DISSERTATION

SPATIAL DIMENSIONS OF NATURAL RESOURCE DECISIONS: PRIVATE RESPONSES TO PUBLIC RESOURCE DECISIONS

Submitted By

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ABSTRACT

SPATIAL DIMENTIONS OF NATURAL RESOURCE DECISIONS: PRIVATE RESPONSES TO PUBLIC RESOURCE DECISIONS

This dissertation illustrates how the use of spatial economics, as opposed to non-spatial methods, can enrich economic research related to natural resources decision-making. This research encompasses three distinct, but complementary, papers, based on two datasets that vary in richness and scale, and one data-driven model that will detail how data will need to be collected to inform natural resource infrastructure projects in a developing economy. The first essay uses cutting-edge spatial econometric techniques to evaluate the location decisions of private outdoor recreation providers. Here, I find clustering of outdoor recreation opportunities and that private providers are attracted to areas with existing public outdoor recreation opportunities when making their own location decisions.

The second essay focuses on a specific form of privately provided outdoor recreation, agritourism, and again finds that the more existing outdoor recreation, the more agritourism trips will be taken. The second essay uses a hurdle travel cost model and focuses on the demanders, as opposed to the suppliers, of private outdoor recreation. The findings reveal that agritourists gain substantial consumer surplus (with averages ranging from $93 to $465) from their trip, and that the model treatment of multi-destination agritourists impacts the estimated consumer surplus. The first two papers use author-created outdoor recreation measures that are introduced in this dissertation. These measures were created to complement the USDA-Economic Research Service Natural Amenities Index, with input from the creators of the Natural Amenities Index,

and have potential to be used in many natural resource and economic development studies as the Natural Amenities Index has been.

In contrast to the other essays, the third essay recognizes that spatial relationships can be important in evaluating an economic question, even when dense spatial datasets are not available. The study uses an Equilibrium Displacement Model to evaluate water management and storage policies for a canal system in Afghanistan, a country where war and poverty have damaged infrastructure and made it difficult to collect accurate data. Producers' spatial location on the canal is of key importance to understanding their decisions and the failure to account for these spatial relationships could lead to misinformed policy decisions. The Equilibrium Displacement Model results show that water management and storage policies have different impacts on producers based on their spatial location on the canal. Through the use of three very different models, this dissertation illustrates the importance of incorporating spatial impacts when evaluating policies related to natural resources.

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CHAPTER ONE: INTRODUCTION

Spatial Economics

In the past 10 years, there has been an increased focus on the spatial aspects of economics, the study of where economic activity occurs and why. Space matters in economic decision making because spatially distributed economic agents are not independent of one another; consequently, ignoring these relationships can lead to incomplete conclusions. This increased interest in spatial economics stems at least in part from the increased availability of spatial data, with remotely-sensed data from aerial photography, satellite imagery, and parcel-level data. One set of economic questions that are particularly well suited to the integration of spatial factors relates to place-based economic development (Kline and Moretti, 2012; Deller, 2009). Because that vein of economic development literature demonstrates that there are unique aspects that may give places sustainable comparative advantages in the marketplace, more thorough consideration of spatial factors would improve the effectiveness of empirical research in that realm. One area that has received increasing interest and attention over the past couple of decades is the management of natural resources and amenity-rich locales (Marcouiller and Clendenning, 2005). Of particular interest to that vein of literature are the complementary or competing tensions between the goals of private and public stakeholders.

This dissertation will use three different papers to illustrate how incorporating space into the analysis can be beneficial with regards to private and public decision-making. The three papers will utilize three datasets that vary in richness and scale. One paper will look at the entire United States; one will look at regions in Colorado; while another will focus on a localized scale of a single canal system. The three datasets also differ in richness. The dataset for essay one contains information about the management designation on over 500,000 spatially-explicit observations of land parcels. Essay two uses a detailed survey of agritourists; while there are fewer observations, there is greater individualized detail on each observation. Essay three looks at an area where poverty and conflict make it very difficult to collect complete and reliable data, so that the development of a general characterization of place-based decisions is necessary.

Framing the Empirical Research

Benefits of outdoor recreation opportunities have been acknowledged by both researchers and policy makers. While much attention has been focused on the positive benefits of access to the outdoors, little research has focused on the distribution of outdoor recreation land. Essay one, *"Does Existing Public Outdoor Recreation Land Repel Private Outdoor Recreation Provision? A Spatial Econometric Analysis,"* applies a cutting edge GIS-based econometric technique, the spatial probit, to explore the location decisions of private outdoor recreation providers at a national level. Demand for outdoor recreation is increasing while government provision for outdoor recreation opportunities are remaining constant, thereby creating a gap between government supply (the dominant source for such lands in earlier development phases) and demand from the public. This gap is increasingly being filled by private outdoor recreation opportunities. To better understand the behavior of private outdoor recreation entities in newly emerging economic development schemes that are more natural resource-based, this first dissertation essay uses an author-created index of outdoor recreation access.

While essay one explores the supply side of outdoor recreation, essay two, *"An Analysis of Consumer Surplus from Colorado Agritourism: Utilizing a Multi-Destination Travel Cost*

Model of Demand by Region for Colorado Agritourism," looks at the demand for one particular form of outdoor recreation enterprise, agritourism. Farm-based recreation, or agritourism, is a growing economic sector in the U.S., raising new interest in terms of the potential benefits for consumers/travelers and communities. Moreover, it provides an interesting extension of the first paper, since it is an example of how private and public recreation may be driving specific travel plans and consumer welfare from access to recreation. To this end, the second essay utilizes a hurdle travel cost model to investigate demand for and economic benefits of agritourism, including estimating consumer surplus as one means to estimate the market size for this sector. The standard travel cost model is designed under the assumption of a single-purpose recreational trip; but, as is the case with a number of categories of tourism, this assumption may not hold for all agritourism outings because travelers often visit other destinations. This paper analyzes and compares four different models, each using different methods to distinguish between multiple-destination and primary-purpose trips. The findings reveal that the treatment of multi-destination travelers has a significant impact on the calculated consumer surplus. In addition, the study finds that the more outdoor recreation available (as measured using the measure created in essay one) the more agritourism trips are taken to an area. Implications for accurately estimating the market size of agritourism, as well as a broader set of recreational sectors, are discussed.

Finally, essay three, *"Efficiency Impacts of Water Conservation and Storage Policies: A Spatially Dependent Equilibrium Displacement Model of the Balkh Watershed, Afghanistan,"* utilizes mainly secondary data to estimate impacts to agricultural producers from the implementation of water storage and conservation techniques. By examining a micro-level set of decisions on resource management, this essay complements the other chapters by showing how the spatial dimensions (location on canal) will impact economic choices and outcomes for producers. This paper focuses on a small canal in the Balkh province in northern Afghanistan. In this province, the majority of the rain falls in the winter, while the majority of the demand is in the summer. This study looks at the producers' differences based on their spatial location on the canal. The allocation system results in a shortage of water in the tail during the summer months, which can be seen in the crop choices made in the tail. This third paper will use an equilibrium displacement model (EDM) to look at the impacts of water storage and conservation techniques on the different stretches of the canal.

CHAPTER TWO

Essay One: "Does Existing Public Outdoor Recreation Land Repel Private Outdoor Recreation Provision? A Spatial Econometric Analysis"

Introduction/Literature Review

It is difficult for public agents providing outdoor recreation opportunities or making decisions about the location of such enterprises to make optimal site location choices when supplying outdoor recreation opportunities without knowing how changes in outdoor recreation provision would influence the location decisions of private outdoor recreation providers. Although there has been a push for increasing private provision of outdoor recreation opportunities (Anderson and Leal, 1988), little is known about how existing public outdoor recreation sites impact private entity site selection. The joint (or competing) provisions of such enterprises may have implications for the competitiveness of private providers as well as the broader economic development implications of recreation within a community (Outdoor Industry Association, 2012).

To analyze this gap in the research I look at county level spatial data on public and private outdoor recreation provision, exploring the relationship between public and private outdoor recreation site location. Specifically, the research question of interest can be framed as, "is private provision of outdoor recreation opportunities attracted to or repelled by public provision?" Because of the relationship between outdoor recreation and rural and economic development the results on agent location decisions are likely to have broader impacts for rural and economic development. I extend the existing conservation site selection literature (Albers, Ando and Chen, 2008) by analyzing the unique characteristics or site factors that would be appropriate for outdoor recreation, drawing from a national database of land designations and using a linear spatial econometric model as well as a spatial probit model to analyze the spatially-interdependent relationships. This research finds that there is clustering of both public and private outdoor recreation provision.

Benefits of Outdoor Recreation

Understanding the spatial location decisions of public and private outdoor recreation providers can be important to economic development. Outdoor recreation is a significant driver of the U.S economy and outdoor recreation expenditures grew 5% a year in the recession years of 2005 to 2011 (Outdoor Industry Association, 2012). Americans spent $646 billion on outdoor recreation last year, and outdoor recreation directly created 6.1 million U.S based jobs (Outdoor Industry Association, 2012). Beyond recreational sites, studies have found positive and significant economic values of more broadly defined open space (McConnell and Walls, 2005; Bolitzer and Netusil, 2000; Shultz and King, 2001; Riddel, 2001) and connections between natural areas and rural growth (McGranahan et al., 2010). The relationship between outdoor recreation and economic development, illustrates the importance of understanding the behavior of outdoor recreation agents to policy makers.

In addition, outdoor recreation provision provides many health benefits, which have been acknowledged by researchers and policy makers alike. Researchers have shown a link between access to the outdoors and positive health outcomes such as lower obesity rates, lower heart rates and faster stress recovery (Lauman et al., 2003; Hartig et al., 2003; Wells and Evans, 2003; Mitchell and Popham, 2008; Ellaway et al., 2005). In July of 2010, Secretary of Agriculture

Tom Vilsack highlighted the importance of privately provided outdoor recreation with the announcement of a new effort to encourage owners of privately held farms and ranches to provide public recreational access to their lands (Carter, 2010).

Distribution of Outdoor Recreation Land

While much attention has been focused on the positive benefits of outdoor recreation provision, little research has focused on outdoor recreation location decisions. What research has been done on the distribution of outdoor recreation provision has looked at the socioeconomic equity of that distribution. These studies find that socioeconomic groups and demographic factors play a role in the spatial distribution of outdoor recreation areas (Tarrant and Cordell, 1999; Porter and Tarrant, 2001; Chung et al., 2005). Specifically the studies mentioned above indicated that lower income households are more likely to be located near outdoor recreation than higher income households. Another study looking at distribution of sites across places finds that nature reserves are most frequently found at high elevations and on less productive soils (Scott et al., 2001), a finding that may have implications for the complementary essay on agritourism that follows this essay. The current research will expand upon the existing outdoor recreation distribution literature by exploring how outdoor recreation agents make location decisions, with a particular focus on public versus privately designated sites.

Understanding and managing outdoor recreation location decisions in the U.S can be a challenge as outdoor recreation is owned and managed by a variety of different public (at local, state and federal levels) and private agents. While complex, understanding outdoor recreation agents' location decisions is becoming increasingly important as demand for outdoor recreation is increasing but government provision for outdoor recreation opportunities are remaining constant, creating a gap between government supply and the demand from the public. The increasing demand for outdoor recreation is increasingly cited as a reason for over-crowding in our local, state and national parks (BLM, 2000). This gap in outdoor recreation demand is increasingly being filled by private landowners who create opportunities for public outdoor recreation on their land as they see the opportunities to attract visitors and monies that are seeking alternatives to more congested public recreation options. In addition, some critics have argued that agencies responsible for U.S public lands have not encouraged private investment in recreation development sufficiently to address this growing public demand and overcrowding of public outdoor recreation opportunities (Quinn, 2002). These issues are particularly relevant for economic development professionals who seek options for less developed rural areas of the US. Through the use of two outdoor recreation indices, the first reflecting government outdoor recreation land ownership and the other private outdoor recreation land ownership, this research is able to look at the relationship between government and private outdoor recreation location decisions.

Public and Private Interactions

There is a well-established literature on the impact of government provision of public goods on the quantity of private provision. This literature focuses on the potential for "crowding-out" or "seeding in" of private provision by public provision. The general definition of crowding-out is that government spending pushes out private investment by producing disincentive effects. One study (Jimenez and Sawada, 2001) explores whether increased provision of public education crowds out private provision of education. The researchers argue that if there is an existing and active private sector providing education, then an increase in the public provision of education may take students who would have enrolled in private education had public options not been available. They find that the large expansion in the public secondary education sector is negatively associated with private secondary enrollment, but the crowd-out effect is insignificant at the primary and tertiary levels of education. In contrast, a group of researchers in Scotland analyzed the overall impact of public spending on a country's economic performance, finding no clear evidence that countries with high levels of public spending have poorer economic performance than those with lower levels (Cumbers and Birch, 2006).

Much of the crowding out literature, including the literature summarized in the previous paragraph, focuses on traditional public goods where spatial elements of goods provision are not important; yet, one area of research that looks at a public good where spatial patterns do matter is the area of conservation. The clustering of conservation lands can create different ecosystem benefits and promote biodiversity (ReVelle et al., 2002; Albers, 1996; Swallow et al., 1990), because of the role of spatial location plays in conservation public conservation reserves may influence the location of private conservation decisions. Parker and Thurman (2004) analyze panel data of county-level conservation acreage, and find evidence that increased government conservation in a county tends to crowd-out private conservation in that same county (Parker and Thurman, 2004). Albers et al. (2008) complement the Parker and Thurman study by exploring the empirical relationship between public and private conservation, with an emphasis on the spatial pattern of conservation. The authors test whether government conservation appears to stimulate (attract) or stifle (repel) nearby private conservation, finding mixed results of attraction and repulsion depending on the state.

The current dissertation research hypothesizes that, like conservation land, spatial location of public outdoor recreation agents may influence the location decision of private outdoor recreation agents. Private providers may be attracted to existing outdoor recreation land, as more outdoor recreation in an area may allow more investments in supporting infrastructure (developed road access, travel services) or unique recreation experiences that come with a critical mass of recreation lands (wildlife population, viewscapes). In contrast, private providers may be repelled by existing outdoor recreation and the competitive pressure of gaining recreators' business, and instead perceive that they will gain more by locating in areas where recreationists do not have as many other options.

In summary, this research will build from the methodology of Albers et al. (2008) to look at the spatial distribution of outdoor recreation provision location decisions. While, the conservation or public management of land is sometimes thought of as a barrier to economic development (Power, 1996), in contrast, the investments that support outdoor recreation have been shown to have positive impacts on economic and rural development. This impact on economic development, as well as quality of life impacts, motivates this research's aim to improve the understanding of dynamics surrounding outdoor recreation agents. This research will be of key importance to policy makers as they frame future land use planning, target investments that may leverage existing and new recreational enterprises, and inform key players in the travel and leisure sectors.

Methodology

Theoretical Model

Below I outline the simple theoretical model from Albers et al. (2008) with a new application to outdoor recreation, to motivate the hypothesis that private agents are either attracted to or repelled by existing public outdoor recreation. This simple theoretical model will lead to hypotheses about the spatial distribution of outdoor recreation land provision. In this analysis, outdoor recreation provision refers to land that is accessible to the public for outdoor recreation purposes. I will then identify empirical approaches to test the stated hypotheses. First, suppose there are two different types of outdoor recreation providers: government agents and private agents. Each of these providers chooses where to supply outdoor recreation, square miles supplied by the government are denoted with a G, and square miles provided by private entities are denoted with a P.

To frame the research, I make a few assumptions: each parcel costs the agent the same and that the government has already chosen how much area to protect and where; and, the government outdoor recreation is fixed and unchanging (which is realistic as the government made location decisions for outdoor recreation opportunities, such as national parks, many years ago). To support the latter assumptions, there have only been two U.S national park additions since 2000 (nationalparks.org, accessed October 2012). To begin to illustrate this let G_i equal the number of square miles of outdoor recreation provision by the government in area i and G equal the total square miles of outdoor recreation provision by the government over all i:

$$(2.1) \qquad \sum_{i=1}^{N} G_i = G$$

Next, the private outdoor recreation agent decides where to allocate the fixed amount of outdoor recreation square miles, given the known government outdoor recreation locations. Let P_i equal the number of square miles of outdoor recreation provision by the private entity in area i and P equal the total square miles of outdoor recreation provision by the private entity over all i, such that:

$$(2.2) \qquad \sum_{i=1}^{N} P_i = P$$

Assuming that private agents can benefit at least somewhat from all square miles (public or private) that are in outdoor recreation, the total benefits to the private agent is as follows:

$$(2.3) \quad B_P = \sum_{i=1}^{N} (\lambda_P P_i + \lambda_G G_i)^{\propto}$$

Where:

B_P= the total benefits to the private agent

λ_P, λ_G and α are exogenous parameters which impact the marginal benefit and substitutability of government and private outdoor recreation provision

Assuming that $\lambda_G > 0$, $\alpha > 1$ indicates that there are increasing marginal benefits of outdoor recreation provision in a given area. While, $0 < \alpha < 1$ indicates decreasing marginal benefits of outdoor recreation provision in a given area. A rational private agent will look to maximize their total benefits, given the constraint on the square miles they are able to convert, P which is fixed:

$$(2.4) \quad (\max_{P_i} \quad \sum_{i=1}^{N} (\lambda_P P_i + \lambda_G G_i)^{\propto} \ s.t \ \sum_{i=1}^{N} P_i = \bar{P}$$

Let P_i^* denote the benefit maximizing P_i. Based on this equation where the private agent maximizes the net benefits from outdoor recreation provision, three hypotheses are generated. The private outdoor recreation agent may not be affected by the location decisions of the government agent, in which case λ_G*=0 or* α*=1* and $\frac{\partial P_i^*}{\partial G_i} = 0$. Alternatively, if $\lambda_G > 0$ and $\alpha < 1$ there are decreasing marginal benefits and the private entity would maximize total benefits by having the minimum outdoor recreation in each area (spatial repulsion), thus they would spread provision equally among each area, and $\frac{\partial P_i^*}{\partial G_i} < 0$. Lastly, if $\lambda_G > 0$ *and* $\alpha > 1$, there are increasing marginal benefits and private outdoor recreation providers will maximize their total benefit through concentrating their provision in a single area (spatial attraction). Since government outdoor recreation provision comes first and then the private entity locates taken the existing public sites into consideration, for this last scenario the private entity will maximize total benefit by locating in the areas with the most existing government outdoor recreation provision and $\frac{\partial P_i^*}{\partial G_i} > 0$. Thus, the three hypotheses are as follows:

$\mathbf{H_0^1}$: Private agents are unaffected by government outdoor recreation provision and/or average marginal benefit of outdoor recreation provision is constant, indicating no spatial effect.

$\mathbf{H_{1a}^1}$: Private agents respond to government outdoor recreation provision and the average marginal benefit of outdoor recreation provision is increasing, indicating spatial attraction.

$\mathbf{H_{1b}^1}$: Private agents respond to government outdoor recreation provision and the average marginal benefit of outdoor recreation provision is decreasing, indicating spatial repulsion.

In the next section, an empirical model is developed to test the hypotheses stemming from the theoretical model.

Estimation Strategy

I use a cross-sectional county level United States dataset of proportion of county land area in public and private outdoor recreation provision to test the three hypotheses above. The data allows me to identify how the current county level proportion of private outdoor recreation provision is distributed throughout the United States in a manner that is attracted to, repelled by or unaffected by government outdoor recreation provision. As stated in the theoretical section, this analysis assumes that government provision of outdoor recreation access existed before private provision of outdoor recreation access. With government provision of outdoor recreation already determined, my dependent variable is the proportion of county area that is owned by a private entity and allowing outdoor recreation access to the public, which I denote, P_i (please note that in the theoretical section P_i is slightly different in that it denotes square miles rather than proportion of county square miles). Suppose that there is a total amount of private outdoor recreation provision which is equal to $\bar{P}$. If that provision was distributed uniformly over space, i.e. the same proportion of private outdoor recreation provision in all counties, then one would expect the private provision of outdoor recreation in area i to be as follows:

$$(2.5) \quad P_i = \bar{P} \times \frac{L_i}{L} \equiv \gamma L_i \;\; where\, \gamma \equiv \frac{P}{L}$$

Where L_i is the number of square miles in area i, and $L = \sum_{i=1}^{N} L_i$.

If private provision of outdoor recreation is not distributed uniformly over space it indicates either spatial attraction or spatial repulsion. Spatial attraction would be evident if private outdoor recreation provision is disproportionately drawn towards areas with relatively high amounts of existing public outdoor recreation provision. In contrast, spatial repulsion would be evident if private outdoor recreation provision is disproportionately drawn away from areas with relatively high amounts of existing public outdoor recreation provision. If G_i is the proportion of total square miles in area i in government provided outdoor recreation access, than the average proportion of area nationally that is in government outdoor recreation provision, $\breve{G}$, is as follows:

$$(2.6) \quad \breve{G} = \frac{\sum_{i=1}^{N} G_i}{N}$$

If X is a matrix of other variables expected to influence the amount of private outdoor recreation provision (for a list of variables included in X, see Table 1), the regression model is:

$$(2.7) \quad P_i = \beta_1 + \beta_2 X_i + \gamma L_i + \eta(G_i - \breve{G}) + \epsilon_i \,.$$

Where ϵ_i is a disturbance term that is independently and identically distributed across i. (G_i- $\breve{G}$) is the proportion of land area in county i that is in the government provision of outdoor recreation minus the national average proportion of county land area in government outdoor recreation provision, it represents the normalized amount of government land in area i. Here, I am especially interested in the parameter η as it relates to hypotheses presented in the theoretical model, showing the significance of the normalized amount of government outdoor recreation provision. My null hypothesis, $\mathbf{H_0^1}$**,** stated that private agents are unaffected by government outdoor recreation provision; if this is the case, η=0. If η>0, $\mathbf{H_{1a}^1}$ holds**,** and spatial attraction is present. Lastly if η>0, $\mathbf{H_{1b}^1}$ holds, and spatial repulsion is present.

If either of the alternative hypotheses ($\mathbf{H_{1a}^1}$ or $\mathbf{H_{1b}^1}$) is true, indicating that private outdoor recreation provision is influenced by existing outdoor recreation provision; it may also be true that government provision in a neighboring county, j, also influences private outdoor recreation provision in county i. This leads to three new hypotheses on county level systematic spatial spillovers in outdoor recreation provision:

$\mathbf{H_0^2}$: There is no spatial spillover in county i from outdoor recreation provision in county j.
$\mathbf{H_{1a}^2}$: Positive spatial spillovers to county i from outdoor recreation provision in county j.
$\mathbf{H_{1b}^2}$: Negative spatial spillovers to county i from outdoor recreation provision in county j.

