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Incentives, risk, and the role of private investments in Louisiana coastal wetland restoration

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INCENTIVES, RISK, AND THE ROLE OF PRIVATE INVESTMENTS IN LOUISIANA COASTAL WETLAND RESTORATION

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DEDICATION

I dedicate this humble work to:

My mother, Faitma, and my grandmother, Eye, ……………

In remembrance of my father who passed away……………

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ABSTRACT

The coast of Louisiana, with more than three million wetland acres, accounts for about 40 percent of the nation's total wetlands. Louisiana is estimated to have lost more than 1.2 million acres of its coastal wetland in the last century. Although 75% of Louisiana's coastal wetlands are privately owned, little has been done to encourage private landowners to undertake wetland restoration projects. This dissertation examines the factors that influence the decisions of the landowners to undertake wetland restoration projects. We develop a theoretical framework for understanding the landowner's decision-making process in the presence of high uncertainty and increasing restoration costs. The condition under which landowners will invest in wetland restoration and maintenance is derived under the assumptions of risk aversion and relatively high restoration costs. The validity of the theoretical model is tested using data from a mail survey of private wetland landowners in coastal Louisiana that was conducted in Fall of 2009. Two econometric (Tobit and double hurdle) models are estimated to determine the importance of various factors including risk aversion on the probability and the level of private coastal wetland investments.

The Likelihood ratio (LR) test shows that the double hurdle model statistically outperforms the Tobit model. The results suggest that the decision to invest in wetland restoration and how much to invest appear to be determined by different processes. The results of the double hurdle model show that risk plays an important role in landowners' decisions to invest in wetland restoration and maintenance activities. Landowners who are risk averse make less investment in wetland restoration and maintenance projects than other landowners, and landowners who own properties that are located in risk prone areas are less likely to invest in wetland restoration than other landowners. In addition, the results show that landowners' attitudes toward conservation, income related to the property, participation in government wetland programs, ownership structure, and wetland property size are all important determinants of the landowners' investment decisions. The analysis emphasizes the need to incorporate risk into the design of wetland incentive programs to encourage private landowners to undertake wetland restoration projects in coastal Louisiana.

CHAPTER 1

INTRODUCTION

The coast of Louisiana, with more than three million wetland acres, accounts for about 40 percent of the nation's coastal wetlands (Lipton *et al.*, 1995). In the last century, however, Louisiana is estimated to have lost more than 1.2 million acres (1,875 square miles) of its coastal wetlands (CWPPRA 2006). A number of factors have contributed to this loss. Topping the list is the construction of flood-control levees along the Mississippi River (Boesch *et al.* 1994) which prevent wetlands from receiving adequate fresh water and nutrients that are necessary to their survival. In addition, the dredging of access canals and navigation channels led to the redirection of alluvial sediments away from the coast which has exacerbated erosion and saltwater intrusion. As a result, it is estimated that about 160-200 million metric tons per year of sediments that once supplied the coastal wetlands are now delivered directly onto the outer continental shelf (Caffey and Shexnayder 2003; Caffey, 2005). Besides these human-induced factors, wetland losses are also caused by natural factors such as hurricanes, sea level rise, land subsidence, and nutria herbivory activities. For example, the U.S. Geological Survey estimates that 219 square miles of Louisiana coastal wetlands were destroyed as a result of Hurricanes Katrina and Rita (Barras *et al.*, 2008). According to some estimates, the economic cost of projected wetland loss from all sources by 2050 under a "no action" scenario is in the range of $27-$100 billion (LADNR 1999).

In an effort to address the problem of Louisiana's coastal land loss, the U.S. Congress passed the Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) in 1990. But, given the estimated price tag for coastal restoration of $20 billion (Galloway et al., 2009), only a fraction of the needed funds have been allocated, with CWPPRA, the largest program, accounting for only $60 million annually. Several other public restoration projects in the coastal zone of Louisiana have been funded by programs such as the Coastal Impact Assistance Program (CIAP), the Louisiana Coastal Area (LCA) program, the Coastal Wetland Reserve Program (CWRP), the Chrismas Tree Projects Program, and the Vegetation Planting Program initiated under the Louisiana's Coastal Wetlands Conservation Plan. CWRP, introduced to restore coastal wetlands on areas previously converted to agriculture, has succeeded in restoring hundreds of acres of coastal wetlands (CPRA, 2007). However, the limited availability of public funding, along with the magnitude of the problem, increases the importance of finding alternative approaches to addressing the issue of wetland loss in coastal Louisiana. Given that the vast majority of wetland properties are privately owned, incentive-based mechanisms to encourage private actions may be an appealing alternative approach.

Encouraging landowners to undertake private restoration and maintenance activities can be a difficult task for several reasons. First, the decision to invest in wetland restoration and maintenance is subject to a high level of uncertainty associated with future climate change, changes in restoration technologies, and changes in wetland regulatory policy. Second, the majority of benefits associated with wetland restoration and maintenance activities accrue to the public rather than to private landowners. Other reasons that may prevent private investment include diminishing surface and sub-surface incomes, increasing regulatory constraints, and a current property tax policy that fails to account for the use value for the wetland property (Caffey *et al.*, 2003).

1.1 Problem Statement

Louisiana is projected to lose an additional 431,000 acres (673 square miles) of its coastal wetlands by the year 2050 if the current wetland loss rates continue (CWPPRA 2006).

The economic implications of this projected loss are often debated, but there are billions of dollars that are directly or indirectly derived from activities occurring on these wetlands. Although 75% of these wetlands are privately owned Caffey *et al.*, 2003), little is known about how much private investment has been allocated to restoration and maintenance, nor is there a good understanding of what can be done to encourage private landowners to maintain and protect their coastal lands. This dissertation seeks to fill this information void by estimating the amount of private investment (at least for a subset of landowners) and investigating the factors that influence private Louisiana landowners to invest in coastal wetland restoration and maintenance activities, with particular emphasis on the influence of risk aversion and public subsidy programs on the private investment decision. More specifically, the following questions are addressed in this dissertation: First, what are the factors that motivate a landowner to undertake wetland restoration and maintenance activities? Second, what are the factors that deter a landowner from investing in wetland restoration and maintenance activities? Third, how does uncertainty influence a landowner's decision making process? And finally, how do potential government subsidy programs influence the landowner's investment decision?

1.2. Justification

Given that 75% of the wetland acreage in Louisiana's coastal zone is privately owned, successful coastal wetland restoration efforts will at least partly depend on the decisions of the private landowners who hold the ownership rights. Little or no effort, however, has been employed to encourage private wetland landowners to undertake wetland restoration projects in coastal Louisiana. The majority of wetland restoration projects in the coastal zone are still addressed through public programs such as the Coastal Wetlands Planning, Protection and

Restoration Act (CWPPRA). These public programs, which generally fail to engage the landowners in the restoration process lack the monetary resources to adequately address all of the wetland loss problems in the coastal zone. Even if additional government funding was to be secured, the cost effectiveness of these public restoration projects by CWPPRA and other public programs remains an issue of debate. At the same time, several factors have been proposed as reasons for the lack of private investment by landowners, including increasing investment risk, diminishing surface and sub-surface incomes, increasing regulatory constraints, and the public nature of the majority of the benefits of private restoration projects. Given these problems, there has been a call for the use of incentive based voluntary programs to encourage the landowners to invest in wetland restoration and maintenance activities.

In this dissertation, I investigate the factors that influence the landowners to undertake wetland restoration projects in coastal Louisiana. Understanding these factors is important for the design and implementation of voluntary programs to encourage private investment. For example, an estimated empirical model of landowner investment decision making can be used to provide information about the expected probability of participation, the expected level of investment, and the characteristics of the landowners who are most likely to participate. This information can provide the policy decision makers with the information needed to design wetland incentive programs that are both more cost effective and have higher participation rates than nontargeted wetland incentive programs. In addition, the information provided by an empirical model may allow policy makers to design incentive programs targeting restoration projects in areas that are most affected by wetland losses. This information is important when policy makers have to prioritize among competing wetland restoration projects given limited funding resources.

1.3 Objectives

The overall objective of this dissertation is to investigate the factors that influence landowners' decisions to invest in coastal wetland restoration and maintenance when these decisions are made in the presence of uncertainty and fixed costs. Specific objectives include:

1. Develop a theoretical model of the landowners' decision-making process in the face of uncertainty and fixed costs;
2. Determine the characteristics of wetland landowners in coastal Louisiana, including their risk preferences, attitudes toward private restoration and maintenance, the actual use of their properties, attitudes toward various government incentive programs, and their general socioeconomic profile;
3. Empirically estimate the importance of risk aversion, public subsidy programs, and other factors affecting landowner decisions to invest in coastal wetland restoration and maintenance projects; and
4. Examine the policy implications of the study results and devise policy recommendations that address the desirability and potential magnitude of private landowner investment in restoring and maintaining coastal Louisiana wetlands.

The remainder of the dissertation is organized as follows. Chapter 2 examines the economic and investment literature that relates to restoration-type decision making, including the potential roles of general factors, risk aversion, and option values. Chapter 3 takes this literature base and develops a theoretical model of the private wetland restoration decision making process and draws some tentative implications from the model structure. Chapter 4 presents the empirical model. Chapter 5 then presents the design of the survey questionnaire used to collect data and summarizes the information reported by respondents.. Chapter 6 presents the results of the model estimation, with Chapter 7 summarizing the main findings and discussing the potential policy implications**.**

CHAPTER 2

LITERATURE REVIEW

Although there have been a number of studies that have identified factors that are important to private landowners' investment decisions concerning other activities, private investment in coastal wetland restoration and maintenance has not been seriously studied to date. A review of these studies is presented in this chapter, beginning with a set of studies that looked at factors that influence investment decisions under the assumption of risk neutrality. The second section presents the results of empirical studies concerning the effect of risk aversion on investment decisions, while the third section examines the results of empirical studies on the role of option values in investment decisions.

2.1 General Factors Affecting Investment Decisions

Even though there are no studies that specifically examined those factors influencing decisions to privately invest in wetland restoration and maintenance in coastal Louisiana, there are a number that have identified general factors that may be important to wetland conservation efforts in the U.S. and other countries, including the factors influencing participation in publicly-financed wetland restoration programs. Jones *et al.* (1995) surveyed private landowners in New Zealand to determine their attitudes toward wetland protection and potential conservation mechanisms. The survey results showed that the majority of private landowners placed importance on the role of wetlands in maintaining water quality and providing species habitat. With regard to landowner preferences toward various conservation instruments, the survey revealed that incentive and voluntary instruments were most preferred. One of the authors' conclusion from this result was that conservation programs should use a range of land-use planning mechanisms, including ones based on economic incentives and financial compensation. Simple correlation tests showed that property size and the proportion of income derived from the property were significantly related to the landowners' attitudes about the importance and appropriate use of wetland areas. In addition, landowners who were engaged in farming activities were found to have negative attitudes toward the protection of wetlands.

