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CRISTIN POPELIER HOSMER

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THE SUCCESS OF AGRICULTURE IN MICHIGAN COUNTIES: A WEAK TEST OF SUSTAINABILITY

By

Cristin Popelier Hosmer

A THESIS

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ABSTRACT

THE SUCCESS OF AGRICULTURE IN MICHIGAN COUNTIES:
A WEAK TEST FOR SUSTAINABILITY

By

Cristin Popelier Hosmer

Due to growing concerns about issues such as population growth, resource depletion, and social inequity, the concept of sustainability has received significant attention in academic, environmental and policy circles. In the context of agriculture, sustainability implies that three main objectives (economic, environmental, and social sustainability) are compatible and synergistic. To date, little effort has been devoted to developing an analytical framework for evaluating this goal in agriculture. Despite a growing body of literature about sustainability, there is no framework for testing for the sustainability of agriculture at the local level. Therefore, this thesis proposes a Weak Test of Sustainability for Michigan, as it relates to short-term agricultural economic sustainability.

This thesis research advances the concept of agricultural sustainability by estimates a series of equations and tests for complimentarity and substitutability between economic, environmental and social indicators. The finding that increased environmental and social performance does not necessarily diminish economic performance suggests that the goal of sustainability is feasible. Results suggest that there are structural differences in the ability of various regions in Michigan to achieve short-term economic sustainability.

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1.1 Background

Agriculture is a key industry in the United States. It provides numerous economic, environmental, and social benefits to the public. Not only does agriculture provide American consumers with eighty-three percent of their food and fiber needs (USDA-ERS, 2006), it is also a major conduit for environmental and cultural resources (Hellerstein and Nickerson, 2002; Boody and Krimke, 2000). Activities in the agriculture and food-processing sector represent the largest economic sectors in many states.

In Michigan, the subject state for this study, the agri-food system, which includes farming and allied activities, generates $70 billion in economic activity annually, provides 1.05 million jobs and has made $8.6 billion in capital investments over the past five years (Knudson and Peterson, 2009; Peterson et.al., 2006). Agriculture also serves as the primary steward of forty-six percent of the land in the US (USDA-ERS, 2005). Its amenity benefits include open space preservation and a 'rural character' that contributes to tourism, employment, and quality of life ("Understanding the Non-Economic Impacts of Agriculture," 2006). Agriculture also contributes other non-pecuniary benefits such as wildlife habitat, water and air recharge, and greenery (Kline and Wichelns, 1996).

Despite the importance of these benefits, their non-pecuniary nature makes it difficult to capture their values monetarily. This is a significant issue especially at a time when the agricultural sector is predicted in 2009 to experience declining commodity prices, increasing input prices and disrupted credit markets, (Morehart and Johnson, 2009). Even though we have seen record levels of farm income being set in the past 10 years, many states agricultural sectors are experiencing an increase in the consolidation of farms, regulation, and urban pressures, along with a decline in the farm population, all of which have had adverse impacts on domestic agriculture (Morehart and Johnson, 2009; Adelaja and Sullivan, 1998; USDA-ERS, October, 2005; Gardner, 1992). The profit squeeze in agriculture is also affecting the industrial organization of the agricultural industry. Mid-sized farms have been particularly hard hit by the changing business climate of agriculture.

According to the USDA, agricultural land is being converted because farmers can produce more with less land, higher land values, and increased population pressure (USDA-ERS, October, 2005). The economic well-being of farm households has historically been largely dependent on farm-related income. However, farmers are increasingly relying on off-farm income to supplement farm income (Fernandez-Cornejo et.al., 2007). In fact, the percentage of the labor force employed in farming continues to decline and is now close to 1 percent (US Census Bureau, 2009; USDA-NASS, 2007).

Simultaneously, agriculture is the subject of increasing environmental and social welfare concerns (Feenstra, 1997). The off-farm environmental impacts of agriculture, such as erosion and excess nutrients that impair surface and ground water, have led to regulation that is more stringent (Feenstra, 1997). The rapid conversion of farmland to development has also spurred greater desire by the public to stop growth. Various growth management tools are emerging; however, these tools may limit the ability of farmers to profit from their rising land values (Adelaja and Gottlieb, 2009).

Increased competition, rapid consolidation and the concentration of farms near processors, has also driven smaller farms out of the market and raised a host of other economic, environmental, and social problems (MacDonald et.al., 1999). Other budding concerns include the limited diversity in the agricultural labor force and limited access to the amenities provided by agriculture, despite the community, human, and physical resources that support agriculture. The ability of the farm household enterprise and the adjacent communities to sustain themselves (or its viability), in other words, is increasingly problematic.

Agriculture's success is not dependent solely on the economic performance of the industry. It is also intrinsically linked to the overall social and environmental climate within which it exists. Farmers must coexist with non-farmers and neighbors. In fact, the social and environmental benefits that agriculture conveys affect the climate in which agriculture must exist, and in-turn affect the economic bottom-line. Increasingly, the term sustainability is used to describe the modern optimization challenges of agriculture. Farmers must be economically, environmentally, and socially sustainable to be successful. While the market has not been well developed for farmers to capture some of the benefits of their positive environmental externalities positive feedback through the regulatory environment and business climate could offer indirect rewards to farmers' positive externalities.

Sustainable agriculture is an alternative philosophy to conventional agriculture. It suggests that farmers can indeed capture some of the potential returns associated with their positive externalities (i.e. do economically well, by doing good). Because sustainable agriculture considers the natural environment and seeks to minimize negative environmental and social externalities of agricultural production practices such as excessive nutrient and water use, it is often expected to be more profitable for farmers (USDA-ERS Amber Waves, 2004; Schaller, 1993). The conservation of natural resources on farmland can improve the environment while providing financial benefits in the form of increased efficiency and a technological competitive advantage (USDA-ERS Amber Waves, 2004). Considering the growing importance of policy and regulation, sustainable and responsible farming can also yield dividends in terms of public support at the local, state, and national levels, which can translate into long-term survival and viability (Bird and Ikerd, 1993).

The key to understanding the concept of agricultural sustainability is to recognize that farmers need a nurturing environment and business climate to be able to maintain viable operations. Agricultural sustainability is tantamount to long-term viability, not just short-term economic viability, as typically evaluated by economists. For agriculture to be sustainable long-term, it must be economically sustainable in the short run. Since long-term viability is tied to long-term policy support and the regulatory environment, agriculture's survival is a multi-dimensional problem. Farming must be economically, environmentally, and socially compatible with the objectives of the public in order to thrive. By definition, therefore, a sustainable agricultural system is one that is: (1) economically viable, (2) enhances the environmental quality of the resource base, and (3) enhances the quality of life and social objectives of farmers and society as a whole (Schaller, 1993).

The best understood aspect of agricultural sustainability is economic viability. Numerous studies have examined economic viability by identifying its determining factors through regression analysis. The determinants identified in previous studies fall into four broad categories: farm financial characteristics, location and structural factors, operator characteristics and policy climate factors. The key determinants include farm financial characteristics such as household income from farm and non-farm activities, debt service, asset holdings, and diversity of the revenue stream. Operator characteristics including age, experience, and education are also key determinants. Community and location variables including urban influence, access to markets and input services, and regional factors also impact the viability of farms. Socio-demographic and attitudinal characteristics including beliefs about regulations, right-to-farm conflicts and the degree of optimism are also viability factors (Adelaja and Rose, 1988; Adelaja and Sullivan, 1998).

Despite the fact that agriculture does not exist in a vacuum and its survival may be linked to its compatibility with non-farm objectives, few, if any, of these studies have looked at the relationship between economic viability and social and environmental viability. There is little empirical evidence, to date, that relates the environmental and social aspects of sustainability to the profitability of agriculture in the short-term. While Adelaja and Sullivan, (1998) included a few environmental and social variables, such as farmers' political involvement in the community and chemical use, they did so without acknowledging the concept of sustainability and the critical nature of the interaction between elements of sustainability and farm survival. Furthermore, it is expected that previously defined models, which do not include such factors, are not adequately specified. The failure of economists to account for environmental and social factors implies that the standard viability model suffers from model specification error. Because some of these concepts are unobservable, conceptual indicators need to be developed as a precursor for measuring and modeling the affect of the environmental and social aspects of sustainability on farm success.

Considering that economic viability, environmental stewardship and social compatibility constitute the holistic elements of sustainability, it is important to sort out how they interact with each other. This thesis seeks to understand the interactions between the elements of sustainability in agriculture by estimating the relationship between farm sector profitability and some key sustainability factors. Secondly, in the absence of an existing framework for linking agriculture's success to economic, social, and environmental variables, a novel framework labeled a weak test of sustainability (WTS) has been developed.

WTS involves comparing the economic base model for short-term agro-economic sustainability to three augmented models through a series of model specification tests and F-tests. The augmented viability models specified herein are hypothesized to improve specification in comparison to the base sustainability model. A positive relationship between profitability and sustainability factors suggests that sustainability is (in a weak sense) possible and synergies between the three components of sustainability exist. Alternatively, a strong test of sustainability would not be a test on the profitability of agriculture in the short-term, but instead a test of the long-term holistic concept of sustainability, a concept that this point to too large and too complex to measure and therefore outside of the scope of this thesis.

The general objective of this thesis research is to improve the knowledge base surrounding sustainability by evaluating the effect of economic, environmental, and social sustainability factors on net farm income. The conceptual framework used herein will help improve the perception of profitability and help to clarify the roles of environmental and social factors in enhancing agriculture's success, as well as identify the monetary tradeoffs of pursuing the multiple goals of sustainable agriculture. At a minimum, this thesis will contribute to a better understanding of model specification and determinants of short-term agro-economic sustainability. Furthermore, this thesis research proposes that a comprehensive sustainability index, generated from the predicted values of the augmented viability models, is possible.

1.2 Research Objectives

The prime research objective of this thesis is to explore and investigate the concept of short-term economic sustainability as it applies to local (county-level) agriculture. By investigating the relationship between the three aspects of sustainability, which are economic viability, environmental stewardship and social compatibility, the hope is to gain a better understanding of the monetary trade-offs associated with pursuing multiple agricultural objectives. Because the framework for modeling and measuring viability and profitability is well documented, it is used as a framework for developing a Weak Test of Sustainability (WTS). Alternatively, if an actual direct measure (dependent variable) for sustainability could be identified one could carry out a strong test for sustainability. Unfortunately, we do not have a precise and clearly defined measure of sustainability in agriculture; therefore, we must rely on the WTS.

Net farm income per acres (NFI_ac) is a good indicator (dependent variable) of short-term sustainability because if a farm is not profitable, it will go out of business (and is not sustainable). The basic framework is based on the following philosophy: 'if sustainable principles and practices are implemented and profitability is not impacted, then it suffices to say that farmers can sustain themselves and the environment and socially coexist within the community by doing well environmentally and within the community'. Using Michigan agriculture as a case study, WTS (Weak Test of Sustainability) is the test in this thesis for assessing whether increasing levels agro-economic sustainability detracts from profitability.

The specific research objectives are operationalized by estimating a series of conceptual models and their predicted values. First, a standard model of economic sustainability (or viability) is estimated by regressing economic factors against net farm income per acre. Next, three augmented models of economic sustainability are estimated. The first includes environmental factors. The second includes social factors. The third includes both environmental and social factors. The signs of the coefficients of the augmented models provide insight on sustainability. The efficacy of the augmented models can further be compared to the standard viability model via specification error testing to determine appropriateness. The predicted values serve as a county-level index or benchmark of short-term agro-economic sustainability, which can be used as a broad assessment tool for counties interested in the parameters that effect profitability in the agricultural sector.

1.3 Organization of the Study

Chapter Two is the review of literature in which the economic viability and sustainability literature are explored. Relating to the concept of sustainability, literature on environmental stewardship and social compatibility are also reviewed.

Chapter Three presents the conceptual framework for a series of agricultural economic sustainability models; one standard and three augmented models are included.

Chapter Four presents an empirical framework and describes the data and estimation processes for the standard and augmented viability models specified for Michigan. Chapter Four also highlights the joint F-Test the basis of the weak test of sustainability in agriculture.

Chapter Five summarizes the empirical findings of this research.

Chapter Six summarizes and draws conclusions on the research and provides recommendations for future research in the area.

Chapter II: Review of Literature

As mentioned in Chapter I, the goals of this study are to review the literature on sustainability in agriculture, develop a framework for short-term economic sustainability and a weak test of sustainability, and identify the determinants of sustainability as it applies to the success of the agricultural sector in Michigan. In this chapter, the literature on sustainability and other related agricultural concepts is reviewed. A good starting point is to highlight the broader paradigm of sustainability and its numerous definitions. Literature on the application of the sustainability concepts in the agricultural sector is also reviewed. A brief discussion of past modeling efforts is also included.

2.1 Origin of the Sustainable Development Concept

The concept of sustainability is a broad and encompassing paradigm that has allowed interested parties in the academic, public policy, and business communities to assess and address issues related to growth and development patterns, intergenerational fairness, and resource use. Sustainable development is an intrinsic framework that links survival to various economic, environmental, and social objectives. It is essentially a triple-bottom-line approach to development, which addresses the modern challenges of meeting the needs of a growing worldwide population. In fact, many of the discussions surrounding sustainability tend to focus on the role of environmental, natural, and cultural resources in sustaining economic well-being into the future (Woodward, 2000).