The empirical model is expanded to test the above hypotheses. I use the linear spatial autoregressive model (SAR) to incorporate spillover effects in to the empirical model. The SAR model says that levels of the dependent variable, proportion of county area in private outdoor recreation provision, depends on proportion of outdoor recreation provision in neighboring regions. This is a formulation of the idea of a spatial spillover from one county to another. The SAR model can be modeled as the following spatial reaction function:

$$(2.8) \quad P_i = \varphi \sum_{j \neq 1} w_{ij} P_j + \beta X_i + \gamma L_i + \eta (G_i - \breve{G})$$

Where the variables are defined as they were for the first empirical model with the addition of the following variables: φ is a scalar coefficient (the slope of the area's reaction function, commonly referred to as Rho which will be discussed in the results section); and w_{ij} are the weights assigned to all other observations j, the sum of all w_{ij} weights aggregates into the spatial weights matrix which I denote, W. Equation (8) shows that county i's neighbors, and all the characteristics of that neighbor (X_j,L_j and (G_j-$\breve{G}$)), have an influence on the amount of outdoor recreation provision in county i. The weighting matrix, W, assigns weights to all other observations, j, based on their spatial relationship with area i. Note that if the county j is not a neighbor to county i the weight w_{ij}=0 and has no impact on P_i. For this analysis, I use a Queen's contiguity-based weights matrix. Queen's contiguity says that two regions are considered neighbors if they share any part of a common border, no matter how short; it is named from how the "Queen" piece moves on a chessboard. The weights matrix, W, was created in GeoDa for all 3,141 US counties, making the matrix 3,141 by 3,141. This sheer size of this matrix can cause computational difficulties, as it contains almost 10 million elements (3,141 X 3,141). In order to save considerable matrix space, I track only the elements of W that are not zero by using a sparse matrix representation of W. Instead of keeping track of the entire W matrix, a sparse matrix records only non-zero elements. MATLAB contains routines to work with sparse matrix representations without having to expand the matrix to its full form. Even with the use of the sparse matrix, some of the spatial models took sixteen plus hours to compute.

A large percentage of the counties in my analysis have no private outdoor recreation provision, indicating a limited-dependent variable. This can be seen in Figure 1.1, where the dark green represents counties for which the value of private outdoor recreation is zero. To account for this limited dependent variable, I use the spatial probit model and compare results to the spatial lag model. Past research has used either the linear spatial model or the spatial probit on an area, with a majority of studies using the SAR. Due to the computational complexities of the spatial probit model, the spatial lag model is often used in its place. Due to the large number of counties with no private outdoor recreation opportunities and the small values for the counties that do have private outdoor recreation, the SAR model focusing on the magnitude of private provision may not be appropriate. Instead, an argument can be made for a tipping point, and looking at what contributes to that tipping point where private outdoor recreation opportunities are provided.

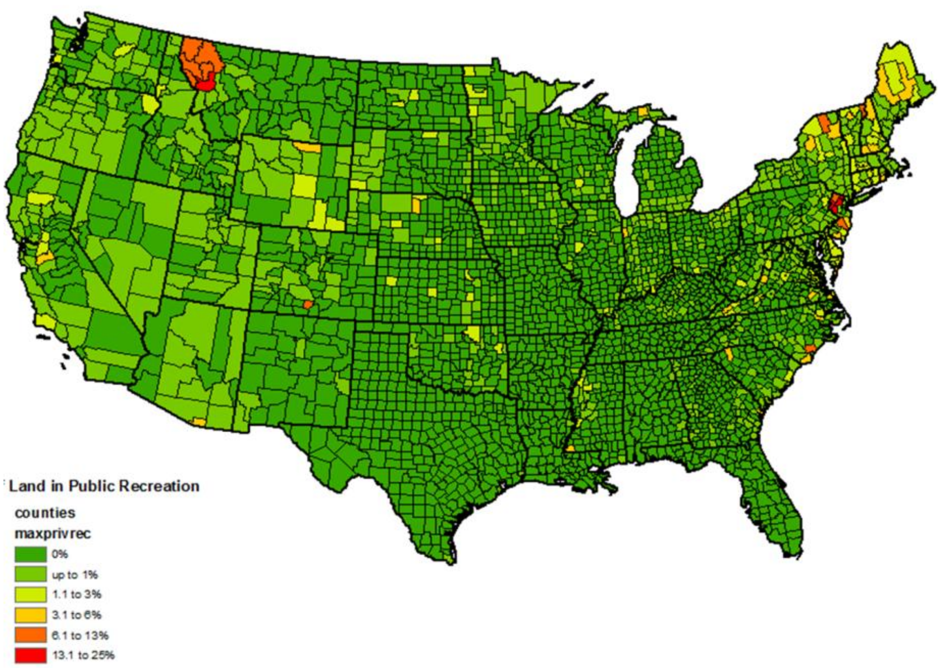

Figure 2.1: Private Outdoor Recreation as a Proportion of Total County Area

With the spatial probit, the observed value of the dependent variable is a 1 or 0 reflecting the decision to provide private outdoor recreation or not, as opposed to looking at the magnitude of provision. It is a proxy for the theory that when net utility of providing private outdoor recreation is negative, there is a decision to not provide ($P_i = 0$), and when the net utility is positive, there is a decision to provide ($P_i = 1$). The Bayesian approach is to replace this unobserved latent utility with parameters that are estimated. More formally, the choice depends on the difference in utilities associated with the observed [0,1] choice: $U_{1i} - U_{0i}$, where i is the location (county). The probit assumes that this difference, denoted P_i^*, follows a normal distribution. We do not observe P_i^*, only the choices which are actually made, P_i (LaSage, 2009). This is shown in equations (2.9) and (2.10) below:

(2.9) $P_i = 1,\ if\ P_i^* \geq 0$

(2.10) $P_i = 0,\ if\ P_i^* < 0$

This introduces an additional set of N P_i^* (where N in this analysis is the number of counties, 3141) into the model. I estimate the spatial autoregressive probit (SARP) using a Bayesian Markov Chain Monte Carlo (MCMC) framework that was first introduced in the non-spatial probit literature by Albert and Chib (1993) and expanded to the spatial probit by LeSage (2000). A MCMC framework is used because of two problems that arise when using traditional spatial autoregressive models to carry out a spatial autoregression using a binary response variable. First, the errors are heteroscedastic and second, the predicted values can take on values outside the [0,1] interval (LeSage, 1999). This Bayesian approach to modeling the limited dependent variable treats the [0,1] observation in P_i (proportion of area in private outdoor recreation in location i) as an indicator of latent utility, which underlies the observed choice outcome. MCMC estimation for the spatial autoregressive model cycles through the sequence of conditional distributions for all model parameters, taking samples from each. The conditional distribution for the latent variables takes on the form of a normal distribution centered on the predicted value. This distribution is truncated by zero from the left for P=1 and truncated by zero from the right for P=0. During the sampling, a conditional distribution for the latent (P^*) observations conditional on all other parameters is introduced. The distribution is used to produce random draws for each P^*. A large number of cycles produce a sequence of draws for the model parameters that converge to the unconditional joint posterior distribution. For this analysis, I specified 1100 draws to be conducted, with the first 100 draws omitted for burn-in. Using this form of analysis allows the use of conditional distributions to produce estimates for the model despite the fact that the posterior distribution is not tractable.

Data

In order to test my hypotheses regarding the spatial interactions of public and private outdoor recreation provision, I needed county level data on both public and private outdoor recreation provision. In this analysis I defined outdoor recreation provision as land that is accessible to the public for outdoor recreation purposes. No such dataset was publicly available, so I created the needed dataset from a publicly available dataset. The dataset created has two variables described below and shown in Figure 2.2:

1. *Public Outdoor Recreation Provision* (G_i) – percent of county's land area owned by the government and allowing for public outdoor recreational use.
2. *Private Outdoor Recreation Provision* (P_i) - percent of county's land area owned by a private entity and allowing for public outdoor recreational use.

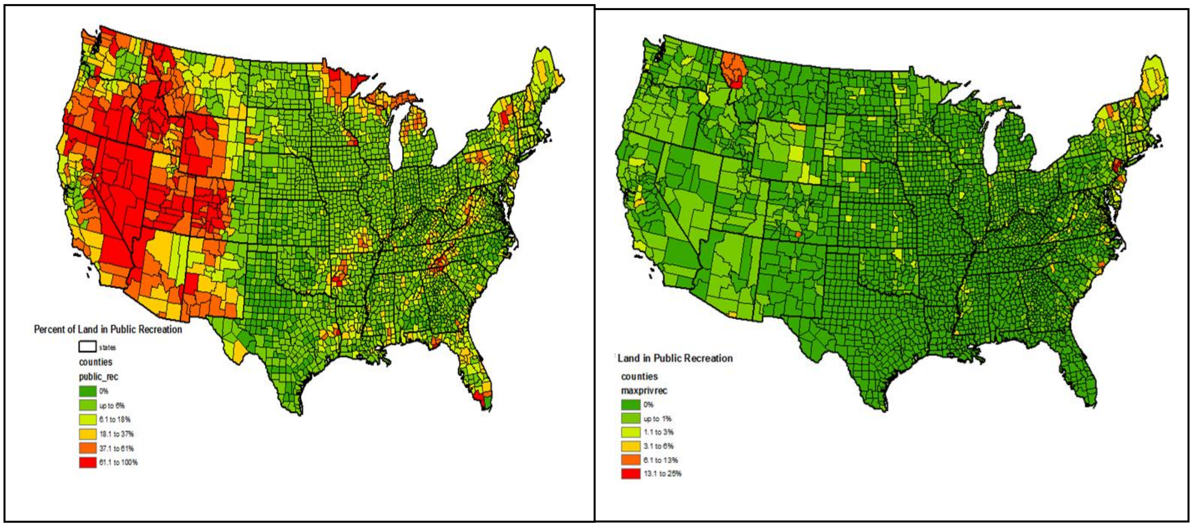

Figure 2.2: Public (panel A left) and Private (panel B right) Outdoor Recreation as a Percentage of Total County Area

The outdoor recreation provision variables were complemented by gathered spatial data on features of each county in order to control for things other than existing outdoor recreation provision that might affect the amount of private outdoor recreation provision in the county. A full list of variables used in the analysis is displayed below in Table 2.1, and a map illustrating how the regions are defined is displayed in Figure 2.3.

Table 2.1: Variable names and descriptions

Variable Name	Varible Definition	Units	Source
Private	Pi (Dependent variable)	Proportion	Author created, PADUS
G_minus_avgg	Gi minus average G	Proportion	Author created, PADUS
SQMI	County area	Square miles	ArcGIS
ag land value	median county ag land value	Dollars	Census
Medhomeval	Median home value	Dollars	Census
median income	Median County income	Dollars	Census
incchg	Income change for the county	Percentage	Census
netm	net migration into the county	Percentage	Census
empchg	county employment change	Percentage	Census
PccKrss	recast creative class in county	Percentage	Wojan
Breadth	Measure of entrepreurship, self-employment over total employment	Proportion	Low
ag emp	county employment in agriculture	Percentage	Census
Const emp	county employment in the construction industry	Percentage	Census
fire emp	county employment in the fire industry	Percentage	Census
gov emp	county employment in the government industry	Percentage	Census
prosci emp	county employment in professional/science employment	Percentage	Census
rec emp	county employment in the recreation industry	Percentage	Census
rest emp	County employment in the resteraunt business	Percentage	Census
noblm	County BLM land presence	Dummy (0,1)	Author created, PADUS
fmrkt_1000	Farmers' mrkts per 1000 pop	Percentage	FEA
Foreign	Foreign born county population that	Percentage	Census
under 5	Population under 5	Percentage	Census
over65	population age 65 and higher	Percentage	Census
pctobese	county population that is obese	Percentage	Food Envt Atlas, 2010
pctai	american indian	Percentage	Census
Pctbl	black	Percentage	Census
perdrop	population age 25+ with a highschool diploma	Percentage	Census
per vote Bush	vote for bush in the county	Percentage	
popsqmi	Population per square mile	Population/sqm	Census
Northeast Region	Northwest region of the United States	Dummy (0,1)	Census
South Region	South region of the United States	Dummy (0,1)	Census
West Region	West region of the United States	Dummy (0,1)	Census

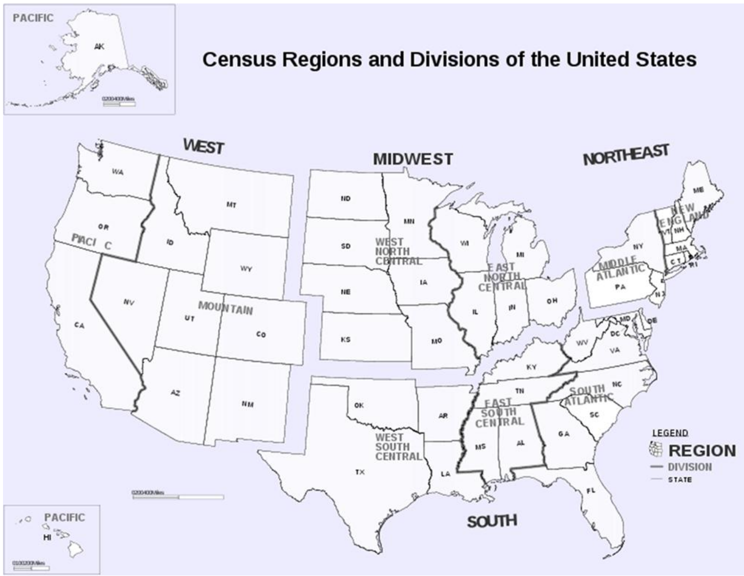

Figure 2.3: Map of regions defined for analysis

The Protected Areas Database of the United States (PADUS) version 1.1, which was released in May 2010, was used to create the two variables above. The PADUS dataset was created through a partnership between the United States Geological Service and National Biological Information Infrastructure through the creation of the Gap analysis program (note that the dataset was publically available at time of research, but recently has been taken down and is no longer accessible). The database is a national geo-database that represents public land ownership and conservation lands, including voluntarily provided privately protected areas, for the United States, Alaska, Hawaii, and Puerto Rico. All of the lands in the database are assigned conservation status codes and attributed with their designation type and land owner type. Being a geo-database, all PAD_US data is spatially connected to the geographic boundary of the conserved land (a visual representation of this database can be seen in Figure 2.4). All the shaded areas are classified as protected in the PAD_US dataset; but, note that Figure 2.4 has not yet been broken down by county or outdoor recreation.

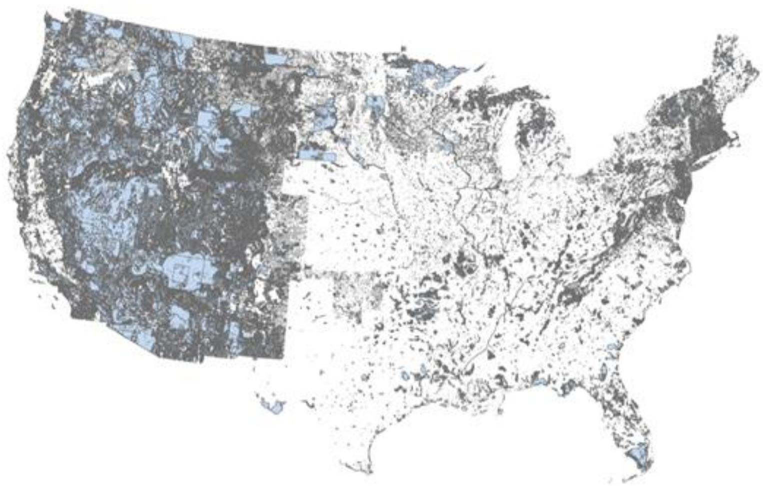

Figure 2.4: Protected areas in the PAD_US database

An overlay of county boundaries onto the PADUS dataset showed that not all shapes fell within a single county boundary so the first processing step was to use spatial software (ArcGIS) to attribute all the shapes in the dataset based on county boundaries. In order to create spatial units based on county, it was necessary to split the approximately 500,000 shapes of the PADUS dataset by the desired boundaries, and then aggregate the dataset. Next, research was performed on the 350-plus different land designation types to determine which were open to the public for outdoor recreation; this part of the process involved many educated judgment calls. Once the designation types of interest were selected, I extracted the shapes containing those designation codes from the larger dataset. The extracted designation types were then divided further to distinguish between outdoor recreation that was provided by government (public) entities and private entities. Once all parcels were extracted and assigned managing entities the public outdoor recreation and private outdoor recreation provision variables were created with the following equations, let $Parcel_k^{gi}$ represent the area in square miles of parcel, k, located in county, i, managed by a government entity, g; and $Parcel_k^{pi}$ represent the area in square miles of parcel, k, located in county, i, managed by a private entity, p:

$$(2.11)\quad G_i = (\sum_{k=1}^{N_i} Parcel_k^{gi})/a_i$$

$$(2.12)\quad P_i = (\sum_{k=1}^{N_i} Parcel_k^{pi})/a_i$$

Where:

N_i = the total number of parcels in county i.

a_i = the area in square miles of county i.

Results

The local indicator of spatial association (LISA) test (Anselin, 2010), calculated using the software program GeoDa, identifies statistically significant clustering in both measures. Figure 2.5 below displays the results of the LISA analysis and indicates that there are clusters of high-recreation regions and low-recreation regions. The areas that appear red on the map are areas where there is high outdoor recreation next to another area with high outdoor recreation, while the blue indicates a low area next to another low area.

The LISA analysis indicates that outdoor recreation provision in neighboring county, j, also influences outdoor recreation provision in county, i, and thus the need for a spatial econometric analysis. Both the spatial autoregressive (SAR) and the spatial probit (SARP) regressions were run for the entire United States. The results of the analysis of private outdoor recreation provision by county for the United States are displayed in Table 2.2 below.

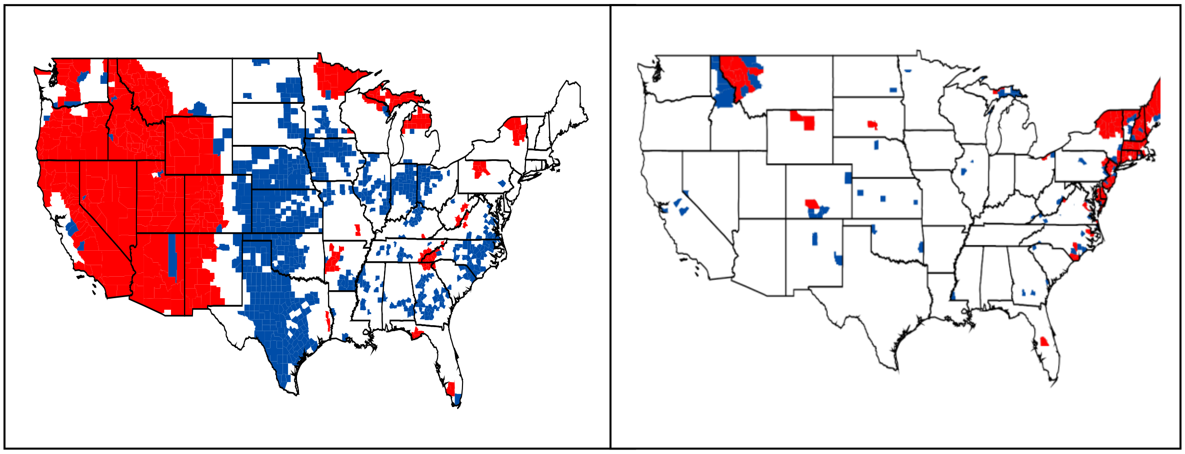

Figure 2.5: Spatial clustering in county level public (panel A left) and private (panel B right) outdoor recreation, from LISA analysis

As expected, the specification of the model (SAR vs. SARP) is very important to the analysis, and it is important to use the correct model even if it is more complex. The two models differ in the variable of key interest to this analysis; the coefficient on the g_minus_avg_g variable. In the SAR analysis, this coefficient is not significant, $\mathbf{H_0^1}$**,** indicating that private outdoor recreation agents are unaffected by existing government outdoor recreation provision. When the SARP model is used, there is a tipping point in providing private outdoor recreation; $\mathbf{H_{1a}^1}$ prevails indicating that private agents respond to government outdoor recreation provision and that there is spatial attraction. As can be seen in Table 2.2, other variables differ with the SAR or SARP specifications. Also of key interest to this analysis is the Rho variable which is positive and significant, indicating positive spatial spillovers from neighboring counties. While the magnitude of Rho is small (0.076 in the SARP model), which may suggest that spillovers die off quickly, it should be compared to the equally small dependent variable in the analysis, P_i.

Table 2.2: Spatial Regression Results

Dependent Variable: Proportion county area in private outdoor recreation					
Variable Name	**SAR**	**SARP**	**Variable Name**	**SAR**	**SARP**
G_minus_avgg	-0.350	0.005*	rest emp	-33.163	-0.527***
	(-1.507)	(0.002)		(-0.909)	(0.362)
SQMI	0.001	0.001*	noblm	16.804	2.456*
	(0.005)	(0.001)		(1.332)	(0.233)
ag land value	-0.029*	0.001	fmrkt_1000	-55.324	0.366
	(-5.076)	(0.001)		(-1.250)	(0.460)
Medhomeval	0.001	0.001*	Foreign	4.731*	0.002
	(0.150)	(0.001)		(5.569)	(0.008)
median income	-0.001	-0.001**	under 5	5.246*	0.132*
	(-0.341)	(0.001)		(7.012)	(0.008)
incchg	-0.739*	0.006**	over65	-1.650**	-0.035*
	(-2.458)	(0.003)		(-1.943)	(0.008)
netm	0.566***	-0.004	pctobese	-0.282	-0.048*
	(1.623)	(0.003)		(-0.283)	(0.010)
empchg	0.001	0.002	pctai	0.007	-0.001
	(0.001)	(0.002)		(1.321)	(0.001)
PccKrss	633.386*	-3.624*	Pctbl	0.867*	0.008*
	(6.043)	(1.057)		(2.786)	(0.003)
Breadth	-48.882	-0.812*	perdrop	-0.075	-0.030*
	(-1.101)	(0.466)		(-0.121)	(0.006)
ag emp	-0.937	-0.002	per vote Bush	-27.182	-0.796*
	(-1.476)	(0.009)		(-0.905)	(0.297)
Const emp	-0.580	0.003	popsqmi	-0.014*	-0.001*
	(-0.522)	(0.012)		(-6.455)	(0.001)
fire emp	3.245**	0.013	Northeast Region	-71.383*	0.922*
	(2.324)	(0.014)		(-5.156)	(0.111)
gov emp	-2.192*	-0.007***	South Region	-24.668**	0.145***
	(-4.432)	(0.005)		(-2.334)	(0.102)
prosci emp	0.589	0.024***	West Region	-63.129*	-0.168***
	(0.444)	(0.016)		(-4.655)	(0.120)
rec emp	-0.856	0.004	RHO	0.030*	0.076*
	(-1.041)	(0.008)		(352.924)	(0.005)
Significance Levels: *(1%), **(5%). ***(10%)					
Rho measures the average influence on observations by their neighboring observations					

Many of variables in vector X, variables that are expected to influence the amount of private outdoor recreation provision, were significant. One such variable is the size of the county in square miles. And, as expected, the larger the county, i.e. the more square miles in the county, the greater the probability the county contains private outdoor recreation. In contrast, while square miles had a positive effect, the population per square mile had a negative effect; this result is intuitive as higher population density means that there is more pressure on alternative land uses. Bureau of Land Management (BLM) land is open to outdoor recreation but is often thought to not have the same characteristics of the other types of government provided outdoor recreation, so to isolate BLM land, a dummy variable for the presence of BLM land in the county was included in vector X. This dummy variable was positive and significant indicating that counties with no BLM land are more likely to have private outdoor recreation; government provision of BLM land may have a negative impact on private provision. This indicates the need for future research that looks not only at government provision of outdoor recreation, but also distinguishes between different types of outdoor recreation provision.

