al. 2011) incorporate similar approaches to that presented above. The method also provides a means to begin handling the data, theory and measurement problems left unaccounted for in some of the earlier sustainability metric techniques. The World Bank model and challenges to it are examined in the next chapter.
CHAPTER IV
THE WORLD BANK SUSTAINABILITY MODEL

Chapter III built the conceptual and theoretical foundations for sustainability up to the introduction of the World Bank's sustainability model. This chapter continues the analysis of sustainability's metamorphosis by examining the World Bank's approach to measuring sustainability up through the model’s recent revision in 2011. Although the World Bank has used its model to produce country level comparative data, the outcome of analysis using such data is only as good as the assumptions and weaknesses behind the model. A description of the World Bank’s sustainability model, its shortcomings, strengths and alternative methods of sustainability measurement are examined below.

World Bank's “The Changing Wealth of Nations”

Building from theoretical foundations of the past (as laid out in the previous chapter), The World Bank developed its model as a continuation of sustainability metrics research, first publishing their model and related findings in a report titled, “Where is the Wealth of Nations: Measuring Capital for the 21st Century.” The work was updated in early 2011 and published as “The Changing Wealth of Nations: Measuring Sustainable Development in the New Millennium.” The purpose of The World Bank study is to provide a means to quantifiably measure sustainability in an economy, or more specifically sustainable growth. The study begins with the economic theory of total wealth of a country being estimated “as the present value of future consumption” (Lange et al. 2011, 94; Hamilton et al. 2006, xiv, 5). The essence of sustainability is, as noted in earlier chapters, the ability to meet the needs (of consumption) of the present while not harming the ability of future generations to meet their own needs. With this essence, the
nexus of wealth and sustainability starts to materialize. The measurement of wealth along the lines of future consumption and sustainability's current and future provisioning of consumption demonstrates the compatibilities of the concepts. If current and future wealth needs can be measured then current sustainability can be determined. The very next issue to determine is how wealth can be quantitatively derived in a way that measures provision for current and future consumption needs.

As stated in chapter three, the stock of total wealth in a given nation is derived in one of two ways. The first is from calculating the net present value of a future flow of consumption. The World Bank wealth formula is presented below (Hamilton et al. 2006, 144-145; Lange et al. 2011, 95):

\[ W_t \int_t^\infty C(t) \cdot e^{-p(s-t)} ds \]

The formula above uses an integral spread between a base time and infinity. The World Bank study's quantitative application of this formula uses a period of 25 years to approximate a generation in time (Hamilton et al. 2006, 25; Lange et al. 2011, 95). In the formula above “W,” is wealth at time “t”, “C” is consumption, “t” is time, “s” is the span of years relevant to the study (25) and “e” is a continuous component in the formula, allowing for continuous discounting at a given pure rate of time preference (“p”) applied between the selected future time period and the current time (“s-t”). As stated in chapter three, the pure rate of time preference selected for the World Bank study is 1.5. This number is small enough to favor more consumption in future years.

The formula above was originally constructed with the social rate of return (instead of the pure rate of time preference, solely) which is calculated as the pure rate of time preference plus elasticity of utility multiplied by the consumption growth rate. With
the assumptions of elasticity of utility equaling one and a constant consumption growth rate the formula can simplify, replacing the social rate of return with the remaining pure rate of time preference (Hamilton et al. 2006, 144; Lange et al. 2011, 116).

With respect to compatibilities of different approaches to measure development as noted in the previous chapter (Arrow et al. (2004, 149) uses intertemporal social welfare and utility of consumption), asset wealth is calculated in the World Bank approach while at the same time taking into account a set marginal utility of consumption within the applied discount rate (Lange et al. 2011, 95). By setting current wealth to equal the present value of future consumption, both social welfare and intertemporal approaches to measuring sustainable development have been addressed. Utility is not “directly observable”; hence a different and measurable variable (wealth) is needed (Hamilton et al. 2006, 15). Per capita wealth is used in the World Bank model as a measure of variation to the standard of living (Lange et al. 2011, 41)

The second wealth equation (below) calculates the sum of a portfolio of assets, the management of which provides income flows (GNI) and inputs for a measure of genuine savings. The World Bank study disaggregates these assets into four categories as shown in Table 4.1 (Hamilton et al. 2006, 22-3; Lange et al. 2011, 29).

The next issue to be addressed is how to determine if consumption is sustainable or not. The stock of wealth allows for production of consumption goods and related income streams. Availability of consumable goods is an indication of a given population’s well-being. If assets are being consumed beyond their replenishment, such activity leads to a reduction in wealth and, as such, a reduction in the ability to produce further income streams which allow for consumption and well-being.
Table 4.1

**World Bank Total Wealth Measurement**

<table>
<thead>
<tr>
<th>Asset</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Produced Capital (Cp)</td>
<td>Sum of machinery, equipment, structures — which includes infrastructure and urban land.</td>
</tr>
<tr>
<td>Natural Capital (Cn)</td>
<td>Sum of non-renewable resources, cropland, pastureland, forested areas and protected areas.</td>
</tr>
<tr>
<td>Net Foreign Assets (Cf)</td>
<td>Total foreign assets minus total foreign liabilities. “... sum of foreign direct investment (FDI) assets, portfolio equity assets, debt assets, derivatives assets, and foreign exchange reserves. Total liabilities are the sum of FDI liabilities, portfolio equity liabilities, debt liabilities, and derivatives liabilities (Lange et al. 2011, 150).”</td>
</tr>
<tr>
<td>Total Wealth (Wt)</td>
<td>Calculated from the wealth integral equation.</td>
</tr>
<tr>
<td>Intangible Capital (Ci)</td>
<td>A residual: the difference between produced capital, natural capital, net foreign assets and total wealth. This category includes the sum of knowledge, skills, institutions, social capital, and net foreign financial assets. By default, this residual will contain all other assets for which data is lacking such as fisheries and subsoil water.</td>
</tr>
<tr>
<td></td>
<td>$W_t = C_p + C_n + C_f + C_i$</td>
</tr>
</tbody>
</table>

Total wealth is composed of the sum of produced, natural, foreign and intangible capital.

The sustainability of a given population's consumption (well being) hinges upon this measurement deemed “Genuine Savings” (Hamilton et al. 2006, 37; Lange et al. 2011, 151-6) but most often referred to as “Adjusted Net Savings” (ANSav):

$$\text{ANSav} = \text{NNS} + \text{ED} - \text{NR} - \text{POL}$$

Net National Savings (NNS) is composed of five separate items as follows:
NNS = (GNI – Cpub – Cpri + Trn) – Dep

Where GNI is Gross National Income, Cpub is Public Consumption, Cpri is Private Consumption, Trn is Net Current Transfers and Dep is depreciation of fixed capital. The remaining ANSav components are listed in Table 4.2.

Table 4.2
World Bank Adjusted Net Savings Components

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ED</td>
<td>Expenditures on Education</td>
</tr>
<tr>
<td>NR</td>
<td>Natural Resource Depletion</td>
</tr>
<tr>
<td>POL</td>
<td>Damages from Pollution</td>
</tr>
</tbody>
</table>

Changes in population play a significant role in the understanding of consumption sustainability. A country may appear to have a net increase in productive assets. Yet, if its population grows substantially its assets may not be able to sustain consumption for a growing population. As such, per capita measurements are conducted (Lange et al. 2011, 31; Hamilton et al. 2006, 61). As revealed in the above formula, assets within a country's wealth portfolio can be exhaustible (such as timber, coal, and frail ecosystems). An
unsustainable flow of consumption of these resources can be revealed by a negative net saving level.

Although other sources of national wealth measurement have been discussed in the literature, net present value of future consumption has been argued by Geoffrey Heal and Bengt Kriström (2008, 6) as the dynamic “analog” and superior measurement compared to static NNP in both dynamic and static contexts. With respect to the problem of determining future prices Heal and Kriström discovers spot prices of capital goods are sufficient in perfect markets. Using Hamiltonian functions of dynamic systems, Heal and Kriström demonstrate that “changes in NI [national income] are accurate measures of welfare changes” (Heal and Kriström 2008, 5). Heal and Kriström also assert that Pareto improvements are possible in an economy in relation to national income, “a small change in resource allocation is a potential Pareto improvement if and only if it leads to an increase in the value of national income” (Heal and Kriström 2008, 2).

Critiques of the World Bank Study

Hamilton et al. (2006) provide one of the first comprehensive models of economic, environmental and social sustainability. Their work is critiqued and enhanced by a variety of scholars. This section briefly summarizes many of their concerns.

Mick Common (2007, 239) critiques the original model's calculation of wealth and genuine savings with several concerns. His analysis questions whether simply adding to the list of assets accounted for in the model will produce greater model accuracy or not, emphasizing that the World Bank model does not provide accurate wealth valuations of a nation but rather simple estimates (Common 2007, 240). Compiling a model inclusive of all possible variables is widely recognized as impossible
in the first place.

Another problem noted by Common is the treatment of all countries as the same with respect to total wealth measurement. Indeed, if one is to calculate $W_t$ with a static time period and pure rate of time preference across countries then $W_t$ would have the same value for all nations, namely 20.72 times consumption. In essence, wealth is calculated as a multiple of total consumption (Common 2007, 243). The World Bank does, however, simplify the wealth formula using assumptions pertaining to elasticity of utility and consumption growth rates. Estimates of these variables can be determined on a country by country basis and be added back into the formula for respective country policy decision support. Pure rate of time preference can also be modified on a country by country basis based on the needs of current and future generations or a given nation's identified need to be more frugal and less wasteful.

Common's points of externalities (as is similarly stated by Catarina Roseta-Palma, Alexandra Ferreira-Lopes and Tiago Sequeira (2008, 16) in terms of instability amidst complex systems) are well taken as is the incompleteness of wealth accounting given the limited set of variables presented in Hamilton et al. 2006 (Common 2007, 243). The latest release of the World Bank model has an expanded data set since Common's critique incorporating (for example) net foreign assets in the World Bank wealth model (Lange et al. 2011, 61). Future modifications to the World Bank model will hopefully incorporate additional, highly determinant variables. It is to be noted, however, that the contribution of each variable in the model’s outcome is apparent, providing a starting point for policy analysis. The World Bank study does not exist in a vacuum.

Hamilton et al. 2006 do not use shadow prices for estimating genuine savings. As
a result, neither does the World Bank data bank. This has some drawbacks, even biases or estimation errors as pointed out by Bulckaen and Stampini (2009, 1207-8). Results reveal greater savings for polluters and less for natural resource extracting countries. Measurements also do not account for the value of amenities. As quoted from Bulckaen and Stampini:

Existing estimates of genuine savings are based on observed market prices and quantities. As real-world markets do not internalize environmental externalities, such estimates are twice biased. ... Relying on market prices leads to underestimating genuine savings. Second, a term measuring the depreciation of the stock of environmental goods providing amenities to consumers is omitted—as the market price is null. This omission leads to overestimating genuine savings. The two biases have opposite signs. It is therefore not possible to determine the overall sign of the error. Nonetheless, our analysis shows that existing estimates of genuine savings are likely to be biased upward for countries with high levels of environmental damage from pollution, and biased downward for natural resource extracting countries. (Bulckaen and Stampini 2009, 1207-8)

The most important point is with respect to what one does with the information provided. Common's final contribution to the critique of the World Bank model is the addition of a caveat to the limitations of the model. He suggests that the study must not be construed to provide an indication of "precisely whether or not an economy is developing sustainably" (Common 2007, 243). As a result, Common asserts that estimates of environmental data belong in “satellite” accounts and not used as adjustments to national income (Common 2007, 244). Although the World Bank report does suggest several limitations it is a start, implying caution in any application. Precision in calculation can increase as indicator behavior is adjusted for country specific circumstances. Policymakers would be ill advised to consider decisions on less.

Instead of using the three primary classes of assets (produced, natural and intangible), other scholars use four in their attempts to calculate wealth (Charles Mueller
2008, 208; Roseta-Palma, Ferreira-Lopes, and Sequeira 2008, 4). Produced and natural capital is retained but intangible capital is split out between social and human capital. Roseta-Palma, Ferreira-Lopes and Sequeira (2008, 3, 15) specifically discusses studies linking social capital, specifically “level of trust, social norms, and social networking,” to growth while discussing its quantifiable measurement to wealth. The study emphasizes the importance of the four separate asset categories noting relationships between each which can more specifically inform policy. Future World Bank model variations may take this path in order to analyze the separate effects of social and human capital. For now, such measurements are aggregated into intangible capital with human capital seen as the most important component of the intangible capital residual (Lange et al. 2011, 137). Social capital (as measured by institutions) is not far behind, particularly for developing countries (Lange et al. 2011, 13-4). The World Bank also acknowledges that measurement of social capital remains difficult yet they await future breakthroughs for incorporation in future models (Lange et al. 2011, 137).

Anna Kulig, Hans Kolfoort and Rutger Hoekstra (2010, 123) argue that many sustainability indicators are policy based and can be different across nations making country level comparisons difficult. As with the authors above, Kulig, Kolfoort and Hoekstra (2010) support the necessity of separating intangible capital into two separate asset classes for measurement (social and human) as well as a “capital approach” that measures asset classes (particularly social and environmental assets) non-monetarily where monetary based measurement methods have difficulty (Kulig, Kolfoort, and Hoekstra 2010, 122). Non-monetrary units suggested for input into sustainability calculations are the very indicators commonly used to measure their respective variations.
Two examples: fossil fuel reserve assets (natural asset class) are measured in the gigajoules of energy these reserves can produce. Human capital, with respect to worker ability, is often (and is recommended by Kulig, Kolfoort, and Hoekstra to be) measured in terms of percentage of the population obtaining higher education levels (Kulig, Kolfoort, and Hoekstra 2010, 126). Such measures suffer from similar measurement problems the capital approach claims to resolve. For example, quality of education is one common distraction when measuring and performing cross country comparisons of equivalent levels of knowledge and skill (human capital) gained from time spent in educational programs (Andrea Bonaccorsi et al. 2007, 72; Hamilton et al. 2006, 90-2). Monetization, however, is not perfect either given indicator measurement variation can exist across nations (see for example David Fielding, Mark McGillivray, and Sebastian Torres 2006, 2).

The capital approach also suffers from how each indicator is weighted in determining overall sustainable valuation. Monetization helps relieve this particular concern. It remains to be seen which approach will be accepted but there is no doubt that additional research is required for both approaches in order to achieve greater reliability.

Similar to Kulig, Kolfoort and Hoekstra (2010), Charles Mueller also discusses the necessity of setting aside a focus on monetization of all model indicators. Instead, he suggests a combination of “economic and biophysical indicators” (Mueller 2008, 222-23) in order to resolve measurement problems associated with ecological assets and difficulties the model has in determining the sustainability of developed countries. Also, Mueller states that the World Bank model lacks any account for the impact of one country's activities on another (“transboundary externalities”) and it does not measure the
effects of environmental amenities. Precisely how such measurements are to be conducted, however, is a matter that is still under a great deal of debate (Mueller 2008, 220, 223). As most all critics seem to agree, model improvements are dependent upon the resolution of measurement related debate in the literature. Again, the World Bank model is a start, reflecting the current state of the literature. Once measurement debates are resolved one can speculate the World Bank team conscientiously updating their model.

Mads Greaker (2008, 1) noted that existing measures of wealth may be flawed, masking unsustainable activities. Greaker suggests to divide wealth stocks into those that are easily measured for economic value and those that are not, or where such measurements may be ethically controversial, allowing for a similar kind of separation suggested by national accounts specialists noted by Common. The technique Greaker and Statistics Norway use to build net national income utilizes their own four general asset categories: natural resources, human capital, physical and financial stocks (Greaker 2008, 2). It is anticipated that future updates to the World Bank model may incorporate asset stocks differently. It is to be noted, however, that the latest World Bank model does take foreign assets into account (Lange et al. 2011, 150).

Limitations with respect to measurement of natural resource weights in determining substitution values have been a concern. Pezzey (1992, 11) considers the sheer number of possible avenues of weighting to be “ legion” adding to other problems such as the lack of theoretical support for weighting and practical problems associated with measuring complex natural resource functions (such as ecosystems). Biodiversity itself is highly challenging to value (Atkinson 2007, 58). With this concern, only time
spent in further research can provide a resolution as to how natural resources can best be measured. The World Bank study recognizes the very sensitive nature of substitutability stating, “… the potential for substitution is limited” with many natural assets simply being irreplaceable (Lange et al. 2011, 8, 18). The equations in the model, however, suggest substitutability pointing to an urgent need to resolve issues surrounding the incorporation and application of strong and weak natural assets to preserve the very natural systems relied upon for life.

Conclusions

The World Bank model provides a starting point in accounting for the complexities of natural, physical and intangible capital. Concerns reflected by the critics above are valid yet do not detract from what the model, in essence, claims to offer. The model does not measure several crucial environmental factors given such measurements are still under an extraordinary amount of debate. The model does, however, provide a base to begin country level sustainability analysis with one primary caution: conclusions gleaned from the model must be used responsibly, considering such conclusions as only a starting point in decision making and policy analysis.

Several decades of data have been compiled for the World Bank model indicators. (This data is available for public access through the World Bank web site). Given availability of data and relative completeness of their initial model (utilizing metrics that have received a measure of consensus in the literature) World Bank sustainability measures form some of the dependent variables of this dissertation. As Pezzey (1992, 46-4) opens up the possibility for, impacts on sustainability from variables on a lesser, or contributing scale can be examined. As such, the next two chapters review the
conceptual impact of biofuel production on a country's sustainable development. Using variables described in Chapters III through V, Chapter VII describes a model that will help answer the primary question of this work. Does the biofuel industry contribute to country level sustainable development?
CHAPTER V

SUSTAINABILITY APPLIED TO THE BIOFUEL INDUSTRY

Chapter I provided background information on the biofuel industry’s influence on all three domains of sustainability. It is from detailed analysis of industry level operations that the impacts of biofuel production can be measured allowing for the industry’s promises and perils to be assessed. Such an assessment of impacts must be examined all the three domains of sustainability: economic, environmental and social. From impacts in these areas appropriate policies can be derived on a country level or on an international scale where appropriate.

Pezzey (1992, 46-7) comments on the application of sustainability measurement at two levels: “system” and “project.” His analysis opens up the possibility of analyzing individual industry level contributors to country level or even international sustainability. Contributions to sustainability can be measured based on the outputs the industry generates whether those outputs are goods (such as clean energy) or bads (such as hazardous by-products). The net outcome of industry operations measured on all three domains of sustainability will determine if that industry positively or negatively contributing to sustainable development.

Fitting Biofuel Industry Characteristics to the World Bank Sustainability Model

This chapter assesses the extent to which biofuel industry sustainability can be measured utilizing the World Bank’s sustainability model. Biofuel industry data is not comprehensibly available for all World Bank sustainability variables at this time. As such, initial sustainability assessment is dependent upon chapter seven estimation components. Two important benefits are gained from the examination conducted in this
chapter. First, the World Bank model of sustainability provides a valuable decision support tool for policy. The ability of the industry to conduct a detailed assessment across several factors important to sustainability will help provide pragmatic inputs toward assuring progress of this industry along sustainable development paths. Second, statistical estimates are helpful but can be limited in explanatory power. If statistical estimation and sustainability model outcomes are not significantly different, reliability is introduced to sustainability assessments.