The concept of sustainability is deeply rooted in society's ethical and moral obligation to the commons (air, land, and water) (Perman et.al, 2003). The concept emerged partly because of concerns about population growth, the farmers' limited ability to feed a growing population, resource constraints, and other land use problems. Early thinkers, such as Mill, Malthus, and Ricardo first identified the limits of the Earth's support system to sustain human consumption and growth in the 19th and 20th Century (Perman et.al., 2003; Pinstrup-Andersen, 2001). These works tended to focus on the externalities of grazing on common lands, the feasibility of continuing long-run economic growth given unfettered population growth, diminishing returns, the scarcity of finite resources, environmental degradation, and declining human welfare (Perman et.al., 2003). In addition, the Progressive Conservation Movement, led by, Aldo Leopold, and Wendell Berry in the United States, further developed the underpinning concepts of sustainable development (Hernandez, 1997: Batie, 1989; Berry, 1987; and Leopold, 1949).

The sustainable development ideology gained significance in the international policy arena with the World Commission on the Environment and Development Report, *Our Common Future* (Brundtland and Khalid, 1987). Better known as the United Nation's Brundtland Report, it defined sustainable development as development which meets the needs of current generations without compromising the ability of future generations to meet their own needs (UNECE, 2005). This particular definition introduced the concept of intergenerational balance and optimization and brought the worldwide community together in an effort to make sustainability a public policy goal (Goodland, 1995). The idea, later adopted as the theme of the UN Conference on Environment and Development (the Rio Conference), inspired the international community to attempt to define and measure sustainability (Munasinghe and Shearer, 1995). However, the challenge of defining and observing sustainability in practice has proven difficult. A list of a few such definitions follows in Figure 1.

Figure 1: Various Definitions of Sustainable Development

"Ecologically sustainable economic development can be thought of as the process of related changes of structure, organization and activity of an economic-ecological system, directed towards maximum welfare, which can be sustained by the resources to which that system has access" (Bratt (1991) in Kuik and Verbruggen, 1991).

"Sustainable development is development without growth in throughput of matter and energy beyond regenerative and absorptive capacities" (Goodland and Daly, 1996).

"Sustainable development can mean a multitude of things to different people but it is generally used to reflect concerns about the living standards of future generations and their right to inherit a natural resource base of undiminished value" (Stoneham et.al., 2003).

"Biogeophysical sustainability is the maintenance and/or improvement of the integrity of the life-support system on Earth. Sustaining the biosphere with adequate provisions for maximizing future options includes provision for maximizing future options...and requires planning and action at the local, regional and global scales..."(Munasinghe and Shearer, 1995).

There are numerous definitions of sustainability, some more useful than others and none universally applicable.

Expanding on the definition in Figure 1, Munasinghe and Shearer (1995) suggest that when developing a definition of sustainable development, one should not freeze the current state, but instead define the boundaries, while considering the number of variables, ease of measurement, generality, applicability, and flexibility. Bratt (1991) suggests that many of the definitions of sustainable development tend to focus on welfare optimization and the self-imposed obligation to maximize welfare in the present. The breadth and scope of this movement is not easily captured in a simple definition, which has allowed the concept to be used so broadly.

The sustainable development literature has tended to focus on three main components. As stated earlier, sustainability promotes a triple bottom-line approach that collectively accounts for economic, environmental, and social objectives and goals. Visually, as shown in Figure 2, it has been represented as a triangle, three-legged stool and as three concentric circles (Goodland and Daly, 1996).

Figure 2: Concentric Representation of the Multiple Objectives of Sustainability

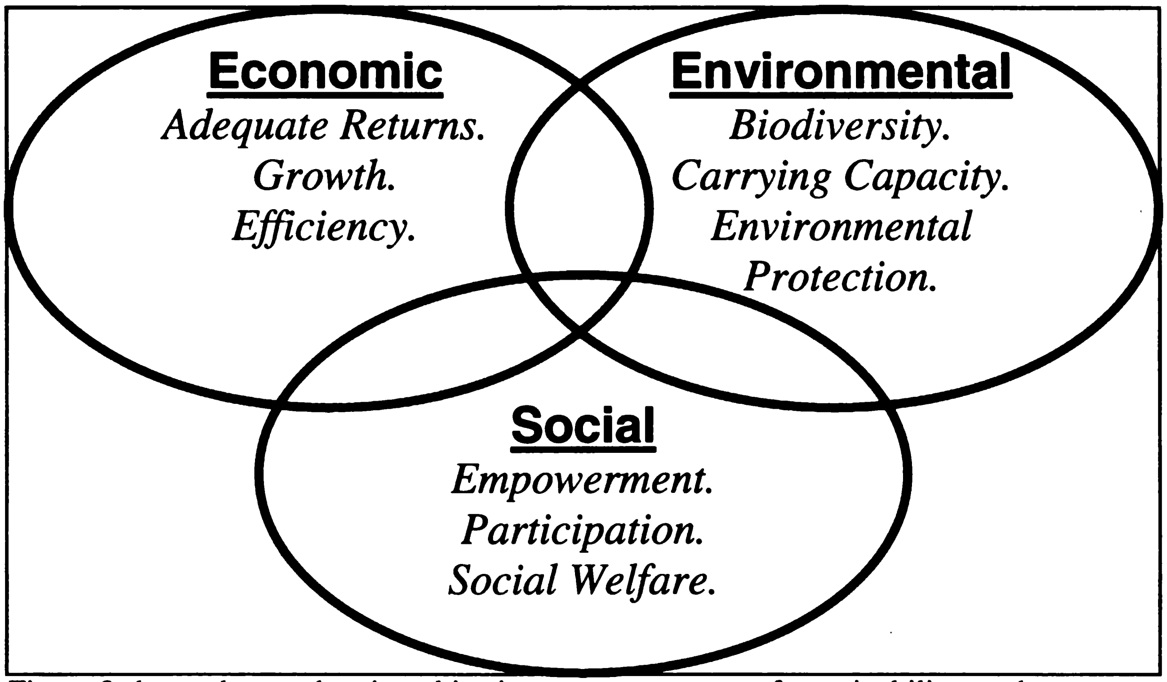

Figure 2 shows the overlapping objectives or components of sustainability, such as economic return and growth, environmental health and biodiversity, and social empowerment and persuasion.

The center of Figure 2 represents the area where the three objectives are overlapping and synergistic. This particular representation shows how a sustainable system is related by introducing a simple framework that integrates the three components of sustainability. Relating the sustainability elements to real world issues however is more complex than the diagram portrays. In agriculture, for instance, in recognizing that it is not just a productive land-based industry, but also a connection for the non-farm population to natural resource amenities, sustainability has become a central farm policy issue. The following section takes an in-depth look at sustainable agriculture.

2.2 The Application of Sustainability to Agriculture

As stated above, earlier concepts of sustainability were first developed in response to the externalities of agriculture such as overgrazing and erosion. The paradigm of agricultural sustainability has been applied to the survival and economic success of the farm sector, the role of farmers in the stewardship of the land, and the necessity of farming within the greater economy (Feenstra, 1997). A deeper assessment of the concept suggests that a transformation in agricultural production and the way our society views agriculture is needed.

The notion of sustainable agricultural development is essentially a systems approach to the production of food and fiber that accounts for economic, environmental, and social elements. In essence, sustainable agriculture seeks to affirm that the profitability of agriculture is inextricably linked to the productivity of the land and welfare of farms and the surrounding community. According to Bird and Ikerd (1993), sustainability in agriculture comes from maintaining an adequate number of owner-operated farms, utilizing family-farm labor, creating partnerships between families and laborers, diversifying crops and markets, and utilizing on-farm resources and site-specific decision-making.

Changes in the farm sector have spurred many emerging sustainability goals. Trends show that the capacity to produce agricultural products in a sustainable fashion is rapidly deteriorating: farmers are losing money and going out of business, environmental impacts are affecting ecosystem health, and social equity disparity is increasing. In

Michigan, the case study of this thesis, there were 17% fewer farms in 2002 then there were in 1974 and total farm production expenses increased by the nominal value of 393%. Table 1 (below) highlights some of the structural changes in Michigan agriculture. The issues identified by Bird and Ikerd (1993) with respect to the changes in agriculture include a declining number of farms, consolidation, dependence on off-farm inputs and energy imports, increased environmental and human health risks, and a declining level of direct interaction between the farm and off-farm population. Therefore, the ability of agriculture to sustain current production levels into the future may be at risk.

Table 1: Historical Highlights of Michigan Agriculture

	1974	1982		1992		2002		
	#	#	% Change 1982-74	#	% Change 1992-82		% Change 2002-1992	% Change 2002-1974
Number of Farms	64,094	58,661	-8%	46,562	-21%	53,315	15%	-17%
Land in Farms (acres)	10,832,234	10,942,172	1%	10,008,170	-9%	10,142,956	1%	-6%
Market value of Ag Products(average per farm)	23,270	44,123	90%	65,043	47%	70,757	9%	204%
Sole proprietorship (number)		52,022		40,654	-22%	48,070	18%	
Sole proprietorship (%)		89%		87%	-2%	90%	3%	
Total farm production expences ($1000)	676,628	2,211,823	227%	2,583,189	17%	3,333,716	29%	393%
Commercial fertilizers expences ($1000)	131,619	242,091	84%	218,185	-10%	241,158	11%	83%

Source: Table 1: Historical Highlights: 1992 and Earlier Census Years, 1992 Census of Agriculture Volume 1: Part 22, Chapter 1 MICHIGAN State-level data

Sustainable agriculture proponents claim that it represents a more diverse, versatile, and less intense form of agriculture than its conventional counterpart (Hansen, 1996; Allen, 1993). The US National Academy of Sciences highlights the incorporation of natural systems, increased use of biological and genetic material, and improved cropping practices as relevant sustainability goals (Allen, 1993). In agriculture, sustainability is a bold end goal that is not necessarily a set of distinct practices that are applicable to all farms. It is instead the center hub of farmer productivity, economic and population demands, healthy/safe food, adequate farm incomes, and social equity (Benbrook and Groth, 1996).

As with the sustainable development concept, there are many interpretations of sustainable agriculture. Hansen (1996) based on the work of Thompson (1992) draws a distinction between goal-prescribing and system-describing sustainability in agriculture. Goal-prescribing definitions of sustainability are related to the ideological and or management approach to agriculture. System-describing definitions relate to the ability of agriculture to fulfill a diverse set of goals or the ability to continue in the future. Many of the definitions can be placed into these two categories based on their underlying goals; a policy interpretation has also been included in Figure 3.

Figure 3: Interpretations of Sustainable Agriculture

Goal Prescribing Interpretation

Sustainability as an ideology is: 'an approach or philosophy...that integrates land stewardship with agriculture. Land stewardship is the philosophy that land is managed with respect for use by future generations' (Neher, 1992 in Hansen 1996).

Sustainability as a set of strategies: '...(a) the development of technology and practices that maintains and/or enhances the quality of land and water resources; and (b) the improvements in plants and animals and the advancement in production practices that will facilitate the substitution of biological technology for chemical technology' (Ruttan, 1990 in Hansen, 1996).

Figure 3 (con't)

System Describing Interpretation

Sustainability as the ability to fulfill a set of goals: '...an agrifood sector that over the long term can simultaneously (1) maintain or enhance environmental quality, (2) provide adequate economic and social rewards to all individuals and firms in the production process, and (3) produce a sufficient and accessible food supply' (Brklacich et.al., 1991 in Hansen, 1996).

Sustainability as the ability to continue: '...the maintenance of the net benefits agriculture provides to society for present and future generations' (Gray, 1991 in Hansen, 1996).

Policy Interpretation

Sustainability as a policy is: 'an integrated system of plant and animal production practices, having site-specific application that will over the long-term satisfy human food and fiber needs, enhance environmental quality, make the most efficient use of non-renewable resources, integrate natural biological cycles, sustain the economic viability, and enhance the quality of life for farmers and society as a whole' (FACT Act, 1990).

While no one widely accepted definition of agricultural sustainability has emerged, people have been applying the term to agriculture.

As discussed in the previous section, Figure 3 highlights the many definitions and applications of sustainability to agriculture. These concepts, Hansen (1996) suggests, can be used to motivate the adoption of alternative approaches to agricultural production. It can also be used as criteria for guiding agriculture, as it responds to changes in the surrounding environment. The three components of agricultural sustainability are discussed in the remainder of this section.

The economic component is the first component of agricultural sustainability. The economic objective, which gets to the root of farm sector survival and the profitability of agriculture, is focused on the growth, efficiency, and returns of farming. Technically, a farm is economically viable when it generates adequate revenues to cover all variable and fixed costs, family living expenses, and replacement costs (Adelaja and Rose, 1988). As one of the components of sustainability, it is the most important to farmers and banks as a predictor of farm sector strength. Unfortunately, Adelaja and

Lake (2007) suggest that, in Michigan, agricultural viability may be threatened by 1) a lack of competitiveness in international markets, 2), increased right-to-farm and environmental compliance issues, 3) a lack of resources to support agricultural innovation, and 4) fragmentation and diseconomies of scale in agricultural support industries.