The breadth and the creative class variables were included as a means to evaluate the role of entrepreneurship and creative employment in the region, and both variables were negative and significant, indicating that a highly entrepreneurial and creative workforce corresponds with a lower probability of private outdoor recreation provision. One possible explanation is that the breadth variable is especially high in rural areas (Low, 2004) and perhaps the rural nature of this variable is driving the result. Several other employment types were also found to be significant in the analysis. Other demographic variables such as age were found to be significant. The two age variables have opposite effects on the probability of private outdoor recreation, with children under five having a positive effect and seniors over sixty-five having a negative effect. Of the two race variables, only black was significant, with a positive relationship with private outdoor recreation. Three other demographic variables had a negative relationship with private outdoor recreation: the percent of the population that was obese, the high school dropout rate, and the percent of the population that voted for Bush in the 2004 election. Just as in past studies of outdoor recreation distribution (Tarrant and Cordell, 1999), a lower median income corresponded with being more likely to be located near outdoor recreation than a higher median income.

With the Midwest region as the reference region, all three other regions were significantly different than the Midwest region. A county located in the Northeast or South region had a greater probability of containing private outdoor recreation than the Midwest region, while location in the West region had a negative relationship with the presence of private outdoor recreation. The regional results could perhaps be driven by the differing private outdoor recreation providers operating in the different regions, or different land characteristics in the different regions. The above results illustrate the need to conduct further research on each region in addition to the United States as a whole.

Conclusions/Future Extensions

It has been well-documented in the literature that access to the outdoors and outdoor recreation opportunities are important in an individual's well-being and a driver of economic growth (Outdoor Industry Association, 2012; McConnell and Walls, 2005; Bolitzer and Neturil, 2000; Shultz and King, 2001; Riddel, 2000; McGranahan et al.; Lauman et al., 2003; Hartig et al., 2003; Wells and Evans, 2003; Mitchell and Popham, 2008; Ellaway et al., 2005). A better understanding of the spatial location decisions of these agents will be beneficial in informing policy maker's in future outdoor recreation policy decisions. This analysis found that, at the county level, private outdoor recreation is attracted to existing public outdoor recreation, and that many demographic characteristics of the county have significant effects on the probability of the existence of private outdoor recreation.

In this analysis I assume that the government has already made all outdoor recreation provision decisions, and this methodological approach was chosen because most of the government provided outdoor recreation provision occurred many years ago. In reality, there have been a few recent additions to public outdoor recreation provision (such as the Colorado Great Sand Dunes) as well as government outdoor recreation provision not being scattered randomly across space.

If the non-random process used in location decisions of the government are the same as those of private outdoor recreation agents there may be an endogeneity problem in the analysis. Variables in vector X (such as employment and no-BLM dummy) may also introduce endogeneity into the analysis. Spatial econometric models are relatively new, and as such no formal tests for endogeneity have been constructed. One method that has been used to get around this shortcoming is a spatial sampling technique. In this technique a subset with no neighbors is created, through randomly picked observations to be included in the sub-sample, eliminating all neighbors, until no neighbor observations remain in the sub-sample. Then non-spatial regressions can be run on this sub-sample, and endogeneity tests can be employed.

This dissertation paper utilizes the newly created Outdoor Recreation Index, which I created while at an internship at the USDA, Economic Research Service with the creator of the complementary data series that this new index serves as an extension of, the Natural Amenities index. This analysis was a functional first use of the newly created public and private outdoor recreation indices; it is my intention to use this paper as an introduction to the public outdoor recreation measure before it is distributed for public use similar to the Natural Amenities Index. Many future extensions, on many different research questions could stem from the release of this outdoor recreation access measure. Beyond just the use of the measure, this research has the potential for many other possible future extensions. First, it is likely that spatial attraction (repulsion) may differ across the United States and it would be beneficial to look individually at each region not just the United States as a whole. Results relating to the BLM dummy also indicate areas for future research since current research treats publicly provided outdoor recreation opportunities as all the same, when in reality there are many quality and infrastructure differences. Future research could distinguish between the different government providers of outdoor recreation. In many cases BLM land covers large expanses of space, and may not be repelling private provision, but instead occupying the available land that could be used for private provision. Future research should not only look at land area in the county but also available land area, with public outdoor recreation provision and developed land netted out. Lastly, in future research it would be beneficial to expand the research beyond the spatial probit to include the new methodology of the spatial heckit developed by Flores-Lagunes and Schnieder.

CHAPTER THREE

Essay Two: "Economic Values of Agritourism to Visitors: A Multi-Destination Hurdle Travel Cost Model of Demand"

Introduction

Agritourism, including activities such as you-pick-pumpkin patches, on-farm weddings, corn mazes, and farmers' markets, as well as many other on- and off-farm activities, is becoming a popular form of outdoor recreation in the U.S. Agritourism also likely intersects with the "foodie" movement, as direct-to-consumer sales have been found to be greater for farms engaged in entrepreneurial activities such as agritourism (Bagi and Reeder, 2012). However, the link may go in the opposite direction as well, and engaging in direct sales may serve as a catalyst for agritourism (Martinez et al., 2010). According to the 2007 US Census of Agriculture, farm and ranch businesses in the United States obtained over $566 million (up from $202 million in 2002) in income from recreational sources. In Colorado alone farm and ranch businesses obtained nearly $33 million in 2007 (up from $12 million in 2002 Census of Agriculture) in income from recreational sources. One factor contributing to this increase is the trend of tourists taking a greater number of shorter trips with a personal car as the form of transport (Maetzold, 2002). The increase has also been connected to an overall increased demand for outdoor recreation in the U.S., as well as increasing individual tastes and preferences for supporting and experiencing local agriculture (Govindasmy et al, 2002).

Nearly two-thirds of all American adults, some 87 million people, took a trip to a rural destination from 1999 to 2001 and this number is climbing (Travel Industry Association of

America; 2001): this rural travel is likely to be driven by outdoor recreation, including or supplemented by agritourism sites. In particular, agritourism is poised to become increasingly significant in Colorado (Gascoigne et al; 2008). Past research has linked rural tourism development directly to physical attributes; meaning that rural tourism is directly related to the availability of, and access to, natural resources (Gartner, 2005). There are differing views on agritourism's potential link to natural resources and the importance of transportation to rural tourism. Some believe that agritourism is highly linked to natural amenities of the area while others believe that the link is to major transportation and population centers. In truth, it is likely both, depending on the region. The current analysis looks at two different variables to explore the relationship of an area's natural amenities on agritourism visitation. The first is the commonly integrated proxy in regional modeling, the natural amenities scale (ERS, 2010), which is a measure of the physical characteristics of the area that enhance the location as a place to live, including things like climate, topography and water area. The second is a new, author-created measure called the outdoor recreation index detailed in Essay one of this dissertation. The state of Colorado as the focus of initial analysis is ideal for exploring the question of the link between natural amenities, transportation centers and agritourism as Colorado has one of the largest metro areas in the Midwest (Denver) as well as areas with very small population and fairly sizable regions that include both high natural amenities and agritourism enterprises.

While it is known that agritourism is an increasingly popular form of outdoor recreation, little is known about the characteristics and perceived value of participants in agritourism, as most previous research focused on the supply side and the motivations of farmers to become involved in agritourism (Brown and Reeder, 2007). More information on agritourism consumers and their behavior will be crucial for producers and policy makers looking to expand or justify further community investments focused on the agritourism industry. This study aims to investigate demand for, and economic benefits to agritourists, including the consumer surplus (CS) generated by agritourism, as one means to estimate the market size, resiliency and potential growth for this sector. As demand for agritourism changes—continuing to grow or potentially shrinking due to stagnant household incomes and increased fuel costs that impact long distance travel —it will be important to understand its value to consumers.

The Colorado Department of Agriculture reports that, in 2006, more than 13 million visitors experienced Colorado agritourism (Sullins et al.). Although the current market forces are favorable to most agricultural enterprises, the variability in returns to production agriculture and increasing opportunity costs of land may be forcing farmers to find new innovative ways to diversify farm incomes. So, documenting the drivers and revealed behavior of travelers may serve to quantify the demand for agritourism and its potential to improve the well-being of Colorado Agricultural producers.

One of the main contributions of this study is to provide the first application of the travel cost method that incorporates Multi-destination trips to estimate the demand for and consumer surplus benefits of agritourism. The Travel Cost Method (TCM) assumes that travel costs incurred to reach a site can be used to approximate the prices for recreational experiences. Although current market forces are favorable for agricultural enterprises, the variability in returns to production agriculture and increasing opportunity costs of land may be forcing farmers to find new ways to augment and diversify farm incomes. Therefore, documenting the drivers and revealed behavior of travelers may serve to quantify the demand for agritourism and its potential to improve the well-being of agricultural producers and their surrounding communities. Our second major contribution is the analysis of different variations in TCM to deal with multiple destination trips, which may be more prevalent for agritourism than many other types of outdoor recreation. This also provides a sensitivity analysis of the robustness of the benefit estimates of agritourism regardless of specification, and will provide insight on model impacts of the failure to correctly account for multi-destination travelers.

Literature Review/Background

Agritourism

The majority of research on agritourism has been comprised of anecdotal case studies and how-to-guides, with little empirical work that focuses on the reasoning behind farmers' involvement in agritourism (Brown and Reeder, 2007). These studies have looked at both the decision to enter the agritourism market and characteristics of successful agritourism operations (McGhee and Kyungmi, 2004; Rilla, 1998). An extensive review of the literature revealed only a few papers analyzing the demand side of agritourism. One comprehensive study integrated supply and demand aspects of farm-based recreation matching 2004 USDA Agriculture Resource Management Survey (ARMS) with a 2000 national survey of agriculture recreation visitors (Brown and Reeder, 2007). The researchers characterize the average agritourist to be in his/her early forties, with a median family size of three and a median income of $50,000. They also find that two-thirds of all agricultural recreation tourists live in the South or Midwest U.S. (Brown and Reeder, 2007). The research reported here will expand on the Reeder and Brown study in that we will explore characteristics and regional differences at a much smaller spatial scale—the state of Colorado—which should allow for a more detailed and accurate picture of a particular type of agritourist.

Utilizing the same dataset as will be used for the research presented here, past Colorado State University research has explored the demand side of agritourism in Colorado. In order to understand the tastes and preferences of agritourists to and within Colorado, Colorado State University created a 2007 survey of agritourism. Using the survey data collected in 2007, Gascoigne et al (2008) utilized a multinomial logit model to determine the factors affecting travel planning by potential agritourists. The model was based around the survey question indicating if agritourism was a "primary", "secondary", or "unplanned" activity to one's trip. They found significant demographic and travel planning strategy differences among these different types of agritourists. The researchers then created a linear expenditure model to reveal plausible factors affecting travel expenditures, finding the following variables to have a positive impact on expenditures: urban influence on visited county, income level, travel planned through the Colorado Tourism Office, and travel planned through travel magazines (Gascoigne et al., 2008). However, the economic benefit to the agritourists was not estimated.

One other research study utilizing the Colorado State University Survey of Agritourism used a cluster analysis to statistically classify consumers into five clusters (Sullins et al, 2010). The authors identified the following five clusters of Colorado agritourists:

1. Out-of-state activity seekers: Out-of-state visitors travelling in small parties, and enjoying active agritourism. This group tends to take longer trips that are often unplanned.

2. In-State Explorers: This group is the second largest share of travelers and comprises Coloradoans who tour the state in their own cars for long weekends or shorter trips.

3. Loyal Colorado Enthusiasts: This group comprises primarily in-state travelers who participate in a diverse set of agritourism activities and return often, based on past experiences.

4. Family Ag Adventurers: This group travels mostly in the summer and travels the farthest of any group.

5. Accidental Tourists: This cluster represents more than 1/3 of Colorado visitors. This group travels to Colorado for largely non-recreational purposes, and is only in the state for a few days with small windows for leisure.

The papers by Gascoigne et al. and Sullins et al. illustrate research on Colorado agritourism demand, but the next step is to quantify the benefits to and the willingness to pay for these agritourism demanders. The research reported here will expand upon past research through the application of a Travel Cost Model, as opposed to an Expenditure Model, while incorporating regions into the analysis.

A review of the literature revealed one TCM study related to agritourism, and this study did not look at multi-destination effects. The TCM study utilized the 2000 National Survey on Recreation and the Environment (NSRE) to implement a two-stage hurdle TCM model (Carpio et al., 2008). The authors aimed to determine the effects of different factors influencing tourists' decisions to visit farms. Carpio et al (2008) first explore the decision to visit a farm, followed by the decision of how many visits were made for those who do visit; the research reported here will follow a similar methodology. The significant results from the first stage of the 2008 study were that Hispanics were less likely to visit, while having children under the age of 6 increased the chances of visitation. For the second stage, they reported that the travel cost variable was significant, as expected, with a greater travel cost equating to fewer trips. The income variable was also significant, with greater incomes equating to more trips taken. As stated previously, another benefit of the travel cost model is the ability to calculate Consumer Surplus (CS) from visitation. Carpio et al (2008) find a CS of $174.82 per trip per person. Here we expand upon the methodology of Carpio et al. to include differentiation of multi-destination and primary purpose travelers using a more limited geographic scope (Colorado) but more detailed set of survey respondents that allow for more delineated travel models. The segmentation of travelers based on purpose of travel will allow for a more accurate estimation of CS, because omission of this distinction can lead to model bias (and we are only trying to capture the CS from the agritourism visit and not the visitor's entire trip).

Travel Cost Model

The Travel Cost Method (TCM) is a popularly-employed method to estimate the economic values of underpriced or un-priced public recreational resources. The basic premise of the TCM is that the price measured by the cost of travel to the site is inversely related to the number of trips to the site, other factors remaining equal (Loomis and Walsh, 1997). Using the measured implicit price (travel cost) and the quantity (number of trips), the TCM estimates the demand curve, from which we can then calculate the Consumer Surplus (CS) from the trip in accordance with demand theory.

The standard form of TCM assumes that travel cost is always incurred for a single-purpose recreational trip; this assumption does not hold for agritourism, as travelers often visit other destinations in addition to the agritourism site. This assumption is problematic because it makes estimation of the benefit solely related to agritourism and to isolate agritourism from the broader tourism sector difficult. This analysis will specifically look at a two-stage hurdle TCM model and explore the changes in performance of the model with different treatments of multi-destination (MD) trips. MD trips refer to trips where an individual has another destination on the way to, nearby, or on the way back home from the recreation site of interest (Loomis et al, 2000) while Primary Purpose (PP) trips refer to travelers whose main purpose of travel is agritourism. This section of the literature review will explore different alternatives for the inclusion of MD trips into the agritourism TCM.

Past studies have found that the failure to account for MD trips can lead to bias in the TCM and in the estimation of visitor benefits. Most of these studies have found that the omission of a variable to account for MD leads to an overestimation of CS (Parsons and Wilson, 1997; Loomis et al, 2000; Martinez-Espinira and Amoako-Tuffour, 2009). While most studies tend to be in agreement over the positive bias, one study finds that the bias can be either positive or negative (Kuosmann et al., 2003). Loomis et al., in their 2000 study, lay out the different options that can be used to account for MD trips. The options they identified are:

1. Identify individuals not travelling for a single purpose and drop them from the sample;
2. Take the average CS per trip gained from the single-destination trip travelers and apply this value to the multi-destination trip travelers;
3. Retain the multi-destination individuals and use different statistical procedures to deal with the joint cost;
4. Identify the cost share of each destination and disaggregate travel cost by directly asking people what proportion of their travel cost is allocated to each destination; or

5. Treat MD visitors as demanding a bundle of sites and value the bundle as opposed to the single site.

The preferred approach of Loomis et al., as well as the other authors cited above, is to use different procedures (option 3) to deal with the joint cost. Specifically, one can distinguish MD trips from PP trips the researchers include a dummy variable in the model. This research will implement all of the proposed solutions above, excluding option 5, and then compare and contrast the model results. In essence, this provides a sensitivity analysis that shows how robust the benefit estimates of agritourism are, regardless of specification.

While the Carpio study was national in scope, the research presented here will focus on Colorado, and will expand upon the methodology of the Carpio et al. study to include differentiation of MD travelers and PP travelers. The segmentation of travelers based on purpose of travel will allow for a more accurate estimation of CS, because omission of this distinction can lead to model bias (and we are only trying to capture the CS from the agritourism visit but not the visitor's entire trip to Colorado).

Data

In 2007, the authors contracted with National Family Opinion (NFO; http://www.tns-us.com/) to implement a web-based survey targeted at travelers to and within Colorado during 2005 and 2006. NFO distributed the survey to individuals already participating in their established panel, but filtered the samples to include only those who had visited Colorado (or Colorado residents who had traveled within the state) during the 2005/2006 time frame. The solicited samples were stratified according to certain demographic characteristics such as age, income, race, and education to ensure they were representative of the broader U.S. population (but taking those regions who most frequently travel to Colorado into consideration). Respondents who met these criteria were invited by NFO to participate in the survey, and they received "reward" points from NFO for completing the survey (through an incentive program NFO maintains). NFO managed the sampling process according to the researchers' specifications and targeted specific sub-samples of respondents until a balanced sample was achieved.

Of 1,003 total survey respondents, 503 were from Colorado and 500 were from targeted metro areas in adjacent states (hereafter referred to as out-of-state). Overall, there was a 38% response rate to the web survey. The targeted out-of state areas were Salt Lake City, Utah; Albuquerque/Santa Fe, New Mexico; and Phoenix, Arizona—chosen because the Colorado Tourism Office (Colorado Tourism Office, 2007) reported that the incidence of travel to Colorado from these metro areas was high and representative of a large share of out-of-state travelers. A national sample would have been even more representative, but budget constraints required the study authors to narrow the geographic scope of the survey. Consequently, a fairly representative sample of visitors to and within Colorado was obtained, except for light representation of respondents reporting Hispanic ethnicity (a challenge faced by many surveys). I recognize that the sample size is smaller than would be ideal, especially when regional dummy variables are included into the analysis. While I recognize this limitation of the data, the richness of each observation helps to make up for the small sample size.

Individuals were presented with a nested question in which they were first asked if they had traveled to Colorado in 2005 or 2006. If they responded "yes," they were then eligible to take the survey. Subsequently, questions were posed about the respondents' agritourism experiences. Agritourism was defined for them as a variety of recreational, educational, and other leisure activities and services provided by farmers and ranchers that could take place on or off the farm or ranch. A list of activities was provided—including wildlife viewing, culinary, educational tours, ranch/farm stays, heritage agriculture/cowboy/pioneer activities, and agritainment (mazes, pumpkin patches, and festivals). Respondents could refer to this definition during the course of the survey. Additional questions were asked on demographic characteristics, perceived quality, expenses, travel times, and whether agritourism was their primary or secondary purpose, or simply an impulse activity, of travel. For more information on traveler responses refer to the 2010 *Journal of Agribusiness* article, "Agritourism in Colorado: A Cluster Analysis of Visitors" (Sullins et al., 2010).

While the dataset is very rich regarding information on the individual visitors, it does not contain information regarding the specific agritourism site that was visited; instead, the survey asked for the nearest city to the site. Since the data were not collected from visitors at the actual agritourism sites, on-site sample bias is eliminated, but the dataset also is limited in that we only know the nearest city to the site visited as opposed to the address of the specific site. Due to the data configuration, it was necessary to group the sites in a systematic way; thus, sites were categorized according to the Colorado region in which they were located. Figure 3.1 below shows the six regions and the sample size in each region from our dataset. Regions were identified based on regions on Colorado Outing a Colorado travel guide web source (Colorado Outing, 2009).

For this analysis, data collected from the agritourism survey were supplemented with data from the US Census and the natural amenities index developed by the Economic Research Service of the USDA (USDA, 1999). The analysis also includes the unique author-created index of outdoor recreation provision highlighted in essay one of this dissertation. This new measure allows the unique contribution to the literature that the natural amenities scale does not allow; the outdoor recreation measure is able to look at amenity access rather than just existence.

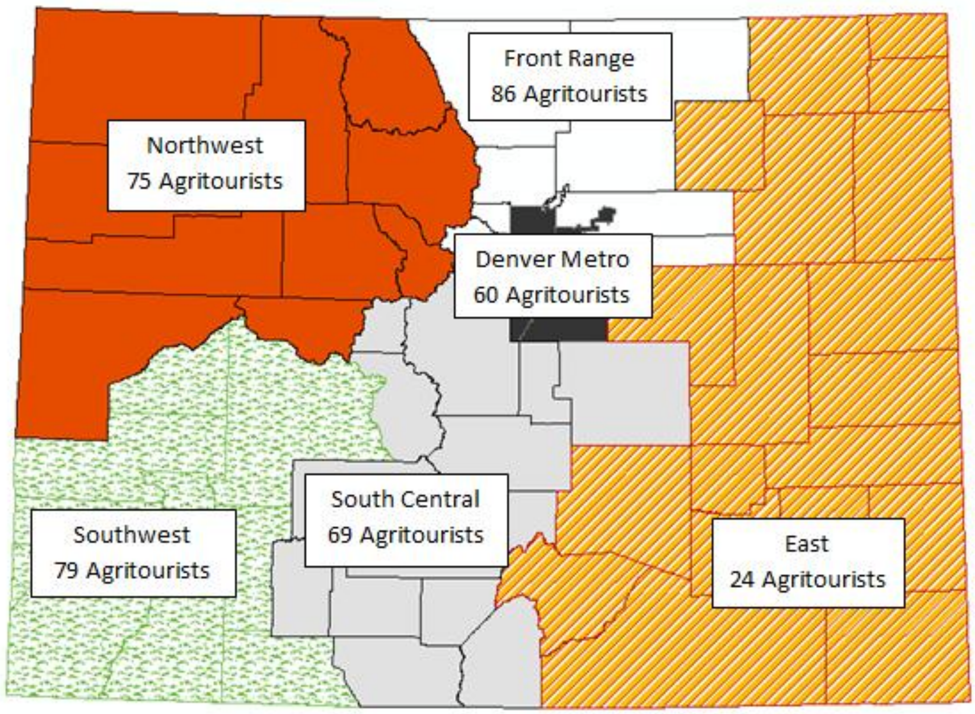

Figure 3.1: Six Colorado regions and the sample size for each region (Colorado Outing, 2009)

<u>Methodology</u>

Empirical Specification of TCM

This analysis applies a hurdle model, based on the assumption that the zero counts are generated from a different process than the positive counts. A hurdle model handles this by partitioning the model into two parts: a binary process explaining positive trip counts versus zero trip counts, and a process analyzing only positive trip counts. The binary process is generally estimated using a binary model; while the positive trip counts process is estimated using a zero-truncated count model (Hilbe, 2011; p. 355). In more intuitive terms, the first stage of this analysis looks at the tourist's initial decision of whether to participate in agritourism, while the second stage looks at the number of agritourism trips taken, given that the individual participated in agritourism.