This chapter seeks to highlight where data is missing in the accounting function of biofuel industry sustainability measurement and, along with subsequent chapters, assesses areas where existing World Bank measurement may not adequately capture sustainability influences of the biofuel industry. In some cases proxy data is used where available biofuel industry variables do not provide the closest match to World Bank variables. The data used here is only a starting point for industry sustainability measurement highlighting the need for statistical estimation as conducted in Chapter VII. The result of both analyses will be a preliminary understanding of biofuel industry contribution to country or aggregated international level sustainability.

Biofuel Industry Effects on Wealth

The first task is to understand impacts the biofuel industry has on a country’s wealth. Wealth deductions or contributions to wealth can be calculated assessing each World Bank wealth variable within the context of biofuel use and operations. Wealth calculations are divided into several parts as detailed in Chapter IV: total wealth, produced capital, natural capital, net foreign assets and intangible capital.
**Total Wealth**

Following economic theory used to build the World Bank’s total wealth estimation (Hamilton et al. 2006, xiv); present value of a future flow of biofuel product consumption is proposed to determine initial industry contribution to country level wealth. On an individual country basis, total contribution to wealth can be calculated as a function of biofuel consumption over a given period of time allowing for the given country’s pure rate of time preference and elasticity of utility. Following the World Bank model the pure rate of time preference will be set in this chapter at 1.5, time will be set at 25 years (to also roughly approximate a generation) and elasticity of utility will equal 1.0 (Hamilton et al. 2006, 144-45; Lange et al. 2011, 142-43). The following aggregate World Bank total wealth function will be used as presented in the previous chapter (Hamilton et al. 2006, 144-45; Lange et al. 2011, 95).

\[ W_t = \int_t^\infty C(t) \cdot e^{-p(s-t)} \, ds \]

For a sample of countries with biofuel production over one million gallons per annum, Table 5.1 lists a limited industry contribution estimate to total wealth by taking 2006 and 2008 biofuel consumption and price data and determining current value of the consumption based on the World Bank’s 25 year discount. International fuel ethanol and biodiesel consumption statistics were obtained from the Energy Information Agency of the United States Department of Energy (EIA 2011). These numbers were multiplied by the average, respective fuel price as reported by the World Bank (World Bank 2011) to come up with an economic value of consumption. Due to limitations in the data sets, price data is only available for every other year providing only two data points in three years as opposed to three years of data averaged over a three year period of time as
calculated by the World Bank. 2010 data has yet to be released at the time of this writing. The World Bank model smoothes out volatilities in all consumption data. The averaging of biofuel consumption is also conducted to smooth out volatilities over the three years of data as recommended by Hamilton et al. (2006, 144) and Lange et al. (2011, 142). An average of constant dollars is not applied given fuel prices represent one of the greatest sources of CPI fluctuation. In cases where zero is present in Table 5.1 a nation has chosen not to produce the given fuel type or has not provided average fuel price data to the World Bank.

Table 5.1

*Biofuel Contribution to Country Level Wealth*

<table>
<thead>
<tr>
<th>Country</th>
<th>Daily Biodiesel Consumption Value Avg. '06 / ‘08</th>
<th>Daily Fuel Ethanol Consumption Value Avg. '06 / ‘08</th>
<th>Annual Total Biofuel Consumption Value Avg. '06 / ‘08</th>
<th>Contribution to Country Level Wealth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
<td>25,243</td>
<td>0</td>
<td>9,213,637</td>
<td>6,332,435</td>
</tr>
<tr>
<td>Australia</td>
<td>104,464</td>
<td>241,602</td>
<td>126,313,989</td>
<td>86,814,272</td>
</tr>
<tr>
<td>Austria</td>
<td>1,242,535</td>
<td>195,751</td>
<td>524,974,470</td>
<td>360,809,416</td>
</tr>
<tr>
<td>Belgium</td>
<td>204,229</td>
<td>47,628</td>
<td>91,927,755</td>
<td>63,180,977</td>
</tr>
<tr>
<td>Brazil</td>
<td>1,634,990</td>
<td>53,077,853</td>
<td>19,970,187,557</td>
<td>13,725,299,265</td>
</tr>
<tr>
<td>Canada</td>
<td>170,985</td>
<td>1,714,799</td>
<td>688,310,807</td>
<td>473,068,757</td>
</tr>
<tr>
<td>China</td>
<td>835,078</td>
<td>4,023,375</td>
<td>1,773,335,309</td>
<td>1,218,794,653</td>
</tr>
<tr>
<td>Colombia</td>
<td>81,126</td>
<td>730,296</td>
<td>296,169,161</td>
<td>203,553,941</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>236,632</td>
<td>123,753</td>
<td>131,540,598</td>
<td>90,406,466</td>
</tr>
<tr>
<td>France</td>
<td>6,098,369</td>
<td>2,252,804</td>
<td>3,048,178,109</td>
<td>2,094,980,662</td>
</tr>
<tr>
<td>Germany</td>
<td>14,877,082</td>
<td>2,975,559</td>
<td>6,516,214,104</td>
<td>4,478,525,221</td>
</tr>
<tr>
<td>Hungary</td>
<td>285,543</td>
<td>202,578</td>
<td>178,164,207</td>
<td>122,450,380</td>
</tr>
<tr>
<td>India</td>
<td>34,927</td>
<td>726,724</td>
<td>278,002,652</td>
<td>191,068,290</td>
</tr>
<tr>
<td>Indonesia</td>
<td>23,719</td>
<td>14,050</td>
<td>13,785,686</td>
<td>9,474,757</td>
</tr>
<tr>
<td>Italy</td>
<td>2,318,928</td>
<td>274,020</td>
<td>946,425,911</td>
<td>650,468,546</td>
</tr>
</tbody>
</table>
Table 5.1 (Continued).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Jamaica</td>
<td>0</td>
<td>5,874</td>
<td>2,144,054</td>
<td>1,473,586</td>
</tr>
<tr>
<td>Korea, South</td>
<td>95,018</td>
<td>0</td>
<td>34,681,519</td>
<td>23,836,242</td>
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<tr>
<td>Malaysia</td>
<td>44,215</td>
<td>0</td>
<td>16,138,351</td>
<td>11,091,718</td>
</tr>
<tr>
<td>Poland</td>
<td>837,459</td>
<td>673,857</td>
<td>551,630,274</td>
<td>379,129,669</td>
</tr>
<tr>
<td>Portugal</td>
<td>466,437</td>
<td>0</td>
<td>170,249,461</td>
<td>117,010,659</td>
</tr>
<tr>
<td>Slovakia</td>
<td>264,177</td>
<td>141,376</td>
<td>148,026,633</td>
<td>101,737,144</td>
</tr>
<tr>
<td>Spain</td>
<td>1,273,255</td>
<td>756,333</td>
<td>740,799,562</td>
<td>509,143,725</td>
</tr>
<tr>
<td>Sweden</td>
<td>452,148</td>
<td>1,437,096</td>
<td>689,574,060</td>
<td>473,936,978</td>
</tr>
<tr>
<td>Thailand</td>
<td>396,344</td>
<td>502,079</td>
<td>327,924,337</td>
<td>225,378,938</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>2,389,100</td>
<td>607,098</td>
<td>1,093,612,307</td>
<td>751,628,203</td>
</tr>
<tr>
<td>United States</td>
<td>2,203,017</td>
<td>45,883,091</td>
<td>17,551,429,477</td>
<td>12,062,912,350</td>
</tr>
<tr>
<td>Total</td>
<td>36,595,019</td>
<td>116,607,595</td>
<td>55,918,953,984</td>
<td>38,432,507,249</td>
</tr>
</tbody>
</table>

Produced and Natural Capital

Publicly available biofuel industry data for produced and natural capital is rare. Few countries have this data. Those countries that do have such industry based data only have data that will span a limited time frame. As will be demonstrated in future chapters, data covering biofuel industry sustainability can be consistently assembled across biofuel producing countries and systematically analyzed to determine the sustainable impact biofuel enterprises have on a country by country basis. Produced capital can be calculated from biofuel industry investments, applying the World Bank’s static 20 year useful life of an asset and a constant 5% depreciation rate. The constant service life and the depreciation rate are based on cross-country studies which developed these mean
constants (Hamilton et al. 2006, 145, 157; Lange et al. 2011, 143). Similarly, value enhancement (or degradation) of urban land is sparsely measured for the biofuel industry. Land improvements alone are captured in the above through calculating investments such as the value of structures built to house refining operations. However, these measures do not completely demonstrate urban land value changes due to such improvements. To rectify this, the World Bank, also in consultation with relevant literature available, utilizes a constant urban land improvement equation that is dependent on the value of the capital stock (capital stock multiplied by .24) (Hamilton et al. 2006, 147; Lange et al. 2011, 144).

With respect to natural capital (timber resources, nontimber forest resources, cropland, pastureland and protected areas), the wealth of a nation may decline should biofuel operations alter land intended for forest and established agricultural use. For example, farmers may choose to replace food crops with agrofuel crops; pasturelands used for grazing may also be converted to biofuel cultivation. Protected areas, such as pristine rain forests may be uprooted to make way for high demand biofuel crops. Improvements to land, however, (such as to land that is deemed “marginal” or “abandoned farmland” prior to biofuel operations being located on it) may have a positive contribution that will provide an overall positive or negative netting effect with respect to land use. These considerations alone, and the calculations currently supported by the World Bank model, are not as yet sufficient to capture all costs associated with change of land use. This leads back to primary concerns regarding economic value substitutability of, for example, food and forest assets for fuel. In addition, as stated in Chapter III, the literature has yet to determine the scope and application of strong and weak assets that may (as is the case of the past) be disturbed in the future for biofuel
production, nor has the literature determined the economic value of such assets. Land use change statistics are rarely available making this, and the related human and environmental concerns, a point of clarification the literature has yet to resolve.

Regardless, the World Bank study does provide a starting point for monetization leaving land use change up to future advancements in the literature. Given the history of the industry (as exemplified by the Rainforest Alliance report of 2010) conclusions drawn by policy makers using this preliminary data for land use change decisions, for example, should consider such conclusions as very tentative until the aforementioned debates are resolved. No policy should be crafted based solely on these initial valuations. The World Banks monetization research is only a start in an effort to help guide policy makers. The broader lesson to be learned at this time is that development is to be considered the “management of a portfolio of assets” of which economic, social and environmental assets all have an interlinked part (Hamilton et al., 2006, xix). With respect to biofuels, using an accepted model of sustainability will allow policy makers to begin to see what impacts biofuel production may be having on all three of the above mentioned domains of sustainability.

Should biofuel operations replace a measure of forest assets, losses limited to natural assets can be measured on a country by country basis should a given country choose to take a census of such activity. These measurements can be totaled and subtracted from the economic value biofuel operations provide to the country, assessing a limited net economic effect. Specific measurement techniques follow.

Timber resources values are the net present value of rents obtained from round wood production incremented for loss of timber production over the time horizon chosen
Measurements of nontimber forest resources are important as timber is only a portion of the benefit forest assets provide. The nontimber portion of forest land values are estimated based on findings in the literature. The World Bank reports these returns as an average: $190 per hectare per year in developed countries and $145 per hectare per year in developing countries. Both timber and nontimber forest asset estimates are applied to forest areas deemed accessible – forest areas within 50 kilometers of infrastructure and approximately 10% of all forested areas, respectively. Again, both timber and nontimber resources are initial estimates of forest land asset values. For example, ecosystem related values are only touched on by accounting for sustainability of non-forest assets, and then only indirectly.

Cropland, pastureland and protected environmental areas are valued next. Although land asset change is not comprehensively measured by international institutions this does not prevent the authorities of a country (or concerned citizen groups) from taking a census of their own country’s experiences determining monetized and non-monetized, activity based impacts as appropriate. As with forest land, land originally intended for other purposes can begin to be netted against biofuel industry activity on those lands to obtain an initial look at netting impacts the biofuel industry has on country level sustainability. The value of cropland is calculated by the World Bank based on the net present value of returns to land output (Lange et al. 2011, 149). Pastureland is similarly calculated with the addition of a calculation to reflect sustainable grazing activity. The later five years (of 25 total discounted production years) are held at a constant over the production growth rates supported in the literature (Hamilton et al.
Protected areas are calculated differently. The World Bank takes the approach to valuing these assets as a population’s willingness to pay for the assets maintenance. Such estimation provides a means to begin measuring environmental amenities. The World Bank’s approach is to apply either the crop or pasture land equivalent value of the protected area, whichever number is lower, discounted over 25 years at 4%. The World Bank considers this approach to be an assigning of a “quasi-opportunity cost” to protected areas (Hamilton et al. 2006, 154; Lange et al. 2011, 150). Energy and mineral resources natural assets measured by the World Bank model are touched on in the next subsection. As reflected in Chapter VI, regardless of the debates over land use change accounting, full implementation of certification program guidelines can result in an insignificant negative to a potentially significant and positive wealth contribution through assessment of biofuel operations on this variable.

*Foreign Assets and Intangible Capital*

Accounting for foreign biofuel assets will allow for foreign operation values (assets or liabilities) to be realized (Lange et al. 2011, 150). Comprehensive, public data sets are unavailable for the biofuel industry at this time. Intangible capital contribution can be calculated by subtracting natural, produced and foreign asset contributions from total wealth (Lange et al. 2011, 150).

The measures above represent an economic valuation that is, as yet, unable to fully grasp what these assets contribute to life and well being. It is, however, a start. If biofuel production cannot net positively to these minimal measurements then the potential detriment of such an industry to a country’s wealth will be evident. Given such
limitations, however, the passing of such a minimum measure should not allow these operations to be considered wealth building. Even if the economic effect of biofuel production nets positively to this minimal measurement, net negative wealth contributions may still be realized based on biofuel production and use as measured by the following adjusted net savings variables.

Adjusted Net (“Genuine”) Savings

*Biofuel Industry Effects on GNI and Net National Savings*

The literature reveals limited studies which calculate the impact of a country’s biofuel industry on its respective economy. One such study was conducted by John Urbanchuk (2011) for the case of the United States (U.S.). The benefit of this study is that it is a starting point to determine biofuel industry contributions on a country level basis, helping policy makers determine how to support the industry both now and in the future. Although Urbanchuck’s study is an excellent start in determining economic valuation the study does point to drawbacks requiring further research. The study does not determine the net effects of biofuel production on GDP (Urbanchuk 2011, 2) as it is difficult at this time to determine, for example, the precise impact biofuel production has on imported crude oil purchasing, processing and marketing. The methodology estimates the impact of the ethanol industry on the American economy by applying expenditures by the relevant supplying industry to the appropriate final demand multipliers for value added output, earnings, and employment. This study utilizes an economic model known as IMPLAN (Impact Analysis for Planning) to develop this understanding of the economy, including the sectors that support the ethanol industry, the links between them, and the level of economic activity. (Urbanchuk 2011, 5)

The author accounts for foreign oil import displacement by domestic production on a one-to-one energy equivalent basis. His results reveal the U.S. fuel ethanol industry
having a positive contribution to the U.S. GDP of $53.6 billion in 2010. Major subsidies are factored in to his analysis (Urbanchuk 2011, 7, 10).

A drawback to the above methodology is the assumption of a one-to-one crude oil displacement outside the effect of price and demand elasticities. The impact domestic production has on prices and consumer demand would, however, be a difficult component to integrate. With these challenges understood, an excellent first estimate is provided revealing a net positive impact on the U.S. economy well over existing subsidies (Urbanchuk 2011, 9).

This dissertation uses country level production multiplied by annual average price (in an expenditure approach) to obtain biofuel industry input to the GNI variable. Biofuel import and export values are not available at this time bringing domestic production figures to bear in proxy. Compared to Urbanchuk (2011), for example, the methodology in building Table 5.2 brings a more conservative estimate of over $21 billion fuel ethanol contribution to the U.S. GDP in 2008. World Bank and Energy Information Agency (U.S. Department of Energy) 2008 data sets were used to build the table below, providing biofuel pricing and production data, respectively. Values of zero indicate areas where final, average fuel price data were not available for a given country or the country did not produce the respective alternative fuel type. A sampling of countries is provided in Table 5.2 for illustrative purposes. Significant contribution to country level GNI is evident from biofuel industry production. Comprehensive data sets for international biofuel trade need to be compiled and utilized to enhance precision. Precision in net national savings calculations is similarly enhanced by the collection of biofuel industry asset depreciation estimates.
<table>
<thead>
<tr>
<th>Country</th>
<th>Daily Ethanol Production Value</th>
<th>Daily Biodiesel Production Value</th>
<th>Annual Total Biofuel Production Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
<td>24,767</td>
<td>1,408,836</td>
<td>523,265,022</td>
</tr>
<tr>
<td>Australia</td>
<td>293,706</td>
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<td>156,226,190</td>
</tr>
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<td>Austria</td>
<td>326,252</td>
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<td>467,113,991</td>
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<td>1,148,787</td>
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<td>Brazil</td>
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<td>35,242,810,802</td>
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<td>Canada</td>
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<td>1,282,781</td>
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<td>282,752</td>
<td>345,303</td>
<td>229,239,914</td>
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<tr>
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<td>0</td>
<td>280,233,626</td>
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<tr>
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<td>4,102,358</td>
<td>7,918,949</td>
<td>4,387,777,128</td>
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<td>Hungary</td>
<td>262,113</td>
<td>591,540</td>
<td>311,583,170</td>
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<td>India</td>
<td>796,023</td>
<td>22,226</td>
<td>298,660,900</td>
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<td>1,328,328,250</td>
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<td>Jamaica</td>
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<td>275,425,151</td>
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<tr>
<td>Malaysia</td>
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<td>378,643</td>
<td>138,204,549</td>
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<td>Poland</td>
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<td>1,111,320</td>
<td>571,361,364</td>
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<tr>
<td>Portugal</td>
<td>0</td>
<td>723,469</td>
<td>264,066,302</td>
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<tr>
<td>Slovakia</td>
<td>398,805</td>
<td>746,807</td>
<td>418,148,438</td>
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<tr>
<td>Spain</td>
<td>1,152,121</td>
<td>873,815</td>
<td>739,466,771</td>
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<td>Sweden</td>
<td>372,451</td>
<td>386,104</td>
<td>276,872,677</td>
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<td>Thailand</td>
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<td>782,369</td>
<td>572,925,944</td>
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<td>Trinidad and Tobago</td>
<td>243,474</td>
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<td>United Kingdom</td>
<td>274,337</td>
<td>969,230</td>
<td>453,901,984</td>
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<tr>
<td>United States</td>
<td>53,838,209</td>
<td>5,462,645</td>
<td>21,644,811,544</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>169,727,247</strong></td>
<td><strong>47,739,662</strong></td>
<td><strong>79,375,421,686</strong></td>
</tr>
</tbody>
</table>
Remaining Net Savings Adjustments

The World Bank defines education expenditure as “Public current operating expenditures in education, including wages and salaries and excluding capital investments in buildings and equipment” (Hamilton et al. 2006, 155). Increased wealth that biofuel operations can represent allows for the choice of education spending growth. It is the availability and extent of this choice that brings value to industry wealth and savings estimates.

Energy depletion can be calculated depending on industry use of coal, crude oil and natural gas. The industry may choose to utilize its own product as a source of energy. In the case of unblended biodiesel a neutral affect to savings will be realized. If any non-renewable energy source is used by the industry, however, such activity will have a negative impact on savings. The World Bank calculates the value of non-renewable resource use as the product of production (industry use), average international market price and unit resource rent (Hamilton et al. 2006, 156; Lange et al. 2011, 153). The World Bank model measures rent by taking the unit world price of the resource, subtracting the average cost of production, taking the result and dividing it by unit world price. The World Bank notes that world prices are often used in its calculations in order to account for the social costs of depleting a given resource (Hamilton et al. 2006, 156). Industry estimates depend on industry player self reporting. Such data is not publically unavailable in comprehensive form at this time and may not be available for past operations impacting initial wealth and sustainability estimations.