With respect to agricultural viability, even though the rise in productivity and technical efficiency in the farm sector has been substantial in the past few decades, farmers are still struggling to make a living wage from farming. Farmers, in turn, either exit farming or rely on off-farm employment to cover family living expenses (e.g. health and property insurance, household debt and educational expenses) (Fernandez-Cornejo et.al, 2007). Identified as the "farm problem," the reduced demand for labor, asset fixity, adjustment costs, low returns, and the elasticity of export demand generate less viable farms (Garder, 1992). Hughes et. al (1985) suggest that farm financial stress is caused by a host of macroeconomic policies and individual management decisions which generate a less resilient, less productive and more concentrated farm sector.

The second component of agricultural sustainability is environmental. It is concerned with the agro-ecosystem biodiversity and carrying capacity. The agricultural environment, which provides many non-pecuniary and intangible benefits such as conservation of wildlife habitat and open space, is being increasingly targeted for preservation for future generations. The externalities of agriculture (i.e. chemical, energy and erosion issues) however, raise doubts about the sustainability of agricultural production practices. Therefore, alternative strategies for improving the agro-ecosystem have been identified as relevant agricultural sustainability objectives. These strategies include: 1) managing the ecosystem to maximize the economic and ecological functions of agricultural land, 2) maintaining the diversity of land uses, crops, and families, and 3) protecting the land, air, and water from undue harm, according to the Canadian International Development Agency (1992).

Indeed, farm stewardship practices can affect the viability of the farm itself. Goodland (1995) has identified a strong link between the profitability of agriculture, the health of the environment, and the scarcity of natural resource inputs (land, energy, and water). Adelaja, Sullivan, and Govindasamy (1999) suggest that the potential of sustainable agricultural practices to increase farm viability will lead to a win-win situation between the agricultural economy and environment.

The third component of agricultural sustainability is social. It relates objectives, like empowerment, participation, and welfare, to the survival of agriculture. Social and cultural support for farming in rural areas that enhance the bottom-line of a farmer's income are imperative to the survivability of the agricultural sector in the future. However, issues such as consolidation and income inequality threaten to drive small and medium farms out of the industry. Goldschmidt (1978) first recognized the link between "industrialized" farming communities and social viability, suggesting that a more concentrated industry, with larger farms, adversely affects the vitality and welfare of a rural community. Therefore, improving the social sustainability of agriculture through its social contributions has been put forth as a goal not only for agriculture but also for rural economic development (Allen, 1993).

Some suggest that the farm sector could enhance social sustainability and rural economic development through public investments in human capital, education, innovation, and a growth-from-within approach (Bird and Ikerd, 1993). Stoneham et.al. (2003) suggest that the key elements of social sustainability ensure the free movement of labor and capital between regions and maintain the existing character of rural communities. The key elements of social sustainability, such as equity, the distribution of income, connectedness, governance, cultural diversity, and quality of life, will in turn maintain and enhance the long-term sustainability of agriculture (Barron and Gauntlett, 2002; CIDA, 1992). In addition, enhancing and improving community cohesion, institutional support, and moral and human capital, will further the sustainability of a rural community (Goodland, 1995).

In conclusion, agricultural sustainability is equated to a positive and growing system, where the farmers are profitable, stewards of their environment and an integral part of the community. It has been shown that farmers who make more money generally spend more money on environmental protection and are more involved in their community (Adelaja and Sullivan, 1998). Furthermore, expenditures on agro-environmental stewardship may increase the profitability of a farm and its ability to withstand the fluctuating market (Batie and Horan, 2001). Local food systems (i.e. direct sales to institutions, farmers' markets, and community-supported agriculture) keep resources in the community and provide agro-tourism opportunities, suggesting that there is overlapping energies between the three objectives of agricultural sustainability.

Interdependency between the numerous economic, environmental, and social relationships exists, which adds to the complexity of understanding the makeup of a sustainable and balanced system (MAFF, 2000). Nevertheless, farmers, policy-makers, and academics desire an increased understanding of the relationship between short-term economic sustainability and its economic, environmental, and social factors. Empirical evidence, concluding that short-term agricultural economic sustainability is complementary to economic, social, and environmental objectives, would provide evidence of the interconnectedness of the multi-faceted goals of sustainability. The following section includes a discussion about measurement.

2.3 Measuring Sustainability

Although it is difficult, measuring sustainability has its benefits. For example, it could be used to inform farmers and policy-makers on how to evaluate agriculture's progress towards a sustainable state. Information on progress towards farm sustainability will aid in the collective assessment of the interrelated sustainability aspects. In lieu of a direct measure for sustainability, many organizations have sought to develop measurement schemes, such as indicators, to assess the health of economic, environmental, and social aspects of agro-economic sustainability. This section delves into the topic of measuring agricultural sustainability.

Given that sustainability is a big concept to measure, simple proxy or indicator schemes have been developed to highlight the state of agriculture. Indicators are the key assessment tools created for farmers, academics, and policy-makers to help build consensus and implement sustainable policy (IISD, 2006). The Ministry of Agriculture Fisheries and Food in the United Kingdom (MAFF), for example, has developed regional and local reference indicators with the intention of

1) Tracking the impact of agriculture over time to show how agriculture is becoming more or less sustainable,

2) Providing policy makers with the tools to assess the effects of current policies, identifying new policy options and appraising the merit of such policies,
3) Raising awareness about the externalities of agriculture and its contribution to sustainable development, and
4) Effectively influencing the international debate about indicators and sustainability targets (MAFF, 2000).

Furthermore, Zhen and Routray (2003) believe that the international desire for tools that aid in the assessment and implementation of sustainability for farming are becoming more important at local and national levels.

Quantitative measures of sustainability, such as indicators, are also an important prerequisite to legislative action intending to enhance sustainable agriculture (Zhen and Routray, 2003). Indicator development programs, like the ones being developed in the UK, Netherlands, and Australia, measure progress towards economic, environmental, and social sustainability. Through such programs, the documentation of sustainability and the respect for indicators, as a measurement tool, have been greatly enhanced.

There is much debate about what makes a good indicator. Scientists, policy makers, producers, and researchers agree that relevant, easily understandable, and measurable indicators are the best (OECD, 1999). They should also overlap in time so that they capture the majority of interactions in agriculture. A good indicator should be spatially and temporally relevant to the study area in question and should be able to integrate the economic, environmental, and socio-economic elements of sustainability.

Indicators can be conceptualized for many purposes. For instance, indicators can be used for planning or communication purposes. According to Kuik and Verbruggen (1991) they can be retrospective to establish a baseline and contribute to our understanding of changes in the agricultural system. They can also be predictive and help us understand what the future agricultural system will look like.

Indicators provide an assessment tool for the individual components of sustainability, but could also provide useful information for a comprehensive look at sustainability through economic modeling. A number of sustainability modeling approaches are discussed in the following section. Notably, the economic viability literature (one component of sustainability and some would say the most important to farmers) is the most abundant and the starting point of the modeling discussion.

2.3.1. Past Modeling Efforts

The framework for modeling and measuring agricultural viability and profitability is well documented. Historically, the general approach to viability modeling was to develop proxy measures of viability, such as debt-to-asset, viability, and cash flow or net income (NFI) approximations and to regress these on hypothesized causal factors. The four measures of economic viability have been used interchangeably. Intuitively farms with negative cash flows and high debt to asset ratios should be less financially stable.

There have been several inherent flaws in these previous models. First, the proxies used to estimate economic viability are only indicators of profitability and are not direct measures. Second, some of the previous models may be incorrectly specified and biased, given that the relationship between viability and its determinants seems to be simultaneous (Adelaja and Rose, 1988). The possible causality of the debt-to-asset ratio in the viability equation an issue. It has been argued that debt-to-asset ratio may be a determinant of economic viability rather than an endogenous variable (Adelaja and Rose, 1988). Jolly et.al. (1985) imply that farm financial stress is related to a high debt to asset ratio and negative cash flows. Viability ratio defined as the ratio of net household income to financial obligations, may be inadequate because it is a scaled measure and not in actual dollar terms (Adelaja and Rose, 1988). Viability is best approximated in terms of NFI given the inherent flaws in previous proxies and the fact that cash flow and the impact of the determinants are measured in actual dollar terms.

Hosts of agricultural economists have attempted to identify the explanatory variables that affect the short-run economic viability of farms (Jolly and Doye, 1985; Adelaja and Rose, 1988; Tanewksi et.al., 2000). The studies that have previously attempted to pinpoint the factors that determine agricultural viability do so by estimating single equation models. From these models the determinants of farm viability can be assessed using proxy measures for farm financial characteristics, structural factors and demographic characteristics (Adelaja and Rose, 1988; Adelaja and Sullivan, 1998). Previous studies have included financial variables (gross farm income, off-farm income, debt, depreciation, farm asset values, and revenue from asset sales), structural factors (commodities, region, and acreage), and demographic factors (operator age, experience, and education). Empirical findings from New Jersey, using a simultaneous cash-flow model, suggest farm economic viability is positively related to size, gross farm income, off-farm income, operator's education and experience, and the number of adult operators, but it is negatively impacted by debt and the age of the operator (Adelaja and Rose, 1988). Attitudinal characteristics, such as planning horizons, the farmer's beliefs with respect to the business and regulatory climate, and the Farm Bill, were also found to influence viability (Adelaja and Sullivan, 1998).

Despite the prevalence of economic viability studies, there is still a limited knowledge of the structure of farm profit and how it relates to the environmental and social components of sustainability. The absence of knowledge about viability's relationship to environmental and social variables is especially confounding. It has not been well documented in the literature. Attempts to understand the relationship between farm income and the externalities associated with agriculture, the dependence on federal price support programs and social equity are imperative to sound farm policy and market intervention (Gardner, 1992). It has been suggested that the factors that drive many national agricultural intervention policies aimed at aiding the viability of farm sector, are likely to perpetuate the farm problem if a broadened view of economic viability is not taken (Gardner, 1992; Hughes et.al., 1985; and Jolly et.al., 1985). Viability studies that do not factor in the environment and social dimensions of agriculture are not likely to explain what viability and sustainability in agriculture truly entails. One of the objectives of this thesis is to test whether or not the specification of the four agricultural viability models presented in Chapters 3 and 4 are improved by the addition of environmental and social indicators of sustainability.

2.4 Summary

In summary, Chapter II provides a broad overview of the origin of the sustainability concept in the 19th and 20th centuries. The paradigm of sustainable agriculture, its definition, and components are also discussed in detail. In addition, the current framework for measuring sustainability is highlighted.

The lack of a detailed framework for understanding the relationship between agro-economic, environmental, and social objectives for agriculture limits one's understanding of the complex relationship between NFI and other sustainability factors. This thesis develops a novel approach to modeling economic sustainability that incorporates many of the indicators put forth by the OECD, MAFF and others. Chapter III highlights the conceptual framework for modeling short-term economic sustainability.

Chapter III: Conceptual Framework

In Chapters I and II, it was suggested that the concept of agricultural sustainability is important and relevant to maintaining a viable agricultural sector, short-term. The issue that this thesis focuses on is how to develop and apply a conceptual framework for evaluating the monetary trade-offs associated with pursuing the multiple elements of agricultural sustainability in counties across Michigan. One indicator of short-term sustainability is the profitability or viability of the agricultural sector, which is well documented in the economic viability literature. In this thesis, this framework is expanded to account for environmental and social factors. Net farm income per acre (dependent variable) is therefore decomposed via simple linear cash flow models in an effort to study the contributions of economic, environmental, and social factors to short-term agro-economic sustainability. The first, economic viability, has been well addressed in the literature.

The WTS is a test for the county level agro-economic success based on the sequential inclusion of economic, environmental, and social sustainability factors. It is called the WTS because it is simply a one-sided test on the profitability of the farm-sector, not a direct measurement of an observed variable for agricultural sustainability. This is further explained in the rest of Chapter III.

3.1 The Agro-Economic Sustainability Models Conceptualized

As shown in Chapter II, the profitability of agriculture has been well studied. At a minimum, NFI must be greater than zero in order to satisfy the very basic conditions for sustainability (Zhen and Routray, 2003). Leaning on the work of Adelaja and Rose

(1988); Adelaja, Derr and Rose-Tank (1989); Adelaja and Sullivan (1998); Jolly et.al. (1985) and Zhen and Routray (2003), this thesis develops a conceptual framework for assessing short-term agricultural sustainability. With the purpose of identifying the determinants of economic sustainability and estimating the impacts of those determinants on net farm income per acre, the model begins by accounting for many of the factors found in previous studies.

Following previous studies, the economic component of sustainability can be explained by farm sector (1) finances, (2) structural assets and resources, and (3) socio-demographic characteristics. Adelaja and Rose (1988) suggest that farm financial determinants include gross farm income, off-farm income, debt, profitability ratio, total assets (equipment and land), revenue from asset sales and acreage. Structural farm resources include the type of commodities grown, changes in amount of agricultural acreage, tenanted/rented acres, and the location of the farm (Adelaja and Rose, 1988; Jolly et.al, 1985). Socio-demographic characteristics, such as the number of operators, age of farmers, the number of farm residences, and operator experience, are also identified in the literature as determinants of viability (Adelaja and Sullivan, 1998). The EU Commission on Agriculture and the Environment (2001) suggests that indicators of farm income include the net worth of resources, financial stress, and the gross value added to production. The financial, structural, and social-demographic characteristics mentioned here are hypothesized to be determinants of agricultural economic sustainability.