The first stage is modeled as a probit, indicating whether the respondent participated in agritourism or not:

$$(3.1) \quad P = \begin{cases} 1\, if \;\; Q_{ij}\,(trips) \; > \; 0 \\ \quad 0\, otherwise \end{cases}$$

Where Q_{ij} *(trips)* is the number of trips taken by individual *i* to agritourism location *j* (one of the six regions) and is given as follows for this first stage:

$$(3.2) \qquad Prob\, P > 0 \; = G\gamma + V$$

Where *G* is a vector of the independent variables, γ is a vector of the coefficients of the variables that are expected to influence whether an agritourism visit is taken, and *V* is the error term.

The second stage looks at the quantity of trips taken, given that the individual participated in agritourism, represented below:

$$(3.3) \quad Q_{ij}\,(trips) = f(TC, Inc, d_i, A_j)$$

Where Q_{ij} *(trips)* is the number of trips taken by individual *i* to location *j*, *TC* is the implicit price or travel cost of individual i to visit location j, *Inc* is the individual's income, d_i is a vector of characteristics of individual *i*, and A_j is a vector of characteristics of location *j*. Variables included in vectors d_i and A_j are those defined in Tables 3.1 and 3.2. As stated in the introduction one area of key interest is the relationship between the region and characteristics of the area of the agritourism site on the visitation to that site. Vector A_j contains several variables that help us explore this question including the natural amenities scale, the outdoor recreation index and regional dummy variables.

Table 3.1: Variable Descriptions Stage One of the Hurdle Model – Probit Selection Equation

Variable name	**Variable Description**
Age	Respondent's age
Income	Variable ranges from 1 (under $7,500/year) up to 35 (over $300,000/year)
Co_res	Indicates if the respondent is from Colorado or one of the targeted metro areas
Married	Indicates if the respondent is married, dummy variable
Nights	The number of nights respondent stayed in Colorado on last trip
Gender	Gender of the respondent, dummy variable
Num_party	How many people were in the travel party
Own_car	Indicates if the respondent's mode of transportation was his/her own vehicle

Where travel timemultiplied by one-third the wage rate is included as a way to value the individuals opportunity cost of time, it is used as an approximation of the shadow price of time. The travel cost literature has adopted the value one-third the wage rate as an approximation of an individuals travel time cost as it reflects the median of revealed values of travel time in transportation literature (Cesario, 1976). The use of one-thrid of the wage rate in travel cost literature has faced much critisim (Shaw and Feather, 1999; Bockstael et al., 1987), but a study by Phaneuf and Smith has found that more complex approaches for determining the opportunity cost of time find results close to that of the standard one-third of the wage rate (Phaneuf and Smith, 2004). Phaneuf and Smith argue that there is a lack of compelling evidence for the replacement of traditional one-third of the wage rate strategies to value the opportunity cost of time.

Table 3.2: Variable Descriptions Stage Two of the Hurdle Model – Poisson Trip Frequency Outcome Equation

Variable Name	Variable Description
Vector d_i	Vector of agritourist characteristics of individual i
Age	Respondent's age
Gender	Gender of the respondent
Race	Indicates if respondent is white or other race
Acc_child	Indicates if the respondent was accompanied by child(ren) on trip
Married	Indicates if the respondent was married, dummy variable
Num_party	How many people were in the travel party
Homeortime	Indicates if the respondent owns a second home or timeshare in area of visit
Vector q_i	Vector of characteristics of agritourism location j
Northwest	Indicates if the region visited was in Northwest Colorado
Southwest	Indicates if the region visited was in Southwest Colorado
Front range	Indicates if the region visited was in Front Range Colorado
South central	Indicates if the region visited was in South Central Colorado
East	Indicates if the region visited was in Eastern Colorado
Denver Metro	Indicates if the region visited was in Denver Metro area of Colorado, excluded a reference point
Public_or	Author-created outdoor recreation score for county in which destination is located, percent of county area publicly available for outdoor recreation
Nat_amen	County natural amenity score from ERS Natural Amenities Scale, the greater the number the greater the natural amenities
Avg_sat	Average participant satisfaction ratings for all agritourism activities in which respondent participated
On_farm	Category of activities that take place on a farm or ranch and are more closely aligned with traditional ag sector activities
Food	Activities operated by farmers or ranchers that do not necessarily take place on the farm or ranch
Heritage	Activities related to the celebration of farm or ranch heritage and history that do not necessarily take place on the farm or ranch
Other Variables	
TC	Respondent Travel Cost associated with travel to agritourism
TC_MD	Travel Cost calculated as described in Scenario 4
TC_exc_MD	Travel cost calculation that excludes all respondents for whom agritourism was not the primary purpose of travel
TT	Estimated travel time from home zip code to destination zip code
Inc	Income variable ranges from 1 (under $7,500/year) up to 35 (over $300,000/year)
Jdummy	Indicates if agritourism was the primary purpose of travel
IMR	Inverse Mills Ratio from Selection Equation

For the second stage of analysis, a count data functional form is the best choice, as the number of trips must be a non-negative integer, and count data models can be consistent with a utility maximization process involving repeated choices (Hellerstein and Mendelsohn, 1993). Specifically, the Poisson or Negative Binomial distributions assign positive properties to only non-negative integers. The Negative Binomial is used when over-dispersion[1] of trips is present. In our data, both the Pearson statistic and z-tests indicate that over-dispersion is not present so a Poisson distribution was selected for this analysis.

The Poisson probability mass function with the trip quantity parameter, λ, is as follows:

$$(3.4)\ f(y|\lambda) = e^{-\lambda}\,\lambda^{y}/y!$$

The regression model to specify λ, which is the mean number of trips, can be specified as follows:

$$(3.5)\ \lambda = \exp\ (TC, Z\ ;\ \beta)$$

Where:

λ = the mean of *Q (Trips)*

TC = the travel cost variable

Z= the demand shift variables

β = a vector of parameters

The fully-specified Poisson model is as follows:

$$(3.6)\ \ \mathrm{Log}\ (Q) = \beta_0 + \beta_1 TC_i +\ \beta_4\, I_i +\ \beta_5 d_i + \beta_6 A_j + \beta_7 IMR$$

where IMR is the inverse mills ratio from the first stage probit model (Heckman, 1979).

The estimated demand equations are used to calculate the Consumer Surplus (CS) for each of the individuals in the sample. The CS is the area under the demand function, from the observed travel price (*TC*) to infinity:

$$(3.7)\quad CS = \int_{TC_0}^{\infty} f(TC, x)dtc$$

For count data models this formula reduces to $1/\beta_1$ for per trip CS.

Past studies have found that the failure to account for MD trips can lead to bias in the model, and agritourism is a classic case of a recreational outing that often is bundled with other travel purposes. For example, agritourism may be a side trip as individuals travel to see family or other attractions. Because this was assumed a priori, the survey instrument was detailed enough that we have information on the purpose of the individuals' trip as well as other activities in which they participated. This study will analyze and compare four different options, identified by Loomis et al. and informed by this additional survey information, to account for MD trips in the second stage of the hurdle model. In Model one, we assume that MD travelers are different from PP travelers and drop all MD travelers from the sample running the TCM on only the individuals who identified themselves as PP travelers. Dropping the observation greatly reduces an already small sample, so Models 2 and 3 use different methods that do not require the loss of sample size. For each of the three scenarios distinguishing MD travelers, CS will be calculated slightly differently. Using multiple approaches will serve as a type of sensitivity analysis, thereby providing a range of values that represent agritourism's contribution to travelers' welfare.

Model #1

a. Identify individuals not travelling for a single purpose and drop them from the sample

The survey instrument asked individuals to state if the trip to the agritourism site was their primary reason for travel, secondary reason, or an unplanned "incidental" trip. This permits the isolation of only those individuals who were traveling with the primary purpose of visiting the agritourism site. The inclusion of only PP travelers reduced the agritourists sample from 393 respondents to 130 respondents. The CS for the 130 PP travelers is calculated as:

$$(3.8)\ CS_{PP} = 1 / \beta_{tc}$$

Where β_{tc} is the parameter corresponding with the total cost of the trip variable (Creel and Loomis, 1990).

b. The CS gained from the single-destination trip travelers is applied to the multi-destination trip travelers

This approach is similar to Model #1 a. except that the CS for PP travelers generated from the model will not only be applied to the PP travelers but also to the additional 263 MD travelers.

Model #2:

Retain the multi-destination individuals and use different procedures to deal with the joint cost

This approach is becoming a more popular correction approach in the literature. MD and PP visitors will be distinguished by including a dummy variable. Visitors who stated that agritourism was the primary purpose of their trip will be coded PP, all others will be coded MD. This dummy variable, as well as its interactions with travel cost, will be included to capture the shift and rotation of the demand function due to the existence of complementary sites (Loomis et al., 2000).

$$(3.9)\quad Q_{ij}(trips) = f(TC, I, d_i, A_j, JDummy, JDummy * TC, IMR)$$

Where *JDummy* equals one if it is a MD trip and zero if it is a PP trip, and *IMR* is the inverse mills ratio from the first-stage, probit selection equation (on the initial decision of whether to participate in agritourism). The inclusion of the joint dummy variable interacted with the travel cost, aims to eliminate an error in variables problem that occurs when not accounting for the differences between PP and MD travelers. In essence the errors in variables problem, is because we are grouping together individuals who may have unknown differences in TC, the dummy-TC interaction variable acts to vary the slope of the demand curve for these different grouping of individuals. The variable *Jdummy*TC* tests to see if the slope for PP and MD travelers is different and would thus indicate that the CS is also different between the two groups. CS for PP travels will be calculated as described in Model #1. If travel behavior of MD visitors is found to be significantly different from PP travelers; then MD travelers' CS will need to incorporate the different slope of the demand curve and thus will be calculated as follows:

$$(3.10)\ CS_{MD} = 1 / (\beta_{tc} + \beta_{dummy*tc})$$

Where β_{tc} is the parameter corresponding to the total cost of the trip variable and $\beta_{dummy*tc}$ is the parameter corresponding to the *Jdummy*TC* variable.

Model #3:

Identify cost share of each destination and disaggregate travel cost by directly asking people what proportion of their travel cost is allocated to each destination.

This approach assumes, as in Model 2, that there is an error in variables problem with the TC variable for MD travelers. Since I have such a dense dataset on individual travelers, rather than dealing with the problem through a dummy variable, Model 3 calculates the TC variable differently based on the type of traveler the individual is. Due to the nature of the survey, travel cost can be disaggregated based on individual responses. If the respondent stated that agritourism was his/her primary purpose of travel, then *TC* was calculated as:

$$(3.11)\ TC_1 = f\{(C_{gas}, C_{fee}, C_{rentals}, C_{lodging}, C_{Dining}, C_{LocTrans}, C_{liscense}) + \left(\frac{1}{3}(wagerate * tt)\right)\}$$

If agritourism was reported as a secondary reason for the individual's trip, then all the expenses in *equation 12* were included but divided by the number of nights. The assumption is that these individuals only spent one day of their trip on agritourism and invested (an assumed) one hour in additional travel time.[2] Finally, if they stated that the trip was purely incidental, then only the agritourism entrance/participation fees were included in the *TC* variable.

Empirical Results

Statistical Results for the Probit Selection Equation

Table 3.3 below presents the results for the first stage probit of the hurdle model. This stage analyzed the decision to participate in agritourism or not. The coefficient on the variable accounting for the number of nights is positive and statistically significant at the 1% level, indicating that the longer the trip, the more likely the traveler was to have participated in agritourism. The positive and significant coefficient on number in travel party indicates that a larger party, like a family or group outing, is more likely to participate in agritourism. Those respondents who indicated they were traveling with their "Own car" had a positive and statistically significant effect at the 5% level. This is logical because agritourism opportunities are often in areas that are difficult to access using public transportation.

Table 3.3: Statistical Results for the Probit Selection Equation

Selection Equation	**Coefficient**
Age	0.0001 (0.04)
Income	-0.001 (-0.17)
Co_res	-0.0126 (-0.13)
Married	0.1483 (1.50)
Nights	0.0841 (4.47***)
Gender	-.0807 (-0.79)
Num_party	0.0287 (2.09**)
Own_car	0.2610 (2.44**)
_cons	-0.5483 (-2.22**)
Z-statistics are presented in parentheses Significance levels: ***(1%), ** (5%)	

Statistical Results for Trip Frequency Model Specifications

Table 3.4 presents the results for the three different treatments of multiple destination trips in the second stage Poisson, while Table 3.5 presents the CS calculations. This stage looked at the quantity of agritourism trips taken, given that the traveler participated in agritourism. The three different models outlined in the methodology section were analyzed separately. For Model #1 the coefficients are the same for both part a. and part b.; the only difference between the scenarios is whether the PP CS is applied to just PP trips or all trips. As described above the CS is calculated using the coefficient on the TC variable, but in the case of Model #1 the TC variable is positive and CS cannot be calculated from a positive TC coefficient. Thus scenarios a. and b. are identical. Below we offer an explanation for this counterintuitive result.

Model #2 interacts a dummy variable with the TC, where the dummy variable indicates whether the individual is a PP or MD traveler, while Model #3 includes a modified *TC* variable to account for differences between the costs faced by PP and MD types of travelers. For all models, the positive and significant demographic variable *age* indicates that the older the individual, the more trips they take. The respondents' race and stated number in party were also significant for Model #1, but not for Models #2 and #3. For all models, it was evident that the region of visitation impacted the number of trips. The Denver Metro region was the comparison region, and all but the East region were found to have significantly lower numbers of trips than the Denver Metro region. This could, in large part, be due to the accessibility of the Denver Metro region to the population center, a major airport, and the amenities that come with a large city.

Table 3.4: Statistical Results for Poisson Trip Frequency Equations

Outcome Equation	**Model 1**	**Model 2**	**Model 3**
Age	0.0196	0.0168	0.02541
	(3.51***)	(3.29***)	(4.33***)
Gender	0.0324	0.2213	0.3335
	(0.18)	(1.14)	(1.81*)
Race (= white)	-0.6215	-0.1452	-0.3322
	(-2.49***)	(-0.55)	(-1.27)
Acc_child	0.1959	0.0055	0.1817
	(1.24)	(0.04)	(1.25)
Num_party	0.0385	-0.0258	-0.0149
	(2.71***)	(-1.23)	(-0.85)
Homeortime	-0.5095	0.4526	0.0146
	(-1.06)	(-1.49)	(0.05)
Northwest	-1.5364	-1.0671	-1.0872
	(-4.13***)	(-3.14***)	(-3.25***)
Southwest	-1.4412	-1.6776	-1.8943
	(-4.19***)	(-4.52***)	(-5.18***)
South Central	-0.054	-0.7542	-0.812
	(-0.18)	(-2.52***)	(-2.83***)
Front Range	-0.399	-0.8973	-0.7475
	(-1.36)	(-3.22***)	(-2.78***)
East	-0.9316	-0.401	-0.1538
	(-1.92**)	(-1.23)	(-0.48)
Public_or	2.6657	1.6572	1.9931
	(6.96***)	(3.78***)	(4.68***)
Nat_amen	-0.5245	-0.6789	-0.0395
	(-4.43***)	(-0.77)	(-0.44)
Avg_sat	-0.1548	-0.06719	0.0064
	(-1.22)	(-0.66)	(0.06)
On_farm	1.078	-0.1469	-0.1385
	(4.73***)	(-0.94)	(-0.95)
Food	-0.2473	0.2327	0.0181
	(-1.55)	(1.62)	(0.13)
Heritage	0.1812	0.0048	-0.0525
	(1.09)	(0.03)	(-0.32)
IMR	1.5203	0.0927	-0.7484
	(2.67***)	(0.15)	(-0.90)
TC	0.0018	-0.0061	-0.0046
	(6.23***)	(-6.93***)	(-4.69***)
Inc	0.0164	0.0281	0.0143
	(1.52)	(2.81***)	(1.27)
Jdummy		-0.4301	
		(-1.96**)	
Jdummy * TC		0.0038	
		(3.61***)	
_cons	-0.7348	0.3677	-0.4753
	(-0.74)	(0.43)	(-0.58)
Pseudo R2	0.1936	0.2873	0.2032

Z-statistics are presented in parentheses

Significance levels: *** (1%), ** (5%)

Table 3.5: Per Person Consumer Surplus of Agritourism Trips

	Model 1	**Model 2**	**Model 3**
Per Person PP	N/A	164	$217
Per Person MD		435	

It should be noted that the only characteristic of agritourism location that was significant for all models was the newly created Outdoor Recreation Index, which was intended to more carefully measure each area's outdoor recreation access. As was expected, the greater the proportion of the geographic area available for outdoor recreation access in the area the greater the number of trips. Another measure of the properties of land in the area was the natural amenities scale, which was negative and significant for Model #1; so, the greater the natural amenity base, the fewer trips taken for agritourism. The negative sign on this variable may be due to topographic elements of that index; areas with mountains are given greater scores in the Natural Amenities Index, but such areas are not conducive to agricultural production (where agritourism may be more available). This result on Natural Amenities falls out in Models #2 and #3. To explore the relationship between natural amenities and agritourism it could be valuable to pull individual pieces of the natural amenities scale and include them in the analysis as opposed to the aggregated Natural Amenities scale. Model #1 found that the agritourism category "on-farm" was significant, suggesting that more repeat visits are taken if the activity is at the site of a farm or ranch, possibly representing those enterprises that allow hunting, fishing, horse activities or other nature-based recreation which could be adjacent to, if not directly nearby, high natural amenity areas. In contrast, food and heritage activities that do not necessarily take place on the farm or ranch do not drive as high of frequency of trips.

As expected, the *TC* variable is significant for all Models, but Model #1 presents the counterintuitive result that the greater the travel cost, the more trips taken. This counterintuitive result is not present in Models #2 and #3, which take into account the difference between PP and MD travelers. So it appears that how multiple destination trips are modeled is important to the findings, and leads to more economically intuitive findings. Once the model accounts for distinctions between PP and MD travelers, the expected sign on the *T*C variable is observed, indicating the importance of accounting for the differences in MD and PP travelers in this travel cost model. This illustrates one of the advantages of distinguishing between PP and MD visitors so that valuable observations and data are not fully discarded, but rather, customized to more reflect estimated differences in trip intentions.

I compare my results to Carpio et al.'s 2008 study that focused on farm recreation and found a CS value of $174.82 per trip. In our Model #1 the CS per person cannot be calculated because of the positive sign on the travel cost variable. The inclusion of a dummy variable to account for MD and PP ultimately yields a negative coefficient on the travel cost variable and the CS per PP traveler decreases to $164 and the CS for MD travelers is $435. This greater CS for MD travelers may be due to the fact that, on MD trips, much of the cost of getting to the region is incurred for other purposes which lowers the marginal cost of the agritourism side trip, and produces a very large CS from these MD visits. Another important observation is that the CS is different for PP and MD travelers and, specifically, that MD travelers gain a greater CS than do PP travelers. Modifying the TC variable to reflect the different costs that PP and MD travelers face gives a CS of $217, which lies between the ranges based on the type of traveler of $164 - $435 found in Model #2. If MD and PP travelers are inherently different, not just different in the costs that they face, research extensions should include the joint dummy (but not the TC-dummy interaction, as it has already been accounted for in the modifications of the TC variable) in Model #3. If MD and PP travelers are not inherently different than the joint dummy variable (but NOT its interaction with TC) should be removed from Model #2. This would allow for more direct comparison of CS estimates from the two models. The differences in key variables across models are substantial enough to suggest that policy implications from TCM studies may need to be conditioned on the methodological approach that is used.

Conclusions

This dissertation essay contributes significantly to the academic literature on tourism and travel cost modeling, as it underscores the importance of the treatment of MD travelers in a travel cost analysis. In terms of empirical results, this analysis shows that the CS from a primary purpose agritourism trip ranged from $93 to $164, based on data from Colorado travelers from several metro areas during the period 2005 to 2006—depending on the empirical treatment of multiple destination travelers. This is consistent with the findings of Loomis et al. 2000, which also found a large variability in CS, suggesting that TCM derived-benefit estimates are sensitive to the inclusion of multi-destination visitors. Future extensions of this research would be to look differently at the three models. First, Model 1 currently removes all Multi-destination travelers from the sample. In the future, for comparison reasons, it would be beneficial to also run the model just on the MD travelers and to run it with all the travelers together (as a sort of control equation). For Models #2 and #3, similar inclusion of the joint MD/PP dummy variable (but not the TC-Dummy interaction) would allow for comparisons across the two models. If MD and PP travelers are inherently different, not just different in the costs that they face, research extensions should include the joint dummy (but not the TC-dummy interaction, as it has already been accounted for in the modifications of the TC variable) in Model #3. If MD and PP travelers are not inherently different than the joint dummy variable (but NOT its interaction with TC) should be removed from Model #2. This would allow for more direct comparison of CS estimates from the two models. For those who are trying to evaluate the role of agritourism in the broader tourism sector, differences found between MD and PP travelers may imply the ability to leverage the impact of a region's natural endowment of recreational demand options by supporting the development and promotion of agritourism enterprises.

One of the more general contributions of this work is the insights it provides on travel cost modeling approaches. Our findings suggest that the failure to correctly account for MD travelers can lead to incorrect interpretations of the travel cost variable. In this study, greater travel costs were found to have a counterintuitive positive effect on the number of trips when only PP trips were included and MD travelers were dropped from the sample, although we suspect this is due to the PP sample being so small and unrepresentative of the broader set of travelers. Once MD travels were introduced into the model and methods were introduced to distinguish between PP and MD travelers, the travel cost variable was negative and significant for the PP trips, as theory would suggest. Our study also indicated that there is a substantial CS gained by agritourists from their agritourism experience. Significant differences in trips were found across regions of Colorado, with most regions having a statistically significant smaller number of trips than those to the Denver Metro region. This indicates that individuals traveling to regions not near a metro area take fewer trips. This combined with the negative and significant sign on the travel cost variable highlight the importance of agglomeration of infrastructure and a suite of opportunities on agritourism visitation.