Parks and Kramer (1995) investigated farmer participation in wetland restoration programs in the United States. Results from logit analysis showed that increases in agricultural benefits decreased the probability of participation in wetland restoration. Farmer knowledge of government programs and their potential benefits, as measured by government payments received per acre, were also found to significantly (at the 10% level) increase the probability of participating. Age and ownership structure were important factors in the participation decision as well, with older farmers and owner operators being more likely to become involved in wetland restoration programs. The authors also examined the probability of participation by county and used this information to calculate the expected acreage restored and the expected government costs for the restoration.

From an international perspective, Soderqvist (2003) used a random sample of 200 Swedish farmers to determine the factors that influence their willingness to participate in a catchment-based program for wetland creation in Sweden. The results of a probit analysis showed that factors such as age, attitudes of farmers, and perceived advantages and disadvantages of the program were important determinants of participation decisions. The study concluded that financial factors (i.e., subsidies) were not the sole determinant of a farmer's willingness to participate in the program, as various private and public environmental benefits of the program were also significantly related to participation decisions.

Aside from the above studies that focused on wetlands, other studies have examined private landowner investment decisions concerning other activities. For example, Ervin and Ervin (1982) examined the factors that determine the use of soil conservation practices using a random sample of Missouri farmers. The study found that education, perception of the degree of erosion problem, the susceptibility of soil to erosion, and cost sharing subsidies were positively correlated with the farmers' soil conservation efforts. However, when the number of soil practices was used as a dependent variable, only education, perception of the degree of erosion problem, farm type, and risk aversion were statistically significant in their model. The number of practices used was negatively related to the risk aversion of the farmers, and positively related to education and the perception of erosion problem. Similarly, Norris and Batie (1987) used a Tobit model to investigate the soil conservation decisions among Virginia farmers. Using total conservation expenditures as a dependent variable, the study found that financial factors - such as income and debt level - are the most important determinants of a farmer's investment decision. Income had a positive influence on the level of conservation expenditures, and debt level had a negative influence on the level of conservation expenditures. Other factors, such as perception of erosion, farm size, education, off-farm employment, tenure arrangement, tobacco acreage, and the existence of conservation plan were also important factors in the decision to invest. More specifically, farm size and education were positively related to the level of conservation investment while tenure arrangement was negatively related to the level of conservation investment.

Featherstone and Goodwin (1993) analyzed the factors that influenced Kansas farmers to invest in long-term conservation improvements. Employing a Tobit analysis, the authors showed that farm characteristics - such as farm size, debt, erosion level, type of farm, and participation in government programs - were important explanatory factors. In particular, the larger the farm size is and the larger the government payments, the higher the likelihood of participation and the higher the level of investment that would be made. The authors also found that operator and farm characteristics, such as age and ownership type, had significant influences on conservation expenditures. More specifically, the older the farm operator is, the less likely an expenditure would be made and, if made, the smaller the investment that would be undertaken. At least in Kansas, farms organized as corporations made larger investments than sole-owner farms. Unlike Norris and Batie (1987), income was not found to significantly influence overall conservation expenditures. In another study examining the role of ownership, Soule et al. (2000) used a logit model to estimate the influence of land tenure on the adoption of conservation practices by U.S. corn producers. The authors extended previous analyses by distinguishing renters based on lease type and by distinguishing conservation practices based on the timing of costs and returns. The results of their long-run conservation tillage model revealed that adoption was significantly and positively associated with farm size, education, the proportion of the farm in corn and soybeans, and the susceptibility of the land to erosion, and negatively related to age. Tenure and participation in government programs were not significant factors in the conservation tillage model. The authors' medium-term practices model showed similar results to the conservation tillage model, with the exception that the coefficient on tenure was negative and statistically significant. Overall, study results suggested that cash-renters were less likely to adopt conservation tillage than owner-operators, and share renters were less likely than owner-operator to adopt medium-term practices. In an international context, Layva *et al.* (2007) analyzed the adoption of soil conservation practices among 223 olive tree farmers in Spain. Three probit models were estimated for the three different conservation practices (tillage, terraces with stonewalls, and non-tillage practices). The study found that farm profitability, age of the farm operator, and the probability of passing on the farm to a relative were the most important determinants of the farmer's adoption decision.

Similar to the agricultural examples, a number of factors have been identified as important in forestry management investment decisions. Alig (1986) and Straka *et al.* (1984) found a significant positive relationship between household income and forestry investment. Later, however, Kline *et al.* (2000) found the relationship between income and forestry investment to be negative. Romm *et al.* (1987) used a logit regression to determine the factors that influence private forestry investment in northern California. The results of the study confirmed that income, age, and full time residency were the most significant factors in explaining forestry investment. More specifically, high income and full time residency were positively related to forestry investment, but absentee ownership, middle-ranged incomes, and old age were negatively related to the forestry investment. Property size was found to be an important factor in explaining investment in timber harvesting, but not in general forestry management. Nagubadi *et al.* (1996) used a probit model to analyze the participation of nonindustrial forest landowners in government forestry programs. The study found that property size, ownership reasons, government sources of information, and membership in forestry organizations were the most important determinants of program participation. Age, risks associated with the loss of property rights, and years of ownership were also important factors.

In considering the interactions between public and private decision making, Zhang and Flick (2001) examined the influence of environmental regulations (i.e., Endangered Species Act) and public financial assistance programs on private reforestation behavior. A two-step selection model was employed in the analysis. First, a probit model was used to estimate reforestation decisions. Second, the residuals from this model were retained and a selection model was estimated for the landowners who had replanted by using the level of investment as a dependent variable. The results of the probit model showed that the probability of reforestation investment was positively related to technical assistance and awareness of cost-share program, but negatively related to the distance from known endangered species habitats. None of the demographic variables, such as income or age, were found to be important factors in the reforestation decisions. The results of the selection model showed that the level of investment is positively related to the use of reforestation tax incentives and negatively related to the use of cost-share subsidies. The later implies a substitution effect between public and private capital. In addition, landowner characteristics such as income, age, and knowledge of forestry influenced the decisions about the level of reforestation investment. Income and knowledge of forestry were positively related to the level of investment, but age was negatively related to the level of investment. Property size was not a significant factor in either the probit or selection models.

In a more recent study, Dhakal *et al. (*2008) investigated the factors that influence the decision of small landowners to invest in forestry plantations in New Zealand. Using a double hurdle model, the authors found that property size, ownership type, period of landholding, land use in dairy production, experience in grain farming, perception about forestry tax policy, expectation about future log prices, and percentage of off-farm income were the most important predictors of the decision to undertake forestry plantation investments. In addition, the study found that property size, perception about forestry tax policy, expectation about future log prices, location of the land, and area used in sheep and beef production were strong determinants in the decision about the extent of forestry plantation investment. Thus, unlike Zhang and Flick (2001), property size was important in both the decision to invest and the level of investment undertaken. Property size was positively related to the probability of investing, but negatively related to the extent of investment.

2.2 Risk Aversion and Investment Decisions

The majority of the empirical studies summarized in the previous section (with the exception of Ervin and Ervin 1982) relied on the assumption that all decision makers are risk neutral even though it is likely that this assumption does not match reality. In the context of wetland restoration and maintenance, landowners face substantial levels of uncertainty about how future climatic, economic, and institutional factors will affect the payoffs from their investments. As a result, it is likely that risk aversion plays an important role in a landowner's investment decision. The potential impact of risk aversion on investment decisions in the presence of uncertainty has been empirically explored using a variety of frameworks, including the expected utility framework (Koundouri *et al.* 2006; Kim and Chavas 2003; Antle 1983) and stochastic dominance analysis (Goldstein *et al.* 2006; Benitez *et al.* 2006. This section presents a summary of the main findings of these studies and discusses the econometric modeling techniques used in the applications.

Stordal *et al.* (2007) applied stochastic efficiency with respect to a function (SERF) to analyze the impact of risk aversion on the optimal tree replanting decision. Risk aversion was profoundly influential in determining the certainty equivalence for all rotation strategies considered. Specifically, the results showed that certainty equivalence was a decreasing function of the risk aversion of owners. The results also indicated that risk-averse forest owners chose a higher optimal age of replacement of trees than risk neutral landowners. Hence, risk aversion influenced both the optimal tree replacement strategy and the reinvestment decision. The authors concluded that risk aversion needs to be considered when designing policy measures to influence forestry investments.

Goldstein et al. (2006) used stochastic dominance (SD) analysis to identify specific Koa forestry business strategies that were associated with risk-efficient land-use options in Hawaii. The study designed a set of hypothetical business strategies based on income from timber harvest, two existing government conservation programs, integrated cattle grazing, and selling carbon offset credits. The results of the analysis were based on cumulative net present value (NPV) distribution functions of the land-use business strategies generated from Monte Carlo simulation, and they showed that business strategies in which the landowners receive rental payment plus cost-share assistance were the most efficient. This implies that programs like the Conservation Reserve Enhancement Program (CREP) – in which the landowners received payment and cost share subsidies – could create viable business strategies for risk-averse landowners in Hawaii. Benitez *et al.* (2006) also used stochastic dominance (SD) analysis, but in this case to study land allocation problems under risk for shaded coffee production in the Choco region of West Ecuador. Study results indicated that shaded coffee is not a risk efficient land use, regardless of the degree of diversification. Hence, conservation payments required for preserving shaded coffee would need to be much higher than conservation payments calculated under risk neutrality assumptions. These results stressed the need for considering risk aversion factors when implementing conservation policy instruments.

In another international context, Hagos and Holden (2006) studied the influence of risk aversion, land tenure, public programs, and resource poverty on soil conservation investment decisions in northern Ethiopia. The study measured the risk preferences of households using hypothetical questions based on a utility function with constant partial risk aversion. A Probit model was then used to model the factors that influence the decisions to invest in soil conservation, with a subsequent Tobit model employed to model the factors that influence the intensity of investment. The authors found that risk aversion played an important role in a household's decision to intensify soil conservation measures but not in the decision to use soil conservation measures. Risk aversion was negatively correlated with the level of investment made in soil conservation. In addition, the study revealed that public conservation programs had a positive influence on private investment. Other factors, including land characteristics and the perception of returns on conservation investments, were found to be important in a household's decision to invest and intensify soil conservation.