The implicit function for agro-economic sustainability incorporates financial, structural, and operator characteristics, and helps to explain what it takes to maintain adequate profits in the farm sector. The basic relationship for short-term agro-economic sustainability is such that sustainability (Y_i) is specified as follows:

$$Y_i = Y_i (W_i, X_i, Z_i) = Y_i (V_i) \qquad (1)$$

where Y_i is agro-economic sustainability, measured as net farm income per acre (dependent variable) of i^{th} county in Michigan, W_i is a vector of variables depicting the financial characteristics of farms in the i^{th} county, X_i is a vector of county structural factors for farms and Z_i is a vector of socio-demographic characteristics for farms in the i^{th} county. Collectively W_i, X_i and Z_i account for the economic viability (V_i) component of the agricultural sector. A simple linear relationship is assumed.

The conceptual model framework is based on the notion that an agricultural economic viability model that includes economic variables alone is incomplete, because it does not consider the effect of environmental and social factors on farm income. It is also based on the notion that previous models of viability are insufficient indicators of sustainable agriculture. This study is different from others in that it seeks to evaluate the effect of additional environmental and social factors on farm income. The rationale for including the environmental and social sustainability variables is that they are critical determinants of economic viability itself. In other words, if profitability is environmentally and socially compatible, it should be reflected in the economic bottom-line.

The environmental resources (e.g. soil and water conditions) of a farm, and the management of those resources for agricultural production should affect the sustainability of the natural environment on and off the farm. The indicators identified in the literature, such as crop diversity, are also expected to affect the short-term viability of the farm, by increasing resilience and productivity (OECD, 2001). The health and state of farm resources, such as the nutrient content of soil, influence the farm ecosystem and could raise environmental degradation concerns. Policy responses to the externalities of farm production practices, i.e. conservation payments, have the ability to improve the agri-environment and profitability of farms through incentive payments. These environmental sustainability factors, which include the management of farm resources, the externalities of harmful production practices, and the response to those practices, are hypothesized to affect the short-term economic sustainability and the bottom-line of a farm. However, a farm that is economically sustainable and simultaneously is environmentally sustainable in the short-term is likely to be more sustainable that one that is only economically sustainable. This is the essence of the WTS.

In Equation 2, environmental sustainability variables are added to economic viability variables. They are assumed to impact upon short-term agro-economic sustainability, such that:

$$Y_i^* = Y_i^* (V_i, E_i) \qquad (2)$$

where (E_i) is a vector of environmental measures to be added to V_i, to test whether or not they improve estimates of short-term sustainability. V_i characteristics are defined above in Equation 1 and the environmental (E_i) factors in Equation 2 are secondary. It is hypothesized that the specification of the short-term economic sustainability model is enhanced by including a vector of environmental determinants.

Agriculture affects the society in which we live by altering the social fabric of rural and urban places and changing the roles of individuals. One goal of this thesis is to capture the effects of societal interaction in a sustainable agricultural system, such as the population pressures at the urban/rural fringe, direct sales to consumers, farm agro-tourism opportunities, and access to input suppliers. The economic development potential of agricultural jobs, incubators for agri-business start-ups, and ag-based festivals is of particular interest to local governments and economic development organizations looking to spur sustainable agricultural development.

Subsequently in Equation 3, social sustainability variables are also added and assumed to impact upon short-term economic sustainability, such that:

$$Y_i{}^{**} = Y_i{}^{**}(V_i, S_i) \tag{3}$$

where (S_i) is a vector of social sustainability indicators added to V_i. Augmenting the agricultural sustainability equation with the hypothesized indicators of social sustainability is expected to improve the specification of the equation. Note that the E_i vector is missing from Equation 3. This is to allow for the independent assessment of the effects of environmental and social factors.

Given the theoretical model of short-term agro-economic sustainability and the vectors of environmental and social indicators described above, this thesis suggests that agricultural economic sustainability is collectively defined by economic, environmental, and social sustainability determinants. Therefore, farm income can be treated as a dependent variable that is affected by a host of economic viability determinants as well as environmental and social sustainability measures. The model that captures the collective effect of economic, environmental, and social vectors on net farm income is such that:

$$Y^{***}{}_i = Y_i{}^{***}(V_i, E_i, S_i) \tag{4}$$

In Equation 4, agricultural economic sustainability (Y_i) is better estimated by including the effect of the economic (V_i), environmental (E_i) and social (S_i) factors in estimating the net farm income equation. It is hypothesized that the collective effect of factors capturing the objectives of sustainability will improve model specification when comparing Equation 1-4. If Equation 4 is better specified than Equation 1, then sustainability in a weak sense (WTS) is possible. By providing evidence that the movement towards a more sustainable agricultural system does not detract from short-term economic sustainability, one can conclude that economic, environmental, and social objectives are compatible.

3.2 Summary

Chapter III presents a conceptual framework for a Weak Test of Sustainability, which is expected to expand the knowledge surrounding the potential economic trade-off between economic, environmental, and social sustainability objectives in agriculture. The series of additive linear equations described in Chapter III are expected to improve the specification of the short-term economic sustainability model. Chapter IV presents the empirical framework used in this thesis to test the hypotheses that previous models are incomplete because they fail to include environmental and social determinants, that model specification is improved by including environmental and social factors of sustainability, and that the objectives of sustainability are not separate from one another but inextricably linked.

Chapter IV: Analytical Framework, Data and Estimation

The analytical framework put forth in this thesis is to identify the determinants of agro-economic sustainability and to estimate a series of economic sustainability functions. The framework for examining the monetary trade-offs associated with the three independent but interrelated goals of (economic, social, and environmental) sustainability in agriculture in Michigan counties is proposed as a Weak Test of Sustainability (WTS). Chapter IV highlights the findings of previous studies of farm viability and specifies four models of agro-economic sustainability. The comparative framework for choosing the best model is also defined, which involves comparing a standard economic sustainability model to three additional augmented models, through a series of F-tests and the creation of benchmark index based on the predicted outcomes of the models. Finally, a section on the data and estimation procedures used in this thesis is presented.

4.1 Analytical Framework for WTS

The analytical framework for the WTS in Michigan includes four equations. All four equations include the economic determinants of sustainability. The first model includes only economic factors. The other three allow for testing the individual and collective effects of environmental and social sustainability variables on farm income. This section describes the results of previous studies that provide the rationale for including many of the variables in the economic sustainability model. It also specifies the equations used to perform the WTS.

Recall from Chapter III that the basic agro-economic sustainability (Y_i) model includes the economic characteristics (V_i), which is comprised of farm financial characteristics (W_i), county structural factors (X_i) and operator characteristics (Z_i).

Previous studies have identified the following farm financial variables (W_i) as important to enhancing economic sustainability, profitability, and viability in the agricultural sector: gross farm income, off farm income, profitability, assets value, and farm acreage or size (Zhen and Routray, 2003; Duffy, 2002; Adelaja and Sullivan, 1998; and Adelaja and Rose, 1988). For example, in their study of farm viability at the urban fringe, Adelaja and Sullivan (1998) showed that total and per acre gross farm income affects viability, indicating that larger farms with more intense production practices are more viable.

Duffy (2002) estimated a profit index for small farms in Iowa, concluding that, farms that used land and machine resources more efficiently were more profitable. Financial factors that have been shown to detract from farm viability include high debt service and the high cost of production (Adelaja and Sullivan, 1998 and Adelaja and Rose, 1988). Another variable, considered, but not been found to be significant, is the revenue from land sales. On one hand, such revenue can help farmers pay the bills during slow market times. On the other hand, such sales are a warning sign that a farm may be going out of business.

County structural characteristics (X_i) that may affect the viability of the farm sector have also been identified in the literature. Adelaja and Rose (1988) show that fruit and vegetable farms in New Jersey are generally more viable than grain farms because they can utilize more land with fewer assets. Regional variables included in a study by

Adelaja and Sullivan (1998) suggests that farms in urbanized areas are less viable. Reductions in farmland acreage have been shown to detract from viability, indicating that suburbanization further erodes the agricultural sector (Adelaja and Sullivan, 1998). However, when farming choices and prices are factored in, previous studies show suburbanization increases the profitability of the vegetable sub-sector, (Lopez et. al., 1988).

The characteristics of farm operators (Z_i) also affect the sustainability of farms. The number of operators per farm, experience, education, and the number of members in a household have been shown to enhance viability (Duffy, 2002 and Adelaja and Rose, 1988). Farming experience was empirically shown to enhance the viability of farms because more experienced and older farmers have less debt (Adelaja and Rose, 1988). However, Duffy (2002) found that the owners of successful small farms in Iowa are younger and better educated. Education was shown to provide a substantial benefit and returns to a college degree could be well over 200% by Adelaja and Sullivan (1998). Past studies also show that farms with appropriate managerial, financial, and marketing practices are more viable (Duffy, 2002).

Recall from Chapter II, that the literature highlights many of the environmental factors (E_j) of agricultural sustainability. A few of these environmental variables have been included in previous farm viability, profitability, and sustainability studies. Empirical results from New Jersey show that a reduction in the use of chemicals does not detract from farm viability, indicating that lower input and sustainable agriculture practices are compatible with economic viability (Adelaja and Sullivan, 1998). Other suggested environmental indicators of sustainability include soil nutrient content and the use of fertilizers/pesticides (Zhen and Routray, 2003). MAFF (2000) includes indicators like the direct energy consumption by farms and characteristic features of farmland.

Social (S_r) sustainability factors are important elements to incorporate into short-term sustainability models. A number of social variables have been included in previous viability studies. For instance, how extensively a farmer utilizes information, such as extension and the Department of Agriculture in New Jersey, ultimately enhances farm viability (Adelaja and Sullivan, 1998). The skill and knowledge base available to farmers is expected to be important to the survivability of the farm sector (Smith and McDonald, 1998). Attitudinal indices were also included in the New Jersey study and the marketing and supply indices were both significant (Adelaja and Sullivan, 1998). This suggests that farmers, who feel that the marketing environment is not conducive to selling their products or that it is difficult to procure supplies, are less viable. Zhen and Routray (2003) suggest that social sustainability for agriculture should include access to resources and support services.

To facilitate econometric estimation, the empirical models conceptualized in this thesis are a series of additive equations. The following Equations 5-8 were specified:

$$Y_i = a_0 + \sum_{f=1}^{n} \alpha_f V_f + \varepsilon_i = a_0 + \sum_{f=1}^{n} a_f W_f + \sum_{f=n+1}^{n} a_f X_f + \sum_{f=n+1}^{n} a_f Z_f + \varepsilon_i \quad (5)$$

$$Y_j = a_0 + \sum_{f=1}^{n} \alpha_f V_f + \sum_{j=1}^{h} \beta_j \mathrm{E}_j + \varepsilon_j \quad (6)$$

$$Y_r = a_0 + \sum_{f=1}^{n} \alpha_f V_f + \sum_{r=1}^{p} \gamma_r S_r + \varepsilon_r \quad (7)$$

$$Y_k = a_0 + \sum_{f=1}^{n} \alpha_f V_f + \sum_{j=1}^{h} \beta_j \mathrm{E}_j + \sum_{r=1}^{p} \gamma_r S_r + \varepsilon_k \tag{8}$$

where, $Y_{i,j,r,k}$ is the dependent variable net farm income per acre for counties in Michigan, V_f is the vector of economic variables, E_j is the vector of environmental variables, S_r is the vector of social variables, and the $\varepsilon_{i,j,r,k}$ are the errors terms assumed to be normally distributed with means of zero and constant variances. The variables included in the vectors of the four models are defined in Table A1: Definitions of the Independent Variables and Source in the appendix and discussed below. The Equations to be estimated are 5-8. Equation 8 is expected to exhibit the least specification error or the highest adjusted R-square. Equations 6 and 7 include either environmental or social indicators and are therefore expected to be less than optimal in terms of specification. Equation 5 is expected to be the least efficacious because it totally ignores environmental and social factors.

Consistent with the literature on economic viability and sustainability, nine economic (V_f) factors are included as independent variables in the estimation of Equation 5-8. W_f contains off-farm income (OFI_ac), equipment assets (Equip_ac), revenue from asset sales (RAS_ac), and operating expenses (opEx_ac). X_f contains access to key services (AKS_ac), diversity of farms by size (SizeDiv), and MSU Extension Educators (EXT_ac). Z_f contains the average age of farmers (avg_age) and young farmers (Farms25_34).

Equation 6, added to Equation 5, is augmented with a list of environmental (E_j) variables based on available data. They include land diversity (LDiv), chemical dependence (CD_ac), conservation acreage (ConA_ac), and NRCS management acres

(NRCS). The determinants of environmental sustainability are expected to enhance the model specification of the short-term agro-economic sustainability equation when collectively estimated.

Equation 7 is estimated with social (S_r) variables added to the economic variables in Equation 5. They include direct sales to consumers (Direct_ac), migrant labor capacity (MLC), population interaction index (PII), farm opportunities (Fopps_ac), and project fresh coupons granted (PFresh_ac). The inclusion of these social sustainability factors are expected to enhance the specification of the short-term sustainability model.