The first stage of this analysis looked at how tourists who visit agritourism sites differ from tourists who do not, finding that agritourists tend to travel in larger groups and on longer trips using their own cars as transportation. The next stage of the analysis looked only at agritourists and how many trips on average they took in a year. The only demographic variable that was consistently significant was age, indicating that older individuals take more trips. Another innovation of this study was the development of a new variable to explore whether outdoor recreational offerings influence the size of the agritourism sector, a key element given the objective to explore complementarities between natural resource and agriculturally oriented tourism strategies. The Outdoor Recreation Index was the only variable associated with agritourism location that had a statistically significant impact on the number of trips: the greater the outdoor recreation access in an area where the agritourism site is located, the greater number of trips the agritourist took to that region. This result can have important policy implications related to location decisions for outdoor recreation provision and economic development activities. As demand for outdoor recreation grows, agritourism can augment public land offerings by providing public access to private lands. And similarly, as agritourism continues to grow, it will be important to have an understanding of who the agritourists are and what influences the number of trips they take. This study found significant regional differences that will be important in the development of regionally targeted promotion and development efforts.

However, additional future research is needed to explore regional differences in more depth; individual analysis by region should be conducted to gain more insight than can be gained through the simple inclusion of regional dummy variables. In the future, a follow up study on Colorado agritourism could be conducted and analyzed to better understand how Colorado agritourism and agritourism demand are changing over time, or in response to specific new activities and infrastructure. Future agritourism surveys could improve the accuracy of estimates if they were to more directly ask respondents to identify the specific site visited and, if they are on MD trips, the portion of their costs directly attributable to the agritourism site.

There are several limitations to this study that should be acknowledged, including the fact that data collection occurred online as opposed to on-site, suggesting the possibility that individuals may not remember key details of their trip ex-post, and the fact that direct individual site comparisons were not possible. There is also a small sample size, which makes regional comparisons and conclusions difficult. In addition, the results of this research are applicable only to agritourists visiting Colorado from the targeted areas, and Colorado residents traveling within the state. A nationwide survey would be necessary to draw meaningful conclusions about other regions or states in the U.S.

CHAPTER FOUR

Essay Three: "Efficiency Impacts of Water Conservation and Storage Policies: A Spatially Dependent Equilibrium Displacement Model of Canals in the Balkh Watershed, Afghanistan"

Introduction:

The allocation of natural resources to their highest and best use is not only an important economic decision with respect to land (as discussed in the first two dissertation essays), but also water, where spatial dimensions may be anchored in gravity fed stream flows and associated infrastructure for delivery. This is particularly the case in developing countries, where there are few mechanisms to manage the uncertainty of water shortages. For this reason, the micro-focused analysis of this third paper will look at such decisions. This third essay utilizes a farmer survey in rural Afghanistan to gain insights into crop producers' behavior, stratified based on the producer's spatial location on the canal. Knowledge gained from the survey will facilitate the selection of output and input elasticities, which will be used to populate an Equilibrium Displacement Model (EDM). The EDM model will be used to evaluate different water management policies on crop production, with attention being paid to the producer's spatial location on the canal. The datasets used for the first two essays were very dense, while this essay illustrates the incorporation of spatial methods when rich datasets are not available. The purpose of this third essay is to evaluate the economic impacts of water management strategies on producers in Balkh, Afghanistan.

Poverty and conflict in Afghanistan have caused strain on both agricultural producers and infrastructure in the country. The impacts and importance of water allocation on poverty alleviation have been well documented; water is one of the most important factors in persistent poverty (Husain and Hanjira, 2003). There is a close correlation between hunger, poverty, and water since most hungry and poor people live in regions where water challenges pose constraints on food production. In Afghanistan there are large fluctuations in stream flows, and a lack of formal institutions for assigning water rights, thereby creating economic and food security risks for Afghan farmers. This makes Afghanistan a prime example of a region where water management has the potential to alleviate poverty in rural areas. This research will analyze the impacts of water conservation and storage on the production of three summer crops (cotton, melon and onion) in an agricultural canal system in Balkh, Afghanistan through the use of a partial equilibrium model.

As will be discussed in more depth in the background section, the traditional water rights system in Afghanistan often results in inequitable water distribution, favoring land in the head of the canal at the expense of producers in the tail end (Aleppo, 2002). Due to this spatial relationship of water distribution, the location of a producer on the canal is an important aspect of the current crop production in Balkh and should be included in a model of water management. Without the inclusion of space on the canal, the impacts of a constrained resource which does not otherwise have formal markets, water, would not be properly accounted for. In contrast, developed countries have markets and allocation schemes allowing for valuation of water, such markets are critically dependent on three pillars: well-defined property rights, public information on supply and demand, and the physical possibility of trade (Dudu and Chumi, 2008). In developing countries, these critical pillars are often not established and there is no formal water market, making it more difficult to determine water's value.

Thus, by including the spatial location of the producers, this study will be able to better examine the value of changes in the availability of water in a system without the benefit of prices or trades made in a formal market for the resource. (We did however see that some informal trading did take place, and in fact, producers in the tail of the canal informally gave their surface water rights to those upstream in return for funds to dig wells and use groundwater). Moreover, the incorporation of space allows the evaluation of the allocation of water, a non-priced input that is crucial to crop production. This dissertation essay measures the potential effects of three water management strategies on the production of three spring crops, where water availability is the most constrained: cotton, melon/watermelon, and onion. An EDM model is created for the small canal system in Balkh, Afghanistan using realistic parameters based on a household level survey of producers on the canal. To quantify the economic impacts of water management strategies three scenarios are considered:

Scenario 1: Increase water storage by 10%, through the creation of a reservoir.

Scenario 2: Reduce water lost in application by 25% through the adoption of land leveling in the head of the canal.

Scenario 3: Installation of farm turnouts throughout the canal that reduces seepage by 10% from the water course walls, thereby increasing input supply of water.

The EDM model estimates changes in input and output quantities for different spatial locations on the canal, which would be due to policies that would result in the scenarios above. If significant benefits are found, this study could help justify public sector investments into water saving and storage technologies in the province; it also illustrates one methodology for looking at water allocation strategies when spatial location is important and data availability is limited. The results of this research will provide valuable insights to a wide variety of groups, such as policy makers, government agencies and future researchers, operating inside Afghanistan but also those doing more global research. Policy makers and government agencies will have scientific evidence of potential impacts of implementing new water storage and conservation policies. Future water development researchers can also benefit as Afghanistan is not the only region where water management strategies can help reduce poverty.

Literature Review:

Partial Equilibrium

According to the World Bank (2008), partial equilibrium models are a suitable way to assess the economic and social effects of water policy. A large amount of the economic research on irrigation water management has focused on partial and general equilibrium models (Vaux and Howitt, 1984; Horbulyk and Lo, 1998; Michelson and Young, 1993; Brill et al., 1997). The seminal application to water markets was a 1984 study using a static, non-linear model finding substantial gains to California of interregional water transfers (Vaux and Howitt, 1984). More recent studies have applied more complex computer modeling to look at issues such as drought (Michelson and Young 1993) and different pricing mechanisms (Brill, Hochman and Zimmerman 1997).

Modeling was expanded even further to include constraints and risk, with the advent of positive mathematical programming models (PMP) (Howitt, 1995). The PMP method permitted relaxation of many assumptions, does not require large datasets and has been applied to irrigation research (Hall, 2001; He et al., 2004). More recently water allocation modeling has combined partial equilibrium models with other models, such as biophysical models or hydrologic models (Schmidt et al., 2009). While the combined models provide more precise results, they are more data intensive and the current research is focused on an area where data is limited.

The current research will use a partial equilibrium model that is commonly used in agricultural policy analysis called the Equilibrium Displacement Model (EDM). The EDM was originally developed in Muth in 1964 and has since extensively been used for agricultural policy analysis. Some areas of agricultural policy analysis that have been evaluated using EDM have been poverty impacts for semi-subsistence crops (Takeshima, 2009); market effects of the European Common Agriculture Policy (Salhofer and Siabell, 1999),and the adoption of animal identification and tracking systems on the U.S. meat and livestock industries (Pendell et al., 2010).

Pendell’s 2010 study is the most similar to this dissertation as they use a multi-market EDM, as does the current analysis which includes cotton, melon and onion. Pendell’s study also looks at different marketing margins which is mathematically similar to the way this dissertation incorporates multiple locations on the canal. Pendell’s research uses an EDM to represent a multi-market simulation that allows for the vertical linkages along the marketing chain for each sector, as well as the horizontal relationships with respect to international trade. This dissertation essay will also look at a multi-market simulation, and will look at horizontal relationships. Instead of the vertical relationships represented in the Pendell et al., the current research will look at the relationships between different locations on the canal. Another characteristic of both models is that they allow for input, in addition to output, substitution to occur in response to changes in input and output prices. Even more similar to this research is a 2010 study looking at wheat production in another country that is mountainous and has a low yearly rainfall, Saudi Arabia. Alhashim developed an EDM model to observe changes in wheat quantity and price when the Saudi Arabian government enacts policies related to wheat production. In the creation of the EDM Alhashim incorporates two inputs, water and other, just as we will in this paper. Alhashim's analysis finds significant impacts on the quantity and price of wheat from different government policies with regards to wheat.

While similar in some ways to past studies utilizing an EDM model, this dissertation paper will contribute to the literature in several unique ways. Water has been difficult to incorporate into EDM models as both space and timing of the water matters in its value, and in my review of the literature I have not found an EDM applied to canal modeling. This research will contribute to the literature through the inclusion of space to better value water by treating the production differently for location on the canal. In this way, I am able to look at water as an input that differs based on the producer's spatial location. Utilizing the small area of a canal system will allow the incorporation of the space aspect of water without the added complexity of linking the partial equilibrium model to a broader hydraulic model as past studies have done. In addition, this dissertation paper also contributes to the literature with its unique focus on a country without established water markets, Afghanistan. In addition, lack of data in developing and war torn countries makes it difficult to perform a country wide analysis that can improve welfare. However, using this small canal level, we are able to collect data and create a model to serve as a starting point for the improvement of conditions for Afghanistan agricultural producers, which might be applicable to forecast broader potential gains.

Water Resource Management

The study of managing water resources is in many ways more complex than the study of other resources in that the barriers to efficient use of water resources are often socially constructed and highly political. In addition, water prices are often not determined by markets and do not reflect resource scarcity. Water is also unique in that it is essential for life and misallocation can have large impacts on human health and livelihoods (Olmstead, 2010). Much of the past economic literature on water resources has focused on the econometric estimation of water demand parameters, such as elasticities (Olmstead, 2010). Past meta-analysis of the price elasticity of demand for residential water has found the range of values to typically be between -0.38 and -0.64 (Espey et al., 1997; Dalhuisen et al., 2003). Elasticity estimates for industry and agricultural water demand are more difficult to calculate and the majority of research has used a process of modeling outputs as being generated with water and non-water inputs to obtain estimates. A meta-analysis of 24 U.S. agricultural water demand studies finds a mean price elasticity of -0.48 for agriculture, noting that estimates in the literature have high variability (Scheierling et al, 2006). A more detailed discussion of specific elasticity estimates used for this analysis can be found in the methodology section of this paper.

Another vein of literature has focused on efficient water pricing, indicating that water prices often lie below what would be efficient (Munasinghe, 1992; Brookshire et al., 2002; Sibly, 2006). While there is literature on water pricing in formal markets, little research has been conducted on pricing of water in informal markets (Olmstead, 2010). Research in areas with informal markets for water have looked at the benefits of the development of markets, which would allow for the movement of water to its highest- valued uses (Harman and Seastone, 1970; Vaux and Howitt, 1984). In the recent years, the economic impacts of water projects for the purpose of development and poverty reduction have been researched. A study looking at India found that dam construction can lead to significant increases in irrigated area downstream of the dam (Duflo and Pande, 2007). The study finds that dam creation increases rural poverty in the districts where it is located but decreases poverty downstream. Much past research has focused on the economics of water conservation. One focus has been on technology standards as a common policy implemented for long run water conservation. . The literature has found that water savings from the implementation of technology standards can be smaller than would be expected because of behavioral changes that offset the greater water use efficiency (Greening et al, 2000).

In 2010, Torrell and Ward published research looking at water management in the Balkh region of Afghanistan (Torrell and Ward, 2010). The research uses an Integrated Water Resources Management (IWRM) decision support framework to look at different arrangements for allocating water among a system of canals. They look at the benefits and drawbacks of various water allocation institutions in terms of their effects on food security and farm income, finding that total water supply and institutional arrangements have important influences on farm income and food security. As it is likely that these institutions will take a long time before they can be effectively enacted in war torn Afghanistan, this current dissertation research will look at water management strategies that can be implemented much more quickly.

Study Area Description:

Survey Instrument

The specific location of interest for this analysis is a canal system in the Balkh Ab watershed, which forms part of the Northern river basin in Afghanistan, which can be seen in

Figure 4.1. The research stemmed from research conducted by the USAID funded Afghanistan Water, Agriculture, and Technology Transfer Program (AWATT), which had the aim to increase agricultural productivity and re-establish healthy watersheds through the improvement of irrigation and agronomic practices. The current dissertation research helps to reach this goal through the creation of a tool to evaluate economic impacts of the improvements to irrigation practices. The Balkh watershed is the largest watershed in the Northern basin of Afghanistan and it contains approximately 1,600 settlements, a population exceeding 1.3 million people, and covers 28,835 square km. Balkh, as well as most of Afghanistan, is very arid and access to water is critical for food sufficiency and security.

In the Balkh watershed, there is very little direct precipitation and most of the available water comes from snow melt from the Afghanistan Mountains of the Central Highlands, making irrigation essential for agricultural production. In Afghanistan, 85% of the available water is utilized for agriculture, most of the irrigation water in the Northern Basin comes from surface water. The surface flows in the Balkh River basin account for 2% of the total surface water flowing through the country. Because of this reliance on snowmelt, there is extreme seasonal variation in river flows, seen in Figure 4.2, with little or no reservoirs to store peak flows (more discussion of this variation can be found in the scenario section of this essay). Most of irrigated agriculture gets its water from surface water, and uses the water in its entirety, fully drying up the irrigation canals before they reach the northern border of Afghanistan.

Figure 4.1: Map of Afghanistan showing the area of the Balkh River Basin. Source: Torrell and Ward, 2010

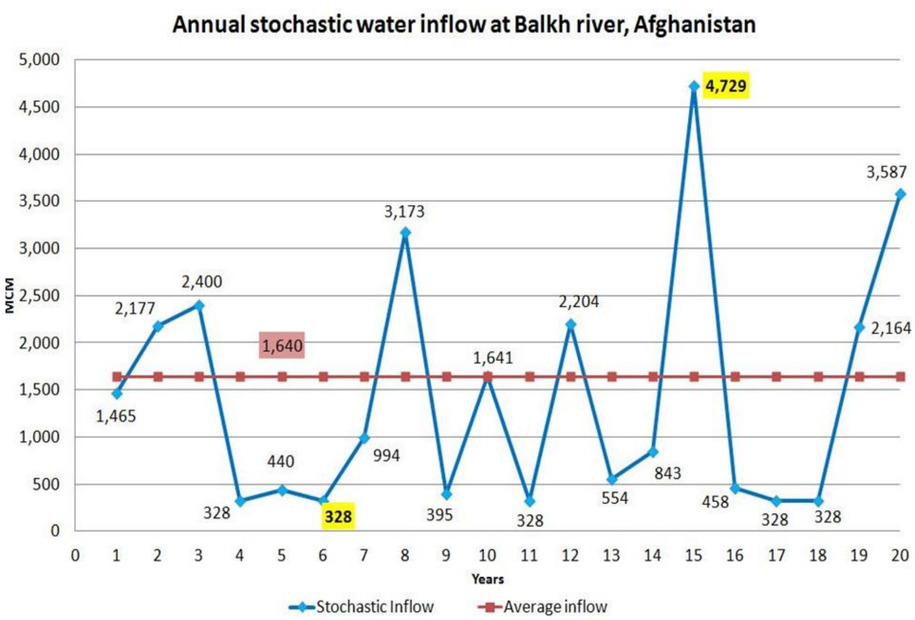

Figure 4.2: Annual Stochastic Water Inflow at Balkh River Afghanistan

To gain a better understanding of the unique production challenges and characteristics of the canals in Balkh, Afghanistan, AWATT conducted a household level survey of farmers located on the canal. The survey was implemented in the summer of 2009 and gathered information on cropping patterns, livestock ownership, water use, water availability, water management, water distribution, canal maintenance and demographic characteristics of farmers. The survey was stratified based on three spatial locations on the canal, the head of the canal where producers get first access to the water, followed by the middle and lastly the tail of the canal which often does not receive their fair share of the water. Summary analysis of the three different reaches of the canal, found differences in crop mixes and yields across all reaches of the canal. While differences were found, it was deemed that the water challenges faced by the tail of the canal were very different from those faced by the head and middle. For this reason, the EDM model, created to estimate the economic impacts of different water management strategies, merged the head and the middle of the canal into one spatial location. In addition, the survey gathered information on three canals in the Balkh Ab watershed: Nahr Shahi, Siyagard and Balkh, shown in Figure 4.3. Again, summary statistics for the three canals differed but since the three canals were in the same area and shared many important similarities and the benefits to sample size, this EDM model draws from data from the averages of the three canals. The area containing the three canals is referred to as Balkh Ab in this dissertation chapter.

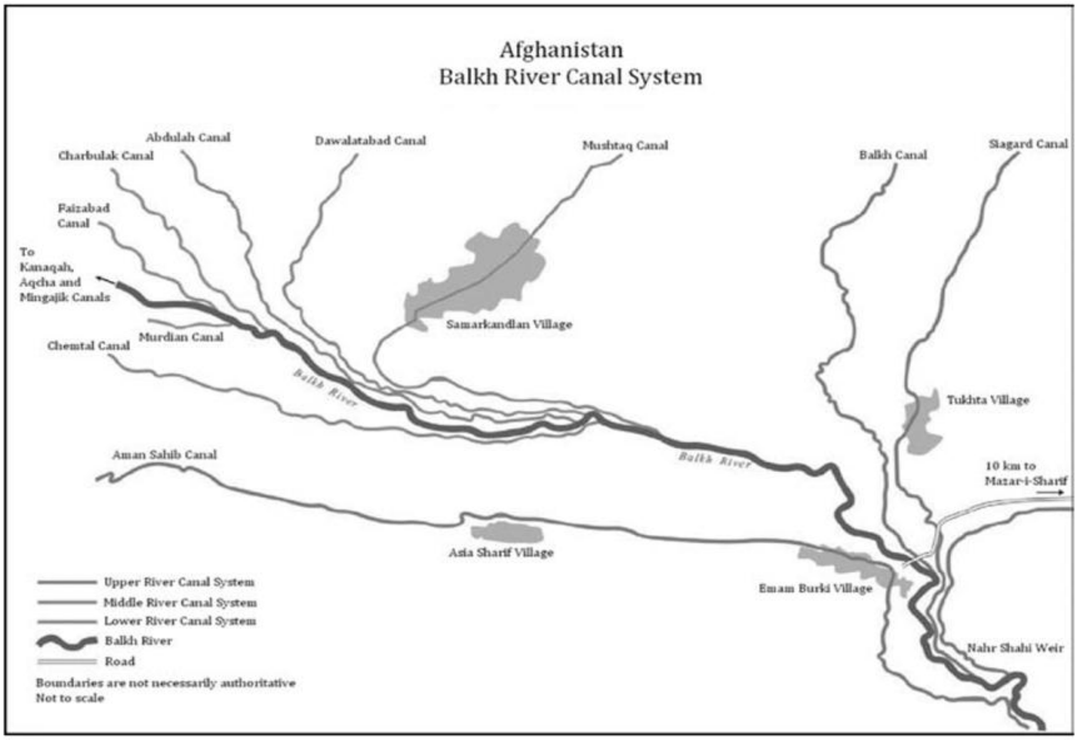

Figure 4.3: Schematic of the Balkh River Canal System, Afghanistan Source: Torrell and Ward, 2010

Description of Canals

The survey instrument used to characterize the canals was a formal detailed questionnaire, which sampled producers on all reaches of the canals. Additional information on the production in the region was supplemented with Balkh Ab enterprise budgets (AWATT, 2009). The average landholding per household in the sample area was 9.36 hectares (around 23.1 acres) ranging from 3.76 ha to 15.66 ha (9.3 acres to 38.7 acres). Basic summary statistics of the three canals surveyed (Mirzai, Siyagard and Balkh) are contained in Tables 4.1 and 4.2 below.

Table 4.1: Canal description, Source: Diagnostic Assessment (AWATT, 2009)

Name of Canal	Service Area (ha)	Length	Discharge in May 2009 (m3/s)	No. of tertiary canals
Siyagard	10,800	40	1.56	9
Mirzai	1,620	6	0.40	11
Balkh	4,816	15	0.67	9

Table 4.2: Cultivated area by canal and season, Source: Diagnostic Assessment (AWATT, 2009)

Name of Canal	Sample Size	Avg. Household Land Holding (ha)	Cultivated Area Summer (ha)	Cultivated Area Winter (ha)
Siyagard	16	15.66	1.83	7.25
Balkh	27	8.67	2.40	4.61
Mirzai	16	3.76	0.74	1.75

The survey indicated that cropping intensities in the basin are low, between 21 and 28% of available land in the spring season and 45 and 53% of available land in the winter. The significant portions of the land holdings not cultivated each season, is due in large part to the non-availability of irrigation water. Table 4.3 below shows yields of some of the major crops based on the farmer's location on the canal. Interesting to note is that the yield in the head of the canal (where water flows first) is lower than in the middle and, in some cases, the tail. One explanation, identified by the AWATT diagnostic assessment, for the low yields in the head is overwatering. When stream flows are high farmers at the head of the canal have a strong incentive to store water in the soil root zone and in the plants by overwatering. Survey data shows that there is a lack of knowledge in the area of the potentially negative impacts of overwatering. Figure4. 4 below illustrates that often the head takes so much water that it does not make it to the tail of the canal.