Among the various variables included in of the analyses of technology adoption, risk has been recognized as a major factor in the adoption decision (Feder, Just, and Zilberman 1985). Saha *et al.(*1994) developed an empirical and analytical framework for divisible technology adoption under incomplete information diffusion and output uncertainty. The analytical framework showed that neither risk aversion of the producers, nor their risk perceptions, should play a role in the adoption decision. These risk factors, however, should play an important role in the degree of adoption if the producers decided to adopt the technology. Koundouri *et al*. (2006) extended the theoretical framework of Saha *el al. (*1994) to allow risk aversion and uncertainty to influence the technology adoption decision. The model was empirically tested using survey data of irrigation technology adoption practices by 265 Greece farmers. Using the first four moments of the profit distribution to approximate production risk in a logit model, the study found that risk influenced the farmer's decision to adopt the new irrigation technology. Specifically, farmers who faced more production risk were more likely to adopt new irrigation technology, suggesting that farmers chose to adopt new technology in order to hedge against production risk. In addition, the study found that farmers value the prospects of receiving new information to use in their adoption decision making. In a more recent paper, Torkamani and Shajari (2008) applied a logit model to investigate factors affecting adoption of new irrigation technologies by wheat farmers in three major Iranian districts. The study used a moment based approach to estimate the risk premium associated with water use, which was then used to estimate the risk attitudes of the farmers. Assuming that the risk preferences of the farmers exhibited constant relative risk aversion, the results showed that the risk attitudes of farmers have positive and significant effects on the decision to adopt new irrigation technologies. As a result, risk averse farmers were more likely to adopt new irrigation technologies that allowed them to save water and reduce production risk during the times of water shortage. Beside the risk aversion factor, the study found that location, debt level, education, and age were important determinants in the decision to adopt new irrigation technologies. Education had a positive effect on the probability of adoption and age had a negative effect on the probability of adoption. Not surprisingly, farms located in arid areas were more likely to adopt new water irrigation technologies.

Using as somewhat different approach, Isik and Khanna (2003) employed a nonlinear mean-standard deviation expected utility function to determine the impacts of risk aversion and uncertainty about weather and soil conditions on the decision to adopt site-specific technologies and the levels of cost-share subsidies required to induce adoption. The study found that uncertainty and risk-aversion had negative impacts on adoption decisions such that ignoring risk aversion and uncertainty would overestimate the economic and environmental benefits of site specific technologies and underestimate the subsidy level required to encourage adoption. Abadi Ghadim *et al.* (2005) analyzed the importance of uncertainty and risk aversion in decisions to adopt crop innovation in Western Australia. Farmers were interviewed over a three-year span to elicit their risk preferences and risk perceptions concerning a new crop technology for the area (chickpeas). In the survey, farmers were asked if they would adopt the new crop and how much area they would devote to it. Two limited-dependent variable models (probit and Tobit models) were used to analyze the responses. The study found that risk aversion negatively influenced both the decision to adopt and the extent of adoption, with risk aversion reducing adoption to a greater extent when both the perceived riskiness of the new technology and the area of the farm suitable for chickpeas were large.

A shortcoming of the empirical studies summarized above (with the exception of Koundouri *et al.* (2006)) is that they ignore the dynamic aspect of the investment decision – a factor that might be very important in the context of wetland restoration. Even though these empirical models adequately explain why some landowners choose to invest or not to invest at a given time, they fail to explain why some landowners choose to delay investment and wait for more information.

2.3 Option Values and Investment Decisions

Risk aversion is known to play an important role in static decision making under uncertainty, but it may be of less importance in a dynamic context (Knapp and Olson, 1996). Instead, the value of information tends to be the most important factor affecting dynamic decision making. In option theory literature, the value of information is called the option value of an investment and, if measured correctly, can have a profound effect on the decision-making process of landowners (Dixit and Pindyck (1994)). The majority of the real option models have been developed under risk neutral assumptions, and they do not allow the effect of risk aversion to be incorporated. This section summarizes the finding of empirical studies that have examined the role of option value on investment decisions, particularly in decisions similar to those of wetland restoration and maintenance.

Focusing on the relationship between the option value to convert and the valuation of the conservation easements, Tegene *et al.* (1999) examined decisions to convert farmland to urban use using an option value model. . The study showed that uncertainty and the growth in the urban return increase the threshold value of the conversion, so the landowner will not convert farmland to urban land use when the value of the land in urban use is equal to the direct opportunity cost of the land. Rather, landowners will convert only when urban land values exceed the opportunity cost of the land by a large margin. Hence, an increase in uncertainty and a growth of returns to urban use tends to increase the value of the convertible agricultural land by increasing the land option value, causing a delay in development even for a risk-neutral landowner. This suggests that not incorporating the option values in the conservation easements offered to the landowners might under-price the values of the conservation easements and make landowners reluctant to sign up for these easements. In another study, Quigg (1993) examined the difference in the value of vacant and developed land by applying an option values model to a large sample of real estate transactions in Seattle. The author found that the option value associated with uncertainty and irreversibility in the decision to develop explains the difference in these values of the different types of land. The author calculated a premium for the option value to wait, and found that this option premium averaged about 6% with a range from 1% to 30% for the total sample.

Looking at a more subtle type of land conversion, Schatzki (2003) examined the effects of uncertainty and sunk costs on the decisions to convert land from agricultural to forestry use using a sample of agricultural plots in the state of Georgia. Empirical results suggested that uncertainty in returns to either forestry or agricultural use increases the conversion threshold and thus decreases the likelihood of conversion. The results also showed that the higher the correlation between changes in returns to agriculture and forests, the lower the conversion threshold, thus increasing the likelihood of conversion. The estimated option value for this study ranged from 7% to 81% of the expected value of the land asset.

In terms of program participation, Isik and Yang (2004) examined the factors affecting farmer participation in the Conservation Reserve Program (CRP) under uncertainty and irreversibility using an option value model. Results showed that uncertainty and irreversibility, and thus option values, influence farmer decisions to participate in CRP, with higher levels of uncertainty in the returns to agricultural use or the CRP rental payments decreasing the likelihood of participation in the CRP. In addition, land benefits, land attributes, and farmer characteristics had significant impacts on the participation decision, with age, higher production costs, and lower crop revenues increasing the probability of participation in the CRP.

Option values also play a role in technology adoption decisions. Winter-Nelson and Amegbeto (1998) used an option value model to analyze the impacts of output price variability and sunk costs on terrace adoption in eastern Kenya. Simulation results compared the incentives to invest in terraces under both administered and world prices, showing that the option value associated with the variability of world prices was an important factor in the decision to invest in that the variability of world prices tended to delay terrace adoption in Kenya. Purvis *et al.* (1995) investigate the impacts of uncertainty about the costs and requirements associated with environmental compliance and sunk costs on a producer's decision to invest in free-stall dairy housing. Empirical results demonstrated that, even though free-stall dairy housing units increased milk production and reduced water pollution, the uncertainty about the costs of the system and future environmental regulations significantly delayed the adoption decision. More specifically, the simplified net present value (NPV) rule predicted that a risk neutral producer will invest in free-stall technology if the expected return of investment were equal to $83,448. The option-value investment rule, however, predicted that the producer would wait until the expected return on investment was greater than or equal to $190,063. This example demonstrates that uncertainty can substantially increase the hurdle required to trigger adoption.

Continuing with the adoption theme, Carey and Zilberman (2002) used an option value model to determine the effect of input uncertainty and emerging water markets on a farmer's decision to adopt water irrigation technologies. The results indicated that farmers value the option to wait when making technology adoption decisions, with the risk neutral farmer being unwilling to invest in irrigation technologies until the expected value of investment exceeds the cost by a large hurdle rate. Simulation results showed that, according to the net present value (NPV) rule, farms would invest in irrigation technologies if the expected NPV was greater than or equal zero and the water market price was greater than or equal $48 per unit. From an option value rule perspective, however, investments would only occur if the expected NPV was greater than or equal to $1,594 per acre and the water market price reached $112 per unit. Thus, the larger the level of uncertainty, the higher the hurdle rate required to trigger adoption. Finally, the study found that the introduction of water markets would likely induce farms with accessible water supplies to adopt earlier compared to farms with scare water supply. This outcome was attributed primarily to the lack of a well-functioning water market.

In considering conservation measures, Bulte *et al.* (2002) looked at the optimal holding of primary tropical forests in Costa Rica when the future nonuse benefits of forest conservation are uncertain and increasing. The authors demonstrated that benefit uncertainty has a significant and positive effect on the optimal forest holding stocks, with the option value associated with the uncertainty being an important factor to consider. Thus, using deterministic cost-benefit analysis can be misleading because it ignores the fact that the option value associated with uncertainty is a component of the return to investment. The results also showed that even though the effect of the uncertainty factor is substantial, rising trends in future benefits and compensation by the international community for beneficial spillovers may be more important factors in determining the optimal forest stock.

In summary, previous studies have found education, technical assistance, conservation attitudes, the perception of the erosion problem, and the degree of erosion to have positive effects on the landowners' investment decisions. Age was negatively related to the decision to invest in soil conservation and forestry, but it had a mixed sign with respect to the decisions to participate in government incentive programs. Income and property size did not have consistent signs across all studies; however, the majority of the studies found positive correlations between the decision to invest and total household income and property size. Similarly, results from the literature were not consistent regarding the signs of the variables cost-sharing and debt level. They were found to be negatively correlated to the decision to invest in some studies and positively related to the decision to invest in other studies. Finally, risk aversion was found to negatively influence the level of investment in both soil conservation and forestry investment. However, risk aversion was found to have positive (negative) effects on the decisions to adopt new technologies depending on whether these technologies are risk decreasing or risk increasing. Some studies found a negative relationship between risk aversion and technology adoption, and other studies found a positive relationship between risk aversion and technology adoption.

The discussion in this chapter focused on identifying the landowner and land characteristics, along with institutional structures, previously linked to private decisions about land use. The next chapter will present a theoretical model of landowner decision making in the face of uncertainty and fixed costs, particularly with respect to how uncertainty about the benefits and costs of wetland restoration and maintenance influences a landowner's investment decision.

CHAPTER 3

THEORETICAL ANALYSIS

This chapter presents the development of a theoretical model describing a landowner's investment decision making process with respect to investments in wetland restoration and maintenance when these decisions are made under uncertainty, irreversibility, and high fixed costs. The first section presents a simple wetland restoration model when future benefits and costs of wetland restoration and maintenance are known with certainty. The second section extends the basic investment model to incorporate the effects of risk and uncertainty through risk aversion channels. The next section extends the basic model to include risk and uncertainty through the option value of investments, also known in the environmental literature as the conditional value of information. The final section extends the model to include the effects of some potential subsidy programs.

3.1 Investment Under Certainty: Net Present Value (NPV) Approach

Assume that a risk neutral landowner owns a property size A_t at time t. Part of this property is wetland, denoted by w_t, and the rest of the property (A_t-w_t) is upland. Following the Zhao and Zilberman (1999) and Parks (1993) model specifications, let $B(w_t)$ be the private net benefit derived from wetland acreage w_t. This net benefit can be written as follows:

$$B(w_t) = R(w_t) - C(w_t) \tag{1}$$

where $R(w_t)$ is the total revenue and $C(w_t)$ is the total cost derived from the wetland resource.