Equation 8 is the fully specified model that is meant to augment the standard model with environmental and social determinants introduced in Equation 6 and 7. The expected outcome of the comprehensive Equation 8 is an enhanced agro-economic sustainability model that includes economic, environmental, and social variables that both enhance and detract from the profitability of the sector. The WTS provides a collective scheme for incorporating economic, environmental, and social variables, which is expected to enhance the predictive capabilities of the model, increase the significance of included variables, and increase the adjusted R-square statistics. The following section explores the framework for comparing the models.

4.2 Framework for Comparing the Different Models

The basic framework for comparing the four models involves subjecting the results to a series of F-tests. It is expected that model specification will improve with the inclusion of environmental and social sustainability factors. Short-term agricultural sustainability is concerned with the monetary tradeoffs associated with economic, environmental, and social variables. The Chow F-test is used here to jointly test the significance of the subset of environmental and social of variables on viability, labeled here as the WTS. The F-test requires the comparison of a full (or unrestricted) model with a restricted model. In this analysis, the restricted model is the standard economic sustainability model. The three augmented specifications are the unrestricted models. The F-test is specified as follows:

$$F_{q,N-k} = \frac{(R^2_{UR} - R^2_{R})/q}{(1 - R^2_{UR})/(N-k)} \tag{9}$$

In Equation 9, q is the number of restrictions, N is the number of the variables, and k is the number of parameters in the unrestricted model (Pindyck & Rubinfeld, 1998). This is a test on the R^2. The three null hypotheses are that all of the coefficients of the environmental and social variables in Equations 6-8 are jointly equal to zero. The three alternative hypotheses are that the added coefficients in the models specified herein are non-zero. A positive economic relationship between the economic and other environmental and social sustainability factors would suggest that short-term economic sustainability is consistent with social and environmental sustainability. If the groups of environmental and social variables significantly affect profitability then the WTS is passed. The predicted values of Equations 5-8 are used as a tool for assessing the benchmark structural difference in county's agricultural sector.

4.3 Definitions and Calculations of the Data and Variables

The county is the unit of analysis in this study. County level data is collected on all dependent and independent variables included in the models. There are 83 observations given the number of counties in Michigan. The year of analysis was 2002, with a few exceptions where some non-census data was obtained from other sources for which matching census year data were unavailable. The basic assumption is that variability across counties in the dependent variable (net farm income) can be explained by variability in the independent variables. If the added variables, described in this section, exhibit signs that suggest that improved environmental and social compatibility contribute to short-term sustainability, then one can conclude that agriculture passes the WTS.

In this case study of Michigan counties, in addition to data from the US Census of Agriculture, other data sources include the Bureau of Economic Analysis, many USDA sources like the Economic Research Service (ERS) and the Natural Resource Conservation Service (NRCS), and others such as The Michigan Department of Agriculture (MDA), and the Michigan State University Extension (MSUE). Table A1, found in the Appendix, provides a list of the independent variables used in estimating Equations 5-8. It includes a descriptor for each variable, the description of the variable, the source of data, and the mean and the variance of the data. In Table A1, these variables are listed in the order of modeling. Presented first are the standard economic determinants, second are the environmental variables, and last are the social sustainability variables. Given that the data used in the analysis are for a single year, the resulting parameter estimates are reflective of the effects of causal factors on short-term sustainability.

Net farm income per acre (NFI_ac) of farm operations in Michigan is the dependent variable in Equations 5-8. NFI_ac is a measure of the profitability per acre of farms in a county. Eight counties in Michigan experienced negative net income in 2002, while the others experienced positive NFI (Census of Agriculture, 2002). In Michigan, 57% of farms lost money in 2002, with animal-based commodities faring the worst (Census of Agriculture, 2002; Adelaja and Lake, 2007).

Off farm income per acre (OFI_ac), measures the degree of dependence of the farm sector on the non-farm economy. Income from outside sources has become increasingly financially important to sustaining farms in the US. The additional income from off-farm employment helps farm families pay down debt and make additional capital investments in farming operations. Some farmers may also use off-farm jobs to cover their health insurance and retirement benefits. On the other hand, off-farm employment may be necessary for farms that cannot make ends meet or may decrease a farmer's interest in farming. Information on OFI_ac was collected from the US Bureau of Economic Analysis, which reports off-farm job income for farmers (US-BEA, 2002). OFI_ac is expected to be positively related to NFI_ac.

Equipment assets (Equip_ac) are measures of capital investment and machinery infrastructure per acre. It has been shown that farming operations with high liquidity and returns on assets are more profitable (Adelaja and Rose, 1988). If equipment assets adequately reflect the level of capital intensity then they should be positively relate to NFI_ac.

The *revenue from the sale of assets* (RAS_ac) provides a measure of the potential internal source of capital generated by the county's farms. This variable is included because (arguably) the revenue can be spent on investment in new technology. RAS_ac is calculated by multiplying the change in total acreage (from 1997 to 2000) by the average easement value for the county and dividing it by the number of harvested acres.

The statewide average easement value of agricultural land in Michigan, estimated by Adelaja, et.al. (2006), suggests that the value of farmland minus the cost of buildings is $2,078. RAS_ac is expected to be positively related to NFI_ac.

Operating expenses (opEx_ac) are a measure of the size of the farming budget, an alternative measure of size and a measure of efficiency. High opEx_ac indicates that the farms in the county are not efficient. In fact, most of Michigan is experiencing losses in efficiency, given that opEx_ac in Michigan have increased by over 400% in the last 4 decades, as shown in Chapter II. The effect of opEx_ac is expected to be negative.

Services key to agriculture are necessary to maintaining a viable farm sector. These services include licensed nursery, grain, pesticide application business and wholesale potato dealers (MDA, 2006). The total number of businesses in each county across all of these services divided by the number of harvested acres creates the *access to key services per acre* (AKS_ac) indicator. Higher levels of AKS_ac indicate that there are more key support services available, which will contribute to a more viable agricultural sector. The relationship between AKS_ac and NFI_ac is expected to be positive.

A Simpson's Index for *farm size diversity* (SizeDiv) was created for each county based on the size make-up of farms in the county. The value between {0,1} indicates the level of diversity. The closer the value is to {1} the more diverse the sizes of farms in a county are (Bastian and Stienhardt, 2002). Physically, larger farms can operate more efficiently by taking advantage of economies of scale in equipment and land. However, physically smaller farms can quickly adapt to changing market conditions and tend to focus on niche crops. More physically diverse areas are expected to be more profitable.

Michigan State University Extension (MSUE) provides many valuable education and research services in each county of the state. Adelaja and Sullivan (1998) found that the returns to research and the extent to which farmers utilize information contribute to viability. The *Extension Educators* (EXT_ac) in the county per acre are an invaluable support network for the farm community. Using MSU's Extension Web Portal, an indicator for agriculturally related Extension Educators was created from all of the listed staff members (MSUE, 2006). The Extension coefficient is expected to be positively relates to NFI_ac.

The *average age of farmers* in a county (avg_age) and the *number of young farmers* (Farms25_34) are two age variables included in the model. The literature suggests that there is a positive relationship between experience or the number of years in business and viability (Adelaja and Schilling, 1998; Adelaja and Rose, 1988). The expectation is that more experienced farmers have less debt and interest and are therefore more profitable. On the other hand, young farmers tend to be educated and enthusiastic entrepreneurs who are willing to pursue direct and niche markets, adding to the success of the farm. Therefore, avg_age and Farms25_34 are expected to have a positive impact on NFI_ac.

The environmental indicators included in the second and fourth augmented viability models are calculated from various data sets, such as the USDA Census of Agriculture and the USDA-NRCS PRMS Database. Many of the environmental variables included in this thesis have not been empirically tested in previous models, making a clear judgment about their expected relationship with NFI_ac difficult. The collective effect, measured via F-test, however is expected to enhance the specification of the short-term sustainability model.

Michigan ranks second in the nation for the diversity of agricultural products grown. There are fruit and vegetable belts along the western coast of Michigan, grain farms across the central interior and cattle, dairy and tree farms in the north. Farmers who grow different types of crops in different parts of the state are expected to face different market conditions, business circumstances, growing conditions, and external pressures. *Land Diversity* (LDiv) is a Herfindahl index calculated from the share of land by major land classes (pastureland, cropland, idle, failed, summer fallow, woodland, rangeland, houses, CWRP, organic, enrolled in federal programs, vegetables, orchards). It measures the diversity and concentration of land uses. The statewide average is 69.85 indicating that agro-ecosystem is relatively unconcentrated. A small index means that the county is diverse and a large index (greater than 1,800) means that the agricultural sector in a county is dominated by one or more commodity. LDiv is expected to contribute to a more diverse ecosystem and may enhance the bottom line of farms in a county by diversifying income sources and harvest times.

The use of natural resources and synthetic materials for the production of agricultural commodities can have a lasting effect on the surrounding environment, create dependencies in the ecosystem by making it less resilient, and affecting the bottom-line of the farm operation when expenses become insurmountable. *Chemical dependence* (CD_ac) includes acres treated with chemical, fertilizer, lime, and other soil conditioners per harvested acre. The impact on NFI_ac is expected to be negative.

Conservation acreage (ConA_ac) like the land Conservation Reserve and Wetlands Program (CRWP), certified organic, and the land fertilized with manure is expected to enhance the sustainability of the agro-ecosystem. CRWP enrolled land restores, protects, and enhances the function of the ecosystems services provided by agricultural land. Organically produced farm products use no chemicals, are the fastest growing market segment of the food economy, and through marketing efforts fetch a higher price premium for farmers. Manure is expected to influence the bottom-line of a farm though the substitution of manure-related nutrients for expensive chemical-based nutrients. ConA_ac is expected to contribute to NFI_ac.

Natural Resource Conservation Service total enrolled program acres including, *nutrient, pest, residue management* (NRCS_ac), improve not only the ecological environment surrounding the farm, but also the profitability the farming enterprise because they enhance the money available for agri-environmental expenditures. The data, collected with the aide of NRCS State Economist June Grabemeyer, was obtained from the USDA-NRCS PRMS Database. NRCS_ac is expected to contribute to the sustainability of farms in a county.

The social characteristics of an agricultural community include population interaction variables, support services, and agro-tourism opportunities. Social characteristics are hypothesized to influence the viability of farms in a county, although relatively few studies, if any, provide evidence of their sign or significance. Data sources of the indicator variables used herein include the USDA-ERS, MDA, and others. The collective effect of the social sustainability indicators/variables that are included in Models 3 and 4 are expected to enhance viability positively.

Direct sale per acre (Direct_ac) is the indicator used to measure how important direct marketing is to farm success. Value of agricultural products sold directly to individuals for human consumption is the total income from roadside stands, farmers' markets, pick-your-own sites (Census of Agriculture, 2002). Adelaja and Sullivan (1998) found that direct sales combined with the use of a dummy variable for innovative marketing techniques are positive aspects in the viability equation, although not consistently significant. Direct_ac is expected to be positively related to NFI_ac.

Migrant Labor Capacity (MLC), or the number of beds in certified migrant labor sites, provide short-term migrant laborers with housing for the short growing season when many of Michigan's crops such as asparagus, blueberries, and grapes must be hand harvested. Given the debate in the Unites States right now about migrant labor and security at the border, knowing how MLC influences viability in agriculture will become increasingly important. There are over 4,500 labor-housing units according to the *MDA 2006 Licensed Migrant Labor Housing Sites (by County)* (MDA, 2006). MLC is expected to influence NFI_ac positively, especially in areas with many hand-harvested crops.

Population Interaction Index (PII) is an index that estimates the potential interaction between urban populations and agriculture, across the US, in five-kilometer grid cells (USDA-ERS, 2005). Any PII that exceeds the rural threshold is then classified as a low, medium, or high population-interaction zone, depending on the population nearby (USDA-ERS, 2005). On one side of the fence, Lopez et.al. (1988) argues that the nearby population can enhance revenues at the urban fringe, especially through direct markets. On the other side of the fence, the proximity of a highly urbanizing are can cause right-to-farm conflicts and trespassing issues. Nonetheless, the relationship between PII and NFI_ac is expected to be negative.

There are numerous opportunities (Fopps_ac) to visit on-farm markets, u-pick operations, and agricultural tourism operations in the state of Michigan, where families can participate in everything from apple pressing for cider to strawberry picking (MDA, 2006). The number of u-pick operations, Community Supported Agriculture (CSA's) and on-farm markets per county was obtained from the online MDA Farm Market, U-Pick & Ag Tourism Directory and Localharvest.org. Wineries represent an ever-growing segment of the beverage and tourism market. It is estimated that wineries in Michigan generate $800 million in sales per year. The wine indicator in this thesis is the number of wineries per county and the data was obtained from the 2006 *Michigan Wine County Magazine*. The effect of Foops_ac on NFI_ac is expected to be positive.

Fresh fruit and vegetables are essential to a well balanced diet. However, they are out of reach for some consumers given the expense. Project Fresh, a WIC education program, seeks to put the fresh fruit and vegetables sold at local farmers markets into the hands of those most in need. The data on the total amount granted (for 71 counties = $774K) of *Project Fresh spending per county* (PFresh_ac) was obtained by Viki Lorraine of the Michigan Department of Community Health (MDCH, 2006). PFresh_ac not only contributes to the social well-being of the community by putting fresh fruits and vegetables into the hands of those in need, but it also puts money directly into the hands of farmers. The relationship is expected to be positive.