Table 4.3: Yields of Major Crops by location in the canals, Source: Diagnostic Assessment (AWATT, 2009)

Crop	Yield at the Head (kg/ha)	Yield at the Middle (kg/ha)	Yield at the Tail (kg/ha)	Average Yield (kg/ha)
Wheat	2090	2920	2150	2210
Barley	1725	2115	1895	1912
Cotton	2065	2445	1735	2082
Melon	13950	16925	16825	15900

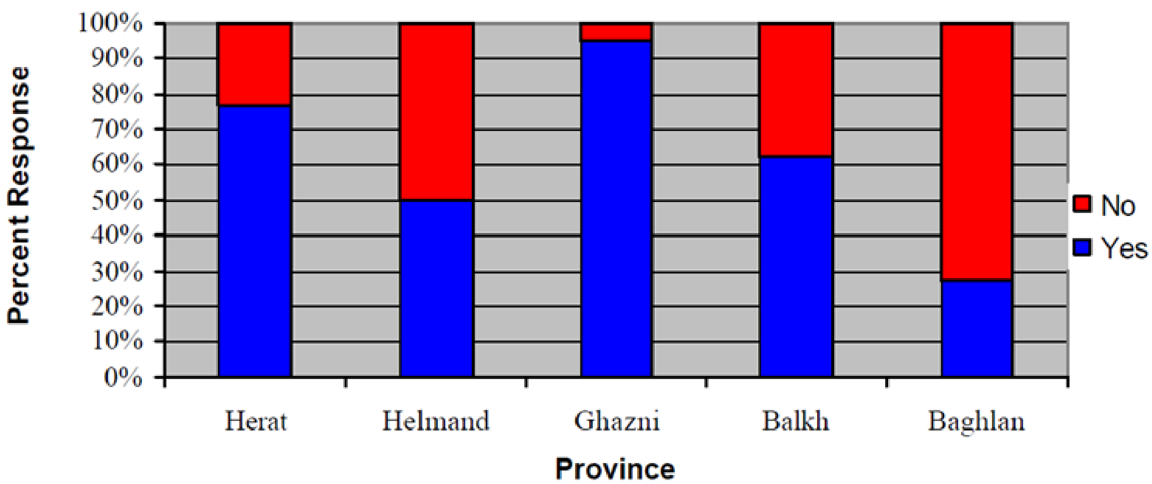

Figure 4.4: Does Water Reach the Tail End of the Canal? Source: (Aleppo, 2002)

In wet years, there is enough water for everyone on the canal; the upstream users use all they need and have excess to send down the river. As noted above, the AWATT survey indicated that the head may even overwater, to the point of reducing overall yields. However, in dry years there is not enough water to satisfy demand, resulting in limited availability for downstream users. Differences in the canal management outcomes were also seen systematically between the head, middle and tail regions of the canals. Producers drawing water from the canal are responsible for maintaining the canals with their own labor, and the survey found differences in cleaning efforts based on canal location, Figure 4.5. The head of the canal spends 15 days a year cleaning the canal, the middle 17 and the tail 21 days; not only does the tail clean the canal more frequently it spends more time cleaning the canal when it does.

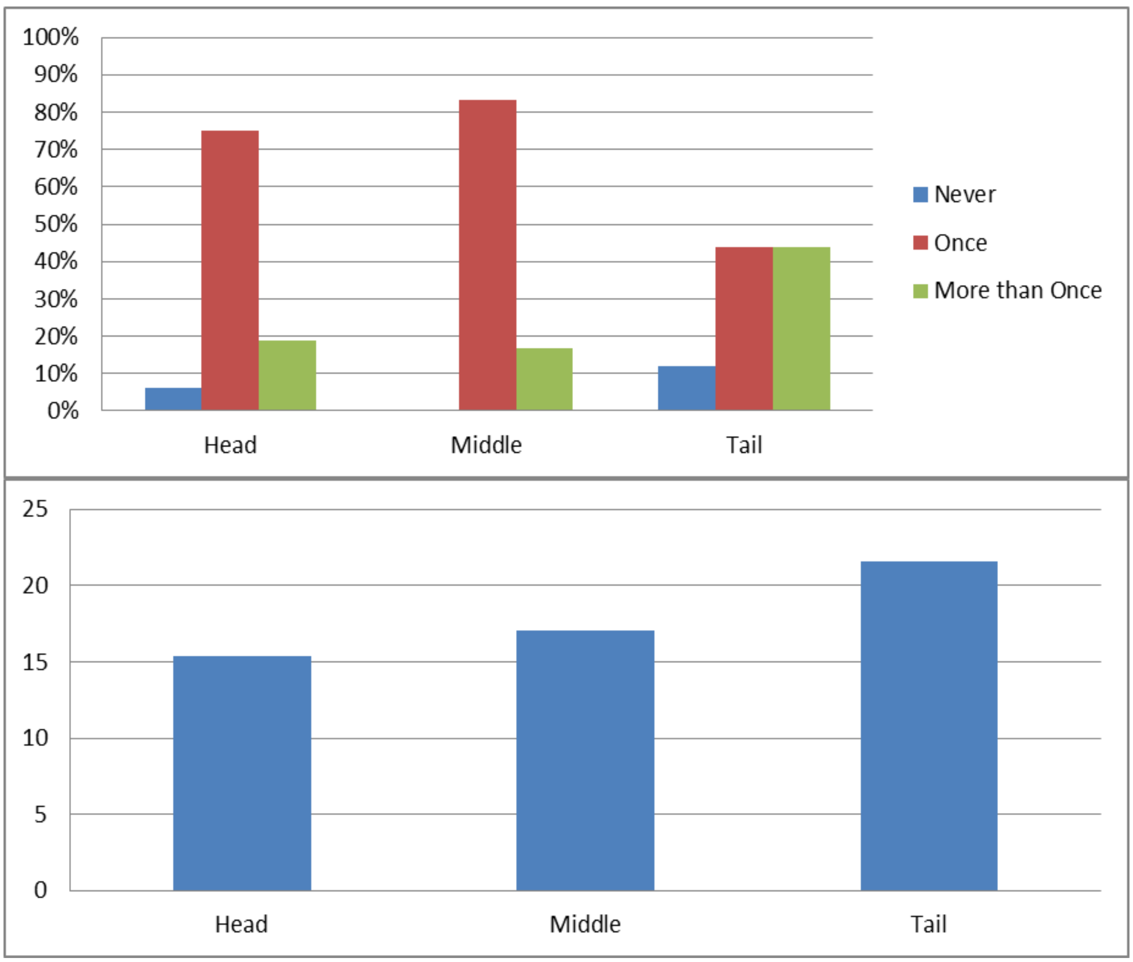

Figure 4.5: Frequency of canal cleaning, Top Frame, and days spent cleaning, Bottom Frame. Source: Diagnostic Assessment (AWATT, 2009)

During winter months there is greater precipitation and more river flows than in the spring months, as shown in Figure 4.6. Unfortunately this does not correspond with peak water demands which occur in the spring. This leads to severe water shortages with farmers forced to cultivate only a small percentage of their land due to lack of irrigation water.

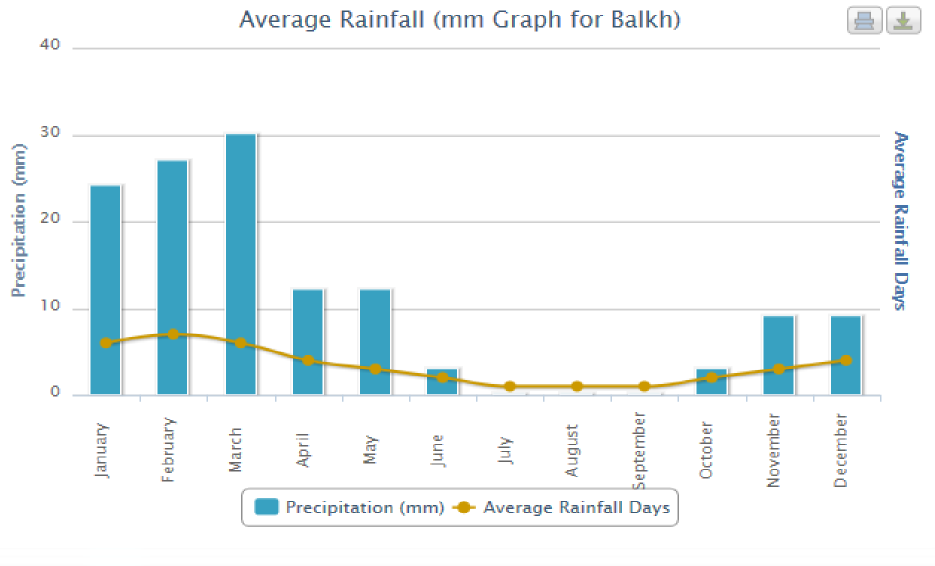

Figure 4.6: Average rainfall in mm in Balkh, Afghanistan (Source: world weather online)

The warm climate and moderate winter frosts are conductive to intensive double cropping agriculture in the Balkh Watershed. While producers are able to double crop, the temperatures in the winter do not allow as wide a variety of crops to be grown as in the spring. Not only do cropping patterns differ by season, but different crop mixes are found based on the producers' spatial location on the canal. Panels A and B in Figure 4.7 shows crop mixes in the two different seasons by producers location on the canal. As can be seen in Figure 4.7, a more diverse, higher valued, crop mix is grown in the spring while the winter is dominated by Wheat and Barley production. As discussed above, more water is available in the winter months than the spring months. Figure 4.8 below shows crop water requirements of many of the crops grown in either the spring and the winter, illustrating that there is a disconnect between the timing of precipitation (Winter) and when high water use crops are grown (Spring). This dissertation research will focus on water management strategies for three spring crops, cotton, melon/watermelon, and onion, as producers face water scarcity in the spring.

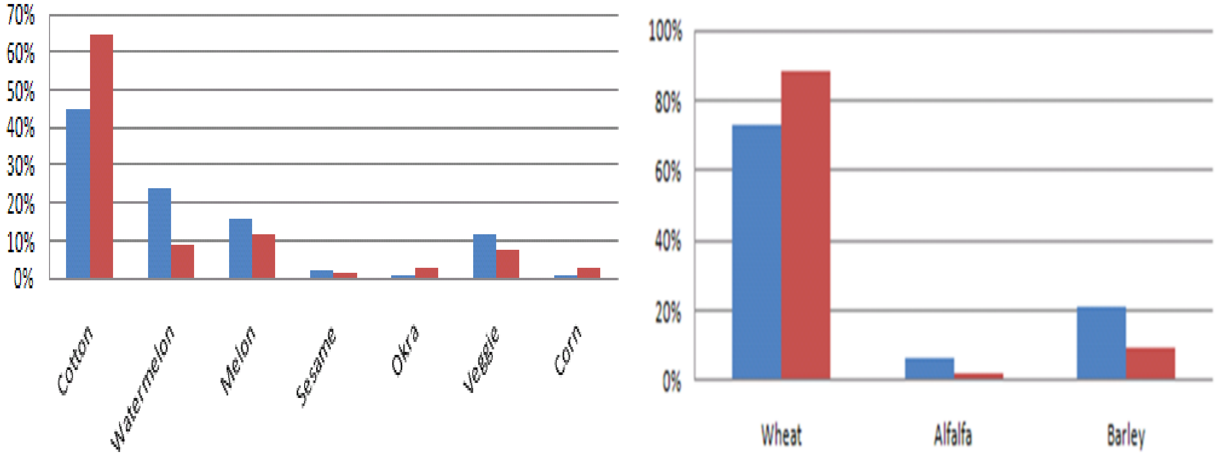

Figure 4.7: Crop Mix on Cultivated Land in the Spring (Panel A) and Winter (Panel B) Blue bars head/ middle of the canal and red bars tail of the canal. Source: Diagnotic Assessment (AWATT, 2009)

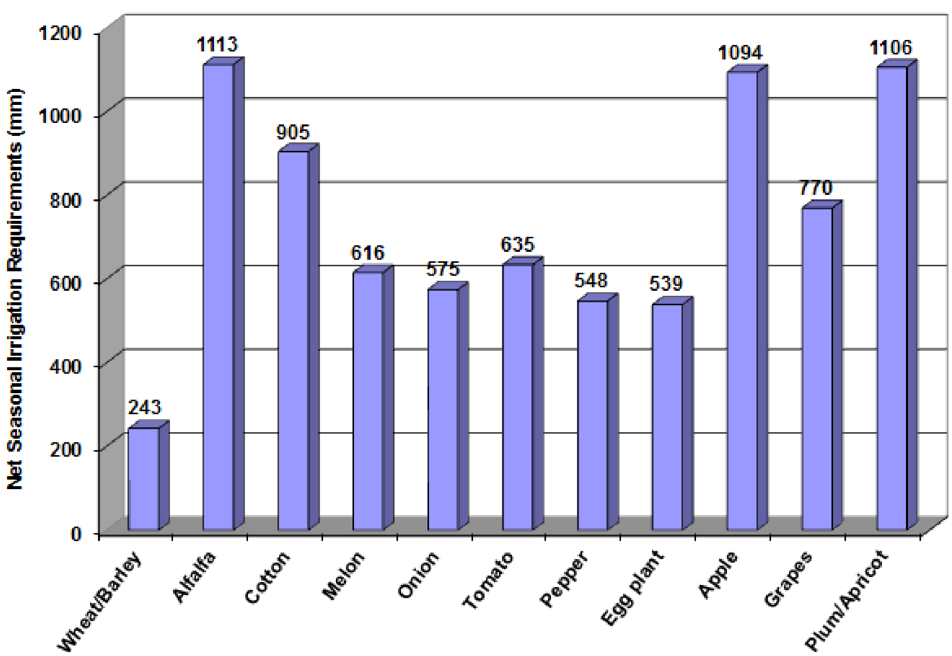

Figure 4.8: Net Seasonal Irrigation Requirements in Balkh, Afghanistan. Source: (De Brito, 2010)

The results of the survey discussed above regarding the large proportion of land left fallow, illustrate that water is scarce in Afghanistan, and if it is not properly allocated farmers will face water shortages. The survey also indicated that farmers located in the head of the canal are less likely to face scarcity issues, while farmers in the tail are more susceptible. Due to the conflict and other political constraints, it is unlikely that markets provide more equitable distribution of water. There are no official water markets in Afghanistan which poses many problems for water distribution, infrastructure, water pricing and organizing farmers. Afghanistan has a traditional system, called warabandi, where water is allocated through water rights which define how much and when the water get used, which is often tied to land ownership. Under the warabandi allocation system, farmers take turns diverting water, and turns are defined as an amount of time that water can be drawn from the watercourse, which is based on farmer landholdings (Rout, 2008). This system of water rights often works well in societies that are stable, but with poverty and conflict in Afghanistan the system is currently not working well. In Afghanistan total irrigated cropland has declined from 3.3 million hectares to 1.6 million hectares because of the negative impacts of war and disrepair on infrastructure. Flow records show that the availability of water in the area has decreased around 34.4% due to conflict. For these reasons this research focuses on water management strategies that may allow more water to reach the tail of the canal.

The variability in stream flows in the Balkh Watershed discussed above and the mismatch water available and crop need, seen in Figure 4.9, indicate that benefit could be gained through the storage of water during high flows in the winter for use in the spring. Without storage the water flows are continuous, with surpluses lost and benefits limited by the availability of water during the months when peak water demand is needed. Scenario 1, presented below, represents the building of storage that will increase the total water supply in the Spring by ten percent.

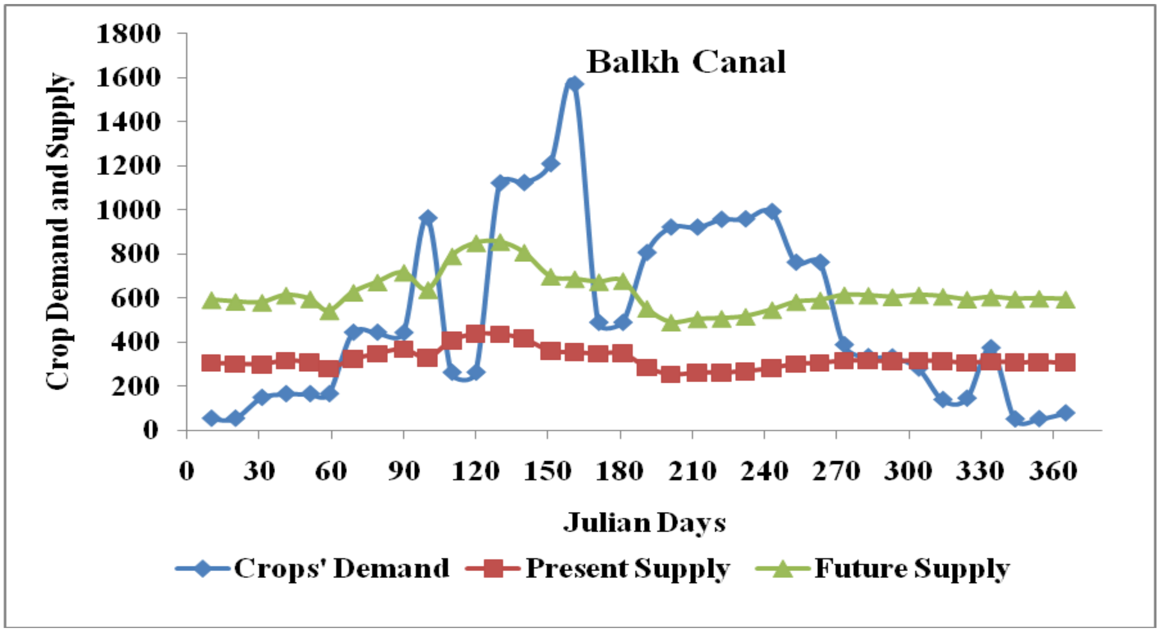

Figure 4.9: Supply and demand of water, Source: Diagnostic Assessment (AWATT, 2009)

Another water conservation practice that has been implemented in developing countries is land leveling. Existing literature has shown that land leveling leads to water savings as well as positive impact on crop productivity, such as increased crop germination and yield (Jonish, 1991; Clemmens et al, 1995; Ren et al, 2003; and Rickman, 2002). The AWATT survey asked producers along the canal if there was poor leveling status, finding that farmers did report poor land leveling (Figure 4.10). A study of land leveling in Egypt found the water savings from land leveling to be between 19% and 29% (Tantaway et al., 2006) while another study looking at India found even greater water use reductions of 31% to 50%. Scenario 2 of this analysis represents the fairly conservative water savings of 25% for the adoption of land leveling on the studies canals in Balkh, Afghanistan.

Results of the AWATT research shows that the condition of canal infrastructure, along with the distribution and management systems are not in good shape. The research found that around one-third of water in two of the three sampled canals is lost due to poor maintenance and weed growth on the side of the canals. The third scenario represents the installation of farm turnouts to reduce this water loss from water course walls. Scenario 3 represents a reduction of 10%, a reduction of one-third of the current water losses across the entire system, thereby increasing the available supply to farmers.

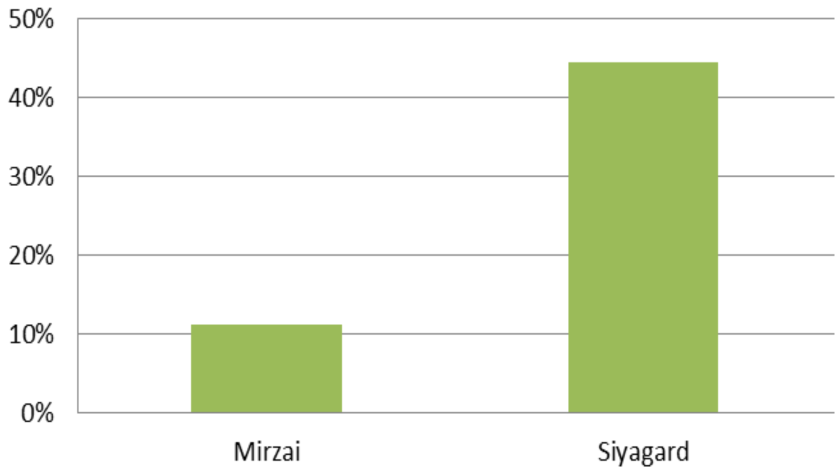

Figure 4.10: Self-Reported Percentage of Farms with Poor Land Level Status; Source Diagnostic Assesment (AWATT, 2009)

Methodology

For this research, a partial equilibrium model, specifically an equilibrium displacement model (EDM), will be applied. A partial equilibrium model is appropriate because the focus is on a small canal, where changes will have a limited effect on the whole economy. The EDM is widely used in agricultural policy analysis, as it can be used to evaluate impacts on the market equilibrium of changes in exogenous variables that affect supply and demand. Once these impacts are calculated, an EDM also allows the evaluation of welfare effects to different agents in the system, through the calculation of producer surplus. Due to the nature of the EDM, it is an ideal model for our situation as it is relatively easy to parameterize, and the elasiticities can be taken from the literature as current data is difficult to obtain in unstable conditions as in Afghanistan. In addition, this model allows the differentiation of producers based on location on the canal, while also considering the production of multiple products. Lastly, the results are such that they can be easily understood by policy makers.

An EDM is a price endogenous model that allows a sector-wide comparative statics analysis of the production of crops. The model enforces optimality conditions on the perfectly competitive equilibrium over all products and factors, and has been used extensively in evaluating the effects of different policies on producer and consumer surpluses. This analysis will look at the effects of the adoption of three different water management strategies in our target Afghanistan canal system. These policies are highlighted in scenario descriptions and include storage creation through the installation of a reservoir, water savings during application through land levelling, and canal seepage reduction through the installation of farm turnouts.

The basic structure of the EDM models, in matrix form, is shown below; the EDM will be used to solve for percentage changes in the endogenous variables resulting from percentage changes in exogenous variables (shocks resulting from the outlined scenarios) to the system:

$$(4.1)\ AY=BX$$

Where:

A = a 24 x 24 non-singular matrix of elasticities.

Y = a 24 x 1 vector of changes in the endogenous variables.

B = a 24 x 27 matrix of parameters associated with the exogenous variables

X = a 27 x 1 vector of percentage changes in the exogenous demand and supply variables

The equation can be reorganized to relate changes in the endogenous variables (Y) caused by changes in the exogenous variables such that:

$$(4.2)\ Y = A^{-1}BX$$

This EDM is a linear approximation to unknown supply and demand functions. If deviations from initial equilibrium are small, the EDM's linear approximation of supply and demand curves is an accurate measure of the supply and demand functions. Here I will use the relatively simply multi-market output side of the EDM used in this research to illustrate the development and structure of the model, and later I will present the more complex relationships that represent the input side of the market.

This analysis looks at three of the most prevalent summer crops; cotton, melon/watermelon, and onions. The model also includes two different inputs into production; water and all other inputs combined. Lastly, the model integrates the spatial location and relationship that effect on water availability in the canal. The survey looked at spatial location on the canal based on three producer locations: the head, the middle and the tail. Due to the complexities of a multi-market and multiple spatial locations on the canal, the head and middle were combined to make the complex model more easily managed. This simplification still leaves us with two spatial locations on the canal, one where water is more frequently available than the other. Subscript definitions are contained in Table 4.4.