Now assume that there is wetland loss equal to α_t . For a risk neutral landowner, the decision problem is to choose the optimal level of restoration I_t that maximizes the present value of the expected net benefits from the wetland resource over all future time periods[1], or

$$V_1 = \int_{t=0}^{\infty} e^{-\delta t} E[B(w_t) - C(I_t) - C_0] dt \quad (2)$$

subject to $w_t^{'} = I_t - \alpha_t; I_t \geq 0$

where E is the expectations operator, δ is the discount rate, and C_0 and $C(I_t)$ are the fixed and variable costs (respectively) associated with restoration level I_t. The constraint defines the change in wetland acreage at the end of period t ($w_t^{'}$). This change is a function of both the level of restoration I_t and the wetland loss α_t. The net benefit function $B(.)$ is assumed to be increasing and concave in I_t, so that $B^{'}(.) > 0$ and $B^{''}(.) \leq 0$. In addition, the variable cost function $C(I_t)$ is assumed to be increasing and convex in I_t so that $C^{'}(I_t) > 0$ and $C^{''}(I_t) \geq 0$ for all $I_t \geq 0$. If the cost per unit of wetland restoration is constant, then $C(I_t) = cI_t$.

The traditional net present value (NPV) model of investment predicts that the landowners will invest in wetland restoration and maintenance activities when the NPV of the expected cash flows from the investment exceeds the cost of the investment. Therefore, the landowner will invest in wetland restoration and maintenance if $V_1 > 0$, and he/she will not invest in wetland restoration and maintenance if $V_1 < 0$. Thus, the landowner maximization problem for each time period can be expressed as follows:

$$\max_{I_t} [B(w_t) - C(I_t) - C_0] \quad (3)$$

[1] The plus infinity symbol ∞ that was used in the net present value function represents the end of the landowner's planning horizon

subject to $w_t^{'} = I_t - \alpha_t$

The landowner's optimal wetland restoration level can then be found by solving the Hamiltonian function:

$$H = [B(w_t) - C(I_t) - C_0] + \lambda(I_t - \alpha_t) \tag{4}$$

whose first-order conditions for maximization are:

$$H_{I_t} = \frac{\partial B(w_t)}{\partial I_t} - \frac{\partial C(I_t)}{\partial I_t} + \lambda = 0 \tag{4.1}$$

$$H_{\alpha_t} = \frac{\partial B(w_t)}{\partial \alpha_t} - \lambda = 0 \tag{4.2}$$

$$\lambda^{'} = -H_{w_t} = -\frac{\partial B(w_t)}{\partial w_t} \tag{4.3}$$

$$H_\lambda = I_t - \alpha_t \tag{4.4}$$

From equations 4.1 and 4.2, the landowner will choose a level of restoration that satisfies the following relationship:

$$\frac{\partial B(w_t)}{\partial I_t} = \frac{\partial C(I_t)}{\partial I_t} - \frac{\partial B(w_t)}{\partial \alpha_t} \tag{5}$$

The term in the left hand side (LHS) of equation (5) can be interpreted as the marginal benefits associated with restoration level I_t, while the first term on the right hand side (RHS) can be interpreted as the marginal cost associated with restoration level I_t. The second term on the RHS can be interpreted as the marginal negative benefits (i.e., costs) associated with α_t wetland loss. Thus, equation (5) states that under certainty, a landowner will optimize NPV by choosing a level of restoration $I_t = I_t^*$ that equates the marginal benefit of restoration with the marginal cost of restoration plus the marginal negative benefit associated with wetland loss α_t that might occur in the absence of no action. On the other hand, the landowner will prefer not to invest in wetland restoration and maintenance if the additional benefit of restoration is less than the sum of the marginal cost of restoration plus marginal negative benefit associated with wetland loss.

3.2 Investment under Uncertainty

The simple NPV model has a major shortcoming in that it ignores the role of risk and uncertainty in the decision-making process. In the context of coastal wetland restoration, several sources of uncertainty can arise. First, there is uncertainty associated with changes in the global climate that may result in sea level rise and/or adverse weather variations, such as the increased frequency of hurricanes and storms. Currently, sea-level rise is estimated to be approximately 1cm/yr, and this rate is expected to increase to 30 to 50cm by the end of 21st century (Day et al. 2005). The potential impact of future sea level rise on wetland restoration and maintenance projects is unknown at the time the investment decisions are made. The same can be said for the uncertainty associated with the use and performance of various wetland restoration technologies. Another possible source of uncertainty is related to future changes in wetland regulation and incentive policies. The evolution of these policies over time will almost certainly influence the ultimate benefits and costs generated by current wetland restoration and maintenance projects.

The uncertainty associated with climate change, restoration technologies, and wetland policy can influence the landowner's decision process through several channels. First, risk averse landowners might prefer not to invest in wetland restoration and maintenance activities because such investments would expose them to high levels of income risks even if they can realize higher average returns under the investments (Arrow, 1971, Pratt 1964). On the other hand, risk-averse landowners who have faced continuous wetland losses might consider investing in wetland restoration projects in order to reduce the risk of losing more wetlands in the future. In this case, the benefits of wetland restoration and maintenance potentially include loss-based risk reduction. In addition to the uncertainty factor, investment in wetland restoration and maintenance incurs fixed and variable costs that might be quite high due to the need for extensive water control structures and compliance with wetland regulatory constraints. Zhao and Zilberman (1999) demonstrated, using dynamic analysis, that high fixed costs reduces the level of private restoration for each time period. In fact, if the fixed costs are high enough, it can lead to a complete lack of private restoration regardless of the magnitude of marginal costs. This combination of uncertainty and fixed costs implies that additional information about the future benefits and costs of wetland restoration and maintenance might have positive economic value. Therefore, a risk neutral landowner should prefer to delay investment in wetland restoration and maintenance in order to gain more information and avoid the downside risk of a costly restoration project (Arrow and Fisher 1973; Henry 1974; Fisher and Hanemann 1990; Dixit and Pindyck 1994). Consequently, a simple NPV rule tends to underestimate the required trigger value for an uncertain investment decision, and it might lead to an early or overinvestment. In the next section, the NPV model is extended to account for the importance of risk aversion.

3.2.1. The Role of Risk Aversion

At the time a landowner makes the decision to invest in wetland restoration projects, the expected net benefit of a wetland restoration project is subject to several sources of uncertainty including future climate change, future changes in wetland policy, and future improvement of wetland restoration technology. For the sake of this discussion, assume that the main source of uncertainty the landowner faces is the uncertainty about future climate change, and this uncertainty is represented by a random variable φ with the distribution density function $f(\varphi)$. To account for the effects of risk aversion and uncertainty on the landowner's investment decision, the landowner's objective function described in equation (2) must be restructured to incorporate the von Neumann-Morgenstern utility function (u) for the net benefit of wetland restoration. The landowner's decision problem is to choose the optimal level of restoration I_t that maximizes the present value of the expected utility of the net benefits from the wetland, or

$$V_2 = \int_{t=0}^{\infty} e^{-\delta t} Eu[B(w_t, \varphi) - C(I_t) - C_0]dt \tag{6}$$

subject to $w_t' = I_t - \alpha_t$

where E is the expectation operator, $u(.)$ is a von Neumann-Morgenstern utility function that is continuous and twice differentiable, with positive first derivatives (u'). The sign of the second derivative (u'') is negative for a risk-averse landowner and positive for a risk-taking landowner. Based on this model specification, investment in wetland restoration and maintenance occurs only if the expected discounted utility of the benefits of wetland restoration exceeds the discounted utility of the restoration costs (i.e., $V_2>0$).

The landowner maximization problem for each time period can be expressed as follows:

$$\max_{I_t} Eu[B(w_t, \varphi) - C(I_t) - C_0] \tag{7}$$

subject to $w_t' = I_t - \alpha_t$

The Hamiltonian function for this dynamic problem is:

$$H = Eu[B(w_t, \varphi) - C(I_t) - C_0] + \lambda(I_t - \alpha_t) \tag{8}$$

with the first-order conditions for maximization

$$H_{I_t} = E\left\{u^{'}(.)\left(\frac{\partial B(w_t,\varphi)}{\partial I_t} - \frac{\partial C(I_t)}{\partial I_t}\right)\right\} + \lambda = 0 \tag{8.1}$$

$$H_{\alpha_t} = E\left\{u^{'}(.)\frac{\partial B(w_t,\varphi)}{\partial \alpha_t}\right\} - \lambda = 0 \tag{8.2}$$

$$\lambda^{'} = -H_{w_t} = -E\left\{u^{'}(.)\frac{\partial B(w_t,\varphi)}{\partial w_t}\right\} \tag{8.3}$$

$$H_{\lambda} = I_t - \alpha_t \tag{8.4}$$

Equations (8.1) and (8.2) can be combined to yield

$$E\left\{u^{'}(.)\left(\frac{\partial B(w_t,\varphi)}{\partial I_t} - \frac{\partial C(I_t)}{\partial I_t}\right)\right\} = -E\left\{u^{'}(.)\frac{\partial B(w_t,\varphi)}{\partial \alpha_t}\right\} \tag{9}$$

Using the property of the expected value of the product of two random variables,

$$Eu^{'}(.)E\left(\frac{\partial B(w_t,\varphi)}{\partial I_t} - \frac{\partial C(I_t)}{\partial I_t}\right) + cov\left(u^{'}(.), \frac{\partial B(w_t,\varphi)}{\partial I_t} - \frac{\partial C(I_t)}{\partial I_t}\right) =$$

$$-Eu'(.)E\left(\frac{\partial B(w_t,\varphi)}{\partial \alpha_t}\right) - cov\left(u'(.), \frac{\partial B(w_t,\varphi)}{\partial \alpha_t}\right) \tag{10}$$

Simplifying

$$E\left(\frac{\partial B(w_t,\varphi)}{\partial I_t}\right) = E\left(\frac{\partial C(I_t)}{\partial I_t}\right) - E\left(\frac{\partial B(w_t,\varphi)}{\partial \alpha_t}\right)$$

$$-\frac{cov\left(u^{'}(.),\frac{\partial B(w_t,\varphi)}{\partial I_t}-\frac{\partial C(I_t)}{\partial I_t}\right)+cov\left(u^{'}(.),\frac{\partial B(w_t,\varphi)}{\partial \alpha_t}\right)}{Eu^{'}(.)} \tag{11}$$

or

$$E\left(\frac{\partial B(w_t,\varphi)}{\partial I_t}\right)=E\left(\frac{\partial C(I_t)}{\partial I_t}\right)-E\left(\frac{\partial B(w_t,\varphi)}{\partial \alpha_t}\right)$$

$$+\frac{cov\left(u'(.),\frac{\partial C(I_t)}{\partial I_t}\right)-cov\left(u'(.),\frac{\partial B(w_t,\varphi)}{\partial \alpha_t}\right)-cov\left(u'(.),\frac{\partial B(w_t,\varphi)}{\partial I_t}\right)}{Eu'(.)} \tag{12}$$

The term on the LHS of equation (11) is the expected marginal benefits associated with restoration level I_t . The first term on the RHS is the expected marginal cost associated with restoring I_t acres of wetland, while the second term is the expected marginal negative benefit (costs) associated with α_t wetland loss. The third term on the RHS is different from zero in the uncertainty case and measures the deviation of the risk-averse landowner from a risk-neutral landowner. It represents the additional cost of risk and it is a function of both the risk preference of the landowner (captured by the curvature of the utility function) and the variability of the net benefit represented by the variance of the net benefit. This tern will be positive for a risk averse landowner and negative for a risk taker landowner. In this formulation, a landowner will choose the optimal level of restoration according to the expected net benefit of wetland restoration, expected cost of wetland restoration, negative opportunity cost of wetland loss, risk preference, and the variability of wetland net benefit. Therefore, a risk-averse landowner will invest in wetland restoration and maintenance as long as the expected marginal benefit of wetland restoration exceeds the expected marginal cost plus the expected negative marginal benefit and an additional risk premium associated with wetland investment.