Mineral depletion is calculated by the World Bank in a similar manner to energy depletion. The use of mineral resources can be obtained from such activities as fertilizer
use. At this time the World Bank limits accounting of mineral depletion to tin, gold, lead, zinc, iron, copper, nickel, silver, bauxite and phosphate (Hamilton et al. 2006, 156; Lange et al. 2011, 153). For use in the biofuel industry, this list contains several elements of fertilizer. Phosphate, for example, is used in the production of a macro soil nutrient.

The calculation of net forest depletion is similar to the two items above. The product of round wood production, price and rent is calculated along with an increment of the harvest that exceeds natural replenishment (Hamilton et al. 2006, 37, 156; Lange et al. 2011, 154). This data is not available on a comprehensive industry level requiring a census of the industry or estimation.

Pollution damages make up the final calculation for net saving impact. Savings can be considered on a country wide level from biofuel use by all consumers as well as a direct pollution charge from biofuel industry operational use. Until recently, measurements on only two pollutants are calculated by the World Bank: carbon dioxide and particulate matter. Global damages of carbon dioxide are calculated as total emissions (in tons) multiplied by a static cost of $20. Twenty dollars was taken from estimates currently available in the literature (Hamilton et al. 2006, 37, 156; Lange et al. 2011, 155). Particulate matter damages are calculated by the product of “disability adjusted life years lost due to particulate matter emissions” multiplied by a willingness to pay to avoid harm from particulate pollution (Hamilton et al. 2006, 156-57; Lange et al. 2011, 155).

Biofuels (from cultivation through fuel combustion) can have a direct impact on carbon dioxide (CO2) volumes measurable through the following simple mathematical representation for a given country, using B20 biodiesel as an example:
Where ΔCO2 is the change in CO2 cost to national wealth, CO2e is carbon dioxide emissions of road diesel in tons per gallon combusted (EPA 2002, 74); Di is gallons of total diesel used in a year by the biofuel industry in a given country; B is the decrease in CO2 emissions based on biofuel use within the industry and fuel blending conducted in a given country. (An 11% discount in carbon emissions, for example, is based on the common use of soy biodiesel in the United States at B20 biodiesel blending. B20 blending is composed of 20% biodiesel and 80% common road diesel (EPA 2002, 74; McCormick 2007, 7-8); and $20 is the damage cost per ton of CO2 to a nation’s wealth producing assets. Should a country’s biofuel industry choose to utilize a higher blend a lesser impact to savings can be achieved.

The equation is repeated for ethanol blending with gasoline. The results of both equations are combined for total pollution effect. Indirect CO2 impacts are not measured given the controversial nature of indirect measurements in the literature at this time (see, for example, U.S. Congress 2009 discussion on the complexities of indirect measurements within the biofuel industry).

Particulate matter (PM) calculations are similar to the CO2 formula above, substituting CO2 emissions for PM emissions and PM cost figures taken from Hamilton et al. (2006, 17). Using biodiesel as an example, a 10.1% reduction in PM emissions is achieved, based on the use of soy biodiesel at B20 blending (EPA 2002, 74).

Conclusions

As noted in Chapter IV, the World Bank sustainability model has two primary components, wealth and adjusted net savings. The biofuel industry can begin to be
measured for its country level impact on both. At this time, such measurements are hampered in two primary ways. First, the variables of the World Bank model itself are limited (only measuring two primary sources of pollution, for example). Second, availability of biofuel industry data related to the given World Bank variables is similarly limited at this time. These current impediments highlight the necessity for compiling the estimations detailed in Chapter VII. When the industry is able to analyze comprehensive data on the full set of World Bank variables the accounting function and the estimates can be compared. If both approaches to measurement are not significantly different this first approach to determining biofuel industry impact on sustainability will gain a measure of reliability within the confines of the existing World Bank sustainability model.

Following the warnings from earlier chapters, any conclusions and policy assessments based solely on information obtained from following the World Bank model must be handled with caution. Data obtained from existing public sources are very sparse for many of the variables requiring industry player self study, audit or government and institutional census activity. Initially, biofuel industry gross contributions to global wealth and savings appear very positive, prior to deductions, with a gross contribution of over $79 billion in 2008 from the sample countries listed in Table 5.2 (This number does not including specific industry investment). With enormous and growing demand worldwide for energy, and alternative energy in particular, this gross contribution is anticipated to increase.

Demand and industry growth outcomes are notable. Yet, to avoid the nightmares associated with this industry (as briefly described in chapter one) a method of controls and self examination is crucial given environmental economics can not provide a means
to adequately measure the dangers at this time. Biofuel certification programs hold out the promise of enhancing sustainability outcomes, even pushing biofuel industry players in operational directions that will neutralize wealth decreasing activities associated with specific sustainability variables. The next chapter seeks to describe the contributions certification programs offer the biofuel industry. The chapters that follow will examine if, and how far, certification programs can push the biofuel industry to greater sustainability.
CHAPTER VI
BIOFUEL CERTIFICATION PROGRAMS

Certification programs offer a means by which biofuel stakeholder concerns can be addressed as well as a guide to help the realization of biofuel industry promise for sustainable development. As stated in chapter one, a key component to making the biofuel industry sustainable is making certain the guidelines by which it operates do, in fact, ensure sustainability. Should enactment of certification guidelines produce limited sustainability then improvements to the certification program require attention. It is one goal of this study to present additional criteria that can enable greater sustainability and more productive means to achieve and measure certification outcomes on sustainability. This chapter will begin to examine certification program potential by describing biofuel industry certification programs, highlighting several certifications and certification guides that are currently being released, and examine how they can contribute to sustainable development measurement within the industry. Two premier biofuel certification programs, developed by the Roundtable on Sustainable Biofuels (RSB) and the Council on Sustainable Biomass Production (CSBP) will be the focus of this chapter.

Certification for the Biofuel Industry

Biofuel producers going through a given certification program are analyzed and evaluated as to their ability to operate in a sustainable manner. Evaluation applies to entities throughout the industry whether they are energy crop farmers, processors or oil refining operations. Results from certification assessments of biofuel enterprises will alert stakeholders to entities that are, or are not, acting in an economically, socially or environmentally sustainable manner. Those industry actors that are operating according
to a given certification program's guidelines are considered by that evaluative entity as being a certified provider of biofuel products or services. As certification programs become an expectation on biofuel enterprises, market options for non-certified biofuel producers will be increasingly limited. The European Union (E.U.), for example, is encouraging the use of “voluntary schemes” (such as certification programs) in order to ensure that biofuel products used in the E.U. are produced in a sustainable manner (European Union 2009, 24, 39). Such schemes may become increasingly mandatory.

Many guidelines and criteria of existing certification programs have been normatively derived (see for example Roundtable on Sustainable Biofuels 2009, 4) but have recently evolved into more quantitative measures of performance while still holding to some normative requirements (see Roundtable on Sustainable Biofuels 2010a, 5). In addition, some program elements rely upon subjective evaluation of biofuel entity performance within a point based system (Roundtable on Sustainable Biofuels 2011a, 22). Such evaluation processes can be subject to variation in its application, even corruption, despite evaluator training. As Walter Christof and Hartmut Stutzel (2009) state, transparency and validity are issues of concern. Specific to agriculture industry experience, sustainability itself has multiple definitions, is abstract and lacks quantitative measures (Christof and Stutzel 2009, 1275). The consistent provision of strictly quantitative sustainability measures will help enable more objective elements into sustainability evaluations. In the end, the goal of all stakeholders is to develop guidelines that can be reliably depended upon to provide valid measurements of responsible, sustainable activity within the biofuel industry. Certification criteria, as it builds more universal quantitative guidelines, can be evaluated to determine objectively whether
criteria can contribute to sustainability and to what extent. This will be demonstrated in the final chapters of this work where elements of both certification programs and the World Bank model will be combined to reveal an approach that will allow consistent, comparative assessment of biofuel industry sustainability performance across the globe.

Current Biofuel Certification Programs

Although many certification programs are in existence, or are currently being developed, this dissertation will focus on two of the better known programs (RSB and CSBP). In addition, some certifications or certification guides are narrow in scope, focusing on a particular aspect of biofuel industry sustainability (such as the U.N.'s Bioenergy and Food Security Criteria and Indicators) or biofuel sustainability within a specific geographic region. Many programs are still in draft stage, opening their currently developed criteria to public comment and testing prior to formal release. The bulk of this chapter will describe several of these programs, first examining RSB and CSBP within the three domains of sustainability. Examples of four, better known, smaller certification efforts are briefly described before the chapter concludes.

Roundtable on Sustainable Biofuels

The Roundtable on Sustainable Biofuels (RSB) is coordinated through the Energy Center at EPFL (École Polytechnique Fédérale de Lausanne), one of the Swiss Federal Institutes of Technology located in Lausanne, Switzerland (École Polytechnique Fédérale 2011). RSB provides the biofuel industry with a significant, positive start in guidance for responsible activity within the biofuel industry, worldwide (Roundtable on Sustainable Biofuels 2011c). The first draft principles and criteria were released in 2008, revised, and then opened up for comment from stakeholders around the world. The result of this
broad scope effort is the RSB's current standard, version two, explored in this work (Roundtable on Sustainable Biofuels 2010a, 2). The guidelines cover concerns of vulnerable stakeholders across an array of principles and criteria. Although the RSB certification version two guidelines were released for implementation late in 2010, these guidelines are expected to undergo continued testing and revision by its creators as the biofuel industry grows and changes (see for example RSB 2010a, 3).

RSB standards are provided in twelve general principles which are broken into specific performance criteria. The standards are further detailed through several documents that break down measurement expectations where incorporated into the criteria. The supplemental RSB documents provide additional guidance for criteria implementation.

_Council on Sustainable Biomass Production_

The Council on Sustainable Biomass Production released their draft standards, divided into nine principles and related criteria, in 2010. CSBP seeks to research standards that can be used by biofuel industry participants as well as create a method that will determine the extent of standard implementation. Their final set of standards is expected to be released in late 2012 (Council Sustainable Biomass Production 2011). The Council made it clear that their work is focused on sustainability in the U.S. biofuel industry. The current draft standard applies to growers. The final standard, set to be released in 2012, will be applicable to both growers and energy producers (Council Sustainable Biomass Production 2011). The standard, with modification, may have applicability to other advanced countries.

CSBP has adopted the Brundland Commission definition of sustainability in their
objective, “Adopting practices and developing products that are environmentally, socially and economically sound, and that can meet present needs without compromising the ability of future generations to meet their needs [emphasis added]” (Council Sustainable Biomass Production 2010, 5). The program is intended to be scalable to the widest range of biofuel crop producers, providing the ability to demonstrate sustainability at two separate levels of certification attainment (silver and gold) the level of which is verified by third party, CSBP accredited, auditors (Council Sustainable Biomass Production 2010, 6). The provisional standards are constructed with the intent of bringing focus to bear on all three domains of sustainability (Council Sustainable Biomass Production 2010, 10).

CSBP and RSB principles, World Bank sustainability variables and relevant contributions adopted from available literature are compared in the paragraphs that follow, organized by sustainability domain. Planning principles (given such principles apply to all three sustainability domains) and specific measurement concerns are separated into their own subsections. The principles co-locate social and economic concerns prompting the combination of those two domains in a single subsection below. This comparison will help determine how specific certification principles contribute, in a measureable way, to grounded sustainability estimation. Methods to improve the sustainable outcomes of certification principles as well as the enhancement of reliable, quantitative measures will be discussed in the chapters that follow.

Social and Economic Sustainability

__Legality__

Operations receiving CSBP certification are expected to be in compliance with all applicable legal requirements for their respective operations. Compliance with all legal
requirements by a grower is a minimum expectation of the standard (Council Sustainable Biomass Production 2010, 10). Adherence to the standard requires all employees to have at least a working knowledge of legal requirements relevant to their respective areas of responsibility (Council Sustainable Biomass Production 2010, 10, 24).

RSB principle one states, “Biofuel operations shall follow all applicable laws and regulations” (Roundtable on Sustainable Biofuels 2010a, 7). Rule of law is a major element in the World Bank’s intangible capital residual (Lange et al. 2011, 13). No direct measurement of biofuel industry activity with respect to rule of law is available within the literature reviewed. Disaggregating biofuel's contribution to this factor is not possible at this time. This also holds with the twelfth RSB principle, “Biofuel production shall respect land rights and land use rights” (Roundtable on Sustainable Biofuels 2010a, 29).

**Social and Economic Considerations**

CSBP principle six seeks to make certain that opportunities for economic and social advancement are shared equally among all stakeholders of the biofuel enterprise. The principle covers a wide variety of stakeholders, specifically listing land owners, farm workers, suppliers, bioenergy producers, and the local community. Human rights and all laws bestowed on workers are to be followed which includes the use of “worker contracts, limits to hours spent at work, freedom of association, training, hazardous materials safety practices, grievance and fair termination policies” (Council Sustainable Biomass Production 2010, 10, 22-24).

RSB principles four, five and six provide requirements with respect to human rights. These principles are concerned with the conditions workers are subject to as well as the economic enhancement of impoverished regions where biofuel operations are
located. Principle four states, “Biofuel operations shall not violate human rights or labor rights, and shall promote decent work and the well-being of workers” (Roundtable on Sustainable Biofuels 2010a, 13). This principle also makes it clear that employees should be free to organize and associate; free from discrimination; not be subject to forced labor; will not involve child labor unless conducted on family farms with consideration of each child's health and educational needs; pay the legal minimum wage, or a fairly negotiated wage as appropriate for the work conducted; and have a safe workplace in accordance to international safety standards (Roundtable on Sustainable Biofuels 2010a, 13-14). As with principle one, there is no direct measure of this variable within the World Bank methodology.

While principle four primarily focuses on worker relationships with the biofuel enterprise, RSB principle five requires that biofuel operations must show a net positive outcome in social and economic conditions within their respective communities from which they operate. “In regions of poverty, biofuel operations shall contribute to the social and economic development of local, rural and indigenous people and communities” (Roundtable on Sustainable Biofuels 2010a, 15). The RSB guidelines require evidence of socioeconomic improvements for impoverished people groups where biofuel operations reside, making certain that women and youth are not excluded. A baseline socioeconomic status of a community within the region affected by a biofuel operation is mandated. That baseline will be compared to resultant socioeconomic changes biofuel operations bring in order to determine if principle five is being met (Roundtable on Sustainable Biofuels 2010b, 11).

Evidence of socio-economic improvement can be realized in the form of increased
human capital (standing as a proxy for social development) which the World Bank study measures through educational attainment as part of the intangible capital residual (Hamilton et al. 2006, 95). A number of studies exist in the literature revealing high income elasticities for education, meaning that as wealth increases, amount of years in schooling also increases. It is interesting to note that these studies point to agricultural environments as having a lesser elasticity effect. However, in these same instances, the educational opportunities of siblings encourage higher elasticity effects (see S. Al-Samarrai and T. Peasgood 1998, 397; Paul Glewe and Harry Patrinos 1999, 900; Jane Lincoe 2009, 479; B. Wolfe and J. Behrman 1984, 231).

With respect to utilization of education as a development variable, there is debate as to the returns on education if there is no market to employ the newly educated (William Easterly 2002, 71-84). However, Greg Mortenson's (Greg Mortenson 2010; Greg Mortenson and David Relin 2006) experience teaching girls in Central Asia shows benefits of other kinds such as community health improvements and peace dividends through economic development (see also Boswell and Dixon 1990; Crocker 2003, 6; Perkins, Radelet and Lindauer 2006, 298; Williams 1994). Another concern with using educational attainment as a means to measure economic growth and social welfare is recorded by the World Bank (2007b) in their report “Education Quality and Economic Growth.” The World Bank discovered that, as opposed to number of years in school, education quality and international standardized test scores measuring cognitive skills are stronger predictors of a country’s economic development. Cross country data quality issues are an impediment for making this variable useful for the countries analyzed in this report at this time.
Should the literature resolve these issues the World Bank study is able to disaggregate the impact of education on the per capita wealth of a nation. Results vary by the development levels of a country in the initial study. For every one year increase in schooling, the intangible capital residual increases marginally as follows (Hamilton et al. 2006, 95):

Table 6.1

*World Bank Impact of Years in School on Intangible Capital*

<table>
<thead>
<tr>
<th>Country Category</th>
<th>Marginal Return</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-Income Countries</td>
<td>$838</td>
</tr>
<tr>
<td>Lower-Middle-Income Countries</td>
<td>$1,721</td>
</tr>
<tr>
<td>Upper-Middle-Income Countries</td>
<td>$2,398</td>
</tr>
<tr>
<td>High-Income OECD Countries</td>
<td>$16,430</td>
</tr>
</tbody>
</table>

The World Bank study did not take into account “… declining marginal returns to education or the quality of human capital” (Lange et al. 2011, 97). With these issues resolved in the updated (2011) study the World Bank team discovered a contribution to intangible capital across a 115 country data set to be $11,025 per capita for an additional year of schooling (Lange et al. 2011, 98).

In addition, educational expenditures are removed from the consumption portion of national income accounting and placed into investment by the World Bank study (given the returns discovered above) as they are an investment in human capital and represent an increase in genuine savings (Hamilton et al. 2006, 9, 14, 89,155; Lange et al. 2011, 37). Elasticities from other studies have only a limited range of applicability. For example, according to a study by Minh Dao (1995, 73) in a data set of 75 developing
countries, the author discovers the log coefficient of education to per capita income (GDP) to be 1.15. If national income improves from biofuel production, impacts to educational spending can be predicted which will, in turn, positively impact genuine savings. An update to the Dao study to incorporate clear separation of developed from developing countries can be a helpful contribution either directly within an estimate or by comparison to existing estimates for reliability testing purposes.

RSB principle six focuses solely on food security. “Biofuel operations shall ensure the human right to adequate food and improve food security in food insecure regions” (Roundtable on Sustainable Biofuels 2010a, 17). The principle states that improvements to food production are mandated in areas that have food security concerns (Roundtable on Sustainable Biofuels 2010a, 17). A primary concern with respect to biofuel production is the redirection of land use away from food production and into biofuel production. The risks such re-orienting can bring could represent a negative impact to country wealth which can be estimated if an adequate measure of productive food producing land loss can be determined. The World Bank study is limited to only providing values of cropland and pastureland using economic production methods (Hamilton et al. 2006, 151-53; Lange et al. 2011, 58-9). What the purely economic wealth values do not measure is the incalculable cost to human beings from lack of food resources. Such limitations do provide support for using non-monetary measurements in determining impacts to sustainability as suggested by Kulig, Kolfoort and Hoekstra (2010) and Mueller (2008). The transformation, however, of marginalized, non-ecosystem critical land to productive biofuel and food multi-crop farming represents an increase in a country's overall wealth. In keeping with the World Bank approach, this can
be measured as a function of crop production value as determined by Hamilton et al. (2006, 151-53) and Lange et al. (2011, 58-9).

Transparent Communication and Processes

The CSBP certification holder is expected to operate in a manner that allows an appropriate level of transparency in the conduct of its operations (Principle 8). Stakeholders must be given an appropriate amount of data to enable informed decision making. The CSBP pledges, however, to adhere to intellectual property rights and keep competitive related information confidential (Council Sustainable Biomass Production 2010, 11). The second RSB principle covers transparency in stakeholder dealings along with planning and continuous improvement. This RSB principle is described further in the planning subsection below.