4.4 Summary

A series of models for measuring short-term agro-economic sustainability, in Equations 5-8, are specified in Chapter IV. The novel WTS introduced in this thesis is expected to improve upon previous model. The WTS implies that three conditions are met, (1) that the standard model that excludes environmental and social factors is not appropriate specification for short-term sustainability, (2) that the inclusion of environmental and social factors in the model improves specification, and (3) that the nature of observed relationships between the different aspects of sustainability are complimentary to profitability. Chapter V highlights the results of the empirical models defined in this chapter using the above-mentioned data.

Chapter V: Empirical Results

As indicated in Chapters III and IV the conceptual and analytical frameworks for exploring the issue of sustainability in Michigan agriculture is to evaluate the effect of the determinants of short-term agro-economic sustainability on profitability (measured by NFI_ac) in a series of additive equations that include economic, environmental, and social sustainability variables. Equations 5-8 were estimated using the ordinary least squares regression technique. The results from estimating the four models are discussed in Chapter V. The parameter estimates for the four models are shown in Table A2 in Appendix I. The results of the F-tests, which are used to test the efficacy of the collective inclusion of environmental and social sustainability factors, are also included in this chapter. The basic premise of the tests is that if improved environmental and social performance enhances short-term economic sustainability, then, profitability is not compromised by the pursuance of other sustainability objectives.

The first step is to estimate Equation 5, including only economic determinants. The next step is to successively add environmental and social factors individually and test for their impact. The final Equation includes the entire suite of all economic, environmental, and social factors.

5.1 Results of the Standard Short-Term Economic Sustainability Model

Equation 5 was estimated using the OLS technique. This equation allows a comparison to previously specified models. Table A2 shows the parameter estimates and significance levels of the coefficients of the variables included in Equation 5 under the heading of Model 1. The results from estimating this restricted economic equation are similar to results found in previous studies; however, this study relies on cross-section data. The adjusted R-square in Model 1, which is 0.5771, indicates that the included causal factors explain the dependent variable fairly well, considering the cross-section nature of the data.

To investigate the presence of multcollinearity correlation matrices for all included variables were examined and included in Table A3 in Appendix I. Multicollinearity creates biased standard errors, thus leading to inaccurate conclusions in the test of statistical significance (Pindyck and Rubinfeld, 2003). Dropping collinear variables or increasing the sample size are two ways to eliminate the problems associated with multicollinearity. The latter was not possible in this study given that Michigan has 83 counties. Therefore, GFI_ac was dropped. GFI_ac is highly correlated with NFI_ac, the dependent variables, and many of the independent variables like opEx_ac, AKS_ac, and PPI. Given that opEx_ac captures much of the same data, excluding GFI_ac is not necessarily problematic. The resulting Model 1 is a near optimum subset of the originally proposed economic viability indicators.

The estimated coefficients of most of the financial (V_i) characteristics were statistically significant. Furthermore, the operator characteristic variables were statistically significant. Structural variables, which depict the role of location and size, were also significant. In fact, sixty-six percent of the coefficients (6 out of 10 economic indicators) in the restricted model were significant at the 1, 5 and 10 percent levels.

Examine first the effects of the farm financial (W_i) variables on viability. Many of these variables had statistically significant coefficients. The coefficient of off farm income per acre (OFI_ac) in Model 1 was negative and significant at the $\alpha = 0.05$ level.

This is inconsistent with the previous result of Adelaja and Sullivan (1998). For every one-dollar increase in OFI_ac, NFI declines by $1.44. Therefore, the two are at odds. The implication of this is that OFI detracts from viability. This may reflect the fact that OFI may decreases the interest in farming, the inability of the farm to maintain cash flow without off farm employment, or the tendency of part-time farmers to pursue less intensive, and therefore less profitable, farming techniques.

The coefficient for the asset value of machinery and equipment per acre (Equip_ac) is positive and significant at the $\alpha = 0.05$ level in Model 1. This suggests that capital intensity contributes to farm viability. Note that this coefficient is not significant in Equation 3 and 4.

The coefficient for potential revenue from land sales per acre (RAS_ac) is negative and statistically significant at the $\alpha = 0.05$ level in all 4 equation. This supports the findings of Adelaja, Derr and Tank (1989) and Adelaja and Sullivan (1998) that revenues generated from land sales enhance viability. It should be noted that RAS_ac is the potential value of sales (easement value * change in harvested acreage) and may undervalue the true value of land asset sales sold.

The coefficient of operating expenses per acre (Opex_ac) is positive and significant at the $\alpha = 0.01$ level, contradicting the expectation of a negative sign for this coefficient. This suggests that for every additional dollar per acre of operating expenses, net income increases by 22 cents. Opex_ac is essentially a measure of cost, which could reflect efficacy or the type of commodity grown. For example, vegetable farms should have higher opex_ac than grain farms, but also generate greater gross farm income per acres. The fact that the effect on NFI_ac is positive may suggest that such costs create a more viable farm sector. Tree fruit, nursery, and ornamental farms also fall into the category of high rate crop farms.

Many of the county structural (X_i) variables included in Model 1 are statistically significant. Critical support services such as licensed nurseries, grain dealers, pesticide applicators, and wholesale potato dealers are necessary to agricultural viability. The access to key services (AKS_ac) indicator is positive and significant at the $\alpha = 0.01$ level. Moreover, AKS_ac has the largest coefficient in the models, ranging from $5,791 in Model 1 to $12,191 in Model 4. This is a very important finding, suggesting that a 'critical mass' of agricultural support infrastructure is necessary to a viable agricultural future.

The SizeDiv coefficient is positive and significant at the $\alpha = 0.05$ level. In counties where a more diverse set of farm sizes exists NFI_ac increase by $786. Therefore, it can be inferred that in areas where a more diverse set of farm sizes exists the farm sector is more successful. Michigan agriculture is one of the most diverse in the nation. This thesis supports that its diversity is an asset.

The results of the standard model presented here are consistent with findings from previous studies. When applied to Michigan however, some of the coefficients were found to be insignificant including, EXT_ac, avg_age, Farms25_34. This may be a function of the Michigan marketplace or a function of the exclusion of sustainability considerations. The effects of environmental and social factors are discussed in the next sections.

5.2 Results of the Environmentally Augmented Model

One of the objectives of this thesis was to test whether or not environment sustainability variables enhance or detract from profitability. To test the joint effect of four environmental factors, Model 2 was estimated via OLS. The results for the inclusion of environmental variables in the viability equation are discussed in this section. Table A2 in the Appendix I highlights the parameter estimates under the heading of Model 2.

Model 2 confirms that environmental stewardship contributes to our understanding of economic viability in the farm sector. For Equation 6, which includes environmental stewardship indicators, the adjusted R-square value increased from 0.5771 to 0.5986. This is an improvement over Model 1, suggesting that environmental variables should be included in models of economic viability. However, only two of the four coefficients for the environment included in Model 2 are statistically significant, LDiv and CD_ac.

The coefficient of land diversity (LDiv) is negative and significant at the $\alpha = 0.10$ level in Model 2. This suggests that farm in areas with greater levels of agricultural land use diversity (i.e. measured via Herfindahl index) and therefore more land application diversity are less profitable by 38 cents per acre, all else equal. LDiv is not the same as production diversity, for instance the LDiv variable includes uses such as land left fallow, wetlands, Christmas trees, pastureland, woodland, ect. This variable essentially measures land use compatibility or dissimilarity. It is possible that the negative coefficient reflects the growth challenges faced by farms in dealing with non-farmers when there is not a dominant land use in the community.

The coefficient of chemical dependence (CD_ac) measured as acres treated with (insecticides, herbicides, fungicides and other pesticides) per harvested acre, is negative and significant in Model 2. This is a major finding and an addition to the literature. Decreasing the amount of acres treated with chemicals implies greater environmental stewardship. The finding that chemical treatments decrease profitability suggests that increased stewardship would enhance the success of farms and implies that sustainability is possible as conceptualizes through the weak test of sustainability. Farmers can reduce chemical treatments and still enhance their economic viability. This issue is at the very heart of sustainability decisions in the US.

The insignificance of the coefficients for conservation acreage (ConA_ac) and total nutrient, residue, and pest management acres (NRCS_ac) supports the finding that, at the least, environmentally friendly farming does not detract from profitability. For instance, the coefficient for ConA_ac is not statistically significant, indicating that farmers pursuing environmentally friendly farming objectives are not adversely affected, economically. The conservation variable does not affect profitability significantly. Therefore, farmers can implement NRCS conservation practices without negatively affecting the success of their operation, which is often cited as a specific concern relating to voluntary conservation programs. This also indicates to policymakers that the USDA's NRCS Conservation Programs that increase environmental stewardship do not detract from short-term economic sustainability.

In short, while half of the environmental coefficients are insignificant, results indicate that E_i belongs in the equation. The short-term sustainability model is improved (adjusted R-squared increases) by the inclusion of environmental variables. Moreover, these environmental factors included at least do not detract from profitability, indicating that economic and environmental objectives are not at odds and therefore (somewhat) complimentary to one another.

5.3 Results of the Socially Augmented Model

To test the joint effect of the five social considerations, Model 3 was estimated by adding these five variables to the nine economic variables. The coefficients of three of the five social indicators are significant. The contribution of social factors is also confirmed given the increase in the adjusted R-squared value and the cumulative effect of social variables, which is positive. In fact, the adjusted R-squared increased to 0.5771 to 0.7467, indicating that social factors enhance the explanation of short-term sustainability. The specific findings are discussed next.

The coefficient of direct sales per acre (Direct_ac) is positive and significant at the $\alpha = 0.01$ level in both Models 3 and 4. Farms that sell their agricultural products directly to consumers are more profitable. In fact, for every extra dollar of Direct_ac, NFI_ac increases by $5.73 in Model 3 and $5.78 in Model 4, respectively. This is an extremely important finding, which suggests that roadside stands, farmers ' markets, and u-pick sites contribute significantly to short-term sustainability in agriculture.

Given the newly renewed Federal debate over migrant labor and border security, access to migrant labor, which is expected to relate to the success of farming, is becoming more challenging. A large number of seasonal farm workers are needed for planting, cultivating, harvesting and packaging the many labor-intensive crops in Michigan. Migrant Labor Housing Capacity (MLC) allows Michigan to secure about 23,000 seasonal workers (although other estimates suggest that there could be more like

100,000 seasonal workers). The coefficient of MLC is found to be insignificant, suggesting that the social services programs in place that help to secure an adequate labor supply neither enhance nor detract from short-term sustainability in Michigan.

The coefficient of population interaction index (PII) is negative and significant at the $\alpha = 0.01$ level in Model 3 & 4. PII measures the interactions between urban population and agriculture based on the potential interaction between nearby urban-related population and agricultural activities. Increased PII was expected to enhance profitability because farmers in close proximity to higher value retail opportunities (such as restaurants and specialty markets) face more opportunities to direct market and educate consumers (such as farmers markets and u-picks). The estimated negative effect may suggest that right to farm conflicts, competing land uses, rising land values, losses in agricultural support services, and farmers declining political clout cancel out the possible positive effects of proximity.

The coefficient of the summed contributions of the number of u-pick farms, on-farm markets or roadside stands, cider mills, pumpkin patches, Christmas Trees, CSA's, and wineries (wine) per harvested acre, labeled Fopps_ac, is significant at the $\alpha = 0.01$ level in Model 3 & 4. Farmers who offer on-farm agro-tourism opportunities may be making as much as $2.60 more per acre. One thing is for sure, direct market opportunities are related to the success of the farm sector and a major contributor to the social compatibility of agriculture within a community.

Project Fresh coupons' (Pfresh_ac) coefficient is not significant. This means that farms in counties with greater levels of WIC funding are no more or less viable. This may suggest that social programs meant to increase access to fresh fruits and vegetables for low-income residence do not detract from the success of the agricultural community.

Similar to the findings from the inclusion of environmental factors, the necessity of the inclusion of social sustainability factors in confirmed. The overall performance of the model, in comparison to the restricted model, is enhanced. This suggests that social compatibility is a significant contributor to the short-term sustainability of farms.

5.4 Results of the Fully Augmented Model

Model 4 combines the economic, environmental, and social determinants and allows the testing of the combined effects of all categories of sustainability objectives on NFI_ac. When estimated collectively, in Model 4, the adjusted R-Square increases further to 0.7373. This suggests that economic, environmental, and social factors when estimated in concert provide a better explanation of agricultures success in Michigan. Therefore, Model 4 provides a better overall estimate of short-term agro-economic sustainability than the three subsequent models.

Eight of the eighteen variables included in Model 4 are significant. Significant and positive coefficients include opEx_Ac, AKS_ac, SizeDiv, Direct_ac, and Fopps_ac. The negative and significant coefficients, which detract from viability include, OFI_ac, RAS_ac, and PII. Many of the implications resulting from the sign of these coefficients are discussed in the previous sections.

On the positive side the finding, the significance of AKS_ac has huge implications for farmers that rely on local support services in a time when agriculture and its many support industries are failing. Farms with greater access are more profitable, but as access dwindles so will viability. Dir_ac impact viability greatly, in Model 4 results suggests the Dir_ac enhance NFI_ac by over $5.