3.2.2 The Value of Information (Option Value Approach)

Investment in wetland restoration and maintenance has all three characteristics that define real options. First, the decision to invest is, in general, irreversible because it involves considerable (in fact, a high percentage of) fixed and variable costs that cannot be totally recovered if the investment decision is reversed. Second, the decision to invest in wetland restoration and maintenance is uncertain because the economic and environmental conditions that influence the return on investment are uncertain, with information about these conditions only arriving gradually in the future. Third, the landowner has the choice to delay investment in wetland restoration and maintenance and wait for more information to arrive before undertaking costly restoration projects. When the conditions of irreversibility, uncertainty and the ability to wait are met, the decisions are said to entail an option value, where it pays for the landowners to delay investments and wait for more information in order to avoid the downside risk (Dixit & Pindyck, 1994). Investment in wetland restoration and maintenance should occur only when the discounted cash flows from the investment exceed the costs of the investment by a large hurdle equal to the value of the option to invest in the future; a value known in the environmental preservation literature as the quasi-option value (Arrow and Fisher, 1973; Henry, 1974). The quasi-option value (or option value) measures the value of information conditional on delaying investment in the first period. The higher the prospect of receiving new information about future returns of investment, the more likely the landowners will delay partial investments in order to remain flexible and make use of the new information.

In order to account for the option value associated with wetland restoration decisions, the landowner's decision model can be based on real option theory (ROT) for investments under uncertainty and irreversibility (Arrow and Fisher, 1973; Henry, 1974; Dixit & Pindyck, 1994; Epstein, 1980). Several authors have used ROT models for analyzing investment decisions, including those associated with technology adoption (Carey and Zilberman, 2002; Isik 2004; Isik *et al.*, 2001,; Koundouri *et al.*, 2006; Winter-Nelson and Amegbeto, 1998), land use change (Capozza and Li, 1994; Capozza and Hensley, 1990; Capozza and Sick, 1994; Geltner et al., 1996; Plantinga *et al*. 2002; Purvis *et al*., 1995; Tengene *et al.* 1999; Wiemers and Behan, 2004), program participation by farmers (Isik and Yang, 2004), and forest conservation (Bulte *et al*., 2002), and wetland investment (Paulsen, 2007).

In order to examine a similar model in the context of wetland restoration, assume that a risk neutral landowner holds a property size A_t at time t. Part of this property is wetland, denoted by w_t , and the rest of the property (A_t-w_t) is upland. Let $B^t(w_t)$ be the private net benefit derived from wetland acreage w_t at time t, where the value of B^t is a function of several exogenous factors such as global climate change, changes in wetland policies, and restoration technologies. Also assume that new information about the uncertain benefit of wetland restoration will gradually become available, so that this benefit might be modeled using a geometric Brownian motion:

$$dB = \propto Bdt + \sigma Bdz \qquad (13)$$

where α and σ are the growth rate and the variation in the growth rate of the wetland restoration benefit, respectively. Define $dz = \varepsilon\sqrt{dt}$ as the increment of the Weiner process, and $\varepsilon \sim N(0,1)$. Thus, equation (13) implies that the current net benefits of wetland restoration and maintenance are known, but future benefits are changing at rate α (Dixit & Pindyck (1994)). Investing in wetland restoration and maintenance also requires consideration of the fixed and variable costs (C_0 and $C(I_t)$, respectively), where C denotes the total investment costs equal to the sum of the variable and fixed costs. Taking the benefits and costs together, the option to invest in wetland restoration and maintenance is then equal to the maximum difference between the discounted net benefit of investment and the cost of the investment

$$F(B) = \max_T E\{B^T(w_T) - C\}\, e^{-\delta T} \tag{14}$$

where E denotes the expectations operator, T is the unknown future time that the landowner will start the restoration project, $B^T(w_T)$ is the net benefit of the wetland restoration at the time of restoration T, and δ is the discount rate. In order for investment in wetland restoration to be optimal, we assumed that $\delta > \alpha$ which implies that the trend in the net benefit of wetland restoration should always be less than the discount rate. The goal, then, is to solve equation (14) to find the optimal value B^* that maximizes the option value of investment in wetland restoration and maintenance $F(B)$.

Dixit & Pindyck (1994) use a dynamic programming approach to solve for optimal investment regions in problems like the one specified above, and they found that the optimal solution can be expressed as:

$$B^* = \frac{\beta}{\beta - 1} C \tag{15}$$

where C is the cost of the restoration investment and β is a function of the discount rate, drift and volatility of the stochastic process dB. The term $\frac{\beta}{\beta - 1}$ has a value greater than 1 and measures the importance of uncertainty in the investment decision. Specifically, in the presence of uncertainty, one would invest in wetland restoration and maintenance when the net benefits of the investment exceed the investment cost by a hurdle rate equal to the option value of investment. Dixit & Pindyck (1994) go on to show that the critical value of the investment B^* is increasing in the volatility of the growth rate (σ) and trend (α) of net benefit

Although this modeling approach is appealing, it is difficult to test the model's implications because of the intense data requirements. Thus, the majority of studies regarding land use under uncertainty and irreversibility tended to rely on simulation frameworks, where Mont-Carlo or other simulation methods are used to test the implication of the ROT model.

3.3. Implications for a Potential Wetland Restoration Policy

Caffey *et al.* (2003) listed several policy instruments that can be used to encourage private wetland restoration in the coastal zone, including cost-sharing subsidies, tax reduction, wetland mitigating banking, and carbon credits. As an example of how these can be incorporated into the theoretical model, consider the effects of cost-sharing subsidies such as the one offered under Wetland Reserve Program (WRP) or Conservation Reserve Program (CRP). Under the WRP, landowners can enter a contract agreement with the government to reach certain restoration goals, and in exchange they receive rental payments over the contract period. The program also pays a portion of the total restoration costs. It is worth mentioning that subsidy programs such as WRP and CRP were largely designed to address the issue of wetland restoration for land that was devoted to agricultural uses, but modified versions of these programs can potentially be used to address the issue of wetland restoration in the coastal zone (Ryan and Susman, 2003).

Suppose that a coastal landowner participates in a cost sharing program similar to one under the WRP, where the landowner will receive a dollar rental payment equal to s per acre over the contract period k, and the program will pay a portion γ of the total restoration costs. The landowner's decision problem, including the new benefits of the subsidy program, can be expressed as follows:

$$V_s = \int_{t=0}^{\infty} e^{-\delta t} Eu[B(w_t, \varphi)$$

$$+s * \{(e^{-rK} - 1)/re^{-rK}\} * I_t - (1-\gamma) * (C(I_t) + C_0)]dt \qquad (16)$$

subject to $w_t^{'} = I_t - \alpha_t$

The landowner's maximization problem for each time period can be expressed as:

$$\max_{I_t} Eu[B(w_t, \varphi) + s * \{(e^{-rK} - 1)/re^{-rK}\} * I_t - (1-\gamma) * (C(I_t) + C_0)] \qquad (17)$$

subject to $w_t^{'} = I_t - \alpha_t$

Notice that the cost-share subsidy program adds two terms to the maximization problem – the cost share portion that the pays $\gamma * (C(I_t) + C_0)$ and the rental payment over the contract period k, $s * \{(e^{-rK} - 1)/re^{-rK}\}$.

Setting the Hamiltonian function to solve the optimization problem in equation 17 yields:

$$H = Eu[B(w_t, \varphi) + s * \{(e^{-rK} - 1)/re^{-rK}\} * I_t - (1-\gamma) * (C(I_t) + C_0)]$$

$$+\lambda(I_t - \alpha_t) \qquad (18)$$

The first-order conditions for maximization can then be expressed as:

$$H_{I_t} = E\left\{u^{'}(.)\left(\frac{\partial B(w_t,\varphi)}{\partial I_t} + s * \{(e^{-rK} - 1)/re^{-rK}\} - (1-\gamma)\frac{\partial C(I_t)}{\partial I_t}\right)\right\} + \lambda = 0 \tag{18.1}$$

$$H_{\alpha_t} = E\left\{u^{'}(.)\frac{\partial B(w_t,\varphi)}{\partial \alpha_t}\right\} - \lambda = 0 \tag{18.2}$$

$$\lambda^{'} = -H_{w_t} = -E\left\{u^{'}(.)\frac{\partial B(w_t,\varphi)}{\partial w_t}\right\} \tag{18.3}$$

$$H_\lambda = I_t - \alpha_t \tag{18.4}$$

Combining equations (18.1) and (18.2) yields

$$E\left\{u^{'}(.)\left(\frac{\partial B(w_t,\varphi)}{\partial I_t} + s * \{(e^{-rK} - 1)/re^{-rK}\} - (1-\gamma)\frac{\partial C(I_t)}{\partial I_t}\right)\right\}$$

$$= -E\left\{u^{'}(.)\frac{\partial B(w_t,\varphi)}{\partial \alpha_t}\right\} \tag{19}$$