Environmental Sustainability

Biodiversity and Ecosystems

Principle seven contains RSB's requirements specific to ecological concerns. “Biofuel operations shall avoid negative impacts on biodiversity, ecosystems, and conservation values” (Roundtable on Sustainable Biofuels 2010a, 18). Protected areas are given initial monetized value through the World Bank study (Hamilton et al. 2006, 153-54). However, ecosystems are priceless (Hamilton et al. 2006, 24, 101) and cannot be valued (Kerry Smith 2007, 162). Their destruction is difficult to monetize, once again lending credence to Kulig, Kolfoort and Hoekstra (2010) and Mueller (2008). As stated in Chapters III and IV, environmental asset monetization is still under strong debate in the literature limiting the use of this criterion to initial wealth building impacts when protected areas are created. Yet, the net creation of protected areas will have the effect of
building wealth if accomplished in conjunction with plantation establishment which is an option under portions of the guidelines (Council Sustainable Biomass Production 2010, 16). If forest areas increase, a similar logic applies with respect to initial contribution to wealth building (Hamilton et al. 2006, 151; Lange et al. 2011, 146-48).

The third CSBP principle discusses biodiversity whereby certification recipients are expected to, “… contribute to the conservation or enhancement of biological diversity, in particular native plants and wildlife (Council Sustainable Biomass Production 2010, 10).” As with RSB principle seven the effect of creating protected areas increases wealth. Ecosystem degradation destroys wealth and places the biofuel operation's certification in jeopardy (Council Sustainable Biomass Production 2010, 17).

In developing biodiversity conservation, certified operations need to be familiar with “eco-regional, state, and national conservation plans and develop plans and activities to protect biological diversity in consultation with resource agencies, conservation organizations, or expert professionals (who may be employees of the program participant)” (Council Sustainable Biomass Production 2010, 15). It is worth noting that the guidelines presented here are astute to consider the eco-regional level as part of their guidelines. Small changes to local environments can have large overall impacts to regional environmental concerns. Certified biofuel organizations are expected to consult with government and ecological experts on a national to local scale as necessary (Council Sustainable Biomass Production 2010, 15).

For CSBP “silver” certification status only localized and incidental areas are reviewed prior to activities that disturb the area to be planted. Activities conducted must keep conservation in mind for “rare, threatened and endangered species” (Council
Sustainable Biomass Production 2010, 15). The gold standard requires adherents to also contribute to conservation activities outside their area of biomass operations (Council Sustainable Biomass Production 2010, 16). Potentially invasive species are to be avoided and those species grown which are initially not labeled as non-evasive must be controlled so as to avoid invasive propagation outside of the grower's property (Council Sustainable Biomass Production 2010, 17).

In addition, the vegetation category of the land will be noted as of January 1, 2008. If the vegetation characteristics of the land are unknown, the landholder will support ecological inventory efforts (Council Sustainable Biomass Production 2010, 17). The expectation is that land conversion and its implications concerning ecological damage will be under control. This criterion is a point of continued debate within the council and is expected to undergo revision (Council Sustainable Biomass Production 2010, 32). Regardless, intensification of land management is currently not allowed if the area under consideration for cultivation contains threatened species. Where intensification of land management is allowed it can only be one order of management magnitude higher as outlined in the standard (Council Sustainable Biomass Production 2010, 32-4).

Soil Conservation

Soil fertility and erosion requirements are stated in RSB principle eight. “Biofuel operations shall implement practices that seek to reverse soil degradation and/or maintain soil health” (Roundtable on Sustainable Biofuels 2010a, 21). Soil degradation will reduce the value of land assets but, as explained above, strict monetization using existing methods in the literature cannot begin to calculate human and ecosystem loss.
Restoration of degraded lands to higher social, economic or environmental purposes will increase the value of land based asset categories but in a way that is limited to an amount that simply reflects economic production value at this time given the current state of the literature (see Hamilton et al. 2006, 151-54; Lange et al. 2011, 146-50). RSB recommends taking a baseline soil test and conducting periodic soil testing to measure soil nutrient and organic material levels (Roundtable on Sustainable Biofuels 2011c, 3-4).

The second CSBP principle seeks to promote soil conservation by “minimizing erosion, enhancing carbon sequestration, and promoting healthy biological systems and chemical and physical properties” (Council Sustainable Biomass Production 2010, 10) which includes the maintenance of “soil carbon and nutrients at appropriate levels” (Council Sustainable Biomass Production 2010, 14). Aeration and compaction are also listed as a concern along with erosion. Existing soil maps are used as a base from which to calculate changes in soil condition. Certified biomass cultivators are expected to monitor their soil, conduct annual soil tests and submit status reports. CSBP’s expectation is that soil nutrients are to be kept at a level that supports existing flora. In addition, paths through fields should be minimized and, when paths finish their useful life, be rehabilitated (Council Sustainable Biomass Production 2010, 14). Measurements are very quantifiable. For example, erosion is measured by “… score less than or equal to T on RUSLE-II, with recognition of variances for extreme weather events or upgrades to on-farm conservation systems” (Council Sustainable Biomass Production 2010, 14). Also, “a zero or positive score on the Soil Conditioning Index shall be considered an adequate proxy for maintaining or improving soil carbon content” (Council Sustainable Biomass Production 2010, 14). As explained above, certain types of improvements to
land can have the effect of increasing wealth.

**Water Conservation**

CSBP's water conservation guidelines are detailed in its fourth principle.

“Biomass production shall maintain or improve surface water, groundwater, and aquatic ecosystems. Biomass production should not contribute to the depletion of ground or surface water supplies. When irrigation is necessary, the most efficient irrigation technology appropriate to the circumstance should be used” (Council Sustainable Biomass Production 2010, 10). Water quality can be impacted by cultivation operations.

Fertilizer, agrochemical and pesticide application planning and testing is required to include testing of any waste water prior to use. In addition, aquatic ecosystems should not be harmed by operations (Council Sustainable Biomass Production 2010, 18, 21).

Depletion of surface or groundwater is also a concern. Gold standard adherents will demonstrate a net decrease in water consumption through their operations at either the local operation or irrigation district. Silver standard operations must not contribute to further depletion beyond existing water rights obtained prior to the cultivation of biomass crops (Council Sustainable Biomass Production 2010, 20). In essence, biomass crop activity may not be given the same access to water as food crop cultivation activity.

RSB principle nine states: “Biofuel operations shall maintain or enhance the quality and quantity of surface and ground water resources, and respect prior formal or customary water rights” (Roundtable on Sustainable Biofuels 2010a, 22). RSB utilizes Texas A&M University's SWAT (Soil and Water Assessment Tool) for water quality measurement (Roundtable on Sustainable Biofuels 2010b, 19). Although important, lack of widely available data (Hamilton et al. 2006, 24, 38, 87; Lange et al. 2011, 150) makes
measurement of water variables in the World Bank model impossible at this time.

**Climate Change**

Greenhouse gases and climate change concerns provide a stronger link to the World Bank variables and are handled in RSB principle three. Principle three states, “Biofuels shall contribute to climate change mitigation by significantly reducing lifecycle GHG emissions as compared to fossil fuels” (Roundtable on Sustainable Biofuels 2010a, 10). Although the third principle is only concerned with greenhouse gases, linking it directly to the World Bank carbon dioxide variable, particulate matter is handled in principle ten.

RSB principle ten states, “Air pollution from biofuel operations shall be minimized along the supply chain” (Roundtable on Sustainable Biofuels 2010a, 25). This principle discusses air pollution and the biofuel operation's responsibilities to minimize such pollution. Both principles go well beyond existing measurements of the World Bank air pollution variable which, until recently, only takes into account carbon dioxide and particulate matter (Hamilton et al. 2006, 37).

Greenhouse gases are expected to diminish with the production and use of biomass sources of fuel according to the fifth CSBP principle. “This principle embraces full life cycle assessment (LCA) as the primary tool for ensuring substantive reduction in GHG emissions. Emissions shall be estimated via a consistent approach to life cycle assessment” (Council Sustainable Biomass Production 2010, 10). Operational components measured include production inputs such as fertilizer; cultivation practices such as planting and harvesting; soil carbon depletion and transportation (Council Sustainable Biomass Production 2010, 21).
With respect to carbon dioxide, the World Bank method charges net savings $20 per ton of carbon dioxide emissions to compensate for “marginal global damages of the pollutant” (Hamilton et al. 2006, 38; Lange et al. 2011, 155). Particulate matter damage is assessed in the World Bank study as “the willingness to pay to reduce the risk of mortality” (Hamilton et al. 2006, 38; Lange et al. 2011, 155) due to levels of particulates in the atmosphere. Particulate matter cost to a country's wealth is calculated as disability adjusted life years lost due to PM multiplied by willingness to pay (Hamilton et al. 2006, 157).

Earlier studies have determined the pollution reduction properties of biofuels (EPA 2002, 74; McCormick et al. 2007). Using biodiesel as an example, a 10.1% reduction in PM emissions is achieved, based on the use of soy biodiesel at B20 blending (EPA 2002, 74). The RSB, however, has published its own set of guidelines to determine the greenhouse gas emissions of different biofuel varieties.

Emissions reduction standards are based on legislative guidelines (with the exception of blending which must demonstrate a 50% comparable reduction) within a given producer's country of operation (Roundtable on Sustainable Biofuels 2010a, 11). Net reductions in pollution damage due to a country’s use of biofuels, however, should be considered in future country level pollution calculations. How these reductions can be credited to the biofuel industry is another matter.

Calculated reductions in emissions damage on a per ton basis can be valued according to the World Bank methods. The result, after adjustment to changes in fuel demand and cross border effects, will be a net impact to genuine savings. The challenge in obtaining these numbers is that production data is limited to aggregate fuel production.
The data is not broken down by biofuel feedstock type internationally. Biofuel categories are limited to ethanol and biodiesel at this time (see Energy Information Administration 2010b). Until data is collected which reflects quantities of biofuel produced by type of feedstock, air pollution estimate precision will suffer. Regardless, data obtained from an inventory of emissions can be taken at the biofuel industry operational level. Findings will represent a deduction to genuine savings. Such advantages of biofuels will be evident in changes (net reductions) in transportation fuel pollution from one year to the next. Unfortunately, credit for the reduction may elude the biofuel industry given the genuine savings calculations are annualized.

Planning and Continuous Improvement

The first CSBP principle requires certification adherents to create an Integrated Resource Management Plan (Council Sustainable Biomass Production 2010, 10). Operational assessments, management plans, implementation timeline, monitoring and documentation processes are required of each biofuel enterprise seeking CSBP certification. Every five years a review of operations are required with revisions to program management being incorporated into management plans as appropriate (Council Sustainable Biomass Production 2010, 13). Biofuel operations seeking certification will be required to obtain information about the existing natural assets of the land area, determine the impact of operations and how operations can contribute to conservation (Council Sustainable Biomass Production 2010, 12). These evaluation efforts are required to set a baseline for future performance measurement but do not have a direct link to a World Bank model variable. Instead, proper assessment, planning and execution required by this principle will help produce sustainable outcomes for the certification
CSBP adherents are expected to keep up with the latest technological (to include process) improvements in order to move toward greater levels of sustainability. Annual auditing of biofuel operations will provide guidance as to how operators can steadily increase the sustainability of their operations (Council Sustainable Biomass Production 2010, 11). As more sustainable methods are found it is expected that certification adherents will comply with these methods once incorporated into the formal standard (Council Sustainable Biomass Production 2010, 25). With respect to RSB, “The use of technologies in biofuel operations shall seek to maximize production efficiency and social and environmental performance, and minimize the risk of damages to the environment and people” (Roundtable on Sustainable Biofuels 2010a, 26). The impact of this eleventh RSB principle spans many variables within the World Bank study and influence most all other principles.

The second RSB principle covers planning, transparency in stakeholder dealings and continuous improvement. “Sustainable biofuel operations shall be planned, implemented, and continuously improved through an open, transparent, and consultative impact assessment and management process and an economic viability analysis” (Roundtable on Sustainable Biofuels 2010a, 8). An impact assessment itself encompasses multiple sustainability variables. In fact, several impact assessment guides are provided by the RSB in order for a biofuel entity to properly determine its impact on sustainability. The assessment guide applied is based on the “nature, intensity and scale of [the biofuel entity's] operations” (Roundtable on Sustainable Biofuels 2010b, 5). For example, an operation is reviewed through RSB’s screening tool to determine what level
of assessment is required. If a new operation is over 1,000 hectares on one single, continuous area of land an Environmental and Social Impact Assessment (ESIA) is required (Roundtable on Sustainable Biofuels 2011b, 3). As with CSBPs planning principle, given the broad scope of RSB principle two there is no direct match with a World Bank variable.

Measurement and Evaluation Concerns

Measurement of the biofuel enterprise operational impact is described within RSB's second principle. Their method is based on the input of appointed “specialists” who are trained to review industry actor performance. The specialists are responsible for evaluating the biofuel operation, providing recommendations as needed to improve operational outcomes and suggest monitoring activities. Specialists can recommend termination of certification if they determine operational deficiencies warrant such action (Roundtable on Sustainable Biofuels 2011a, 11-3). The extent and type of measurement used to evaluate performance is left up to the specialists as long as data sources and methods are discussed in the specialists' report (Roundtable on Sustainable Biofuels 2011a, 15). Broadly considered, leaving the choice of data and data collection methods up to individual assessors may severely limit the ability to conduct accurate, reliable country or aggregate level impact analysis or comparisons.

The guidelines do provide a sliding scale type of measure. These scales provide a means by which quantitative data can be collected and analyzed. The ratings selected for a given operational assessment is strongly dependent upon the professional judgment of the specialists (Roundtable on Sustainable Biofuels 2011a, 21-3). With any number of specialists operating in diverse environments it is difficult to determine how reliability
can be assured. Even validity, in the face of concerns such as those brought up by Christof and Stutzel (2009), is concerning. The use of this data for cross country comparative purposes or even single country biofuel industry impact on sustainability estimations may be in doubt.

As stated above, CSBP’s program is scalable and allows for two separate levels of certification attainment (silver and gold) as verified by third party, CSBP accredited, auditors (Council Sustainable Biomass Production 2010, 6). Where practical metric evaluations are conducted CSBP does recognize that other approaches to proving sustainability are possible in which case the program offers the flexibility to allow for their inclusion as evidence of sustainable practice (Council Sustainable Biomass Production 2010, 6-7). The criteria do offer specific and measurable components. For example, pesticide use is to be monitored based on “... a score of low risk on the Natural Resources Conservation Service Windows Pesticide Screening Tool” (Council Sustainable Biomass Production 2010, 19).

What is not clear is how the multitude of measurable standards can be implemented on a scale that does include the impoverished small-holder. Finer grain analysis such as that which is presented in the CSBP standards will require time, resources and education on the part of prospective program adherents. CSBP states, “CSBP will provide guidance to program participants and auditors regarding how to appropriately apply the standard at various farm scales” (Council Sustainable Biomass Production 2010, 6) leaving the extent of standards application to question.

Other Sources of Certifications and Guidelines

Article 17 through 22 of the European Union Directive 2009/28/EC provides
sustainability guidelines for biofuel producers and the certification criteria they operate under. Provision of biofuels to the European Union (E.U.) is dependent upon evidence of sustainable operations. Biofuel production must demonstrate contribution to the reduction of greenhouse gases; not be produced on lands with high biodiversity value or containing high carbon stock or on peat land unless specific conditions are met; and that agricultural and environmental practices meet existing legal requirements (European Union 2009, 36-7). Additional environmental criteria covering ecosystem protection land use and water conservation are also stated (European Union. 2009, 39). The criteria are not limited to only environmental factors. Countries supplying biofuels are given, through the directive, a period of time in which to implement social sustainability expectations (European Union 2009, 38). Should “voluntary schemes” developed by bio-energy producers meet E.U. requirements; E.U. recognition will be granted (European Union 2010, 1). The E.U. will review compliance to its guidelines regularly through Commission investigation and industry actor and stakeholder self monitoring (European Union 2009, 41-2).

The Global Bioenergy Partnership (GBEP) was established in a meeting of the G8 in July 2005. A purpose of the Partnership is to develop a set of sustainability indicators for use in the biofuel industry (among other goals) in the furtherance of sustainability in alternative energy production and use worldwide (Global Bioenergy Partnership 2011a, 1). At the time of this writing these indicators are still under development. GBEP sustainability criteria and indicators will come with methodology sheets to help biofuel stakeholders with criteria implementation in a manner that is sensitive to local needs (Global Bioenergy Partnership 2011b, 2.). GBEP may have developed a way to drive
needed consistency into criterion compliance measurement. Such a development will greatly assist sustainability estimations.

The World Wildlife Federation (WWF) published its own set of standards for the conscientious production of bio-energy. What the WWF provides in their work is a set of standards which requires further effort to build respective implementation guides. WWF lists their primary sustainability concerns as the clarification of land ownership; land use change; food priority over fuel; no negative impacts on biodiversity; ensuring worker rights, fair compensation, health and working conditions; and minimizing negative production impacts on water quality, water quantity, green house gas accumulation, soil quality and soil stability (World Wildlife Federation 2006, 21-2). The WWF and other NGO sources report that industrial scale cultivation can exclude smaller producers from growing crops on local land for local populations with the effect of causing conflict and worsening poverty (Smolker et al. 2008, 15, 22-3; World Wildlife Federation 2006, 13) as a further socio-economic concern. These standards are the efforts of WWF to make certain several key sustainability factors are not left out of sustainability guidelines for the industry.

The United Nation's Food and Agriculture Organization (FAO) launched the Bioenergy and Food Security Criteria and Indicators (BEFSCI) project in 2009 as a means to address food security concerns and the food versus fuel debate described in earlier portions of this text. It is the intention of BEFSCI to help inform policy efforts of governments, international organizations and other concerned stakeholders of ways to determine biofuel industry impact on food security issues. Although it does not provide a certification program per se, it does provide specific indicators of sustainability along
four domains of food security: “availability, access, stability and utilization” (Bioenergy and Food Security 2011). Draft indicators currently address staple crop production volatilities; use of staple crops; food inflation; income volatility; land access for the subsistence and small holder farmer; and, to be developed later, biodiversity and “household dietary diversity” (Bioenergy and Food Security 2011). BEFSCI's website does refer to these indicators as showing promise of measurability but provides few details as to how the indicators are operationalized and how causality is to be assessed. BEFSCI is currently undergoing testing of a finalized set of indicators that will be published (Bioenergy and Food Security 2011).

Conclusion

A detailed comparison of all biofuel certification programs and sustainability guides would justify an entire work in and of itself. The goal of this chapter is to examine several of the better known works providing background information for Chapters VII through IX. Chapters VII through IX will provide a contribution toward certification program enhancement that is hoped to influence Pareto style improvements for biofuel industry stakeholders and offer an initial means to provide consistent measurement of biofuel industry performance that is reliable and allows for broad comparative and global performance measurement. Only quantifiable, consistent measurements will allow for reliability in cross country and regional comparisons of industry sustainability. The industry's ability to justify its claim of being a sustainable alternative, in large measure, will depend on consistent measurements that can be aggregated across this burgeoning industry. The World Bank's sustainability model will help ground certification principles into theory, allowing for a foundation from which to
measure and estimate biofuel industry sustainability. The marriage of certification principles and the World Bank model is presented in the following chapters.