Table 4.4: Subscript definitions

Subscript	Definition	Details
i	Summer Crops	i=1; Cotton
		i=2; Melon
		i=3; Onion
j	Producer location	j=1; Head of canal
		j=2; Tail of canal
k	Inputs of Production	k=1; water
		k=2; all other inputs

First, supply and demand relationships for the three outputs are needed. In equilibrium it can be assumed that the demand for each output is equal to its supply, as seen in the identity below:

$$(4.3)\ D_i = S_i = Q_i$$

This will result in three endogenous variables (Q_1, Q_2, and Q_3) representing the quantities of each of the three outputs. Also, the quantity of each output is a function of the prices of all three outputs in this multi-market system. Another identity is used to relate supply (s) and demand (d) output prices, creating the equilibrium price, P_i, to be used in the output equations. The output demand price is equal to the output supply price plus a crop specific marketing margin:

$$(4.4)\ p_i^d = p_i^s + \mu_i = P_i$$

From this, we have an output equation for each of the three crops, where output is a function of own-price as well as the price of the other two crops and an exogenous shift variable, Z_i.

$$(4.5)\ Q_i = f_i(P_1, P_2, P_3, Z_i)$$

The output prices for each crop are a function of the input prices and the exogenous marketing margin. The input price, w, will differ for the two inputs (water and other). In addition the water input price will differ based on the producer's spatial location on the canal.

$$(4.6)\ P_i = f_i(w_{ijk}, w_{ijk}, w_{jk}, \mu_i)$$

The EDM model solutions produce relative changes as opposed to actual values. Therefore, to create the EDM, I totally differentiate the above quantity and price equations to convert them to elasticity form. The equations are then rearranged to solve for the percentage changes in the endogenous variables resulting from selected exogenous shocks, resulting in the six equations below where E denotes the relative change, i.e. $EX = \frac{\partial X}{X} = \partial lnX$. In effect, this means shifting all of the endogenous variables to the left hand side and leaving the exogenous variables on the right:

$$(4.7)\ EQ_1 - \eta_{11}EP_1 - \eta_{12}EP_2 - \eta_{13}EP_3 = \eta_{z1}EZ_1$$

$$(4.8)\ EQ_2 - \eta_{21}EP_1 - \eta_{22}EP_2 - \eta_{23}EP_3 = \eta_{z2}EZ_2$$

$$(4.9)\ EQ_3 - \eta_{31}EP_1 - \eta_{32}EP_2 - \eta_{33}EP_3 = \eta_{z3}EZ_3$$

$$(4.10)\ EP_1 - \theta_{111}Ew_{111} - \theta_{121}Ew_{121} - \theta_{12}Ew_{12} = \theta_1 E\mu_1$$

$$(4.11)\ EP_2 - \theta_{211}Ew_{211} - \theta_{221}Ew_{221} - \theta_{22}Ew_{22} = \theta_2 E\mu_2$$

$$(4.12)\ EP_3 - \theta_{311}Ew_{311} - \theta_{321}Ew_{321} - \theta_{32}Ew_{32} = \theta_3 E\mu_3$$

In the final model, where the equations above are incorporated with input demand and supply equations, input prices (w's) are endogenous to the model. In order to illustrate simply the structure of the EDM model, I will simplify the system by zeroing out all the w's except w_{i2}, and assuming that remaining w_{i2} is exogenous. Thus, equations 4.10-4.12 would be rearranged as follows to have endogenous variables on the left hand side and exogenous variables on the right hand side:

$$(4.13)\ EP_1 = \theta_{12}Ew_{12} + \theta_1 E\mu_1$$

$$(4.14)\ EP_2 = \theta_{22}Ew_{22} + \theta_2 E\mu_2$$

$$(4.15)\ EP_3 = \theta_{32}Ew_{32} + \theta_3 E\mu_3$$

The EDM model in matrix form is shown in equation (4.1) above, where we are solving for the percentage changes in the left hand side endogenous variables Y (Q's and P's). The A matrix is a matrix of elasticities associated with the endogenous variables (η_{ij}'s), while the X matrix is a matrix of the right hand side exogenous variables (Z's and μ's). Lastly, the B matrix is a matrix of the elasticities on the exogenous variables (η_{zi} and θ_is). The system is complete with six endogenous variables (Q's and P's) and six equations. Equation 4.2 for the output system of equations (Equations 4. 7-4.9 and 4.13-4.15) is shown in Figure 4.11 below.

			A					Y								B						X
	EQ1	EQ2	EQ3	EP1	EP2	EP3					EZ_1	EZ_2	EZ_3	Ew_{12}	Ew_{22}	Ew_{32}	$E\mu_1$	$E\mu_2$	$E\mu_3$		
EQ1	1	0	0	(-)η_{11}	(-)η_{12}	(-)η_{13}		EQ1		EQ1	η_{z1}	0	0	0	0	0	0	0	0		EZ_1
EQ2	0	1	0	(-)η_{21}	(-)η_{22}	(-)η_{23}		EQ2		EQ2	0	η_{z2}	0	0	0	0	0	0	0		EZ_2
EQ3	0	0	1	(-)η_{31}	(-)η_{32}	(-)η_{33}	*	EQ3	=	EQ3	0	0	η_{z3}	0	0	0	0	0	0	*	EZ_3
EP1	0	0	0	1	0	0		EP1		EP1	0	0	0	θ_{12}	0	0	θ_1	0	0		Ew_{12}
EP2	0	0	0	0	1	0		EP2		EP2	0	0	0	0	θ_{22}	0	0	θ_2	0		Ew_{22}
EP3	0	0	0	0	0	1		EP3		EP3	0	0	0	0	0	θ_{32}	0	0	θ_3		Ew_{32}
																					$E\mu_1$
																					$E\mu_2$
																					$E\mu_3$

Figure 4.11: EDM in Matrix Form, Output Equations

The system is then reorganized to relate changes in the endogenous variables (Y) caused by changes in the exogenous variables (X), which is shown in Figure 4.12.

Y			A						-1			B										X
			EQ1	EQ2	EQ3	EP1	EP2	EP3				EZ_1	EZ_2	EZ_3	Ew_{12}	Ew_{22}	Ew_{32}	$E\mu_1$	$E\mu_2$	$E\mu_3$		
EQ1		EQ1	1	0	0	(-)η_{11}	(-)η_{12}	(-)η_{13}			EQ1	η_{z1}	0	0	0	0	0	0	0	0		EZ_1
EQ2		EQ2	0	1	0	(-)η_{21}	(-)η_{22}	(-)η_{23}			EQ2	0	η_{z2}	0	0	0	0	0	0	0		EZ_2
EQ3	=	EQ3	0	0	1	(-)η_{31}	(-)η_{32}	(-)η_{33}		*	EQ3	0	0	η_{z3}	0	0	0	0	0	0	*	EZ_3
EP1		EP1	0	0	0	1	0	0			EP1	0	0	0	θ_{12}	0	0	θ_1	0	0		Ew_{12}
EP2		EP2	0	0	0	0	1	0			EP2	0	0	0	0	θ_{22}	0	0	θ_2	0		Ew_{22}
EP3		EP3	0	0	0	0	0	1			EP3	0	0	0	0	0	θ_{32}	0	0	θ_3		Ew_{32}
																						$E\mu_1$
																						$E\mu_2$
																						$E\mu_3$

Figure 4.12: EDM Reorganized with Endogenous as a Function of Exogenous

The model is populated with all elasticities (Matrix A and Matrix B), leaving only Y and X pot be derived and assumed. The scenarios determine the shocks to the X Matrix, and then solving for the unknown changes in the endogenous variables, Y. In this simplified output side example, the exogenous variables are the income of the population (Z), the other input price (w) and the marketing margin (μ). Therefore, if we wanted to see how a 10% increase in the marketing margin for cotton impacts the system we would put a 0.10 in for $E\mu_1$ in the X matrix, in the third element from the bottom, and solve for Y. For this research, we shock selected exogenous shifters to the water input, which will enter the system in a manner similar to the marketing margin example described above, except that it will enter input equations as opposed to output equations. Please see Appendix A.1 for a listing of the entire system of input and output equations. Tables 4.5 and 4.6 below display a full list of all the endogenous and exogenous variables in the system (both output and input).

Table 4.5: Endogenous variables

Endogenous Variables	
Variable	***Definition***
Q_1	output of cotton, in equilibrium
Q_2	output of melon. In equilibrium
Q_3	output of onion, in equilibrium
P_1	price of cotton, in equilibrium
P_2	price of melon, in equilibrium
P_3	price of onion, in equilibrium
$X_{111}{}^d$	demand, for production of cotton in the head, for the input water
$X_{121}{}^d$	demand, for the production of cotton in the tail, for the input water
$X_{112}{}^d$	demand, for the production of cotton in the head, for the input other
$X_{122}{}^d$	demand, for the production of cotton in the tail, for the input other
$X_{111}{}^s$	supply, for the production of cotton in the head, of the input water
$X_{121}{}^s$	supply, for the production of cotton in the tail, of the input water
$X_{112}{}^s$	supply, for the production of cotton in the head, of the input other
$X_{122}{}^s$	supply, for the production of cotton in the tail, of the input other
$X_{211}{}^d$	demand, for production of melon in the head, for the input water
$X_{221}{}^d$	demand, for the production of melon in the tail, for the input water
$X_{212}{}^d$	demand, for the production of melon in the head, for the input other
$X_{222}{}^d$	demand, for the production of melon in the tail, for the input other
$X_{211}{}^s$	supply, for the production of melon in the head, of the input water
$X_{221}{}^s$	supply, for the production of cotton in the tail, of the input water
$X_{212}{}^s$	supply, for the production of melon in the head, of the input other
$X_{222}{}^s$	supply, for the production of melon in the tail, of the input other
$X_{311}{}^d$	demand, for production of onion in the head, for the input water
$X_{321}{}^d$	demand, for the production of onion in the tail, for the input water
$X_{312}{}^d$	demand, for the production of onion in the head, for the input other
$X_{322}{}^d$	demand, for the production of onion in the tail, for the input other
$X_{311}{}^s$	supply, for the production of onion in the head, of the input water
$X_{321}{}^s$	supply, for the production of onion in the tail, of the input water
$X_{312}{}^s$	supply, for the production of onion in the head, of the input other
$X_{322}{}^s$	supply, for the production of onion in the tail, of the input other
w_{111}	price, for the production of cotton in the head, of water
w_{121}	price, for the production of cotton in the tail, of water
w_{12}	price, for the production of cotton, of other
w_{211}	price, for the production of melon in the head, of water
w_{221}	price, for the production of melon in the tail, of water
w_{22}	price, for the production of melon, of other
w_{311}	price, for the production of onion in the head, of water
w_{321}	price, for the production of onion in the tail, of water
w_{32}	price, for the production of onion, of other

Table 4.6: Exogenous variables

Exogenous Variables	
Variable	***Definition***
Z_1	income
Z_2	income
Z_3	income
u_1	Cotton marketing margin
u_2	Melon marketing margin
u_3	Onion marketing margin
G_{111}	technology (cotton, head, water)
G_{121}	technology (cotton, tail, water)
G_{112}	technology (cotton, head, other)
G_{122}	technology (cotton, tail, other)
G_{211}	technology (melon, head, water)
G_{221}	technology (melon, tail, water)
G_{212}	technology (melon, head, other)
G_{222}	technology (melon, tail, other)
G_{311}	technology (onion, head, water)
G_{321}	technology (onion, tail, water)
G_{312}	technology (onion, head, other)
G_{322}	technology (onion, tail, other)
B_{111}	productivity (cotton, head, water)
B_{121}	productivity (cotton, tail, water)
B_{112}	productivity (cotton, head, other)
B_{122}	productivity (cotton, tail, other)
B_{211}	productivity (melon, head, water)
B_{221}	productivity (melon, tail, water)
B_{212}	productivity (melon, head, other)
B_{222}	productivity (melon, tail, other)
B_{311}	productivity (onion, head, water)
B_{321}	productivity (onion, tail, water)
B_{312}	productivity (onion, head, other)
B_{322}	productivity (onion, tail, other)

Full descriptions of the input structure and the fully differentiated equations can be seen in Appendix tables A.1 and A.2, and while I will not derive the input equations as I did for the output equations, I highlight some of the relationships that are of key importance to this analysis. A condensed version of the input demand and supply equations are as follows:

$$(4.16)\ X_{ijk}^{d} = f(w_{i11}, w_{i21}, w_{12}, Q_i, G_{ijk})$$

$$(4.17)\ X_{ijk}^{s} = f(w_{i11}, w_{i21}, w_{12}, B_{ijk})$$

where the w's are input prices, with water input varying both by crop and producer spatial location. The 'other input' only varies by crop, and is assumed to be the same regardless of where the producer is located on the canal. G and B are exogenous shifters to the system, as will be described later. It is these (as well as $\bar{x}$) that will be used to incorporate the different scenarios into the model.

The unique spatial water use differences of the canal need to be incorporated into the EDM model. Let $\bar{x}$ be the total water in the system, which is exogenous, and initially this represents surface water flows, but total water availability could increase with the creation of storage to carry excess water from the winter season. The total water used in the head is (with subscript definitions that are the same as for outputs):

$$(4.18)\ x_{11} = \sum_{i=1}^{3} x_{i11}$$

And the total water used in the tail is:

$$(4.19)\ x_{21} = \sum_{i=1}^{3} x_{i21}$$

Since the head gets first use of the water and the tail only gets whatever is left over, I introduce the following additional behavioral equation that introduces one additional endogenous variable, x_{21}, and one exogenous variable, $\bar{x}$:

$$(4.20)\ x_{21} = \bar{x} - x_{111} - x_{211} - x_{311} + \delta_r r$$

where r is an exogenous shifter. As in the output side, the input supply and demand are equal in equilibrium, as are the input supply and demand prices. Because of the relationship between the three crops, if I know the water input used for cotton and melon, the water input use for onion can be calculated outside the model from the above equations, allowing for a reduction in the endogenous variables that must be estimated. The final equilibrium system contains twenty-four endogenous variables and twenty-seven exogenous variables.

The scenarios in this analysis evaluate the impacts of three different water management strategies: Storage creation through a reservoir, increased water application efficiency through land leveling, and the reduction of water loss through canal seepage from the installation of farm turnouts. The scenarios will be introduced into the X matrix as percent changes in the following exogenous variables: $E\bar{x}$,EG_{ijk}, EB_{ijk}. Storage creation will increase the total water supply by 10%, which is modeled as a 10% change in $E\bar{x}$. Land leveling, which is a water saving technology, will decrease input demand per unit of output by 25% represented with a decrease in the exogenous variable on input demand, EG_{ijk}. Lastly, the installation of farm turnouts will reduce seepage from the water course walls thereby increasing input supply, represented by the exogenous variable in the input supply equation EB_{ijk}. The X matrix for each of the three scenarios can be seen in Table 4.7 below.

One of the reasons for choosing an EDM was that instead of looking at absolute values it looks at relative changes, making the data requirements minimal. In order to estimate the model, the relative changes need to be determined, so elasticity values are assigned to the endogenous and exogenous model parameters (A and B Matrices). There are several approaches to determining elasticity estimates: direct estimation via econometric methods; extrapolating and modifying from previously published studies; and hypothesizing through the use of a combination of published results, intuition and economic theory (James and Alston, 2002). Due to the undeveloped market information systems in the area of the current study, Afghanistan, data is limited so this dissertation research will customize the elasticity estimates drawing from previously published studies, and intuition and economic theory.

Table 4.7: Changes to the X Matrix from the 3 Water Management Scenarios

	Scenario One	Scenaro Two	Scenario Three
EZ1	0	0	0
EZ2	0	0	0
EZ3	0	0	0
Eμ1	0	0	0
Eμ2	0	0	0
Eμ3	0	0	0
EG111	0	0.25	0
EG121	0	0	0
EG112	0	0	0
EG122	0	0	0
EG211	0	0.25	0
EG221	0	0	0
EG212	0	0	0
EG222	0	0	0
EG321	0	0	0
EB121	0	0	0.1
EB112	0	0	0.1
EB212	0	0	0.1
EB221	0	0	0.1
EB321	0	0	0.1
Er21	0.1	0	0
EG311	0	0.25	0
EB311	0	0	0.1
EG312	0	0	0
EB312	0	0	0.1
EG322	0	0	0
EB322	0	0	0.1
EB111	0	0	0.1
EB122	0	0	0.1
EB222	0	0	0.1
EB211	0	0	0.1

Elasticities for both inputs and outputs are needed to estimate the EDM. This dissertation is a multi-market analysis, with three different crops cotton, melon and onion, so on the output side, the model needs to be populated with own and cross price elasticities for each of the three outputs. Own-price elasticity of demand is negative, as the price of the product increases, demand decreases, but it is highly elastic as the canal system is a very small area as compared to the entire region. If producers on the canal increase output prices, consumers will just purchase the output elsewhere, so producers are very much price takers. The model also contains cross-price elasticities between the outputs; the cross-price output elasticities are set to zero as the price of one product increases it is likely to have no effect on the other product as they are such different products and such a small amount of the total market for the goods.

Input shares of total output price, also need to be calculated for each of the three outputs. The model distinguishes between two different inputs in the production of the products, water and 'other'; where other input represents all inputs used in production except for the water input. Thus, if the crop is more water intensive a greater cost share will be associated with the water input. Figure 4.8 in the background section shows that cotton has a greater crop water requirement than the other two outputs, melon and onion. Information on the crop water requirements along with water cost-share values used by Alhashim are used to estimate cost shares for this analysis (Alhashim, 2010). Cotton, which has the greatest crop water requirement, will have the greatest water cost share of the three crops.

Elasticities also need to be populated for the input demand and supply equations. Input elasticities do not only differ based on the three outputs, but vary for the also two inputs and two different spatial locations on the canal. The own-price elasticities of both inputs in all spatial locations are negative indicating that as the price of the input increases, the use of that input decreases. I am also assuming that producers both in the head and the tail of the canal are more sensitive to changes in water prices than changes in 'other' input prices. Unlike the outputs, it is likely that there are cross- price elasticities between inputs. As discussed in the background section, the head gets water first, followed by the tail. Because of this relationship, the cross price elasticity of the water input in the tail on the water input in the head is zero, but all other cross-price elasticities have a non-zero value.

The cross-price elasticity associated with the price of water in head and the other input demand in the tail has a small but positive value because an increase in the water price in the head will cause the head to use less water, thus allowing more to flow downstream to tail users. To determine the other cross-price elasticities between water and the 'other' input, it first must be determined if they are complements or substitutes. Past research has found mixed results on the complementarity/ substitutability of water with respect to other production inputs (Cai et al., 2008). Because the other input in this example is an aggregation of all other inputs, it is difficult to determine if in aggregate they are complements or substitutes. For this reason, this analysis will evaluate each scenario with complement (negative) input cross-price elasticities and substitute (positive) input cross-price elasticities. The results from the two different input treatments will then be compared. Lastly, the cross price input demand elasticities with respect to a product are assumed to be a one-on-one relationship, meaning that an increase in output has a proportional increase on the inputs. Input supply elasticities have been motivated in large part by work done by Alhashim (Alhashim, 2010). The own price elasticity of input supply for the water input is positive and highly inelastic as the supply of water is relatively fixed. The own-price elasticity of supply for the 'other' input is also positive but much more elastic as many trade-offs can occur with the other input. Initially cross-price elasticities of input supply are set to zero, as the water input supply is relatively fixed.

<u>Results:</u>

Three scenarios were analyzed to evaluate the percent changes in output and input prices and quantities for three crops and two different spatial locations. The results are shown below in Table 4.8 if inputs are assumed to be substitutes and Table 4.9 if inputs are assumed to be complements.

Table 4.8: Results Input Substitutes

	Scenario 1	Scenario 2	Scenario 3
EQ1	0.07	0.82	0.33
EQ2	0.00	0.03	0.01
EQ3	0.00	-0.31	-0.07
EP1	-0.04	-0.46	-0.18
EP2	0.00	-0.02	-0.01
EP3	0.00	0.22	0.05
EX111	0.07	0.84	0.28
EX121	0.03	0.16	0.07
EX112	0.09	0.94	0.38
EX211	0.00	0.21	0.02
EX221	0.00	-0.09	-0.03
EX212	0.00	0.06	0.02
EX311	0.00	-0.98	-0.27
EX321	0.00	-0.34	-0.09
EX21	0.03	-0.08	-0.04
Ew111	0.06	0.76	0.30
Ew121	0.09	1.11	0.44
Ew211	-0.11	-1.35	-0.53
Ew221	0.00	0.12	0.04
Ew311	0.00	0.30	0.10
Ew321	0.00	-0.12	-0.04
Ew12	0.00	0.32	0.09
Ew22	0.00	-0.10	0.00
Ew32	0.00	0.45	0.09

Table 4.9: Results, Input Complements

	Scenario 1	Scenario 2	Scenario 3
EQ1	-0.09	0.50	-0.19
EQ2	-0.02	-0.09	-0.04
EQ3	-0.01	-0.07	-0.02
EP1	0.05	-0.28	0.11
EP2	0.01	0.06	0.03
EP3	0.01	0.05	0.01
EX111	0.05	-0.21	0.05
EX121	0.07	0.23	0.11
EX112	-0.17	1.01	-0.35
EX211	0.02	0.17	0.01
EX221	0.06	0.18	0.08
EX212	-0.04	-0.20	-0.08
EX311	-0.01	-0.14	-0.07
EX321	0.00	0.05	-0.01
EX21	0.05	0.18	0.00
Ew111	-0.03	0.25	-0.04
Ew121	-0.05	-0.14	-0.07
Ew211	0.12	-0.63	0.26
Ew221	0.00	0.07	0.02
Ew311	-0.09	-0.32	-0.14
Ew321	0.05	0.18	0.08
Ew12	0.01	0.09	0.04
Ew22	0.00	0.00	0.02
Ew32	0.01	0.10	0.02

Scenario 1: Increase water storage by 10%, through the creation of a reservoir.

The impacts of a 10% increase in water supply were sensitive to how the inputs were treated in the model, as complements or substitutes; this sensitivity was found for all three scenarios. If the inputs are substitutes, then output quantities of cotton increased by 7% and the price of cotton decreased by 4%, and only negligible changes were found in for the prices and quantities for the other two outputs. As would be expected the increase in the output of cotton corresponded with an increase in inputs used for cotton, while there were only negligible changes in input use for the other two outputs.

The results were opposite for cotton if inputs were treated as complements, output decreased by 9% and the price increased by 5%. Changes in the other two outputs were similar to cotton except smaller. Slight increases in input quantity were found for all inputs in the tail of the canal, and for water used for cotton and melon in the head. Interestingly, throughout the head, the other input use decreased; most notably a 17% decrease in the other input used for cotton. The results for cotton in the head is one area that needs to be explored further and may indicate an area for model improvement, as the two inputs are assumed to be complements yet move in opposite directions. As would be expected, small decreases were found in the price of water used for cotton production. Water price in the head increased for melon and decreased for onion, while the opposite was true for the tail with increases for onion and decreases for melon. Indicating that there are policy differences across both spatial locations and crops. Input price changes for the other input were small but positive, which is interesting considering all output quantities decreased. For both input relationships the increase in water storage corresponded with an increase in total water availability in the tail ranging from 3% (input substitutes) to 5% (input complements).