Then, using the property of the expected value of the product of two random variables,

$$Eu^{'}(.)E\left(\frac{\partial B(w_t,\varphi)}{\partial I_t} + s * \{(e^{-rK} - 1)/re^{-rK}\} - (1-\gamma)\frac{\partial C(I_t)}{\partial I_t}\right) + cov\ \left(u^{'}(.),\frac{\partial B(w_t,\varphi)}{\partial I_t} + s * \{(e^{-rK} - 1)/re^{-rK}\} - (1-\gamma)\frac{\partial C(I_t)}{\partial I_t}\right) = -Eu^{'}(.)E\left(\frac{\partial B(w_t,\varphi)}{\partial \alpha_t}\right) - cov\ \left(u^{'}(.),\frac{\partial B(w_t,\varphi)}{\partial \alpha_t}\right) \tag{20}$$

or

$$Eu^{'}(.)E\left(\frac{\partial B(w_t,\varphi)}{\partial I_t}\right) + Eu^{'}(.)s * \{(e^{-rK} - 1)/re^{-rK}\} - (1-\gamma)Eu^{'}(.)E\left(\frac{\partial C(I_t)}{\partial I_t}\right) + cov\ \left(u^{'}(.),\frac{\partial B(w_t,\varphi)}{\partial I_t} + s * \{(e^{-rK} - 1)/re^{-rK}\} - (1-\gamma)\frac{\partial C(I_t)}{\partial I_t}\right) = -Eu^{'}(.)E\left(\frac{\partial B(w_t,\varphi)}{\partial \alpha_t}\right) - cov\ \left(u^{'}(.),\frac{\partial B(w_t,\varphi)}{\partial \alpha_t}\right) \tag{21}$$

Simplifying yields

$$E\left(\frac{\partial B(w_t,\varphi)}{\partial I_t}\right) = E\left(\frac{\partial C(I_t)}{\partial I_t}\right) - E\left(\frac{\partial B(w_t,\varphi)}{\partial \alpha_t}\right) - \Big\{s * \{(e^{-rK} - 1)/re^{-rK}\} +$$

$$\gamma E\left(\frac{\partial C(I_t)}{\partial I_t}\right)\Big\} - \frac{cov\left(u'(.),\frac{\partial B(w_t,\varphi)}{\partial \alpha_t}\right) + cov\left(u'(.),\frac{\partial B(w_t,\varphi)}{\partial I_t} + s*\{(e^{-rK}-1)/re^{-rK}\} - (1-\gamma)\frac{\partial C(I_t)}{\partial I_t}\right)}{Eu'(.)} \quad (22)$$

The term on the LHS of the equation above is the expected marginal benefits associated with restoration level I_t. The first term on the RHS is the expected marginal cost associated with restoring I_t acres of wetland, while the second term is the expected marginal negative benefit associated with α_t wetland loss. The third term on the RHS is the increase in the marginal benefit of wetland restoration due to cost-share subsidy programs. The last term on the RHS is non-zero to the extent that it measures the deviation of the risk-averse landowner from a risk-neutral landowner. It represents the additional cost of risk and it is negative for a risk averse landowner, and positive for a risk taker landowner. From equation (22), the subsidy payment $s * \{(e^{-rK} - 1)/re^{-rK}\}$ and the cost share payment $\gamma E\left(\frac{\partial C(I_t)}{\partial I_t}\right)$ lower the hurdle rate for investment in wetland restoration and maintenance. Therefore, the subsidy program should encourage private landowners to undertake wetland restoration and maintenance.

This chapter presented the conditions under which the landowners would invest in wetland restoration and maintenance, finding that uncertainty and fixed costs can play important role in the decision making process. In a static setting, risk-aversion influences the trigger value of the decision to invest in wetland restoration projects. However, in a dynamic setting, the option value of investment under uncertainty influences the decision making process of the landowners. The remainder of the dissertation develops these ideas in an empirical context with the goal of testing the theoretical implications of this model structure.

CHAPTER 4

EMPIRICAL ANALYSIS

The theoretical framework for the landowners' decisions to invest in wetland restoration and maintenance in the presence of risk and uncertainty was developed in both static and dynamic contexts. The static framework emphasized the role of risk aversion in the decision process, while the dynamic framework emphasized the role of option value in the decision process. This chapter develops an empirical model for the factors that influence decisions to invest in wetland restoration and maintenance. Given that the data for the study came from a cross sectional survey, the empirical model focuses on analyzing the factors that influence the landowner's decision to invest in wetland restoration and maintenance in the presence of risk and uncertainty at the time the survey was taken. Hence, the model developed here is grounded in the static framework approach and emphasizes the important role of risk aversion and fixed costs in the landowners' decision process.

The majority of studies that have looked at factors influencing private investments in resource stocks similar to wetlands have either used discrete choice models with probit or logit estimators (Romm *et al.*, 1987; Soule *et al.,* 2000; Koundouri *et al.*, 2006) or a corner solution model employing a Tobit model (Norris and Batie, 1987; Featherstone and Goodwin, 1993; Hagos and Holden, 2006). The first modeling approach provides useful information on how different characteristics of the landowners and their wetland tracts influence the probability of investment in wetland restoration and maintenance, but it does not provide information on the impact of these factors on the level of investment in wetland restoration and maintenance. Since the objective of this study was to provide information on the level-of-investment decision, using a discrete choice model is not optimal. The Tobit model, on the other hand, is particularly useful for analyzing the impacts of landowners' characteristic and their properties on the probability and the level of investment in wetland restoration and maintenance. In addition, the marginal effects calculated from the estimated Tobit model can be used to predict the effects of changing the levels of explanatory variables on both the amount of investment and the probability of investment. The Tobit model, however, is very restrictive in its parameterization. First, it assumes that the same stochastic process influences the probability of investment and the level of investment. Second, all zero observations of the dependent variable are attributed to corner solutions (Blundell and Meghir, 1987; Moffatt, 2005). Because of these limitations, we explore an alternative approach to modeling the data structure – the double-hurdle model. The double-hurdle model generalizes the Tobit model by introducing an additional hurdle which must be passed before observing any positive investments. The additional hurdle uses a probit estimator to model the decision to invest(discrete variable); therefore, zero observations on the dependent variable can be either attributed to corner solutions or nonparticipation in the market (i.e., landowners have never invested in wetland restoration projects). In doing so, the double hurdle model also allows the decision to invest in wetland restoration and the level of investments to be treated separately. Therefore, a separate stochastic process can be used to model the probability of investment and the level of investment (Carroll *et al.*, 2005).

After briefly introducing the underlying theory of the Tobit model and its limitations, the discussion in this chapter turns to the double hurdle model as an alternative to the Tobit. Also presented is a brief section on how the marginal effects are computed and the associated standard errors for statistical inferences. To close, the last section of the chapter discusses the issues of heteroskedasticity and non-normality of the error terms in the double hurdle model.

4.1 The Tobit Model

Estimating an econometric model of landowner decisions to invest in wetland restoration and maintenance is complicated by the relatively large number of zero observations that are usually observed in the dependent variable (i.e., level of private investment in wetland restoration and maintenance). When the dependent variable is limited in such a way, analyzing the data using ordinary least square (OLS) may result in biased and inconsistent estimated parameter (Amemiya, 1984). Discarding zero observations of the dependent variable is not a viable solution, as doing so and using OLS only with positive values of the dependent variable increases the potential bias and inefficiency while ignoring potentially valuable information embedded in the zero observation responses. (Amemiya, 1984). To address these limitations, Tobin (1958) crafted an approach that came to be known as the Tobit model. To account for the censored nature of data, the Tobit model expresses the observed response variable y in terms of an underlying latent variable:

$$y_i = x_i'\beta + e_i \text{ if } \quad y_i^* = x_i'\beta + e_i > 0 \tag{23}$$

$$y_i = 0 \text{ if } \quad y_i^* = x_i'\beta + e_i \leq 0 \tag{24}$$

$$e_i \sim N(0, \sigma^2)$$

where y_i^* is a latent variable describing the level of investment for landowner i, y_i is the actual level of investment for a landowner i, x_i is a vector of potential explanatory variables that influence the landowner's decisions to invest in wetland restoration and maintenance, β is a vector of the associated parameters, and e_i is the error term. The density of y_i given x_i is the same as the density of y_i^* given x_i for positive observations, so the probability that y_i equals 0 can be expressed as

$$P(y_i = 0/x_i) = P(y_i^* < 0/x_i) = 1 - \Phi\big(x_i'\beta/\sigma\big) \tag{25}$$

where Φ(.) is the standard normal cumulative distribution.

The most common approach to estimating the Tobit model is the maximum likelihood estimator. First, the observations are divided into two groups; censored observations (zero values of the dependent variable) and the observed positive values of the dependent variable. The log likelihood function for the Tobit model is expressed as follows:

$$\text{Log}L = \textstyle\sum_0 \ln\left[1 - \Phi\left(\frac{x_i'\beta}{\sigma}\right)\right] + \sum_+ \ln\left[\frac{1}{\sigma}\,\emptyset\left(\frac{y_{i-}x_i'\beta}{\sigma}\right)\right] \tag{26}$$

where Φ(.) and φ(.) are the standard normal cumulative distribution and the standard normal density functions, "0" indicates summation over zero observations, and "+" indicates the summation over positive observations(Greene, 2003).

The parameter estimates of the Tobit model provide little value besides indicating the significance of the explanatory variable and, if significant, the direction (positive or negative) of its influence on the dependent variable. Thus, marginal effects are calculated from the estimated model to more fully understand the magnitude of the relationship between the explanatory and dependent variables. Using the McDonald and Moffitt (1980) decomposition, the unconditional expected value of the double hurdle model was expressed by Wooldridge (2002) as

$$\text{E}(y_i/x_i) = P(y_i > 0/x_i) * \text{E}(y_i/x_i\,, y_i > 0) \tag{27}$$

From equation (23), the probability of observing a positive investment level for landowner i is

$$P(y_i > 0/x_i) = 1 - P(y_i = 0/x_i) = \Phi\big(x_i'\beta/\sigma\big) \tag{28}$$

while the conditional expected value of y_i given that $y_i > 0$ is

$$\mathrm{E}(y_i/x_i\,, y_i > 0) = x_i'\beta + \sigma * \lambda(x_i'\beta/\sigma) \tag{29}$$

where λ(.) is the inverse mills ratio $\lambda(.) = \frac{\phi(.)}{\Phi(.)}$. Using the McDonald and Moffitt (1980) decomposition, the unconditional expected value of y_i that measures the overall investment level is

$$\mathrm{E}(y_i/x_i) = \Phi\big(x_i'\beta/\sigma\big)\big\{x_i'\beta + \sigma * \lambda(x_i'\beta/\sigma)\big\} \tag{30}$$

Taking the first derivative of equations (28), (29), and (30) with respect to the explanatory variable x_j then gives the marginal effects on the probability of investment and the conditional and unconditional level of investments. Thus, the marginal effect of the variable x_j on the probability of investment is

$$\frac{\partial \mathrm{P}(y_i > 0/x_i)}{\partial x_j} = \big(\beta_j/\sigma\big)\phi\big(x_i'\beta/\sigma\big) \tag{31}$$

the conditional marginal effect of the variable x_j is

$$\frac{\partial \mathrm{E}(y_i/x_i, y_i > 0)}{\partial x_j} = \beta_j\big\{1 - \lambda(x_i'\beta/\sigma)\big[x_i'\beta/\sigma + \lambda(x_i'\beta/\sigma)\big]\big\} \tag{32}$$

and the unconditional marginal effect of the variable x_j is

$$\frac{\partial \mathrm{E}(y_i/x_i)}{\partial x_j} = \beta_j\ \Phi\big(x_i'\beta/\sigma\big) \tag{33}$$

The Tobit model suffers from a number of limitations associated with its underlying assumptions. First, the model is very restrictive in its parameterization because it assumes that the same stochastic process determines both the value of the continuous dependent variable (level of private investments in wetland restoration and maintenance) and the value of the discrete dependent variable (the decision to invest in wetland restoration and maintenance).