Ultimately quantitative analysis of the enacted certification guidelines will reveal the extent of Pareto type effects on stakeholders. As quantified certification data is collected hopefully it will be shared with the academic community. With guidelines still under revision, measurable indicators still under development and data yet to be collected through what is hoped to be a consistent and unified approach, answering the question of biofuel production sustainability is left up to estimations using existing World Bank and U.S. Department of Energy data. Such estimations will be conducted in the next chapters. Certification program influence on biofuel production sustainability can still be theorized. Using this chapter's background information such analysis will be conducted in Chapter VIII.
CHAPTER VII

METHODS AND LIMITATIONS

As suggested by Pezzey (1992, 47) sustainability criteria can be applied to individual projects by examining the project's discounted monetary costs and benefits. In a similar way this work intends to apply sustainability assessment, not on an individual project level, but on a country-by-country, industry scale. The biofuel industry is new. Current data sources only carry a narrow range of sustainability data representing limitations to the depth of this study’s findings. The value of examining these limitations, where they lead to an understanding of data needs required to thoroughly assess biofuel industry sustainability, is that a course for data gathering can be established early on in this new, tumultuous, yet growing industry. Most variables can be estimated with the exception of variables related to investment, depreciation, subsoil assets, timber resources, non-timber forest resources and foreign asset data. Reasons will follow.

Methods and limitations, presented by relevant hypothesis, follow. Results of method application are presented in the next chapter. Data sources and a brief description of the data are explained first.

Data

All non-binary data was obtained in a country-year panel format. Countries with and without biofuel production data are incorporated in the dataset. Information on biofuel production was obtained from the U.S. Department of Energy's Energy Information Administration. Raw data is recorded in thousands of barrels of production per day. Data available at the time of this writing spans ten years from the years 2000 to 2009.
Fallow land data is obtained from the Food and Agriculture Organization (FAO) of the United Nations. FAO defines fallow land as, “…cultivated land that is not seeded for one or more growing seasons. The maximum idle period is usually less than five years” (United Nations 2011). Once fallow beyond the five year classification limit, land is reclassified according to the natural characteristics prevalent such as pastureland or wooded land. This data is recorded in thousands of hectares (United Nations 2011). Available data spans the years 2001 to 2008.

The World Bank is the source of data for adjusted net savings; pollution; forest area, energy and mineral depletion; food production index; education expenditure; total agricultural land area and protected land area. The food production index is based on an average of three years (1999 – 2001) set to an index base value of 100. Adjusted net savings and depletion variables are calculated by the World Bank (Hamilton et al. 2006, 156; Lange et al. 2011, 154) method. Total agricultural land is expressed in square kilometers.

Binary data points have several sources. The tropical country binary variable is built from Jürgen Grieser et al. (2006) and countries that have a majority or a significant portion of land mass between the Tropics of Cancer and Capricorn. Such countries are coded as “1.” The developing country binary variable designates a country as being developed or developing from a list maintained by the International Monetary Fund (IMF) (International Monetary Fund 2010). All countries not listed as “Advanced Economies” by the IMF are designated as “developing” in this study and are coded as “1.”

The country level biofuel production experience binary is author derived. It is
obtained by dividing country level production data between countries that have low or no production (under five million barrels of biofuels produced per year as of 2009) and those countries that have high production (over five million barrels of biofuels produced per year as of 2009). This binary is intended to separate those countries that have little or no biofuel production experience from those with much greater production experience. Biofuel production data exhibit a large gap of over one million barrels between the two groups of countries over the data set. A continuous barrel/year variable is also measured.

Hypothesis 1

\( H_1: \text{There is a Positive Relationship between Country Level Biofuel Industry Production and Sustainable Development as Measured by the World Bank Sustainable Development Model} \)

The first challenge presented by this hypothesis is to bridge the gap between macro and micro economic scales. As is demonstrated in Chapter I the biofuel industry (micro) can have a significant nation scale economic impact (macro) to the amount of several points of GDI. Next, estimations as to the industry’s connection to sustainability (using available data) need to be conducted. OLS regression is used for this task. Arithmetic, accounting type forms will be proposed for those sustainability measurements that have such measureable data. Although lack of complete data prevents a comprehensive conclusion, the data that is available provides a start. Results from this analysis will begin to reveal not only country level biofuel industry sustainability but also the net contribution of a given country’s biofuel industry to that country’s overall sustainability.

Using the World Bank sustainability model, biofuel contribution to a given
country's adjusted net savings and wealth stocks can be derived. Negative overall contributions will indicate that the biofuel industry is on an unsustainable path and is operating in a detrimental way to a given country’s sustainability efforts. Positive numeric outcomes demonstrate the industry may be operating in a sustainable manner and is making a net contribution to a given country's wealth and sustainability. Results at zero demonstrate no impact to wealth or sustainability.

As demonstrated in Chapter IV, current World Bank sustainability variables are broken down into two sets. The first measures country level wealth, the second enables adjusted net savings calculations at the country level. The analysis that follows is similarly organized. Biofuel industry aggregate impacts on country level adjusted net savings, followed by individual adjusted net savings variables, will be detailed first.

**Biofuel Industry Adjusted Net Savings Impacts**

In accounting for the biofuel impacts to adjusted net savings the following equation applies: \( \Delta \text{Adjusted Net Savings (ANSav)} = \text{biofuel industry investment} - \text{consumption of biofuel industry fixed capital} + \text{influence on educational expenditures} - \text{energy depletion} - \text{mineral depletion} - \text{net forest depletion} - \text{net carbon dioxide and particulate matter damage}. \) The sign of the resulting \( \Delta \text{ANSav} \) is an indication of biofuel contribution to the maintenance of a country's wealth producing portfolio. The World Bank does provide guidance as to how the above variables are to be measured (Hamilton et al. 2006, 155-57; Lange 2011, 156). Applying this guidance to the biofuel industry is required to supplement estimates and assess their reliability.

A mix of estimations and accounting functions are used. What turns the evaluation of biofuel impacts to adjusted net savings from an accounting function to an
estimation function is that, at this time, specific biofuel industry data sets are not available for all, relevant World Bank adjusted net savings variables. Specific data sets needed and their importance to sustainability, the biofuel industry and industry stakeholders will be discussed in this chapter and summarized in the last chapters.

*Overall adjusted net (genuine) savings impact.* Data for estimations of country level biofuel production impact on adjusted net savings are obtained from two primary sources: the U.S. Department of Energy (2011) and the World Bank (2011). Specifically, information on biofuel production was obtained from the U.S. Department of Energy's Energy Information Administration. The raw data is assembled in records consisting of year-country panels using Microsoft Excel and comma separated value files. Raw data was imported into Stata version nine where regression and supporting statistics are run.

The OLS regression run follows the equation below:

$$\log(10)\text{ANSav} = F(\beta\log(10)\text{Bp}, \beta\text{D}, \beta\text{T}, \beta\text{BpExp})$$

Table 7.1

*Biofuel Production Impact on Adjusted Net Savings*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANSav</td>
<td>Adjusted net (genuine) savings as measured by the World Bank in U.S. dollars.</td>
</tr>
<tr>
<td>Bp</td>
<td>Biofuel production in thousands of barrels per day.</td>
</tr>
<tr>
<td>D</td>
<td>Binary developing country variable. Developing countries are coded with a “1”; developed countries are coded with a “0.”</td>
</tr>
<tr>
<td>T</td>
<td>Binary tropical country variable. Countries that have significant tropical zones (Grieser et al. 2006) are coded with a “1”, countries without significant tropical zones (those that do not currently...</td>
</tr>
</tbody>
</table>
Table 7.1 (Continued).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>T (cont.)</td>
<td>support high yielding tropical biofuel agriculture – see Jongschaap et al. 2007; Purdue 2010) are coded with a “0.”</td>
</tr>
<tr>
<td>BpExp</td>
<td>A binary variable signifying country level biofuel production experience. Countries producing over five million barrels annually are coded as “1.” Countries producing less than five million barrels annually (as of 2009) are coded as “0.”</td>
</tr>
<tr>
<td>log(10)</td>
<td>Logarithmic transformations are required to resolve skew characteristics in biofuel production and adjusted net savings data. The last three independent variables were not transformed given their binary nature.</td>
</tr>
</tbody>
</table>

In the future, comparisons can be run between the estimate above and results from individual adjusted net savings variable measurements below to determine estimator reliability. Biofuel industry data needs and application to the World Bank model follows.

**Gross national savings.** Biofuel investment activity for a given year contributes to gross national savings. Sources of this data have been slow to respond for data access. No country level, complete, publically available dataset of this nature could be found at the time of this writing.

**Consumption of fixed capital.** Depletion of production assets is included in consumption of fixed capital. A discount can be applied to investment data to proxy for asset depreciation. Such a proxy is dependent upon future availability of investment data.

**Education expenditure.** As explained in chapter five educational expenditures on a country level has a positive impact on adjusted net savings. Chapter V lists some of the debates centered on its use. If a precise elasticity is presented in the literature it may be
useful here. Until then, estimation is conducted using World Bank and Energy Information Agency data. The regression equation is below:

\[
\log(10)EdExp = F(\beta \log(10)Bp, \beta D, \beta T, \beta BpExp)
\]

Table 7.2

**Biofuel Production Impact on Education Expenditure**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>EdExp</td>
<td>Public expenditures on education less capital investments.</td>
</tr>
<tr>
<td>Bp</td>
<td>Total biofuel production (in thousands of barrels per day).</td>
</tr>
<tr>
<td>D</td>
<td>Binary developing country variable. Developing countries are coded with a “1”; developed countries are coded with a “0.”</td>
</tr>
<tr>
<td>T</td>
<td>Binary tropical country variable. Countries that have significant tropical zones (Grieser 2010) are coded with a “1,” countries without significant tropical zones (those that do not currently support high yielding tropical biofuel agriculture – see Jongschaap et al. 2007; Purdue 2010) are coded with a “0.”</td>
</tr>
<tr>
<td>BpExp</td>
<td>A binary variable signifying country level biofuel production experience. Countries producing over five million barrels annually are coded as “1.” Countries producing less than five million barrels annually (as of 2009) are coded as “0.”</td>
</tr>
<tr>
<td>log(10)</td>
<td>Logarithmic transformations are required to resolve skew characteristics in biofuel production and adjusted net savings data. The last three independent variables were not transformed given their binary nature.</td>
</tr>
</tbody>
</table>

**Energy depletion.** Depletion of energy (non-renewable) is an accounting function based on amounts used by a given country’s biofuel industry. Following the World Bank formula, energy depletion would be the product of energy consumed; average international market price and unit resource rents (Hamilton 2006, 156; Lange 2011,
An estimate or census of the given industry operators, given the current state of the data, will lack greater precision given two issues. First, it cannot be determined if the biofuel industry consumes domestic or imported energy sources. Second, under the assumption that optimal operating processes encouraged by certification would involve the use of their own product (particularly in the case of biodiesel) the industry should have little impact on energy depletion to begin with. Utilization of an accounting function can acquire a more conservative measure of industry impacts on adjusted net savings, incentivizing renewable energy use within biofuel industry operations. The OLS regression equation for this estimate is below:

\[
\log(10)\text{EnergyDep} = F(\beta\log(10)\text{Bp}, \beta\text{D}, \beta\text{T}, \beta\text{BpExp})
\]

**Table 7.3**

*Biofuel Production Impact on Energy Depletion*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>EnergyDep</td>
<td>Energy depletion – oil, coal and natural gas (cost to genuine savings in U.S. dollars).</td>
</tr>
<tr>
<td>Bp</td>
<td>Total biofuel production (in thousands of barrels per day).</td>
</tr>
<tr>
<td>D</td>
<td>Binary developing country variable. Developing countries are coded with a “1”; developed countries are coded with a “0.”</td>
</tr>
<tr>
<td>T</td>
<td>Binary tropical country variable. Countries that have significant tropical zones (Grieser 2010) are coded with a “1,” countries without significant tropical zones (those that do not currently support high yielding tropical biofuel agriculture – see Jongschaap et al. 2007; Purdue 2010) are coded with a “0.”</td>
</tr>
<tr>
<td>BpExp</td>
<td>A binary variable signifying country level biofuel production experience. Countries producing over five million barrels annually are coded as “1,” Countries producing less than five</td>
</tr>
</tbody>
</table>
Table 7.3 (Continued).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BpExp (cont.)</td>
<td>million barrels annually (as of 2009) are coded as “0.”</td>
</tr>
<tr>
<td>log(10)</td>
<td>Logarithmic transformations are required to resolve skew characteristics in biofuel production and adjusted net savings data. The last three independent variables were not transformed given their binary nature.</td>
</tr>
</tbody>
</table>

**Mineral depletion.** Mineral depletion, similar to pollution measures, is limited to a small subset of specific minerals. For agricultural use, copper, iron and zinc are considered soil micronutrients; from phosphate a primary soil nutrient (phosphorous) is derived. The measurement of biofuel production’s contribution to mineral depletion can be calculated similar to the way mineral depletion is calculated in the World Bank sustainability study which is a product of mineral use, average international market price and unit resource rents (Hamilton 2006, 156; Lange 2011, 153). In as much as these minerals are used in the biofuel enterprise, their utilization can be measured and accounted for as a reduction in the industry’s contribution to net savings. Similar to energy depletion, estimations will lack complete precision at this time unless biofuel industry use of imported, as opposed to domestic mineral sources, can be determined and calculated. The multiple regression function used to estimate mineral asset depletion is provided below:

\[
\log(10)\text{MineralDep} = F(\beta\log(10)Bp, \beta D, \beta T, \beta BpExp)
\]
Table 7.4

*Biofuel Production Impact on Mineral Depletion*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MineralDep</td>
<td>Mineral depletion (cost to genuine savings in U.S. dollars).</td>
</tr>
<tr>
<td>Bp</td>
<td>Total biofuel production (in thousands of barrels per day).</td>
</tr>
<tr>
<td>D</td>
<td>Binary developing country variable. Developing countries are coded with a “1”; developed countries are coded with a “0.”</td>
</tr>
<tr>
<td>T</td>
<td>Binary tropical country variable. Countries that have significant tropical zones (Grieser 2010) are coded with a “1,” countries without significant tropical zones (those that do not currently support high yielding tropical biofuel agriculture – see Jongschaap et al. 2007; Purdue 2010) are coded with a “0.”</td>
</tr>
<tr>
<td>BpExp</td>
<td>A binary variable signifying country level biofuel production experience. Countries producing over five million barrels annually are coded as “1.” Countries producing less than five million barrels annually (as of 2009) are coded as “0.”</td>
</tr>
</tbody>
</table>

Log(10) Logarithmic transformations are required to resolve skew characteristics in biofuel production and adjusted net savings data. The last three independent variables were not transformed given their binary nature.

*Forest area depletion.* Concerns exist as to biofuel production impact on forest area depletion. This concern can be estimated and later tested for reliability against roundwood harvest raw data collected through certification program site assessment (see Chapter VIII). The regression model below seeks to discover the relationship (if any) between forest depletion and biofuel production. The purpose of adding food production to the forest depletion model is an initial attempt to isolate this contributor to forest depletion, assessing comparative impacts. The other variables in the equation remain for
consistency with the adjusted net savings function. The multiple regression function is as follows:

$$\log(10) F_d = F(\log(10) B_p, \beta F_p, \beta D, \beta T, \beta B_p \text{Exp})$$

**Table 7.5**

*Biofuel Production Impact on Forest Depletion*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fd</td>
<td>Forest area depletion (cost to genuine savings in U.S. dollars).</td>
</tr>
<tr>
<td>Bp</td>
<td>Total biofuel production (in thousands of barrels per day).</td>
</tr>
<tr>
<td>Fp</td>
<td>Food production index.</td>
</tr>
<tr>
<td>D</td>
<td>Binary developing country variable. Developing countries are coded with a “1”; developed countries are coded with a “0.”</td>
</tr>
<tr>
<td>T</td>
<td>Binary tropical country variable. Countries that have significant tropical zones (Grieser 2010) are coded with a “1,” countries without significant tropical zones (those that do not currently support high yielding tropical biofuel agriculture – see Jongschaap et al. 2007; Purdue 2010) are coded with a “0.”</td>
</tr>
<tr>
<td>BpExp</td>
<td>A binary variable signifying country level biofuel production experience. Countries producing over five million barrels annually are coded as “1.” Countries producing less than five million barrels annually (as of 2009) are coded as “0.”</td>
</tr>
<tr>
<td>log(10)</td>
<td>Logarithmic transformations are required to resolve skew characteristics in biofuel production and adjusted net savings data. The last three independent variables were not transformed given their binary nature.</td>
</tr>
</tbody>
</table>

**Pollution.** As described in Chapter V, carbon dioxide and particulate matter pollution measurements can be calculated by the formula that follows: (The variables of this equation are detailed in Table 7.6.) The equation estimating pollution variables is
presented in Table 7.7.

Table 7.6

*Pollution Accounting Equation Components (Annual)*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Δ CO2ci</td>
<td>Total change in CO2 cost to a given country’s (“c”) wealth from biofuel industry production activity for all fuel types “i” used.</td>
</tr>
<tr>
<td>CO2eci</td>
<td>Carbon dioxide emissions “e” of each fuel type “i” used in tons per gallon combusted by a given country’s (“c”) biofuel industry production activity.</td>
</tr>
<tr>
<td>Dci</td>
<td>Total quantity of fuel used, by each fuel type “i”, in gallons, by a given country’s (“c”) biofuel industry production activity.</td>
</tr>
<tr>
<td>Bi</td>
<td>The percent decrease in CO2 emissions based on a given fuel’s (“i”) pollution reduction properties (accounting for fuel blending conducted).</td>
</tr>
<tr>
<td>$20</td>
<td>The cost of damage to wealth producing assets based on each ton of CO2 produced (Hamilton 2006, 38; Lange 2011, 78).</td>
</tr>
</tbody>
</table>

As stated in Chapter V the above equation is run for each different fuel type used in biofuel industry operations. The formula needs to be run for both pollutants tracked by the World Bank model substituting the cost component in the formula above for particulate matter costs (see Hamilton 2006, 157 and Lange 2011, 155). The results from calculating the damages of each fuel type are combined for total pollution damage loss to adjusted net savings.

The pollution estimation is detailed in the following table using the equation
below:

\[ \log(10)CO2 = F(\beta \log(10)Bp, \beta D, \beta T, \beta BpExp) \]

\[ \log(10)PM = F(\beta \log(10)Bp, \beta D, \beta T, \beta BpExp) \]

Table 7.7

*Biofuel Production Impact on CO2 and PM Damage*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bp</td>
<td>Total biofuel production (in thousands of barrels per day).</td>
</tr>
<tr>
<td>CO2</td>
<td>Total cost of carbon dioxide damage.</td>
</tr>
<tr>
<td>PM</td>
<td>Total cost of particulate matter damage.</td>
</tr>
<tr>
<td>D</td>
<td>Binary developing country variable. Developing countries are coded with a “1”; developed countries are coded with a “0.”</td>
</tr>
<tr>
<td>T</td>
<td>Binary tropical country variable. Countries that have significant tropical zones (Grieser 2010) are coded with a “1,” countries without significant tropical zones (those that do not currently support high yielding tropical biofuel agriculture – see Jongschaap et al. 2007; Purdue 2010) are coded with a “0.”</td>
</tr>
<tr>
<td>BpExp</td>
<td>A binary variable signifying country level biofuel production experience. Countries producing over five million barrels annually are coded as “1.” Countries producing less than five million barrels annually (as of 2009) are coded as “0.”</td>
</tr>
</tbody>
</table>

\[ \log(10) \] Logarithmic transformations are required to resolve skew characteristics in biofuel production and adjusted net savings data. The last three independent variables were not transformed given their binary nature.