Scenario 2: Reduce water lost in application by 25% through the adoption of land leveling in the head of the canal.

For both input treatments (substitutes and complements) the adoption of land leveling drastically increased the production of cotton (82% for substitutes and 50% for complements) while decreasing the price of cotton (46% for substitutes and 50% for complements). The drastic increase in the output of cotton was accompanied by an increase in all inputs used in the production of cotton, except for a 21% decrease in water in the head used for cotton when inputs are treated as complements. The percent increase in input use for cotton is as high as 100% for other input use and 84% for water use; both these high values were found in the head of the canal indicating that the extensive increase in cotton production may be coming from producers in the head of the canal.

If inputs are treated as substitutes the production of melon increases and the production of onion decreases. Changes in the use of inputs in the melon market indicate that the increase found in melon production came from increased production in the head of the canal, while the tail of the canal decreased production. If inputs were treated as complements, there was a decrease in the production of melon and onion. Interestingly, the water used in the production of melon increased, but the other input use decreased. Again, since the two inputs are assumed to be complements we would expect them to move in the same direction. An examination of onion inputs indicates that the overall decrease in onion production appears to be from a reduction in the head, while there is an increase in onion production in the tail. Both input complementarity and input substitutability found large changes (greater than 10% in most cases) in both negative and positive directions for input prices. If inputs are substitutes total water available in the head decrease by 8%, while if they are complements, it increases by 18%

Scenario 3: Installation of farm turnouts throughout the canal that reduces seepage by 10% from the water course walls, thereby increasing input supply of water.

If inputs are treated as substitutes, the reduction in seepage would result in a 33% increase in the production of cotton as well as substantial increases in cotton input use and cotton input prices. Melon production also increases but only by 1% and changes in input indicated that there is an increase in production in the head and a decrease in the tail. Onion output decrease as well as a decrease in onion input use. If inputs are complements the reduction in seepage will result in a reduction in production of all three crops, with cotton decreasing the most at 19%. As with the other two scenarios there is a counterintuitive result with input use towards cotton and also in melon, there is an increase in the use of water but a decrease in the use of the other input. As would be expected the decrease in onion output is accompanied by a decrease in onion input use. For both input treatments other input prices increased (or remained unchanged) for all products while mixed results were found for water input prices. If inputs are substitutes the availability of water in the tail decreases by 4%, if they are complements there is no impact on total water availability in the tail.

Conclusions/Future Work:

If the intention of the water management and storage policies is to increase the water availability in the tail of the canal, the relationship of the inputs is of key importance. If inputs are substitutes the implementation of these water management strategies can actually decrease the water available in the tail and thus increase the inequity that the tail faces. If the inputs are complements the model indicates that at the very least the implementation of any of the policies does not decrease the availability of water in the tail, and could increase water availability as much as 18%. Increasing the water supply is the only of the three policies that does not harm the tail regardless of input relationships, indicating that it might be the lowest risk policy option when policy makers know little about production in the area. Also of interest is that policies will impact the head and tail very differently. In some instances in reaction to a policy the head will increase production of a crop, while the tail decreases production and vice versa. The results indicate that spatial relationships along the canal matter and if policy makers ignore these relationships policy enactment may cause undesirable results.

There are many future extensions that could be undertaken to improve upon the base model. In order to reduce complexity, the base model combines the head and the middle of the canal into one spatial location, this simplification could be relaxed and all three locations could be incorporated into the model. In the future more sensitivity analysis (other than just input complements and substitutes) should be conducted. Another future extension would be to use and base values of prices and quantities to present producers surplus changes, as opposed to just percent changes in prices and quantities.

In the future the EDM model could also be modified to explore different policy questions in Balkh, Afghanistan. One research question extension would be to analyze the impacts of changes in livestock management on producers. The AWATT survey identified that livestock are not fed to an optimal weight due to a shortage of forage for the animals, which may be linked to water availability. The modified model could evaluate a program to educate farmers on the return on investment of allocating more resources, including water, to reach the optimal feeding of livestock. Another possible future extension to this research would be to look at the benefits and costs of water pricing strategies in the Balkh canal system. While Afghanistan may not currently have the infrastructure and stability to implement water pricing, there may come a time in the future where it may be an option. This EDM structure could be used to evaluate the benefits and costs of water pricing policies.

CHAPTER FIVE: CONCLUSIONS

The integration of spatial relationships into the framework used to address and analyze economic programs is a relatively new innovation, but it adds a valuable context with which to view some managerial and policy problems. As the availability of spatial data increases, the pool of research exploring how space impacts economic decision-making has also increased. The three essays in this dissertation illustrate the importance of spatial relationships in three very different empirical applications related to public and private decision making, with a particular focus on the spatial relationships of households and enterprises. The range of issues and methodological approaches in these essays is diverse, but the common theme weaving them together is how spatial factors improve the lens with which we view market and policy dynamics.

This dissertation explored three questions where spatial location is important and can have large economic development implications. Essay one looked at the location behaviors of private outdoor recreation agents through the creation of two dense geo-coded measures of county level public and private outdoor recreation access. The research indicates that there is clustering of outdoor recreation provision and that private agents are attracted to existing public outdoor recreation opportunities. The spatial attraction results in this study have broader impacts for rural economic development because outdoor recreation has positive economic and rural development impacts and also health impacts. Moreover, the findings in this study could inform future discussions on how to leverage long-term public investments to create more economic activity, jobs, or resilience in communities that would otherwise be overly dependent on the public sector's continued investments in their recreational lands.

Essay two focused on a specific type of private outdoor recreation, agritourism. Results from the second essay confirmed results found in paper one: more trips on average were taken to agritourism operations in areas with high levels of outdoor recreation access, suggesting that a clustering of recreational opportunities may be a "magnet" to drive more tourism, especially to regions where travel times and distances necessitate a critical mass of options for travelers. Since this essay focused on a smaller area, the state of Colorado, the survey of recent agritourists contained more detail on each individual, although it was at the expense of sample size, particularly in some regions of the state. A Travel Cost Model analysis of agritourists found that there are significant welfare benefits to agritourism visitors. Again, this essay's results are quite timely as the state of Colorado begins a strategic planning process for agricultural and heritage tourism under its Tourism Economic Development Cluster. Not only does it provide evidence of agritourism's fit in a state historically known as an outdoor recreation mecca, but may even suggest that more could be done to leverage the public investment in parks, forests, and other recreational assets.

The third essay creates an Equilibrium Displacement Model to answer an economic problem where spatial location is of key importance but data availability on current spatial dynamics is more limited. By examining how private stakeholders in a water basin behave and evaluating different potential policy levers, it demonstrates the essential role the spatial dimension may play in policy analysis. In Balkh, Afghanistan, water rights are assigned as an amount of time that a rights holder may divert water from the canal; consequently, water can sometimes be depleted before producers in the tail get an opportunity to divert water. This makes a producer's location on the canal an important driver of their economic well-being. In this essay, I evaluate the location-specific impacts of three different water management scenarios, finding that the impacts to producers of policies differ based on the producers spatial location on the canal.

Overall, this dissertation illustrates that spatial relationships do matter, both in model accuracy and the economic development implications of economic research. However, there are limitations to the approaches presented here, and, as is often the case, these limitations suggest where future research could make additional contributions to the literature. As a rule, the main limitations of these essays related to the availability of data, especially data with the specificity needed to address the matter at hand. So, future research investments in GIS-based data appear to be warranted, particularly to inform discussions in the U.S. on the returns to investments in public outdoor recreation. GIS-based data on a broader selection of natural resources is also desirable, as illustrated by the essay on water in a developing country. Making crucial infrastructure investments or policy decisions intended to improve the productivity of a resource-dependent sector will be difficult and imprecise unless more data is collected from key stakeholders while paying close attention to heterogeneity across the spatial dimension.

Clearly, future research into each of these topics will help the economic and regional development fields, as well as the natural resource management and policy sectors, to gain a better understanding of spatial impacts. In essay one, the analysis is conducted at a national level, but it is likely that private agents react differently in different areas of the country. Future analyses should be conducted at a regional and state (or sub-state) level. Moreover, it would be interesting to further improve the outdoor recreation measures to consider more heterogeneity than just public and private ownership. Essay two also indicated that region matters; specifically, regions close to population centers see more agritourism trips, and this is consistent with much of the regional development literature that concludes that agglomeration effects will dominate economic development patterns. Future research should draw upon a large enough sample to look at more individual regional welfare impacts, particularly as it relates to the findings presented in essay one, where public lands and areas can be seen as a catalyst for private enterprise. In addition, the third paper makes several assumptions to reduce model complexity that should be relaxed in the future for richer results. Finally, the model should continue to be extended to incorporate farmer decisions related to things such as crop drought tolerance as ways to manage risk in the face of high variability in water availability.

In summary, this dissertation as a whole, and each piece in its own approach, contributes a great deal to our understanding of how the spatial dimension matters, how to integrate such factors into empirical research, and what more spatially-rich results may mean to improving the efficacy of managerial decisions and policy analysis. Although each piece makes a contribution on its own, together they reinforce the implications of ignoring the spatial dimension in any applied research that focuses on the management and policies surrounding natural resources.

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APPENDIX: A.1

Full List of Structural Equations for the EDM model

Cotton:

(A.1) Output: $Q_1 = f_a(P_1, P_2, P_3, Z_1)$

(A.2) Price $P_1 = f_b(w_{111}, w_{121}, w_{12}, \mu_1)$

(A.3) Water Input Demand, head ${X_{111}}^d = f_c(w_{111}, w_{121}, w_{12}, Q_1, G_{111})$

(A.4) Water Input Demand, tail ${X_{121}}^d = f_d(w_{111}, w_{121}, w_{12}, Q_1, G_{121})$

(A.5) Other Input Demand, head ${X_{112}}^d = f_e(w_{111}, w_{121}, w_{12}, Q_1, G_{112})$

(A.6) Other Input Demand, tail ${X_{122}}^d = f_f(w_{111}, w_{121}, w_{12}, Q_1, G_{122})$

(A.7) Water Input Supply, head ${X_{111}}^s = f_g(w_{111}, w_{121}, w_{12}, B_{111})$

(A.8) Water Input Supply, tail ${X_{121}}^s = f_h(w_{111}, w_{121}, w_{12}, B_{121})$

(A.9) Other Input Supply, head ${X_{112}}^s = f_i(w_{111}, w_{121}, w_{12}, B_{112})$

(A.10) Other Input Supply, tail ${X_{122}}^s = f_j(w_{111}, w_{121}, w_{12}, B_{122})$

Melon:

(A.11) Output: $Q_2 = f_k(P_1, P_2, P_3, Z_2)$

(A.12) Price $P_2 = f_l(w_{211}, w_{221}, w_{22}, \mu_2)$

(A.13) Water Input Demand, head ${X_{211}}^d = f_m(w_{211}, w_{221}, w_{22}, Q_2, G_{211})$

(A.14) Water Input Demand, tail ${X_{221}}^d = f_n(w_{211}, w_{221}, w_{22}, Q_2, G_{221})$

(A.15) Other Input Demand, head ${X_{212}}^d = f_o(w_{211}, w_{221}, w_{22}, Q_2, G_{212})$

(A.16) Other Input Demand, tail ${X_{222}}^d = f_p(w_{211}, w_{221}, w_{22}, Q_2, G_{222})$

(A.17) Water Input Supply, head ${X_{211}}^s = f_q(w_{211}, w_{221}, w_{22}, B_{211})$

(A.18) Water Input Supply, tail $X_{221}{}^{s} = f_r(w_{211}, w_{221}, w_{22}, B_{221})$

(A.19) Other Input Supply, head $X_{212}{}^{s} = f_s(w_{211}, w_{221}, w_{22}, B_{212})$

(A.20) Other Input Supply, tail $X_{222}{}^{s} = f_t(w_{211}, w_{221}, w_{22}, B_{222})$

Onion:

(A.21) Output: $Q_3 = f_u(P_1, P_2, P_3, Z_3)$

(A.22) Price $P_3 = f_v(w_{311}, w_{321}, w_{32}, \mu_3)$

(A.23) Water Input Demand, head $X_{311}{}^{d} = f_w(w_{311}, w_{321}, w_{32}, Q_3, G_{311})$

(A.24) Water Input Demand, tail $X_{321}{}^{d} = f_x(w_{311}, w_{321}, w_{32}, Q_3, G_{321})$

(A.25) Other Input Demand, head $X_{312}{}^{d} = f_y(w_{311}, w_{321}, w_{32}, Q_3, G_{312})$

(A.26) Other Input Demand, tail $X_{322}{}^{d} = f_z(w_{311}, w_{321}, w_{32}, Q_3, G_{322})$

(A.27) Water Input Supply, head $X_{311}{}^{s} = f_{aa}(w_{311}, w_{321}, w_{32}, B_{311})$

(A.28) Water Input Supply, tail $X_{321}{}^{s} = f_{bb}(w_{311}, w_{321}, w_{32}, B_{321})$

(A.29) Other Input Supply, head $X_{312}{}^{s} = f_{cc}(w_{311}, w_{321}, w_{32}, B_{312})$

(A.30) Other Input Supply, tail $X_{322}{}^{s} = f_{dd}(w_{311}, w_{321}, w_{32}, B_{322})$

APPENDIX: A.2

Totally Differentiated System of Equations, One Equation for each endogenous variable

Output

(A.31) EQ1: $EQ_1 - \eta_{11}EP_1 - \eta_{12}EP_2 - \eta_{13}EP_3 = \eta_{z1}EZ_1$

(A.32)EQ2: $EQ_2 - \eta_{21}EP_1 - \eta_{22}EP_2 - \eta_{23}EP_3 = \eta_{z2}EZ_2$

(A.33)EQ3: $EQ_3 - \eta_{31}EP_1 - \eta_{32}EP_2 - \eta_{33}EP_3 = \eta_{z3}EZ_3$

(A.34)EP1: $EP_1 - \theta_{111}Ew_{111} - \theta_{121}Ew_{121} - \theta_{12}Ew_{12} = \theta_1 E\mu_1$

(A.35)EP2: $EP_2 - \theta_{211}Ew_{211} - \theta_{221}Ew_{221} - \theta_{22}Ew_{22} = \theta_2 E\mu_2$

(A.36)EP3: $EP_3 - \theta_{311}Ew_{311} - \theta_{321}Ew_{321} - \theta_{32}Ew_{32} = \theta_3 E\mu_3$

Input

(A.37)EX111: $-\alpha_{y1}{}^{11}Q_1 + EX_{111} - \alpha_{111}{}^{11}Ew_{111} - \alpha_{121}{}^{11}Ew_{121} - \alpha_{12}{}^{11}Ew_{12} = \alpha_{G1}{}^{11}EG_{111}$

(A.38)EX121: $-\alpha_{y1}{}^{21}Q_1 + EX_{121} - \alpha_{111}{}^{21}Ew_{111} - \alpha_{121}{}^{21}Ew_{121} - \alpha_{12}{}^{21}Ew_{12} = \alpha_{G1}{}^{21}EG_{121}$

(A.39)EX112: $-\alpha_{y1}{}^{12}Q_1 + EX_{112} - \alpha_{111}{}^{12}Ew_{111} - \alpha_{121}{}^{12}Ew_{121} - \alpha_{12}{}^{12}Ew_{12} = \alpha_{G1}{}^{12}EG_{112}$

(A.40)EX211: $-\alpha_{y2}{}^{11}Q_2 + EX_{211} - \alpha_{211}{}^{11}Ew_{211} - \alpha_{221}{}^{11}Ew_{221} - \alpha_{22}{}^{11}Ew_{22} = \alpha_{G2}{}^{11}EG_{211}$

(A.41)EX221: $-\alpha_{y2}{}^{21}Q_2 + EX_{221} - \alpha_{211}{}^{21}Ew_{211} - \alpha_{221}{}^{21}Ew_{221} - \alpha_{22}{}^{21}Ew_{22} = \alpha_{G2}{}^{21}EG_{221}$

(A.42)EX212: $-\alpha_{y2}{}^{12}Q_2 + EX_{212} - \alpha_{211}{}^{12}Ew_{211} - \alpha_{221}{}^{12}Ew_{221} - \alpha_{22}{}^{12}Ew_{22} = \alpha_{G2}{}^{12}EG_{212}$

(A.43)EX311: $-\alpha_{y3}{}^{11}Q_3 + EX_{311} - \alpha_{311}{}^{11}Ew_{311} - \alpha_{321}{}^{11}Ew_{321} - \alpha_{32}{}^{11}Ew_{32} = \alpha_{G3}{}^{11}EG_{311}$

(A.44)EX321: $-\alpha_{y3}{}^{21}Q_3 + EX_{321} - \alpha_{311}{}^{21}Ew_{311} - \alpha_{321}{}^{21}Ew_{321} - \alpha_{32}{}^{21}Ew_{32} = \alpha_{G3}{}^{21}EG_{321}$

(A.45)EX21: $Ex_{111} + Ex_{211} + Ex_{311} + Ex_{21} = \delta_r r_{21}$

(A.46)EW111: $EX_{111} - \tau_{111}{}^{11}Ew_{111} - \tau_{121}{}^{11}Ew_{121} - \tau_{12}{}^{11}Ew_{12} = \tau_{B1}{}^{11}EB_{111}$

(A.47)EW121: $-x_{221} - x_{321} + x_{21} - \tau_{111}{}^{21}Ew_{111} - \tau_{121}{}^{21}Ew_{121} - \tau_{12}{}^{21}Ew_{12} = \tau_{B1}{}^{21}EB_{121}$

(A.48)EW211: $\pi_y Ew_{211} + \pi_z Ew_{221} + \pi_{aa} EX_{211} = \pi_{ee} EB_{211}$

(A.49)EW221: $-x_{121} - x_{321} + x_{21} - \tau_{211}{}^{21} Ew_{211} - \tau_{221}{}^{21} Ew_{221} - \tau_{22}{}^{21} Ew_{22} = \tau_{B2}{}^{21} EB_{221}$

(A.50)EW311: $EX_{211} - \tau_{311}{}^{11} Ew_{311} - \tau_{321}{}^{11} Ew_{321} - \tau_{32}{}^{11} Ew_{32} = \tau_{B3}{}^{11} EB_{311}$

(A.51)EW321: $EX_{321} - \tau_{311}{}^{21} Ew_{311} - \tau_{321}{}^{21} Ew_{321} - \tau_{32}{}^{21} Ew_{32} = \tau_{B3}{}^{21} EB_{321}$

(A.52)EW12: $\pi_a Q_1 + \pi_b Ew_{121} + \pi_c Ew_{12} = -\pi_d EG_{311} + \pi_e EB_{311}$

(A.53)EW22: $\pi_f Q_2 + \pi_g Ew_{221} + \pi_h Ew_{22} = -\pi_i EG_{312} + \pi_j EB_{312}$

(A.54)EW32: $\pi_k Q_3 + \pi_m Ew_{321} + Ew_{32} = -\pi_n EG_{322} + \pi_o EB_{322}$

APPENDIX: A.3

Components of pi (In the totally differentiated Equations)

Components of Pi			
π_a	$\dfrac{\alpha_{y3}^{11}}{(\alpha_{311}^{11}-\tau_{311}^{11})}$	π_n	$\dfrac{\alpha_{G3}^{22}}{(\alpha_{32}^{22}-\tau_{32}^{22})}$
π_b	$\dfrac{(\alpha_{321}^{11}-\tau_{321}^{11})}{(\alpha_{311}^{11}-\tau_{311}^{11})}$	π_o	$\dfrac{\tau_{B3}^{22}}{(\alpha_{32}^{22}-\tau_{32}^{22})}$
π_c	$\dfrac{(\alpha_{32}^{11}-\tau_{32}^{11})}{(\alpha_{311}^{11}-\tau_{311}^{11})}$	π_p	$\left(\dfrac{1}{\tau_{12}^{11}}\right)$
π_d	$\dfrac{\alpha_{G3}^{11}}{(\alpha_{311}^{11}-\tau_{311}^{11})}$	π_q	$[\left(\dfrac{\tau_{111}^{11}}{\tau_{12}^{11}}\right)-(\tau_{111}^{22}/\tau_{12}^{22})]$
π_e	$\dfrac{\tau_{B3}^{11}}{(\alpha_{311}^{11}-\tau_{311}^{11})}$	π_r	$[\left(\dfrac{\tau_{121}^{11}}{\tau_{12}^{11}}\right)-\left(\dfrac{\tau_{121}^{22}}{\tau_{12}^{22}}\right)]$
π_f	$\dfrac{\alpha_{y3}^{12}}{(\alpha_{32}^{12}-\tau_{32}^{12})}$	π_s	$\left(\dfrac{1}{\tau_{12}^{22}}\right)$
π_g	$\dfrac{(\alpha_{321}^{12}-\tau_{321}^{12})}{(\alpha_{32}^{12}-\tau_{32}^{12})}$	π_v	$(\dfrac{\tau_{B1}^{11}}{\tau_{12}^{11}})$
π_h	$\dfrac{(\alpha_{32}^{12}-\tau_{32}^{12})}{(\alpha_{32}^{12}-\tau_{32}^{12})}$	π_w	$(\tau_{B1}^{22}/\tau_{12}^{22})$
π_i	$\dfrac{\alpha_{G3}^{12}}{(\alpha_{32}^{12}-\tau_{32}^{12})}$	π_x	$\dfrac{1}{\tau_{22}^{22}}$
π_j	$\dfrac{\tau_{B3}^{12}}{(\alpha_{32}^{12}-\tau_{32}^{12})}$	π_y	$[\left(\dfrac{\tau_{211}^{22}}{\tau_{22}^{22}}\right)-\left(\dfrac{\tau_{211}^{11}}{\tau_{22}^{11}}\right)]$
π_k	$\dfrac{\alpha_{y3}^{22}}{(\alpha_{32}^{22}-\tau_{32}^{22})}$	π_z	$[\left(\dfrac{\tau_{221}^{22}}{\tau_{22}^{22}}\right)-\left(\dfrac{\tau_{221}^{11}}{\tau_{22}^{11}}\right)]$
π_l	$\dfrac{(\alpha_{311}^{22}-\tau_{311}^{22})}{(\alpha_{32}^{22}-\tau_{32}^{22})}$	π_{aa}	$\left(\dfrac{1}{\tau_{22}^{11}}\right)$
π_m	$\dfrac{(\alpha_{321}^{22}-\tau_{321}^{22})}{(\alpha_{32}^{22}-\tau_{32}^{22})}$	π_{dd}	$\left(\dfrac{\tau_{B2}^{22}}{\tau_{22}^{22}}\right)$
		π_{ee}	$(\dfrac{\tau_{B2}^{11}}{\tau_{22}^{11}})$