On the negative side, OFI_ac and PPI remain negative. This is not surprising. OFI_ac is negative and significant in all four models, suggesting that the pursuance of OFI_ac definitely attracts from the success of the farm sector. PII is remains significant and negative in Model 4, further showing that higher levels of PII detract from profitability. This has important implications for farmers at the urban fringe.

Overall, Model 4 suggests that the economic, environmental, and social sustainability concerns are related, compatible, and synergistic. It is therefore safe to purport that previously defined models, which have not included environmental and social aspects, are less appropriate and that future models should include such considerations. The results of the four models are further compared via F-test and those findings are highlighted in the next section.

5.5 Comparison of the Models via F-Tests & Predicted Values

As shown above, the inclusion of environmental and social factors of sustainability improves the adjusted R-Squared values. Furthermore, more of the environmental and social variables detract from viability. However, this thesis is more concerned with the collective effect of the environmental and social variables versus the individuals sign and significance of the eighteen coefficients. The F-test, which involves comparing the resulting R-square of the restricted model (standard viability model, Model 1) to the three unrestricted models (Models 2-4) using Equation 9 described in Chapter IV, is the tool for analyzing joint effects of the 4 environmental and 5 social variables and therefore specification efficacy. Table 2 below shows the results.

Table 2. Results of the Joint F-Tests

	R	UR1	UR2	UR3
	Model 1	Model 2	Model 3	Model 4
R-Squared	0.6235	0.6607	0.7899	0.795
q restrictions	0	4	5	9
N observations	83	83	83	83
K-1 parameters	9	13	14	18
N - K	73	69	68	64
$F_{q, N-K}$		1.89	10.77*	5.95*

*** F-Statistic is significant at the 1 percent level**

The restricted (R) Model 1 is compared to the unrestricted (UR 1-3) Models 2-4 via F-Test.

In Table 2, the reported F-Statistic tests the hypothesis that the model in question significantly enhances specification. In other words, when the F-Statistic is statistically significant, then the coefficients of the added variables (environmental, social, or both) belong in the equation and should therefore not be dropped.

The significance of the F-tests on the R^2 values in the UR Models 3 & 4 suggests that the coefficients of environmental and social variables in the later two of the UR Models are not jointly equal to zero. The F-test for Model 3 & 4, in comparison with the restricted model, are positive and significant at the $\alpha = 0.01$ level. This supports the hypotheses that the subsets of added coefficients in the augmented models specified herein are non-zero. However, the joint effect of the environmental variables alone is insignificant suggesting that the environmental variables alone do not sufficiently add value unless one includes the full slate of environmental and social variables.

Overall, a positive relationship exists between short-term sustainability and the groups of the environmental and social sustainability factors. Therefore, the Weak Test of Sustainability is passed, sustainability is possible, and synergies exist between the three objectives of sustainability: profitability, environmental stewardship, and social compatibility in agriculture. The results of the F-tests prove that joint effects of social and environmental factors are complementary to, rather than detrimental to the profitability of the agricultural economy.

The predicted values of Models 1-4 for each of Michigan's 83 counties are shown in Table A4 in Appendix 1. Each county can be compared via NFI_ac and the resulting fitted values of the Models estimated. Lake County fares the worst (losses of $60-90 per acre) when it comes to short-term sustainability while Oakland County fares the best (gains of $800-1100 per acre). In Allegan County, for instance, the predicted values for the four short-term sustainability models (with the exception of Model 1) increased in comparison to NFI_ac.

5.6 Summary

The empirical results of the four models specified in this thesis were highlighted in Chapter V. Results indicate that the fully augmented model is the best specification and that the environmental and social factors individually and collectively improve the specification of the Models. The results of the F-tests confirm that agriculture in Michigan passes the Weak Test of Sustainability. Hence, sustainability is possible, because holistically environmental and social factors do not detract from the viability of farms in a county. Conclusions and Recommendations are provided in Chapter VI.

Chapter VI: Conclusions & Recommendations

Agriculture is a key industry in the United States; it provides food, fiber, a conduit to the natural environment, income to farmers and farm-related businesses, and jobs to both urban and rural constituents. As shown in Chapter I, Michigan's agri-food system, the subject of this study, generates $70 billion in economic activity annually from farming and allied activities, provides 1.05 million jobs and has made $8.6 billion in capital investments over the past five years (Knudson and Peterson, 2009 and Peterson et.al., 2006). However, agriculture's success is not dependent solely on its economic performance. It is also intrinsically linked to the overall social and environmental climate within which it exists. Increasingly, the term sustainability is used to describe the modern optimization challenges of agriculture.

The concept of agricultural sustainability has been put forth as an alternative to conventional agriculture and it implies that three main objectives economic, environmental and social sustainability are compatible and synergistic. To date, little effort has been devoted to an analytical framework for evaluating this goal in agriculture. This thesis research advances the concept of short-term sustainability by estimating the effects of environmental and social sustainability factors on profitability measures in agriculture in Michigan. The Weak Test of Sustainability (WTS) used here is based on the notion that the inclusion of environmental and social variables enhances the specification of profitability models. This is an alternative to a Strong Test of Sustainability, based on an actual measure of sustainability, which is currently not possible due to data and definitional limitations.

The WTS involves comparing a standard viability model to three other augmented models using F-tests. Results suggest that the three augmented viability models specified herein improve the specification when compared to the standard viability model. In addition, the acceptance of hypothesis that relationship between economic viability and the subset of environmental and social sustainability is non-zero suggests that sustainability is (in a weak sense) possible and that synergies exist between the three components of sustainability.

Many of the determinants of economic, environmental, and social sustainability are found to be complementary to profitability, suggesting that short-term sustainability is a realistic goal for farmers. The factors shown to have a positive effect on NFI_ac include opEx_ac, AKS_ac, SizeDiv, Direct_ac, and Foops_ac. The factors shown to detract from NFI_ac include OFI_ac, RAS_ac, and PII. The sign of these latter factors supports the notion that if farms were sustainable in the first place they would not be working off farm, selling land or competing with alternative land use. Results suggest that future models would have greater efficacy if they account for such economic, environmental, and social sustainability factors.

Farmers are in the business of making money from agricultural production. The empirical findings from this thesis suggest that farmers can pursue the environmental and social objectives of sustainability while simultaneously enhancing (or at least not detracting from) their bottom line. The benefits associated with agriculture are much more than just economic and many synergies between the three aspects of sustainability exist. For instance, farmers that have access to key services and sell directly to consumers are more profitable. Farmers with a reliance on off farm income and greater population pressures are less profitable. Therefore, if farmers wish to maximize the short-term sustainability of farming, they must take a broader view of agriculture.

The positive and significant relationships between economic, environmental, and social aspects of agriculture shown here suggest that future studies should include such measures. The data and analytical systems currently used for assessing agriculture in the US focus on economic variables. It is recommended that greater emphasis be placed on documenting environmental and social variables that quantify agriculture for the rest of society. As shown in this thesis we can no longer rely on corner solutions in agriculture, where the focus is on just one aspect of agricultural viability. Therefore, assessing economic, environmental, and social sustainability objectives simultaneously is important.

Given that the information collected and tested in this thesis is for a single year, results are indicative of short-term viability. Dynamic efficiency, as it relates to intergenerational transfer and long-term viability and sustainability, was ignored. It is recommended that future studies attempt to include time series data. One possible way to do this is through the creation of a comprehensive (20 year) database of viability variables. Due to the lack of data that is packaged correctly and readily available, this type of analysis was not possible.

Information about land tenure and longevity, farm production opportunities and the business climate, farmland preservation and zoning, eco and agro-tourism, the current regulatory framework, animal damage, right to farm issues, communication and computer use, agency support and informational services, training programs, farm management and farmers' attitudes are all necessary viability data components that are not currently collected. These types of questions should be added to current survey tools, such as Census of Agriculture, which are consistently updated. It is recommended that state-level monetary support be made available for such attempts.

Another recommendation following from this research is the potential of a simultaneous cash flow equation model and its ability to explain further the many interactions in agricultural viability. Previous research findings from Adelaja and Rose (1988) suggest that a simultaneous cash flow equation (SECF) may further explain some of the interactions and correlations within the three factions of sustainability. The SECF model allows for further quantification of the effect of causal variables on viability, in terms of cash flow (Adelaja and Rose, 1988).

Lacking a clear measure of sustainability makes the concept difficult to implement in the real world; therefore, policies aimed at sustainable agriculture are limited. One recommendation is that a clear definition of sustainability be adopted for Michigan agriculture. It makes sense that sustainability is a broader concept than farm profitability and that many studies to date have been focused on defining the concept of sustainability, generating priorities, strategies and indicators and obtaining buy-in from policy makers and society (Allen, 1993). To date, the academic, environmental and policy circles interested in sustainability have been unsuccessful in generating adequate measures of environmental stewardship or social equity, which clearly limits our analysis of sustainability. It is recommended that we put these limitations behind us and move forward. Given the findings from this thesis, the need to create a statewide sustainability measurement initiative has never been more necessary. A round table may be one way to do this.

Appendix I: Tables

Table A1. Definitions of the Independent Variables and Sources

Variable Name	Definition of the Variable and Calculation	Source	Impact on NFI_ac	Mean	Standard Deviation
Economic Variables					
NFI_ac (dependent variable)	Net Farm Income of Operations: total sales, government payments, and other farm income, minus farm-related expenses, divided by harvested acres ($/ac)	Census of Agriculture, 2002		$119.45	$153.91
OFI_ac	Off farm income per harvested acre ($)	BEA Table CA45, 2000	–	$19.21	$18.41
Equip_as	Estimated market value of equipment assets divided by harvested acre ($/ac)	Census of Agriculture, 2002	+	$674.88	$392.24
RAS_ac	Potential revenue from asset sales = avg. easement value times the absolute change in acreage from 1997 to 2002 divided by harvested acres ($/ac)	Adelaja et.al, 2006; Census of Agriculture, 2002	+	$780.69	$2,301.44
opEx_ac	Operating expenses per acre is the sum of all farm-related expenses: custom work, fuel costs, livestock, rent paid, chemicals, fertilizer and soil conditioners, property taxes, utilities, seeds, and hired farm labor per harvested acre	Census of Agriculture, 2002	-	513.1692	344.6256

Table A1 (con't)

AKS_ac	Access to Key Services including licensed nursery, grain, pesticide application businesses and wholesale potato dealers per harvested acre (number)	MDA, 2006; Wine Country Magazine, 2006; localharvest.org, 2006	+	0.003597	0.0116833
SizeDiv	Simpson index for farm size diversity based on the size categories (n: 1-9 ac, 10-49 ac, 50-179ac, 180-499, 500-999, over 1000) and the total number of farms N, where the SizeDiv coefficient = 1 - D and D = SUM (n(n-1)/ (N(N-1); 0 = no diversity, 1 = maximum diversity (number)	Census of Agriculture, 2002	+	0.709043	0.0418059
EXT_ac	Number of MSU Extension Educators per harvested acre (number)	MSUE, 2006	+	0.001513	0.0079235
avg_age	Average age of farmers	Census of Agriculture, 2002	+	54.25	1.62
Farm25_34	Farmers age 25 to 34	Census of Agriculture, 2002	+	30.44578	27.50887

Table A1 (con't)	Environmental Variables				
LDiv	Land Diversity is measured by a Herfindahl index for land share by use = the sum of the squared land share of each land use: pastureland, cropland, idle, failed, summer fallow, woodland, rangeland, houses, CWRP, organic, enrolled in federal programs, vegetables, orchards (number)	Census of Agriculture, 2002	+	69.85807	70.92836
CD_ac	Total acres treated with chemical fertilizers, lime, soil conditioners per harvested acre (percentage)	Census of Agriculture, 2002	-	63.09	25.11
ConA_ac	Conservation acres per harvested acre = sum of Organic, manured, CRWP, acres divided by harvested acres (percentage)	Census of Agriculture, 2002	+	194.68	234.46
NRCS_ac	Total number of NRCS Residue, Pest, Nutrient Management acres per harvested acre (percentage)	USDA-NRCS PRMS Database, 2002	+	6.48	6.85

Table A1 (con't)	Social Variables				
Direct_ac	Sales made directly to consumers per acre (number)	Census of Agriculture, 2002	+	8.449659	10.93118
MLC	Migrant Labor Housing Capacity: total number of beds in certified migrant labor sites(number)	MDA, 2006	+	272.40	450134.58
PII	Population Interaction Index: Cardinal measure of the potential interaction between nearby population and agricultural production activities (number)	USDA-ERS, 2000	-	225.3	225.3
Foops	Farm Agro-Tourism and Recreation Opportunities: sum of farmers market, u-pick operations, on-farm markets, cider mills, pumpkin patches, Christmas tree, wineries, and CSA's (number)	MDA, 2006, Wine Country Magazine, 2006, localharvest.org, 2006	+	10.49398	15.08866
PFresh_ac	Project fresh coupons spent at farmers' markets per harvested acre ($)	MI Dept. of Community Health, MSU Viki Lorraine, 2006	+	$0.82	$3.82

Table A2. Parameter Estimates for Short-term Sustainability on Michigan Farms: Models 1-4