*Biofuel Industry Impact on Country Level Wealth*

A country's wealth includes subsoil (mineral and energy) assets, timber resources,
non-timber forest resources, protected areas, cropland, pastureland (their total being the value of natural capital), produced capital (to include urban land), net foreign assets (total foreign assets minus total foreign liabilities) and a residual termed “intangible” capital which includes human capital and all other assets that resist current efforts to measure due to limitations in the literature (requiring further research efforts) such as the value of the stock of fisheries and subsoil water (Hamilton et al. 2006, 22-3; Lange et al. 2011, 29, 142-150).

Wealth calculations reveal a given state of a country’s wealth assets. Biofuel industry impact to those wealth assets, or potential impact to those wealth assets can be assessed. Similar to adjusted net savings variables, biofuel industry data is lacking for many wealth variables. Where data is available, estimations and arithmetic forms are provided in this section along with data needs that will enable future sustainability calculations. Relevant variables for biofuel sustainability assessment for natural capital are: subsoil assets (to a limited extent); timber resources and non-timber forest resources (also to a limited extent), protected areas (should protected areas be destroyed to make room for biofuel plantations), cropland and pastureland (when either created or converted from food production as a measure of social welfare) are relevant. Produced capital and urban areas (a positive contribution of biofuel production) can be estimated from investments in biofuel production capacity. Intangible capital is a residual element in the World Bank study, yet it does contain the human capital required to build and maintain a country's productive assets. Of the two primary variables accounting for the greatest share of the World Bank study residual, human capital proxied by school years per capita is applicable. According to the World Bank, human capital and governance (proxied by
rule of law) account for 90% of the variation in the intangible capital residual (Hamilton et al. 2006, 28). Rule of law data, as stated in Chapter V, is difficult to parse out by industry. An overall wealth impact is arithmetic, partially illustrated in Table 5.1.

**Subsoil assets.** As in the adjusted net savings section above, subsoil assets (minerals, non-renewable energy) data currently can not be found that breaks down industry subsoil asset consumption by domestic or imported sources. In addition, these resources are consumption goods for the industry. Historic consumption data is not available to determine wealth impacts. Instead, depletion of these assets is relevant and can be accounted for in net adjusted savings calculations.

**Forest land and forest resources.** Existing data covering timber and non-timber forest resource has limited use for biofuel production impact assessment. Loss of forest land (forest depletion) is relevant from the perspective of permanent asset loss. However, should forest resources be a biofuel enterprise asset (forest “residues” transformed to biofuel), the sustainable use of those resources can be measured by examining how the resources are capitalized over time. Quantifiable country level data of impacted timber and non-timber forest resources can be compiled and valued based on Hamilton et al. (2006, 151) and Lange et al. (2011, 146-48). Without a comprehensive country level data set covering biofuel industry activity with respect to these two assets, biofuel production impact cannot be precisely assessed. Biofuel production impact on timberland and forest resources may change the nature of the World Bank variables given increased demand may push back the boundaries for harvesting to an unknown distance due to increased demand for these resources.

**Cropland, pastureland and protected areas.** As stated in Chapter V unproductive,
non-ecosystem critical lands that are rehabilitated do represent an increase to national wealth. Where the biofuel industry rehabilitates true wasteland (or abandoned, marginalized farm land) an increase to the value of that land in accordance with crop and pastureland values can be determined. This, in turn, has a positive impact on a given country’s wealth portfolio. In contrast, destruction of food producing land or degradation of land that has eco-system value represents a negative impact to a country’s wealth portfolio, if not to the wealth portfolio of the world. Earlier chapters make it clear that monetization, given the current state of the literature, is not possible for land assets in the negative case. A non-monetized variable may need to be proxied in order to account for biofuel land use change activity, whether that land use change is an appropriate level upgrade to the biodiversity, ecosystem, or economic status of the land or not. The World Bank model does not address land use change, instead it assesses production value of the assets current use. Until a proper variable is determined and shared in the literature it is initially instructive to determine if biofuel production has had a deleterious effect on land assets. An initial estimator is provided below to begin to measure the biofuel industry’s impact on critical land assets. Should accounting level numbers be accumulated, such numbers can be compared to the results of such estimates to determine the reliability of the equations presented.

How land is utilized also needs assessment to determine if existing resources are being used responsibly and if biofuel production is related to significant land use change. For example, if fallow land is on the rise yet food and alternative energy needs are not being met, policies may be required to incentivize utilization of existing fallow land. If more agricultural land is needed fallow land is expected to be on the decline. If fallow
land is on the rise in such a case, land use efficiency and policy may be worth investigating. The following model will examine aggregated crop and pasture land impacts.

\[ \log(10)\text{AgLand}=F(\beta \log(10)\text{Bp}, \beta \log(10)\text{Fd}, \beta \log(10)\text{Fa}, \beta D, \beta T, \beta \text{BpExp}) \]

Table 7.8

**Biofuel Production Impact on Agricultural Land**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AgLand</td>
<td>Total agricultural land (crop and pasture land).</td>
</tr>
<tr>
<td>Bp</td>
<td>Biofuel production (in thousands of barrels per day).</td>
</tr>
<tr>
<td>Fd</td>
<td>Forest depletion (cost in terms of current US dollars).</td>
</tr>
<tr>
<td>Fa</td>
<td>Total fallow land (in square kilometers).</td>
</tr>
<tr>
<td>D</td>
<td>Binary developing country variable. Developing countries are coded with a “1”; developed countries are coded with a “0.”</td>
</tr>
<tr>
<td>T</td>
<td>Binary tropical country variable. Countries that have significant tropical zones (Grieser 2010) are coded with a “1,” countries without significant tropical zones (those that do not currently support high yielding tropical biofuel agriculture – see Jongschaap et al. 2007; Purdue 2010) are coded with a “0.”</td>
</tr>
<tr>
<td>BpExp</td>
<td>A binary variable signifying country level biofuel production experience. Countries producing over five million barrels annually are coded as “1.” Countries producing less than five million barrels annually (as of 2009) are coded as “0.”</td>
</tr>
<tr>
<td>Log10</td>
<td>Logarithmic transformations are required to resolve skew characteristics in biofuel production and genuine savings data. The last three independent variables were not transformed given their binary nature.</td>
</tr>
</tbody>
</table>

Estimations are helpful. However, country level identification of biofuel cultivation
disposition of agricultural assets, and an adequate variable that can determine land use change effects on sustainability, is needed for more precise estimation.

Protected land conversion to biofuel cultivation is a major concern to environmental groups. Although monetization and substitution is a point of unsettled debate in the literature, the need for monitoring protected area destruction is important to overall environmental sustainability. In the absence of precise land use change data the following estimate is a start, providing an initial assessment of biofuel industry impact on protected land areas. The following function is limited further in application to countries where strong efforts are being conducted to increase the amount of protected areas. This method of examination must be followed by land use change assessment to allow for more precision.

\[ \sqrt{PA} = \beta \log(10)Bp, \beta D, \beta T, \beta BpExp \]

Table 7.9

*Biofuel Production Impact on Protected Areas*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PA</td>
<td>Terrestrial protected areas (calculated as a percent of total land surface area).</td>
</tr>
<tr>
<td>Bp</td>
<td>Biofuel production (in thousands of barrels per day).</td>
</tr>
<tr>
<td>D</td>
<td>Binary developing country variable. Developing countries are coded with a “1”; developed countries are coded with a “0.”</td>
</tr>
<tr>
<td>T</td>
<td>Binary tropical country variable. Countries that have significant tropical zones (Grieser 2010) are coded with a “1,” countries without significant tropical zones (those that do not currently support high yielding tropical biofuel agriculture – see Jongschaap et al. 2007; Purdue 2010) are coded with a “0.”</td>
</tr>
</tbody>
</table>
Table 7.9 (Continued).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BpExp</td>
<td>A binary variable signifying country level biofuel production experience. Countries producing over five million barrels annually are coded as “1.” Countries producing less than five million barrels annually (as of 2009) are coded as “0.”</td>
</tr>
<tr>
<td>sqrt, log(10)</td>
<td>Square root and log(10) transformations are required to resolve problematic linearity characteristics in biofuel production and genuine savings data. The last three independent variables were not transformed given their binary nature.</td>
</tr>
</tbody>
</table>

Produced capital and urban land. Comprehensive, industry specific data for this variable is not available at the time of this writing. Data specific to industry investment is critical to valuing this wealth variable.

Intangible capital. As discussed in Chapter V, country level educational gains are a significant portion of the intangible capital variable. The World Bank Hamilton (2006) study is able to statistically disaggregate the impact of education on per capita wealth of a nation. Results vary by the development levels of a country (see Table 6.1). With the updated Lange (2011) study more precision was added to World Bank measurements discovering just over $11,000 improvement to intangible capital wealth for an additional year in school per capita. As sources in Chapter V suggest, given tracking of increases in family income, increases in schooling years can be estimated, the impact of which can be recorded as intangible wealth gains for a given population. A simple arithmetic function can follow to estimate biofuel’s contribution to intangible capital. This assessment, however, will have to wait until the incomes of biofuel stakeholders can be recorded over time. The other significant contributor to intangible capital is institutions as measured by
rule of law. Such a variable has no support for disaggregation by biofuel industry in the literature.

Loss of domestic agricultural land area for biofuel production creates food supply concerns unless food supply can be balanced in some manner by imports. Can the threat of food scarcity be traced to biofuel production, using available data in the literature? In other words, from the perspective of social welfare concerns, does biofuel production replace domestic food production? Although this concern is not represented in the World Bank model, the concern is valid from a social sustainability standpoint and can be initially addressed using an estimate similar to those used above. An OLS regression is initially proposed, the variables of which are developed with consistency to other equations used in this chapter.

Existing data sources are not without their challenges with respect to this estimate. The World Bank assessment of cropland does not distinguish between types of crops (food or biofuel) cultivated. The assessment is more concerned with the production of wealth on these land assets. Similarly, food production data accessible for this study also does not distinguish between ultimate end use of food crop production, whether for human or animal consumption or for fuel creation. These data challenges reveal the initial nature of such estimates. A slight change in classification as to crop product and end use (whether for food or for fuel) will help provide the means to precisely determine the effect of biofuel production on food production. The following regression seeks to initially estimate biofuel production's impact on overall food production with the above limitations in mind. With agrofuel crops removed from food production, a more precise estimate can be gained.
\[
\log_{10} F_p = F(\beta \log_{10} B_p, \beta \log_{10} F_d, \beta D, \beta T, \beta B_{p\text{Exp}})
\]

Table 7.10

**Biofuel Production Impact on Food Production**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fp</td>
<td>Food production index.</td>
</tr>
<tr>
<td>Bp</td>
<td>Biofuel production (in thousands of barrels per day).</td>
</tr>
<tr>
<td>Fd</td>
<td>Forest depletion (cost in terms of current US dollars).</td>
</tr>
<tr>
<td>D</td>
<td>Binary developing country variable. Developing countries are coded with a “1”; developed countries are coded with a “0”.</td>
</tr>
<tr>
<td>T</td>
<td>Binary tropical country variable. Countries that have significant tropical zones (Grieser 2010) are coded with a “1”, countries without significant tropical zones (those that do not currently support high yielding tropical biofuel agriculture – see EPA 2002, Purdue 2010) are coded with a “0”.</td>
</tr>
<tr>
<td>BpExp</td>
<td>A binary variable signifying country level biofuel production experience. Countries producing over five million barrels annually are coded as “1”. Countries producing less than five million barrels annually (as of 2009) are coded as “0”.</td>
</tr>
<tr>
<td>log10</td>
<td>Logarithmic transformations are required to resolve skew characteristics in biofuel production and genuine savings data. The last three independent variables were not transformed given their binary nature.</td>
</tr>
</tbody>
</table>

**Hypothesis 2**

\(H_2: \text{There is a Positive Relationship between Certified Biofuel Industry Production and Sustainable Development as Measured from the World Bank Sustainable Development Model.}\)

For the second hypothesis, to facilitate understanding of certification impact on
sustainability, certification principles and related World Bank sustainability variables are compared. Until pre- and post-data of widely implemented certification programs can be gathered the question as to certification’s impact on sustainability is currently dependent upon analysis of certification implementation cases and an analysis of the criteria itself, compared to available literature. Only when raw performance data is collected will quantitative results be available. Qualitative examination will reveal general positive and potential negative contributions certification programs can have on country level sustainability outcomes. This examination, separated by sustainability domain, is presented in the respective results section of Chapter VIII.

Limitations

Given the plethora of biofuel sources, many of the examples in this work are narrowed down to first generation, agrofuel production. Many other forms of biofuels exist and are included in the estimations and mathematical forms presented in this work such as algae and enzyme processed varieties. Examples from these varieties may have additional illustrative insight into the subject but such an individual analysis is outside the scope of this work.

It is to be noted that estimations and mathematical forms presented are just a beginning. Their intended purpose is to answer broader questions of sustainability on a country-by-country and worldwide basis. With more complete sources of data, findings will provide a clearer picture of industry impacts on sustainability. It is also to be noted that extreme cases of environmental damage and related unsustainable activity do not have monetized data or even adequate variables of measurement at this time. It is readily apparent that abuses in this industry do indeed point to periods of gross unsustainable
activity. Cases of industry abuses to all three domains of sustainability point to the urgent need of successful efforts such as certification endeavors and quantitative sustainability assessment. Initial findings of sustainability could easily loose ground in future assessments from continued cases of extreme abuse.

Shortcomings in the World Bank model are due to lack of data and theoretical limitations in existing sustainability literature. For example, a general limitation is the difference in data quality (data collection consistency) made available by the statistical bureaus of individual nations. Another general limitation is with respect to assets such as ecosystems which can not be completely managed, their loss or costs associated with their damage being difficult if not impossible to calculate. A limitation with respect to the way data is captured is evident, for example, in the way urban land is calculated as a percentage of its value in physical capital (Hamilton 2006, 146-7; Lange 2011, 144). Lack of a reliable means to collect such data hampers model integrity. The lack of some environmental assets in the World Bank model (such as underground water and fisheries) also hampers precision (Hamilton et al. 2006, 154; Lange 2011, 150). The World Bank study notes that asset accumulation is not a significant predictor of welfare in developed countries. Rather, “technological change, institutional innovation, learning by doing, and efficient institutions, to name a few factors, are fundamental drivers of growth” (Hamilton et al. 2006, 10). This places a minor limitation on this study’s application to developed countries. Assets of the nature relevant to biofuel operations are critical to developing country sustainability. Weaknesses in the above noted factors with respect to the biofuel industry can lead to serious damage in any or all of the three sustainability domains. Utilization of sustainability analysis allows for vigilance. Despite the need for
vigilance, given the limitations, the findings in this dissertation have similar empirical effect.

The World Bank model is a significant start, representing a tremendous accomplishment as it seeks to help decision makers begin to understand policy effects of decisions within sustainability’s domains (Hamilton et al. 2006, xiv, xix; Lange et al. 2011, 17, 27, 37-8, 121). Significant statistical outcomes in the World Bank model are encouraging at this early stage of sustainability analysis. As the original study (2006) and the study that follows (2011) demonstrate, the model is receiving attention and improvement. Although not perfected as yet, the model does open dialog for revisions to sustainability analysis and allows for preliminary assessments, informing biofuel policy and certification efforts.

In as much as adjusted net (genuine) savings formulas are in the process of evolution, the analysis above can also evolve for other relevant variables independent of the World Bank model. Such development will allow for greater precision for measurement of biofuel industry performance simultaneously within sustainability’s three domains and within World Bank model variables. For example, the impacts of other pollutants on adjusted net savings such as carbon monoxide (CO), nitrogen oxide (NOx) and sulfur dioxide (SO2) can be incorporated into biofuel industry sustainability analysis. Doing so will require guidance of available literature before it is directly assessed through the World Bank model framework.

Remaining Chapters

Chapter VIII presents the results of statistical estimations and certification program analysis detailed in this chapter. Chapter IX concludes this work by
summarizing the findings above and discussing what it means for sustainable development and the future of the biofuel industry. Chapter IX also states what needs to be done to more precisely measure biofuel industry and certification impacts on sustainable development.
CHAPTER VIII

RESULTS AND PRELIMINARY IMPLICATIONS

This chapter presents the results of estimations and certification document review detailed in chapter seven. Results of estimations will work toward a conclusion with respect to the first hypothesis and are provided in the first section. All data was run through Stata’s (version nine) ordinary least squares (OLS) regression functions. An analysis of certification principles and criteria is presented in the next section, covering the second hypothesis of this work. The final section of this chapter will summarize initial conclusions gained from the data analysis. All statements of significance are based on the .05 level.

Hypothesis 1

\textit{H1: There is a Positive Relationship between Country Level Biofuel Industry Production and Sustainable Development as Measured by the World Bank Sustainable Development Model}

\textit{Biofuel Production Impact on Sustainable Development}

The first equation examines biofuel production impact on country level sustainable development efforts as a whole. Biofuel production experience as well as tropical and developing country binary variables are also used as estimators. The equation and Stata command used follows this paragraph. OLS regression results are presented in Table 8.1.

Before regressions were run the data was tested for regression assumptions. Log transformations were necessary to correct for linearity problems evident though the use of Stata’s “pnorm” plots of the two interval-type variables. Pnorm plots conducted after log
transformation revealed a vast improvement to the linearity of the data. Stata “swilk”
tests for normality reveal a significant p value for the transformed variables. To test for
the presence of multicollinearity Stata’s “estat vif” function was run after the initial
regression. The mean vif score is 1.32 with each variable scoring between 1.01 and 1.64,
causing no concern. Stata’s “estat hettest” function was run to view the Breusch-Pagan /
Cook-Weisberg test for heteroskedasticity. The data failed, revealing highly significant
chi2 values. To correct for assumption problems regressions were run using Stata’s
robust option.

\[
\log(10)\text{ANSav} = F(\beta\log(10) \ Bp, \beta D, \beta T, \beta BpExp)
\]

```
regress log(10)ANSAv log(10)Bp D T BpExp, robust
```

Table 8.1a

**Biofuel Production Impact on Adjusted Net Savings, Model Components**

<table>
<thead>
<tr>
<th>Component</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Observations</td>
<td>367</td>
</tr>
<tr>
<td>F( 4, 362)</td>
<td>174.82</td>
</tr>
<tr>
<td>Prob &gt; F</td>
<td>0.0000</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.5140</td>
</tr>
<tr>
<td>Root MSE</td>
<td>0.64303</td>
</tr>
</tbody>
</table>

The statistical results reveal strong significance for all variables and high overall
model significance. The coefficient signs are in the expected direction with biofuel
production having a positive impact on adjusted net savings. For every 1\% increase in
biofuel production, adjusted net savings increases .34\% \(1.01^{\beta\log(10)Bp}\)
\[1.01^{0.3439706} = 0.34\%\).

Table 8.1b

*Biofuel Production Impact on Adjusted Net Savings, Variable Results*

| Variable | Coef.   | Std. Err. | T       | P>|t| |
|----------|---------|-----------|---------|------|
| log(10)Bp | 0.3439706 | 0.0406118 | 8.47    | 0.000 |
| D        | -0.4951477 | 0.0836354 | -5.92   | 0.000 |
| T        | -0.4043778 | 0.0876508 | -4.61   | 0.000 |
| BpExp    | 0.3751822  | 0.0822456 | 4.56    | 0.000 |
| _cons    | 10.53664   | 0.0606817 | 173.64  | 0.000 |

Biofuel production experience seems to matter in terms of a positive impact on adjusted net savings. The tropical and developing country binaries are both negatively signed. This suggests the difficulties such countries are experiencing with environmental sustainability challenges (such as rainforest depletion). Substituting a continuous barrel-year variable for the binary experience variable increases the biofuel production impact to .56%, moves the model r squared down to .4931 and causes the biofuel production experience variable to lose significance. Despite running Stata’s robust regression, variance inflation factors are high with the continuous biofuel production experience variable suggesting the continuous variable does not play a helpful role in the regression. Of the other independent variables the continuous variable inflated only the biofuel production variable.