This assumption is very restrictive because the factors that affect a landowner's decision to invest in wetland restoration and maintenance (i.e., the characteristics of the landowners and their properties) might differ significantly from the factors that influence a landowner's decision about how much to invest in wetland restoration and maintenance. Furthermore, the same stochastic process assumption implies that if a particular variable is known to have a positive effect on investment level, then a high value for this variable will inevitably lead to the prediction of a high probability of investment (Blundell and Meghir, 1987; Moffatt, 2005). Second, the Tobit model assumes that all zero observations are standard corner solutions or negative values of the underlying latent variable (Blundell and Meghir, 1987). In the context of our study, it is possible to imagine cases where the landowners do not invest in wetland restoration and maintenance for reasons beyond simple economic factors such as income and relative prices. For example, landowners might decide not to invest in wetland restoration and maintenance because they don't believe a wetland restoration technology exists to do the task or because they do not believe that they are responsible for restoration, especially considering that the majority of wetland benefits are public in nature (Heimlich et al. 1998). It is also possible that landowners may perceive wetland investment to be beneficial (i.e., positive value of the latent variable), but for other unmeasured reasons choose not to invest, thus yielding zero values for the dependent variable.

Unlike the Tobit model, the double-hurdle model allows the decision to invest in wetland restoration and the level of investments to be treated separately. Therefore, a separate stochastic process can be used to model the probability of investment and the level of investments. The next section presents the general function of the double hurdle model and discusses its underlying assumptions.

4.2 Double Hurdle Model

The double hurdle model proposed by Cragg (1971) generalizes the Tobit model by introducing an additional hurdle which must be passed before observing any positive investments. Conceptually, a landowner first decides whether or not to invest in wetland restoration and maintenance. Then, if the decision is made to invest, the landowner decides how much to invest. A different latent variable is used to model each decision process, with a probit estimator used to model the participation decision and a Tobit estimator used to model the level of investment decision (Blundell and Meghir, 1987).[2] Therefore, the double hurdle model allows for the possibility that factors affecting the decision to invest in wetland restoration and maintenance might differ from factors that affect the level of investment decision. For example, fixed costs may affect the decisions to invest in wetland restoration and maintenance, but they may not affect the decisions about how much to invest. In addition, the double-hurdle model allows the same explanatory variable to have different impacts on the decisions to invest and the level of investment.

Unlike the Tobit model, which assumes that all zero observation on the dependent variable are attributed to corner solutions, the double hurdle model allows zero observations on the dependent variables to be caused by either a simple corner solution (negative value for the underlying latent dependent variable) or non-participation in the market (i.e., landowner decides not to invest in wetland restoration projects for some non-modeled reasons) (Moffatt, 2005; Carroll *et al.*, 2005). The general equations of the double-hurdle model can expressed as follows:

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[2] The double hurdle model uses a probit model, and not a logit model, in the first stage because the normality assumption of the error term matches the underlying assumption for the Tobit model. Since both the decision to invest and how much to invest are based on the same underlying utility function, then the error terms in both model should follow the same distributional assumptions.

$y_{i1}^{*} = z_i^{'}\alpha + u_i$: first hurdle equation (investment decision) (34)

$y_{i2}^{*} = x_i^{'}\beta + v_i$: second hurdle equation (investment level decision) (35)

$y_i = x_i^{'}\beta + v_i$ if $y_{i1}^{*} > 0$ and $y_{i2}^{*} > 0$ (36)

$y_i = 0$ otherwise (37)

$u_i \sim N(0,1)$, $v_i \sim N(0, \sigma^2)$

where y_{i1}^{*} is a latent variable representing the decision to invest in wetland restoration and maintenance for a landowner i, y_{i2}^{*} is a latent variable representing the level of investment for a landowner i , y_i is the observed level of investment for a landowner i, z_i is a vector of potential explanatory variables that influence the landowner's decision to invest in wetland restoration and maintenance, x_i is a vector of explanatory variables that affect the landowner's level of investment, and α and β are vectors of parameter. In this formulation, *(z_i ; x_i)* may contain the same common explanatory variables, although their corresponding effects on the two hurdle equations might be quite different. The terms u_i and v_i are normal and independently distributed error terms such that $\text{cov}(u_i, v_i) = 0$ (Carroll et al., 2005).

As might be apparent from this discussion, the Tobit model is just a special case of the double-hurdle model, where $z_i = x_i$ and $\alpha = \beta/\sigma$. As a result, the model specification of the double-hurdle model can be tested against the Tobit model using a likelihood ratio test (LR). The LR test compares the log-likelihood values of the two models and determines if they are significantly different from each other (Wooldridge, 2002). The result of this test can be used to determine whether the landowners make investment decisions in a sequential or simultaneous manner. If the LR test rejects the null hypothesis of a univariate Tobit, then the double-hurdle model is preferred and landowners are found to make investment decisions in a sequential two-step process. If, however, the null hypothesis is not rejected, then landowners are found to make investment decision in a simultaneous manner and the univariate Tobit is a better representation of the data.

As in the Tobit model case, the most common method for estimating the double-hurdle model is the maximum likelihood estimator, and its general log-likelihood function can be expressed as follows (Cragg, 1971):

$$\text{Log}L = \sum_0 \ln\left[1 - \Phi(z_i'\alpha)\Phi\left(\frac{x_i'\beta}{\sigma}\right)\right] + \sum_+ \ln\left[\Phi(z_i'\alpha)\frac{1}{\sigma}\emptyset\left(\frac{y_i - x_i'\beta}{\sigma}\right)\right] \quad (38)$$

where "0" indicates summation over zero observations, "+" indicates the summation over positive observations, and $\Phi(.)$ and $\varphi(.)$ are the standard normal cumulative distribution and the standard normal density function, respectively.

Similar to the Tobit model, the parameter estimates of the double hurdle model provide little direct information beyond the significance and direction of influence for each explanatory variable, resulting in the need for marginal effect calculations. Using the McDonald and Moffitt (1980) decomposition, the unconditional expected value of the double hurdle model can be expressed as (Jensen and Yen, 1996)

$$\text{E}(y_i/x_i) = P(y_i > 0/x_i) * \text{E}(y_i/x_i, y_i > 0) \quad (39)$$

where $P(y_i > 0/x_i)$ is the probability of investment and $\text{E}(y_i/x_i, y_i > 0)$ is the conditional expected value of investment (i.e., the level of investment conditional on having made the choice to invest). Following Burke's (2009) notation, the probability of investment is

$$P(y_i > 0/z_i) = 1 - P(y_i = 0/z_i) = \Phi(z_i'\alpha) \tag{40}$$

.From the Tobit model in the second-hurdle, the conditional expected value of y given that $y>0$ is

$$\mathrm{E}(y_i/x_i, y_i > 0) = x_i'\beta + \sigma * \lambda(x_i'\beta/\sigma) \tag{41}$$

where $\lambda(.)$ is the inverse Mills ratio. After substituting equations (40) and (41) into equation (39), the unconditional expected value of y can be expressed as follows

$$\mathrm{E}(y_i/x_i) = \Phi(z_i'\alpha)\{x_i'\beta + \sigma * \lambda(x_i'\beta/\sigma)\} \tag{42}$$

Taking the first derivative of equations (40), (41), and (42) with respect to the explanatory variable x_j yields the double-hurdle marginal effects of the explanatory variable x_j on the probability of investment and the conditional and unconditional level of investments. So, the marginal effect of the explanatory variable x_j on the probability of investment is expressed as

$$\frac{\partial \mathrm{P}(y_i>0/x_i)}{\partial x_j} = \alpha_j \emptyset(z_i'\alpha) \tag{43}$$

and the conditional marginal effect of the explanatory variable x_j given that landowners have made a positive investment is

$$\frac{\partial \mathrm{E}(y_i/x_i, y_i>0)}{\partial x_j} = \beta_j\{1 - \lambda(x_i'\beta/\sigma)[x_i'\beta/\sigma + \lambda(x_i'\beta/\sigma)]\} \tag{44}$$

and the unconditional marginal effect of the explanatory variable x_j is

$$\frac{\partial \mathrm{E}(y_i/x_i, z_i)}{\partial x_j} = \alpha_j \emptyset(z_i'\alpha)\{x_i'\beta + \sigma * \lambda(x_i'\beta/\sigma)\}$$

$$+\Phi(z_i'\alpha) * \beta_j\{1 - \lambda(x_i'\beta/\sigma)[x_i'\beta/\sigma + \lambda(x_i'\beta/\sigma)]\} \tag{45}$$

Although having the calculated marginal effects is useful, for statistical inference there is a need for the standard errors of the estimated marginal effects. These standard errors can be approximated using the delta method. Denoting the parameter estimates of the double hurdle model by the vector $\hat{\theta} = [\hat{\alpha}', \hat{\beta}']$ and the estimated marginal effect for a given continuous variable x_k in the model by the function $\hat{\delta}_k = h(\hat{\theta})$, the estimated variance of the marginal effect $\hat{\delta}_k$ using the delta method can be expressed as (Wooldridge, 2002):

$$var(\delta_k) = \left[\frac{\partial h(\hat{\theta})}{\partial \hat{\theta}}\right] \hat{V} \left[\frac{\partial h(\hat{\theta})}{\partial \hat{\theta}}\right]' \quad (46)$$

where $\hat{V}$ is the asymptotic variance of the maximum likelihood estimator for $\hat{\theta}$ and the standard errors can be computed using the square root of the equation above. This procedure is employed by the '*nlcom'* subroutine in STATA to calculate the standard errors for the estimated marginal effects of the double hurdle model.