	Variable	Model 1		Model 2		Model 3		Model 4	
α_0	NFI_ac (Constant)	-1194.8	*	-1180.9	*	-795.45	*	-862.67	**
α_1	OFI_ac	-1.4499	**	-1.5501	**	-1.4255	*	-1.4092	**
α_2	Equip_ac	0.15375	**	0.19065	*	-0.0554		-0.0437	
α_3	RAS_ac	-0.0355	**	-0.0478	*	-0.0264	**	-0.0265	**
α_4	opEx_ac	0.22459	*	0.22996	*	0.24797	*	0.24188	*
α_5	AKS_ac	5791.3	*	6650.93	*	12627	*	12191.5	*
α_6	SizeDiv	786.056	**	972.84	*	580.419	**	690.757	*
α_7	EXT_ac	-273.13		689.439		1811.5		2119.97	
α_8	avg_age	10.8209		9.05955		7.53123		7.23237	
α_9	Farm25_34	-0.4579		0.60512		0.18286		0.37159	
β_1	LDiv			-0.3828	***			-0.1863	
β_2	CD_ac			-1.2064	***			-0.0108	
β_3	ConA_ac			0.03101				0.02032	
β_4	NRCS_ac			-1.0926				0.01466	
γ_1	Direct_ac					5.73626	*	5.78856	*
γ_2	MLC					-0.0165		-0.0194	
γ_3	PPI					-0.3252	*	-0.3062	*
γ_4	Fopps					2.60775	*	2.75289	*
γ_5	PFresh_ac					1.35487		1.10644	
	R-Squared	0.6235		0.6607		0.7899		0.795	
	Adjusted R-Squared	0.5771		0.5968		0.7467		0.7373	
	*=Significant at the α=0.01 level, ** significant at the α= 0.05 level; *** significant at the α=0.10 level								

Table A3. Correlation Coefficient Matrix

	NFI_ac	OFI_ac	Equip_ac	RAS_ac	opEx_ac	AKS_ac	SizeDiv	EXT_ac	avg_age	Farm2~34	LDiv
NFI_ac	1										
OFI_ac	-0.0127	1									
Equip_ac	0.347	0.1295	1								
RAS_ac	0.1861	-0.1475	0.8406	1							
opEx_ac	0.6454	0.1253	0.5935	0.4462	1						
AKS_ac	0.6328	-0.0615	0.4942	0.4892	0.6214	1					
SizeDiv	-0.1303	-0.109	-0.4927	-0.4369	-0.4087	-0.3859	1				
EXT_ac	-0.0174	-0.1214	0.6753	0.8249	0.2937	0.1665	-0.4711	1			
avg_age	0.0585	-0.0606	-0.0055	0.0573	-0.0856	0.0619	-0.1344	0.1167	1		
Farm25_34	-0.0287	-0.2954	-0.2891	-0.2583	0.0408	-0.1691	0.218	-0.189	-0.1529	1	
LDiv	-0.0877	-0.2493	-0.1043	-0.0683	0.0141	-0.0222	0.2248	-0.0494	-0.0926	0.5927	1
CD_ac	0.0705	-0.0542	-0.2962	-0.434	0.1439	-0.0529	0.192	-0.3859	-0.1693	0.6687	0.397
ConA_ac	-0.1444	-0.1841	-0.3048	-0.2146	-0.1969	-0.1899	0.0451	-0.1396	0.0222	0.3922	0.0587
NRCS_ac	-0.1836	0.0874	-0.1432	-0.2086	-0.2513	-0.1933	0.0272	-0.142	-0.1089	-0.2001	-0.2197
Direct_ac	0.6767	0.117	0.5038	0.2992	0.5406	0.7188	-0.2748	0.0232	-0.0451	-0.2326	-0.0409
MLC	0.2184	0.2491	0.0707	-0.0883	0.3814	-0.0754	-0.049	-0.0693	0.018	0.2027	0.0397
PII	0.4485	-0.1233	0.1882	0.1849	0.5525	0.8166	-0.2732	-0.054	0.0163	0.1081	0.2237
Fopps	0.3654	0.0643	0.0784	-0.0821	0.4162	0.1557	-0.1399	-0.1038	0.1243	0.3127	0.2288
PFresh_ac	0.0634	-0.107	0.2134	0.2219	0.0447	0.0763	0.0441	0.0806	-0.1167	0.1229	0.0961

	CD_ac	ConA_ac	NRCS_ac	Direct~c	MLC	PII	Fopps	PFresh~c
CD_ac	1							
ConA_ac	0.3532	1						
NRCS_ac	-0.0727	0.1148	1					
Direct_ac	-0.0303	-0.2965	-0.1903	1				
MLC	0.3117	-0.0369	-0.0809	0.1066	1			
PII	0.3103	-0.1032	-0.2234	0.6186	0.0523	1		
Fopps	0.4501	-0.0934	-0.198	0.3347	0.6988	0.4088	1	
PFresh_ac	-0.0318	0.0214	-0.0982	0.1172	-0.0569	0.0473	0.0452	1

Table A4. NFI_ac and Predicted Values for each County in Models 1-4

County	NFI_ac	Model 1	Model 2	Model 3	Model 4
Alcona	$ 134.99	$ 87.48	$ 108.23	$ 67.92	$ 65.49
Alger	$ 63.12	$ (7.77)	$ (3.57)	$ 137.61	$ 137.93
Allegan	$ 243.04	$ 211.89	$ 261.31	$ 308.21	$ 313.34
Alpena	$ 88.62	$ 35.66	$ 39.00	$ 65.64	$ 59.35
Antrim	$ 142.22	$ 201.51	$ 176.13	$ 298.54	$ 298.60
Arenac	$ 132.67	$ 86.49	$ 57.72	$ 64.76	$ 73.40
Baraga	$ 66.67	$ 74.35	$ 107.21	$ 84.81	$ 82.69
Barry	$ 15.00	$ 102.76	$ 102.01	$ 70.74	$ 83.17
Bay	$ 80.30	$ 108.10	$ 85.32	$ 59.89	$ 55.51
Benzie	$ 19.43	$ 177.98	$ 182.90	$ 36.79	$ 42.10
Berrien	$ 143.56	$ 158.38	$ 154.79	$ 289.65	$ 292.49
Branch	$ 13.78	$ 81.19	$ 100.54	$ 71.67	$ 76.08
Calhoun	$ 64.78	$ 50.53	$ 40.61	$ 42.81	$ 40.59
Cass	$ 70.72	$ 112.90	$ 105.13	$ 64.42	$ 69.77
Charlevoix	$ (6.18)	$ 126.38	$ 139.98	$ 141.25	$ 140.24
Cheboygan	$ 86.49	$ 131.70	$ 171.62	$ 106.22	$ 108.43
Chippewa	$ 42.00	$ 20.47	$ 77.38	$ 50.83	$ 50.71
Clare	$ 43.73	$ 55.13	$ 92.38	$ 58.41	$ 61.84
Clinton	$ 118.83	$ 92.24	$ 66.20	$ 79.56	$ 73.70
Crawford	$ 341.65	$ 276.06	$ 295.91	$ 333.85	$ 335.44
Delta	$ 57.81	$ 104.68	$ 113.56	$ 185.44	$ 185.46
Dickinson	$ 71.82	$ 119.88	$ 82.75	$ 96.25	$ 97.26
Eaton	$ 68.56	$ 34.45	$ 66.12	$ 37.30	$ 48.35
Emmet	$ 80.43	$ 95.67	$ 103.38	$ 137.29	$ 135.33

Table A4 (con't)

Genesee	$ (22.93)	$ 45.51	$ (3.06)	$ (35.67)	$ (34.70)
Gladwin	$ 51.72	$ 15.71	$ 38.55	$ 49.17	$ 63.53
Gogebic	$ (421.47)	$ 1.94	$ 25.22	$ 53.89	$ 39.03
Grand Traverse	$ (115.42)	$ 143.41	$ 150.26	$ 192.93	$ 196.10
Gratiot	$ 105.22	$ 57.25	$ 80.29	$ 75.43	$ 80.05
Hillsdale	$ 79.94	$ 47.38	$ 83.68	$ 95.20	$ 119.76
Houghton	$ 81.96	$ 88.35	$ 117.59	$ 108.80	$ 109.84
Huron	$ 123.07	$ 126.77	$ 143.98	$ 146.20	$ 148.27
Ingham	$ 77.08	$ 92.53	$ 39.70	$ 27.64	$ 19.37
Ionia	$ 171.56	$ 102.39	$ 114.91	$ 76.69	$ 82.53
Iosco	$ 112.13	$ 139.32	$ 139.33	$ 137.75	$ 145.35
Iron	$ 85.25	$ 75.07	$ 54.21	$ 47.70	$ 47.51
Isabella	$ 74.91	$ 55.30	$ 43.14	$ 70.43	$ 70.72
Jackson	$ 42.15	$ 65.11	$ 48.38	$ 57.56	$ 58.59
Kalamazoo	$ 233.88	$ 267.61	$ 255.38	$ 203.02	$ 197.77
Kalkaska	$ 55.91	$ 140.64	$ 148.51	$ 141.28	$ 136.78
Kent	$ 353.87	$ 243.65	$ 242.23	$ 259.51	$ 270.59
Keweenaw	$ (918.60)	$ 30.17	$ 20.88	$ 1.88	$ 2.74
Lake	$ 30.88	$ (83.64)	$ (63.20)	$ (90.58)	$ (84.07)
Lapeer	$ 29.86	$ 85.06	$ 78.94	$ 87.71	$ 87.22
Leelanau	$ (43.49)	$ 147.63	$ 113.32	$ 114.45	$ 118.41
Lenawee	$ 48.82	$ 86.29	$ 107.70	$ 69.76	$ 84.03
Livingston	$ 2.13	$ 116.77	$ 57.60	$ (15.38)	$ (21.51)
Luce	$ 254.41	$ 153.94	$ 171.46	$ 156.04	$ 160.40
Mackinac	$ 58.06	$ 77.13	$ 97.77	$ 92.05	$ 84.48

Table A4 (con't)

Macomb	$ 223.15	$ 250.35	$ 211.98	$ 139.45	$ 148.79
Manistee	$ 113.46	$ 51.22	$ 39.39	$ 18.06	$ 14.59
Marquette	$ (1.58)	$ 160.70	$ 192.93	$ 119.17	$ 117.63
Mason	$ 17.54	$ 150.89	$ 107.10	$ 159.16	$ 151.54
Mecosta	$ 94.00	$ 51.84	$ 85.12	$ 82.72	$ 85.94
Menominee	$ 123.16	$ 53.61	$ 52.22	$ 81.87	$ 78.75
Midland	$ 91.28	$ 99.43	$ 80.93	$ 32.98	$ 41.32
Missaukee	$ 130.42	$ 139.99	$ 147.00	$ 128.43	$ 124.75
Monroe	$ 67.62	$ 94.64	$ 48.64	$ 17.20	$ 6.33
Montcalm	$ 152.72	$ 126.11	$ 143.77	$ 102.62	$ 106.36
Montmorency	$ 128.24	$ 6.51	$ (23.68)	$ 11.98	$ 5.83
Muskegon	$ 167.03	$ 237.23	$ 236.98	$ 164.15	$ 159.41
Newago	$ 181.53	$ 116.84	$ 121.14	$ 104.94	$ 103.32
Oakland	$ 1,277.17	$ 822.85	$ 870.26	$ 1,066.26	$ 1,067.43
Oceana	$ 132.80	$ 119.47	$ 120.69	$ 140.78	$ 136.47
Ogemaw	$ 113.48	$ 179.75	$ 179.96	$ 151.85	$ 148.93
Ontonagon	$ 25.29	$ 60.16	$ 80.07	$ 74.08	$ 66.71
Osceola	$ 117.43	$ 83.06	$ 96.71	$ 64.63	$ 65.34
Oscoda	$ 121.69	$ 23.36	$ 27.51	$ 88.84	$ 89.11
Otsego	$ 129.46	$ 159.19	$ 173.84	$ 104.95	$ 109.67
Ottawa	$ 467.84	$ 420.09	$ 434.13	$ 412.57	$ 409.00
Presque Isle	$ 116.27	$ 57.35	$ 44.46	$ 56.65	$ 55.59
Roscommon	$ 267.31	$ 66.43	$ 65.00	$ 197.15	$ 192.69
Saginaw	$ 97.27	$ 51.93	$ 65.26	$ 103.72	$ 102.08
Sanilac	$ 116.14	$ 99.75	$ (45.63)	$ 103.86	$ 23.63

Table A4 (con't)

Schoolcraft	$ 131.55	$ 126.09	$ 108.73	$ 87.00	$ 97.89
Shiwassee	$ 36.29	$ 80.54	$ 96.46	$ 108.52	$ 118.85
St. Clair	$ 8.35	$ 42.58	$ 56.08	$ 69.29	$ 75.14
St. Joseph	$ 117.45	$ 78.32	$ 101.51	$ 9.78	$ 14.55
Tuscola	$ 40.05	$ 67.42	$ 77.38	$ 91.58	$ 95.54
Van Buren	$ 247.66	$ 159.88	$ 132.41	$ 185.52	$ 179.69
Washtenaw	$ 44.22	$ 141.77	$ 103.22	$ 135.18	$ 136.28
Wayne	$ 233.37	$ 636.41	$ 603.43	$ 420.58	$ 418.92
Wexford	$ 130.60	$ 39.31	$ 46.10	$ 65.62	$ 56.31

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