Biofuel production impact on education expenditure. The second estimation will test biofuel production influence on education expenditures, examining social impacts.
A positive contribution to education expenditures will help determine if production leads to increased education spending for the benefit of a given population. Before regressions were run the data was tested for regression assumptions. Log transformations were necessary to correct for linearity problems evident though the use of Stata’s “pnorm” plots of the two interval-type variables. Pnorm plots conducted after log transformation reveal an improvement to the linearity of the data. Stata “swilk” tests for linearity reveal a significant p value for the transformed variables. To test for the presence of multicollinearity Stata’s “estat vif” function was run after the initial regression. The continuous biofuel production experience variable also revealed high vif scores in this estimation, prompting its removal from further analysis. The mean vif score using the binary biofuel production experience variable in the estimation is 1.62 with each variable scoring between 1.52 and 1.69, causing no concern. Stata’s “estat hettest” function was run to view the Breusch-Pagan / Cook-Weisberg test for heteroskedasticity. The data failed, revealing highly significant chi2 values. To correct for the homoskedasticity problem regressions were run using Stata’s robust option.

\[
\log(10)\text{EdExp} = F(\log(10)\text{Bp}, \beta_D, \beta_T, \beta_{\text{BpExp}})
\]

\[
\text{regress } \log(10)\text{EdExp} \log(10)\text{Bp} \text{ D T BpExp, robust}
\]

Table 8.2a

*Biofuel Production Impact on Education Expenditure, Model Components*

<table>
<thead>
<tr>
<th>Component</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Observations</td>
<td>418</td>
</tr>
<tr>
<td>( F(4, 413) )</td>
<td>266.33</td>
</tr>
</tbody>
</table>
Table 8.2a (Continued).

<table>
<thead>
<tr>
<th>Component</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prob &gt; F</td>
<td>0.0000</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.6363</td>
</tr>
<tr>
<td>Root MSE</td>
<td>0.52426</td>
</tr>
</tbody>
</table>

Overall the model is significant with a moderate r squared value suggesting other variables are necessary to better explain variations in education expenditure. Individual variable outcomes are presented in Table 8.1b. The results reveal a positive relationship between biofuel production and educational expenditures. As biofuel production increases one percent, education expenditure increases .36%.

Table 8.2b

*Biofuel Production Impact on Education Expenditure, Variable Results*

| Variable   | Coef.    | Std. Err. | T       | P>|t| |
|------------|----------|-----------|---------|-----|
| log(10)Bp  | .3576232 | .0326289  | 10.96   | 0.000|
| D          | -.5168854| .0559373  | -9.24   | 0.000|
| T          | -.4197136| .0607574  | -6.91   | 0.000|
| BpExp      | .4144786 | .0582778  | 7.11    | 0.000|
| _cons      | 10.14782 | .0461129  | 220.06  | 0.000|

*Biofuel Production Impact on Energy Depletion*

Although certification programs should encourage biofuel enterprises to utilize
their own product, energy depletion is a component of the World Bank model and worth estimating for this industry. As the following tables reveal, biofuel production and energy depletion are related positively. As biofuel production goes up 1%, energy depletion increases one-third of 1%.

\[
\log(10)\text{EnergyDep} = F(\beta\log(10) \text{ Bp}, \beta D, \beta T, \beta \text{BpExp})
\]

regr\( \text{ess} \ log(10)\text{EnergyDep} \ log(10)\text{Bp} \ D \ T \ \text{BpExp}, \ \text{robust}
\]

Table 8.3a

\textit{Biofuel Production Impact on Energy Depletion, Model Components}

<table>
<thead>
<tr>
<th>Component</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Observations</td>
<td>304</td>
</tr>
<tr>
<td>(F (4, 299))</td>
<td>21.60</td>
</tr>
<tr>
<td>Prob &gt; F</td>
<td>0.0000</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.2484</td>
</tr>
<tr>
<td>Root MSE</td>
<td>0.96659</td>
</tr>
</tbody>
</table>

The model is significant but does suffer from a low \(r\) squared result. Pnorm plots revealed the need to log modify the energy depletion variable. Pnorm plots and a swilk test reveal the transformation relieved normality concerns. The mean estat vif score for this estimate is 1.56 with individual variables ranging from 1.48 to 1.66. Estat hettest did reveal significance, leading to the necessity to run the regression with Stata’s robust option. Interpreting the results in table 8.3b, for every one percent increase in biofuel production, energy depletion increased by approximately one-third of 1%. All binary variables are significant contributors.
Table 8.3b

**Biofuel Production Impact on Energy Depletion, Variable Results**

| Variable       | Coef.    | Std. Err. | T      | P>|t|  |
|----------------|----------|-----------|--------|-------|
| log(10)Bp      | .3298488 | .0738972  | 4.46   | 0.000 |
| D              | .4530845 | .1367541  | 3.31   | 0.001 |
| T              | .3562142 | .1161178  | 3.07   | 0.002 |
| BpExp          | .4891919 | .1438619  | 3.40   | 0.001 |
| _cons          | 8.666035 | .1295063  | 66.92  | 0.000 |

**Biofuel Production Impact on Mineral Depletion**

As described in Chapter V, fertilizer use can reduce a country’s stocks of important minerals. Although a very limited number of minerals are tracked by the World Bank model, some of these are relevant to agricultural activity.

\[
\text{log(10)MineralDep} = F(\beta \text{log(10)Bp}, \beta D, \beta T, \beta BpExp)
\]

```
regress log(10)Mineral Dep log(10)Bp D T BpExp, robust
```

Table 8.4a

**Biofuel Production Impact on Mineral Depletion, Model Components**

<table>
<thead>
<tr>
<th>Component</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Observations</td>
<td>264</td>
</tr>
<tr>
<td>F( 4, 259)</td>
<td>17.04</td>
</tr>
<tr>
<td>Prob &gt; F</td>
<td>0.0000</td>
</tr>
</tbody>
</table>
Table 8.4a (Continued).

<table>
<thead>
<tr>
<th>Component</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-squared</td>
<td>0.1589</td>
</tr>
<tr>
<td>Root MSE</td>
<td>1.2649</td>
</tr>
</tbody>
</table>

Pnorm plots revealed the need to log transform the mineral depletion variable.
Pnorm plots and a swilk test reveal the transformation relieved normality concerns. The mean estat vif score for this estimate is 1.64 with individual variables ranging from 1.57 to 1.68. Estat hetttest did reveal significance, leading to the necessity to run the regression with Stata’s robust option. The model has significance but a low r squared. Of the primary variables of concern, biofuel production is significant. A one percent increase in biofuel production is related positively to a .31 percent increase in mineral depletion.

Table 8.4b

*Biofuel Production Impact on Mineral Depletion, Variable Results*

| Variable | Coef.   | Std. Err.    | T      | P>|t|   |
|----------|---------|--------------|--------|-------|
| log(10)Bp  | .3109242 | .0881937     | 3.53  | 0.000 |
| D         | .4441975 | .2101937     | 2.11  | 0.036 |
| T         | .5253402 | .2248131     | 2.34  | 0.020 |
| BpExp     | .2943061 | .2122552     | 1.39  | 0.167 |
| _cons     | 7.478105 | .1402558     | 53.32 | 0.000 |
Biofuel Production Impact on Net Forest Depletion

The next equation tests the link between biofuel production and the forest area depletion component of adjusted net savings using the same binary variables as the first equation for consistency. The Fp variable was added which controls for food production impact. Prior to running the regression the Fp variable was tested for regression assumptions. The food production index had some linearity problems. Only minor improvements to linearity were achieved through log 10 transformations of the food production index variable. By comparison major improvements to the forest depletion variable were achieved. Swilk tests reveal significant p values after data transformation. The mean vif score for the data is 1.49 with each variable scoring between 1.14 and 2.05, generating no cause for collinearity concern. Stata’s “estat hettest” function was run to view the Breusch-Pagan/Cook-Weisberg test for heteroskedasticity. The data did not reveal significant chi2 values. To correct for issues with regression assumptions Stata’s robust option was used in the following regression equation:

\[
\log(10)F_d = F(\beta B_p, \beta \log(10) F_p, \beta D, \beta T, \beta B_p^{\text{Exp}})
\]

\[
\text{regress } \log(10)F_d \log(10)B_p \log(10)F_p \ D \ T \ B_p^{\text{Exp}}, \text{ robust}
\]

The results of this regression reveal that variation in the food production index is not a significant factor in forest depletion. Biofuel production, however, is a significant contributor to forest area depletion particularly when combined with the developing country binary. For every one percent increase in biofuel production, forest area depletion increases .234%. Although the model is significant it does lack explanatory power given the low r squared value. The introduction of other significant variables will help explain more of the dependent variable variation.
Table 8.5a

*Biofuel Production Impact on Forest Depletion, Model Components*

<table>
<thead>
<tr>
<th>Component</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Observations</td>
<td>142</td>
</tr>
<tr>
<td>$F(5, 136)$</td>
<td>8.93</td>
</tr>
<tr>
<td>Prob &gt; F</td>
<td>0.0000</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.1505</td>
</tr>
<tr>
<td>Root MSE</td>
<td>0.71734</td>
</tr>
</tbody>
</table>

Table 8.5b

*Biofuel Production Impact on Forest Depletion, Variable Results*

| Variable    | Coef.    | Std. Err. | T  | P>|t| |
|-------------|----------|-----------|----|-----|
| log(10)Bp   | .2346369 | .0900069  | 2.61| 0.010 |
| log(10)Fp   | -.1812738| 1.324991  | -0.14| 0.891 |
| D           | .4888416 | .1649853  | 2.96| 0.004 |
| T           | .0548055 | .1489362  | 0.37| 0.713 |
| BpExp       | .2380743 | .1478649  | 1.61| 0.110 |
| _cons       | 8.003704 | 2.646838  | 3.02| 0.003 |

Biofuel production impact on pollution damage. Carbon dioxide and particulate matter can be calculated as shown in Chapter VII. Given data availability, the OLS regression estimates of the two pollutants are provided below. Both variables were run through pnorm and swilk normality tests.
\[
\log(10)\text{CO}_2 = F(\beta \log(10)\text{Bp}, \beta D, \beta T, \beta \text{BpExp})
\]

\[
\text{regress } \log(10)\text{CO}_2 \log(10)\text{Bp} \text{ D T BpExp}, \text{ robust}
\]

Table 8.6a

**Biofuel Production Impact on Carbon Dioxide Damage, Model Components**

<table>
<thead>
<tr>
<th>Component</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Observations</td>
<td>416</td>
</tr>
<tr>
<td>(F(4, 411))</td>
<td>126.34</td>
</tr>
<tr>
<td>Prob &gt; F</td>
<td>0.0000</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.4990</td>
</tr>
<tr>
<td>Root MSE</td>
<td>0.59811</td>
</tr>
</tbody>
</table>

Table 8.6b

**Biofuel Production Impact on Carbon Dioxide Damage, Variable Results**

| Variable     | Coef.    | Std. Err. | T      | P>|t|  |
|--------------|----------|-----------|--------|-------|
| \(\log(10)\text{Bp}\) | .3527238 | .0385689  | 9.15   | 0.000 |
| D            | -.0046071| .0734824  | -0.06  | 0.950 |
| T            | -.5006215| .0813634  | -6.15  | 0.000 |
| \text{BpExp} | .5079643 | .0743672  | 6.83   | 0.000 |
| _cons        | 8.770605 | .0433836  | 202.16 | 0.000 |

Both variables required log transformation. Heteroskedasticity tests confirmed the need for running the regression using Stata’s robust option. Although the model is good, the r
squared suggests only a moderate amount of explanation for the variation in carbon
dioxide. Biofuel production is shown in Table 8.6b to be positively related to carbon
dioxide damage. For every 1% increase in biofuel production, carbon dioxide damage
increases .35%.

Particulate matter pollution damage is estimated in the tables that follow. The
Assumptions tests turned out very similar between the two pollutants. The particulate
matter variable required log transformation after failing the same tests. Estat vif testing
revealed a mean vif of 1.65. The variable vif ranged from 1.53 to 1.73.

\[ PM = F(\beta_{Bp}, \beta_D, \beta_T, \beta_{BpExp}) \]

Table 8.7a

*Biofuel Production Impact on Particulate Matter Damage, Model Components*

<table>
<thead>
<tr>
<th>Component</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Observations</td>
<td>395</td>
</tr>
<tr>
<td>( F(4, 390) )</td>
<td>69.38</td>
</tr>
<tr>
<td>Prob &gt; F</td>
<td>0.0000</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.3220</td>
</tr>
<tr>
<td>Root MSE</td>
<td>0.86068</td>
</tr>
</tbody>
</table>

The model is significant but explains just under a third of the variation in the
particulate matter damage variable. A 1% increase in biofuel production is related to a
.22% increase in particulate matter damage.
**Table 8.7b**

*Biofuel Production Impact on Particulate Matter Damage, Variable Results*

| Variable     | Coef.       | Std. Err. | T     | P>|t| |
|--------------|-------------|-----------|-------|-----|
| log(10)Bp   | .2241235    | .0482072  | 4.65  | 0.000 |
| D           | .0613540    | .1303905  | 0.47  | 0.638 |
| T           | -.2836769   | .1298710  | -2.18 | 0.030 |
| BpExp       | .8888263    | .0987922  | 9.00  | 0.000 |
| _cons       | 8.10134     | .0820051  | 98.79 | 0.000 |

Biofuel production impact on agricultural land. Agricultural land and fallow land require the same regression assumption tests as conducted above. Log10 transformations are required to improve linearity characteristics. The agricultural land variable exhibited only moderate improvements to linearity as revealed by qnorm graphs. Fallow land showed strong linearity improvements after log10 transformation. Swilk tests for normality reveal significant p values post data transformation. After the initial regression was run, Stata’s estat vif function was run to test for multicollinearity. The mean vif score is 2.82 with each variable scoring between 1.56 and 5.84. Stata’s “estat hettest” function was run to view the Breusch-Pagan/Cook-Weisberg test for heteroskedasticity. The data did not reveal significant chi2 values. To correct for assumption problems Stata’s robust option was used in the following regression:

\[
\log(10)\text{AgLand} = \beta \log(10)\text{Bp}, \ \beta \log(10)\text{Fd}, \ \beta \log(10)\text{Fa}, \ \beta D, \ \beta T, \ \beta \text{BpExp}
\]

```
regress log(10)AgLand log(10)Bp log(10)Fa log(10)Fd D T BpExp, robust
```
Table 8.8a

*Biofuel Production Impact on Agricultural Land, Model Components*

<table>
<thead>
<tr>
<th>Component</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Observations</td>
<td>66</td>
</tr>
<tr>
<td>F( 6, 59)</td>
<td>125.61</td>
</tr>
<tr>
<td>Prob &gt; F</td>
<td>0.0000</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.8939</td>
</tr>
<tr>
<td>Root MSE</td>
<td>0.2505</td>
</tr>
</tbody>
</table>

Of particular interest in the results presented in Table 8.7b is the significant relationship between the fallow land variable (Fa) and the agricultural land variable. As fallow land increases 1%, agricultural land increases .58%. With the model being significant (along with a strong r squared value) this finding has some merit for further investigation for the sake of efficient allocation and utilization of scarce land resources. Biofuel production does not have a significant impact on agricultural land quantities. Of concern is the lack of observations compared to other estimates in this chapter.
Table 8.8b

Biofuel Production Impact on Agricultural Land, Variable Results

| Variable | Coef.        | Std. Err.    | T      | P>|t| |
|----------|--------------|--------------|--------|------|
| log(10)Bp | -.0238543    | .0754530     | -0.32  | 0.753|
| log(10)Fd | .1552002     | .0590931     | 2.63   | 0.011|
| log(10)Fa | .5795486     | .0694879     | 8.34   | 0.000|
| D        | -.440727     | .1356855     | -3.25  | 0.002|
| T        | -.0409127    | .1592544     | -0.26  | 0.798|
| BpExp    | -.1579457    | .1217939     | -1.30  | 0.200|
| _cons    | 2.483961     | .4631299     | 5.36   | 0.000|

Timber and non-timber resources. Non-timber forest resources have a future potential for biofuel production. Given this, and that non-timber forest resources are undervalued based on World Bank assumptions (Hamilton 2006, 151), more guidance from future literature is required before estimations can be determined. Biofuel production impact on round wood harvest can be estimated, however, much of the concern surrounding forest resources loss is with respect to depletion, which is estimated earlier.

Protected areas. The issue of biofuel land encroaching on protected areas is one that can only be accurately measured by census. Until then, estimations of impact can be conducted as is proposed through the function that follows. Protected area data did not pass normality tests (as with the majority of continuous variables used in this study), requiring square root transformation of the variable. Swilk tests reveal significant p
values for the continuous variables after transformation. The mean vif score is 1.60 with each variable scoring between 1.48 and 1.71. Stata’s “estat hettest” function was run to view the Breusch-Pagan / Cook-Weisberg test for heteroskedasticity. The data did not reveal significant chi2 values. Given the above, Stata’s robust option was run on the transformed data for consistency.

\[
(sqrt)Pa = F(\beta \log_{10}Bp, \beta D, \beta T, \beta BpExp)
\]

\[
\text{regress } (sqrt)Pa \text{ log}(10)Bp \text{ D T BpExp, robust}
\]

Table 8.9a

Biofuel Production Impact on Protected Areas, Model Components

<table>
<thead>
<tr>
<th>Component</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Observations</td>
<td>427</td>
</tr>
<tr>
<td>(F(6, 59))</td>
<td>12.90</td>
</tr>
<tr>
<td>Prob &gt; F</td>
<td>0.0000</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.0963</td>
</tr>
<tr>
<td>Root MSE</td>
<td>1.2116</td>
</tr>
</tbody>
</table>

Results reveal a limited r square of less than .10 yet biofuel production did reveal a positive influence on protected areas. Each percentage increase in the biofuel production independent variable was related to only a very small increase in protected areas. Even though the model itself was significant, the r squared value suggests that the model needs far more sophistication to determine impacts to changes in protected areas. Biofuel production experience had no significant impact while tropical nations had a significant positive impact. This is an encouraging finding given current concerns.
Table 8.9b

*Biofuel Production Impact on Protected Areas, Variable Results*

| Variable    | Coef.    | Std. Err. | T      | P>|t| |
|-------------|----------|-----------|--------|------|
| log(10)Bp  | .3027116 | .0781687  | 3.87   | 0.000 |
| D          | -.2310503| .1344516  | -1.72  | 0.086 |
| T          | .3048688 | .1434927  | 2.12   | 0.034 |
| BpExp      | .2117712 | .1585856  | 1.34   | 0.182 |
| _cons      | 3.390918 | .1041499  | 32.56  | 0.000 |

Food production. Although food production is not examined in the world bank model it is helpful to note the impact of biofuel production on food production given the food vs. fuel debates in the literature. Improvements to data collection are necessary but this initial view of estimated impacts is presented in Tables 8.10a and b. As stated earlier, food production data may include food type crops diverted for biofuel production purposes.

\[ \log_{10}Fp = F(\beta \log_{10}Bp, \beta D, \beta T, \beta BpExp) \]

```
regress log(10)Fp log(10)Bp D T BpExp, robust
```

The regression reveals biofuel production having a slightly positive impact on food production on a country level. For every 1% increase in biofuel production, the food production index increases less than one hundredth of one percent. An adjustment in the food production index downward from the absence of food stock transferred to biofuel production may further minimalize biofuel production impact.
Table 8.10a

*Biofuel Production Impact on Food Production, Model Components*

<table>
<thead>
<tr>
<th>Component</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Observations</td>
<td>424</td>
</tr>
<tr>
<td>$F(4, 419)$</td>
<td>60.60</td>
</tr>
<tr>
<td>Prob &gt; $F$</td>
<td>0.0000</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.3098</td>
</tr>
<tr>
<td>Root MSE</td>
<td>.05457</td>
</tr>
</tbody>
</table>

Table 8.10b

*Biofuel Production Impact on Food Production, Variable Results*

| Variable   | Coef.    | Std. Err.  | T     | P>|t|  |
|------------|----------|------------|-------|------|
| log(10)Bp  | .009356  | .0029184   | 3.21  | 0.001|
| D          | .0650041 | .0072039   | 9.02  | 0.000|
| T          | .0113763 | .0087496   | 1.30  | 0.194|
| BpExp      | -.005825 | .0053731   | -1.08 | 0.279|
| _cons      | 1.992617 | .0027471   | 725.35| 0.000|

A slight change to the way data is tabulated with respect to food crop end use will help provide one strong source of evidence to resolve or legitimize food versus fuel concerns.
Biofuel production impact on years in school. The biofuel production relationship with educational progression can also be estimated to a limited extent. The following equation uses persistence to last grade of primary school as a proxy for years of schooling completed. Biofuel production and the three binary variables are used as independent variables. Lack of normality continued despite data transformation efforts. As such, the non-transformed dependent variable is used in the following regression which utilized Stata’s robust option. The mean vif score is 1.64 with each variable scoring between 1.46 and 1.80. Stata’s “estat hettest” function was run to view the Breusch-Pagan/Cook-Weisberg test for heteroskedasticity. The data did not reveal significant chi2 values in the non-robust estimated data.

\[
\text{PersistPri} = F(\beta \log_{10}Bp, \beta D, \beta T, \beta BpExp)
\]

\[
\text{regress PersistPri \ log(10)Bp D T BpExp, robust}
\]

Table 8.11a

**Biofuel Production Impact on Persistence to Last Grade of Primary, Model Components**

<table>
<thead>
<tr>
<th>Component</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Observations</td>
<td>185</td>
</tr>
<tr>
<td>F( 4, 419)</td>
<td>33.96</td>
</tr>
<tr>
<td>Prob &gt; F</td>
<td>0.0000</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.4170</td>
</tr>
<tr>
<td>Root MSE</td>
<td>12.402</td>
</tr>
</tbody>
</table>

In the estimation in Table 8.11b all variables are significant at the .05 level. The
model itself is significant and has a moderate $r$ squared score of .42. It would appear that biofuel production itself is a minor contributor to primary persistence.

Table 8.11b

*Biofuel Production Impact on Persistence to Last Grade of Primary, Variable Results*

| Variable    | Coef.  | Std. Err. | T     | P>|t| |
|-------------|--------|-----------|-------|-----|
| log(10)Bp   | 2.508431 | 1.076981  | 2.33  | 0.021 |
| D           | -3.566302 | 1.538753  | -2.32 | 0.022 |
| T           | -18.9905  | 2.718614  | -6.99 | 0.000 |
| BpExp       | -3.754064 | 1.432652  | -2.62 | 0.010 |
| _cons       | 99.44381  | .7285471  | 136.50| 0.000 |

The ground gained is lost, however, to a net negative when biofuel production experience is high. It could be hypothesized that growing opportunity through the biofuel industry is opening the door for greater amounts of child labor at the expense of educational progress. Could the industry be lax in supporting child educational welfare? The negative coefficients and the model’s inability to predict a majority of the variation in primary school persistence suggests this area as an avenue of additional study.

The reasons for the use of this proxy are two-fold. First, progression in educational attainment is captured by the persistence variable. Second, the data begins to capture the completion of this very important level of education (primary school has higher social returns – see Hamilton et al. 2006, 91) which helps capture variation in income differences across countries (Hamilton et al. 2006, 90). Lange et al. (2011, 102) also points to the importance of human capital on intangible wealth. Their report builds...
on Hamilton et al. (2006) by addressing the weak points of the work: “fixed country characteristics, … common shocks, … declining marginal returns to education” and lack of human capital quality considerations (Lange et al. 2011, 97). Health, quality and returns to education were considered along with years of schooling as components to human capital in the Lange et al. (2011) study. With these components human capital revealed a strong contribution to growth. Biofuel impact on intangible capital can be further enhanced once this data becomes publically available.

Hypothesis 2

H2: There is a Positive Relationship between Certified Biofuel Industry Production and Sustainable Development as Measured from the World Bank Sustainable Development Model

As stated in the first chapter, a key component to making the biofuel industry sustainable is making certain the guidelines by which it operates do, in fact, provide sustainability. Should the guidelines barely produce sustainability, an effort that is only barely sustainable ($\Delta$ Net Savings = 0), then improvements to the certification program need investigation.

All principles presented by both certification programs of focus (RSB and CSBP) do represent substantial, positive contributions to sustainability in the biofuel industry as described in Chapter VI, but do required reliable measurement. Some criteria and guidelines, however, do require specific attention. In summary, on the positive side, both programs focus biofuel industry efforts toward activity that is respectful of legal requirements; well planned in their efforts to achieve sustainable focused goals covering all three domains of sustainability; promote human and worker rights; and utilize the
surrounding ecology in a manner that minimizes harm and in some cases even builds ecological assets.

On the other hand, given continued biofuel industry growth existing certification guidelines can hinder sustainability by limiting economic development and opening loopholes to widespread environmental damage. It is anticipated that program enhancements are already under consideration at the time of this writing as certification programs are undergoing processes of testing and continuous improvement in order to build stronger certification programs and adapt to ever changing environmental demands.

The greatest areas of vulnerability to sustainable development follow, organized by sustainability domain.

**Social and Economic Sustainability**

Criteria of certification programs may expect that a minimum wage must be paid by biofuel enterprises as mandated by relevant government regulations. For example, RSB criterion 4e states, “Where a government regulated minimum wage is in place in a given country, this shall be observed” (Roundtable on Sustainable Biofuels 2010a, 14). Poverty sustaining minimum wages as a guideline may hinder broader development (see Kelly Bird and Chris Manning 2008; Sara Lemos 2005; Ian Livingstone 1995; Carlos Santiago 1989). Should small holder, entrepreneurial models be profitable their implementation can provide greater benefits over unsustaining minimum wage effects (see Bill Baue 2008; Jason Calder 2008; John Omiti et al. 2009). Such small holder farming enterprises can be granted priority by biomass processors in order to encourage these entrepreneurial efforts.

In the desire to increase economic opportunity for indigenous peoples, some
certification criteria may require the biofuel enterprise to focus on enacting or showing some evidence of direct economic benefit. RSB criteria 5.a is an example, “At least one measure to significantly optimize the benefits to local stakeholders shall be implemented within a three year period of the start of the operations …” (Roundtable on Sustainable Biofuels 2010a, 15). Indications of benefit listed in the criteria are:

a. Creation of year round and/or long term jobs.
b. The establishment of governance structures that support empowerment of small scale farmers and rural communities such as co-operatives and micro credit schemes.
c. Use of the locally produced bio-energy to provide modern energy services to local poor communities.
d. Shareholding options, local ownership, joint ventures and partnerships with the local communities.
e. Social benefits for the local community such as the building or servicing of clinics, homes, hospitals and schools.
(Roundtable on Sustainable Biofuels 2010a, 15)

The least costly indicator will have the greatest incentive for being selected. For example, “creation of long term jobs” is an alternative that is vague in measure and is readily enacted as a function of the enterprise. Demonstrated gains to local stakeholders may be limited to a minimal number of long term, minimum wage jobs.

Several criterion release smallholder enterprises from responsibility out of concern for the burden these criteria place upon vulnerable small operations. For example, RSB criterion 6.b states that small holders are exempt from activities that increase food security when placing biofuel operations in food insecure areas (Roundtable on Sustainable Biofuels 2010a, 17). It is conceivable that circumstances may develop where economic incentive may produce many small biofuel concerns in a food insecure area. Although intentions are good, loopholes created may open respective domains of sustainability to significant, aggregate harm. Limited to smallholder
enterprises, in such cases, an expectation can be presented which sets the requirement of food multi-cropping to bolster local food production. Smallholders can be expected to meet criteria if the environments created by the criteria foster the conditions which will make them successful.

Collusion is another concern applicable to all domains. As pointed out in Chapter VI, subjective scoring of criteria could lead to unreliable results. A given biofuel enterprise is evaluated for operational impact on sustainability based on the input of an appointed assessor. Assessor data is presented as a quantitative element, yet assessed scores are developed with a strong dependency on the qualitative judgment of the assessor (see Roundtable on Sustainable Biofuels 2011b, 22). CSBP even allows employees of given biofuel enterprise to conduct environmental analysis (Council Sustainable Biomass Production 2010, 15) which raises similar concerns. Any of these circumstances could open the door to collusion and the recording of inaccurate assessments. Verifiable, quantitative measures and unbiased sources of assessors are helpful deterrents.

Environmental Sustainability

One area of additional criteria is missing and is strongly suggested. Byproduct concerns are not specifically resolved. The dumping of byproducts is a concern that threatens to wipe out environmental gains, causing immeasurable damage to the environment (see Adrians 2006; Kemp 2006; MTA 2010; Punia 2007). The problem of byproduct mitigation can be insidious if not noted in long term growth plans. For example, while there are markets for the primary byproduct of biodiesel production (glycerin) it should not be anticipated that these markets will remain the same if biofuel
production forces more byproduct into the market. Specific plans need to address a contingency should glycerin markets no longer provide an avenue for waste disposal before fuel production and energy dependency momentum (as well as lack of byproduct utilization alternatives) tempt producers to dispose of excess waste in environmentally unfriendly ways.

Conclusion

The data presented above reveal the relevance of biofuel production to country level adjusted net savings as a whole. Biofuel production is also, for the good or bad, estimated to be a significant contributor to many individual components that make up country level wealth and genuine savings characteristics. Given the biofuel industry is still small relative to demand it is anticipated that industry impacts will have more of an effect on sustainable development in the future. As suggested in Chapter V, however, the influence of the biofuel industry on some wealth and genuine savings components can not be measured at this time given lack of support in the literature and the need for direct data collection through efforts such as periodic site assessments of certification program operations. Certification principles and criterion need (and are receiving) fine tuning to make up for industry sustainability vulnerabilities. It is hoped the above will be points of principle and criterion modification to reduce, if not eliminate, apparent threats. The findings above support initial conclusions that incentives, policies and certification programs need review in order to open appropriate opportunities for sustainable biofuel production rather than hamper the development opportunities the biofuel industry provides.

The concluding chapter will draw together an initial path to biofuel industry
sustainability measurement, using both existing and suggested estimates and arithmetic forms that have been presented up through this chapter. The chapter will also suggest how certification programs are crucial in the process of biofuel industry sustainability data collection and can strongly benefit from such quantitative evaluation of industry activity. The chapter will end with a discussion on what can be concluded from the hypotheses of this work.
CHAPTER IX

CONCLUSIONS

The primary concern on the minds of biofuel industry stakeholders is whether or not the biofuel industry can be relied upon to produce sustainable development. Initial estimations presented in the previous chapter are hopeful and are the subject of the next section of this chapter. Yet, some of the estimates raise a set of environmental and human capital concerns that, when viewed in aggregate, appear numerically offset by gains in other variables. Such estimations, based on currently available data, cannot be relied upon to provide all concerned with a comprehensive predictor of biofuel sustainability. Such findings reveal the urgent need for reliable data driven certification programs. To this end, certification programs and policy makers will need to revisit the industry on a frequent, periodic basis to make certain proper development practice is enabled.

Certification programs will need modification in order to bring their full potential to bear on the biofuel industry. These topics are the subject of the second section, covering hypothesis two.

Hypothesis 1

\( H_1: \) There is a Positive Relationship between Country Level Biofuel Industry Production and Sustainable Development as Measured by the World Bank Sustainable Development Model

It is estimated that biofuel production does contribute positively to sustainable development within the framework of the current World Bank sustainability model, specifically, the adjusted net savings component. As is shown in Table 8.1b, as biofuel production increases one percent, country level adjusted net savings (a measure of
productive asset disposition) increases one third of one percent. Although the estimated impact to adjusted net savings is small, the biofuel industry is still very young. The potential market is enormous suggesting large relative impacts to overall country level GNI and adjusted net savings as the industry grows and matures. As the World Bank model gains more sophistication, biofuel estimates obtained from this model will grow in predictive and explanatory power.

Where data is available, simple OLS estimates are possible on individual adjusted net savings and wealth variables. Such estimates, however, may not be helpful for determining the disposition of some individual sustainability assets for a variety of reasons: (a) the current World Bank approach to variable measurement may be incompatible with the operational realities the biofuel industry may face. For example, should non-timber forest resources become more viable for second generation biofuel production it is conceivable that limitations the World Bank has placed on its range of harvest assumptions could very well be exceeded; (b) some variables can not be adequately measured. For example, the literature has not demonstrated a solution to the proper monetization or operationalization of sensitive environmental variables; and (c) variation in some variables, such as energy and mineral use, can be very small should biofuel farmers choose to operate within the spirit certification programs intend such as using their own product for fuel and considering increasing use of “green” manure and vermiculture techniques (for example) rather than relying solely on industrial fertilizer. In cases such as this, industry censuses can provide direct input into sustainable development estimates.

The wealth estimate can still be utilized to help determine how, on a country level,
the biofuel industry contributes to wealth producing assets. Total wealth is determined from the discounted consumption value of the alternative fuel the biofuel industry provides. Subtracted from this are industry capital, depreciation and urban investment; natural capital improvements (such as the movement of land from true marginal land to productive farmland) and Foreign Assets. The resulting number is the biofuel industry contribution to intangible capital. Similar to the aggregate World Bank model, human capital may account for much of the variation in the biofuel industry intangible capital contribution to total wealth. Persistence to last grade of primary school has shown potential as a variable significant to biofuel production. As such it can be used as an estimator of biofuel industry intangible capital.

Food production is a variable used in this work that is specifically applicable to biofuel industry concerns. A resolution to existing food versus fuel debates can initially be addressed through disaggregating food production by end use, whether for fuel or for food. Biofuel influence on such a variable will reveal an industry impact important to social sustainability. Such disaggregation of the data as it is being collected and tabulated is strongly encouraged.

As stated earlier, the World Bank wealth model is static, using the same discount for all countries. It is important for each country conducting estimates to determine their applicable social discount rate and time period that is best suited to their environments. If a country needs to save more than consume, for example, a smaller pure rate of time preference can be considered.

The estimates above show that the biofuel industry is currently, on the whole, operating in a sustainable manner from the perspective of adjusted net savings.
Individual variables can be closely considered for their contribution to sustainability. Biofuel production is estimated to make a positive contribution to expenditures on education. As shown in the previous chapter, for every one percent increase in biofuel production it is estimated that education expenditures increases approximately one third of one percent. Such findings are cautioned by concerns surrounding the biofuel experience variable. Forest resource depletion may be a candidate for intervention, but if the biofuel industry is operating within certification program expectation depletion rates should be quite small. Lesser impacts from pollution damage are also conceivable for the same reason. Net forest depletion, however, is an individual contributor of concern. For every one percent increase in biofuel production, forest resources are estimated to decline by approximately one-quarter of 1%.

Given the availability of data through the World Bank, estimations of biofuel impact to each wealth and sustainability indicator is possible. Running all estimates, however, may not have practical use at this point in time. Several biofuel production impact estimations were provided in the previous chapter, some estimations (as noted above) are not possible, and others may have limited numeric contribution. Given the limitations of estimations a reliable method of industry census can be utilized to obtain the needed data. Such a source for this data collection is obvious: certification programs. The challenge, as described in the next section, is making certain the right data is collected.
Hypothesis 2

H2: There is a Positive Relationship between Certified Biofuel Industry Production and Sustainable Development as Measured from the World Bank Sustainable Development Model

The answer to this hypothesis is more qualitative through analysis of certification program principles and criteria. Until before-and-after program implementation data can be collected this hypothesis is preliminarily conditional to the thoroughness of the principles and criteria certification programs use as well as the accuracy by which they measure performance. As suggested in Chapter VII, these programs hold out considerable hope given the scope and depth of principle and criteria coverage of sustainability variables. For example, in the rush to preserve ecosystems from the onslaught of agrofuel cultivation international organizations appear to have overshot much of the literature with regard to ecosystem sustainability measurement as described in Chapter III. It would appear the boundaries of strong and weak environmental assets are being drawn, at least as applied to the biofuel industry. (See Roundtable on Sustainable Biofuels 2010a, 18). Once again, a case for non-monetary measurements is being made as biofuel certification sources are coming up with practical limitations to biofuel production impact on the existing environment. The contributions of certification programs begin to inform the framing of measurement boundaries for sustainability across a wide variety of industries and activities of other environmental stakeholders.

To bring the biofuel industry impact into sharper focus, independent census of industry impact on the wealth and adjusted net savings components (conducted on a country by country basis) is necessary. Such a census will allow for more quantitative
estimates of biofuel impact on sustainability which will decrease evaluation dependency on qualitative assessor judgment which is still a component of many certification programs. Given many independent certification programs do exist, a general agreement as to a method for reliable data collection will provide the means to make country level or (as Pezzey 1992 suggests) individual enterprise level comparisons possible.

It is not enough to collect data and draw down dependence on qualitative assessor judgment. Certification programs must close the loopholes (discussed in the previous chapter) that can lead to widespread environmental catastrophe. One such concern, to use an example from the previous chapter, is with respect to biodiesel production. Enormous numbers of agricultural land has recently been planted for biofuels. Once yields begin to multiply from these initial plantings alone, more biodiesel will be on the market. As biofuel production grows, so too will its byproduct – glycerin. Refining companies need to make certain, through the watchful eye of certification programs, that they are planning for exponential increases in byproduct and build contingency plans should byproducts no longer have their own markets. It is suggested that current certification criteria contain stronger, specific language to handle the risk byproducts represent when they start to amass. Do biodiesel refining operations have plans to properly dispose of byproducts as their suppliers yields rapidly increase from earlier plantings? What happens if markets for byproducts collapse?

Future Implications

The biofuel industry has much to offer. Not only can the industry offer a new, green energy alternative it can hold out the hope of contribution to economic development. This development has particular potential in tropical, developing world
environments where premier biofuel crops can be grown. This study has shown that, within theoretical boundaries, biofuels do contribute to net sustainable development. The industry, on a case by case basis has shown its potential for the very opposite. Examples of enormous environmental, social and economic downfalls exist in the literature. The hope for solid sustainability in the biofuel industry rests with strengthened certification programs, accurate quantitative performance measurement and industry stakeholders who adhere to the letter and the spirit of certification program principles and criteria. The World Bank model used in this work is insufficient without modification, but it does provide useful foundations for building quantitative sustainability assessment so crucial for this industry. Incorporating indicators important to the biofuel industry will build a quantitative model whereby actors can be evaluated for sustainable compliance. Pezzey (1992) was right, but in an expanded sense. Not only is sustainability analysis applicable on a project or system level, analysis using the World Bank model as a foundation can apply to a broad spectrum of industries, allowing for intra and international comparison of a given industry’s impact on sustainability.


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