4.3 Heteroskedasticity and Non-normality

The maximum likelihood estimates of the double hurdle model are derived under the assumption that the error terms u_i and v_i are homoskedastic. In the case of cross-sectional data, this homoskedasticity assumption is likely to be violated, leading to a situation where the maximum likelihood estimation produces inconsistent parameter estimates (Arabmazer and Schmidt, 1981; Maddala, 1975; Hurd, 1979). Arabmazer and Schmidt (1981) investigated the impact of heteroskedasticity in the Tobit model and found that the size of inconsistency[3] increases with heteroskedasticity and the degree of censoring. Hurd (1979) found that

[3] Consistency is a very important characteristic of any estimator. It reflects the behavior of the sampling distribution of the estimator as the sample size increases. An estimator is said to be consistent if it converges to the parameter estimates of the true population value of the parameter as the sample size increases indefinitely (Wooldridge,2002)

moderate heteroskedasticity in the errors will cause substantial inconsistency in the parameter estimates. One way to overcome the inconsistency is by assuming that the standard deviation of the error term is a function of a set of exogenous variables w_i

$$\sigma_i = \exp\,(w_i^{`}h) \tag{47}$$

where w_i might contain all continuous variables in x_i or just a subset of the continuous variables suspected for heteroskedasticity and δ is a conformable parameter vector (Su and Yen, 1996; Jenson and Yen, 1996). A likelihood ratio test (LR) can be used to test the restrictions (Ho: h =0) against the alternative that h is not 0. A rejection of this test indicates that the errors are heteroskedastic.

Similar to the case of heteroskedasticity, the maximum likelihood estimates of the double hurdle model are very sensitive to the normality assumptions concerning the error terms u_i and v_i. If normality is violated, the maximum likelihood approach produces inconsistent parameter estimates (Arabmazer and Schmidt, 1982). One way of dealing with the non-normality issue is to use a logarithmic transformation of the dependent variable, but this option is not appropriate in the presence of a large number of zero observations. Another way to account for non-normal errors is to use a Box-Cox transformation of the dependent variable, often expressed as (Jenson and Yen, 1996)

$$y_i^T = \frac{y_i^{\lambda} - 1}{\lambda} \qquad 0 \le \lambda \le 1 \tag{48}$$

Notice that the logarithmic and the linear transformations are special cases of the Box-Cox transformation when λ=0 , and λ=1, respectively. In general, however, λ would be expected to take on a value between zero and one (Moffatt, 2005). The log likelihood function of the double hurdle model after applying the Box-Cox transformation can be expressed as

$$\mathrm{Log}L = \sum_0 \ln\left[1 - \Phi(z_i'\alpha)\Phi\left(\frac{x_i'\beta + \frac{1}{\lambda}}{\sigma}\right)\right] + \sum_+ \ln\left[\Phi(z_i'\alpha) y_i^{\lambda-1} \frac{1}{\sigma} \emptyset\left(\frac{y_i^T - x_i'\beta}{\sigma}\right)\right] \quad (49)$$

This chapter presented two potential models (Tobit and the double hurdle) that can be used to investigate landowners' decisions concerning investment in wetland restoration projects. The next chapter examines the process used to collect the data needed to statistically estimate these models and gives an over-review of the data itself.

CHAPTER 5

SURVEY DESIGN AND DATA SUMMARY

Chapter 4 presented an empirical framework for modeling the landowner decision making process with respect to wetland restoration and maintenance. From the theoretical framework discussed in Chapter 3, risk aversion becomes a key determinant of the landowners' investment decisions. In order to test this theoretical hypothesis, however, a measure of the risk preferences for private landowners is required. A survey of coastal landowners in Louisiana was conducted in the fall of 2009 in order to elicit these risk preferences. Three different risk preference elicitation methods were used in the survey: 1) a self ranking question on risk preference; 2) a multi-item scale approach; and 3) the expected utility framework through hypothetical investments distributions with different levels of risk and expected net returns. The survey was also used to collect other information regarding landowners' investment decisions, their socioeconomic characteristics, and the characteristics of landholdings. This chapter describes the survey process and presents a descriptive analysis of the response. The chapter begins with an examination of the survey design and discusses the general response characteristics. Next, the risk preference elicitation methods that were used are described. Finally, a summary of the survey data is presented.

5.1 Survey Design and Response

The survey questionnaire (see Appendix A) was designed using Dillman's (1978) total design method for mail surveys. A mailing list of private wetland landowners in coastal Louisiana was obtained from the Louisiana Department of Natural Resources (LADNR) geographic information system (GIS) database. This database covers all coastal wetland landowners who may have potentially been affected by wetlands loss and/or publically funded wetlands restoration and maintenance activities. In it raw form, the GIS database provided by LADNR had 721 landowners with wetland properties in the coastal zone. However, after eliminating duplicate names, names without mailing addresses, and publicly owned properties (such as state-owned wildlife refuges), the mailing list contained a total of 591 landowners.

Using the 591 landowners as the sample frame, we stratified landowners into three groups based on the number of wetland tracts they owned. The first group included all landowners with only one tract of land. The second group included all landowners with two tracts, and the third group included all landowners with more than two tracts (with this latter group mainly consisting of large corporations). This stratification of the sample based on the number of tracts was used for several reasons. First, the survey questionnaire asked questions that are specific to a tract of land, such as the level of investment that was made, income derived from the land, land use, and the level of wetland loss. Because a landowner with multiple land tracts might make different investment decisions for each tract, it was important to have the landowner focus on a specific tract when answering the questionnaire. Second, stratification (and more specifically, having the responses tied to a specific tract of land) allowed the response data to be merged with the LADNR GIS information for a land tract (i.e., location of the land tract, distance from the shoreline, wetland loss, wetland area, and wetland type).

For this study, the survey questionnaires were mailed to landowners with one or two tracts of land (groups one and two). As mentioned early, the third group of landowners consists mainly of large corporations, and they were excluded from this study in part due to the difficulty in conceptualizing a way to elicit risk preferences from an entity other than an individual. The behavior of these large landholders is certainly of interest when considering coastal wetland restoration and maintenance, and future research will need to focus on this problem.

In early fall of 2009, a pre-test version of the survey questionnaire was mailed to a random sample of 30 private landowners who owned one tract of land (group 1). Based on the result of this pre-test, changes were made to the survey questionnaires and a final version was mailed out to all landowners in the sample frame who owned one or two tracts of land (groups 1 and 2). In total, the survey was mailed to a sample size of 378 private landowners.[4] Each survey questionnaire included an aerial photography map of the landowner's property with location data identified (see figure 5.1 for an example of one of these maps). For landowners with two tracts of land, they were given two separate maps (one for each tract) and asked to select the tract of land that they were going to use when answering the survey questionnaire. As a result, all survey questions that were land-specific referred to well-identified tracts, and thus could be related (both for this study and in the future) to biophysical features tracked by other scientific studies.

The survey questionnaire consisted of five sections with a total of 37 questions. The first section of the survey included a range of questions concerning the participation of the landowners in government programs, their attitudes toward wetland restoration, and their attitudes toward various incentive instruments for wetland restoration. More specifically, landowners were asked about their general attitudes toward wetland restoration, whether they were aware of any wetland restoration programs in their areas, and if so, whether they had

[4] The entire survey process involved the following steps. A pre-notification postcard was sent to all private landowners, followed by a first mailing of the questionnaire; thank you reminder postcards were mailed out to landowners shortly thereafter. Approximately two weeks later, a second mailing of the questionnaire was sent out to all first mailing non-respondents, and shortly after that they were sent a second thank you reminder postcard. Finally, a third mailing of the questionnaire was sent out to all landowners who did not respond in the first two attempts. In all, six attempts were made to reach the landowners for a response.

enrolled in any of these programs. They were also asked whether they would be willing to participate in any government-sponsored restoration program and their attitudes toward various incentive instruments such as tax breaks, subsidies, and cost sharing were elicited. The second section of the survey was designed to collect information on the general characteristics of landholdings, such as property size, percentage of wetland, current land use, ownership type, when the property was first acquired, how it was managed, how much wetland had been lost, the percentage of household income generated from both surface and sub-surface activities, and the expected market value of the property. The third section of the survey asked questions regarding investment in wetland restoration and maintenance. In this section, landowners were asked whether they had conducted any wetland restoration and maintenance activities, the year in which they started these restoration projects, the type of restoration techniques they had used, the level of private investment expenditures they had made on wetland restoration and maintenance activities, and the level of public investment expenditures that had been made on wetland restoration and maintenance activities. In this section of the survey, the landowners were also asked about the factors that motivated or deterred them from conducting wetland restoration and maintenance activities, their perceptions about the source and level of uncertainty faced in wetland restoration and maintenance activities, and their general attitudes toward wetland restoration and maintenance. The fourth section included demographic questions, such as education, income, age, gender, and place of residence. The final section of the survey elicited the landowners' risk preferences. Three risk preference elicitation methods were used: self ranking, multi-item scale, and the direct expected utility method using hypothetical investment distributions with different levels of returns and risk.

Figure 5.1: An example of an aerial photography map of a wetland tract in Louisiana's coastal zone. In the survey questionnaire, the boundary of the tract was clearly marked and geospatial information about the location of the tract was also provided to help respondents identify the wetland tract.

Of the original 378 survey questionnaires that were mailed out, 48 were not deliverable and 75 were returned completed. Removing the undelivered questionnaires from the sample, the survey response rate was approximately 23%. The respondents owned a total of 393,680 acres, or approximately 57% of the total acreage owned by all 378 landowners in the sample frame. In term of the total wetland acreage controlled by the survey respondents, we found that survey respondents controlled approximately 6% of the total wetland acreage in Louisiana's coastal zone (3.4 million acres). If one takes out the total wetland acreage owned by the top 50 corporations and the lands owned by the state such national refuges and wildlife management areas [5] in the sample frame, we found that the survey respondents controlled about 11% of the total wetland acreage in the coastal zone of Louisiana based on a very conservative assumption about the wetland percentage on these properties. Figure 5.2 presents the distribution of the survey respondents across the coastal zone of Louisiana.

5.2 Risk Preference Elicitation Methods

Three risk preference elicitation instruments were employed to measure the risk preferences of landowners: a self ranking question on risk preference, a multi-item scale approach, and the expected utility framework through hypothetical investments distributions with different levels of risk and expected net returns.

5.2.1 The Self Ranking Risk Method

Landowners were asked to rank their personal preferences for taking investment risks using a 10-point scale, with 1 being risk-hating and 10 being risk-loving. Previous studies

[5] The top 50 landowners in our sample frame controlled approximately 2.7 million acres of land, but it is unknown how much wetlands they controlled. Our survey data showed that, on average, landowners reported that 76% of their properties are wetlands(see table 5.3). We used a more conservative estimate to estimate the total wetland acreage controlled by the top 50 corporations. We used 50% rate as a base. Hence, it is estimated that the top 50 corporations controlled about 1.35 million acres of wetlands. The wildlife management areas in the sample frame controlled about 554,215 acres of land in coastal zone of Louisiana.

have employed the self ranking risk method (Cardona, 1999; Henderson, 2007; Thomas, 1987; Schurle and Tierney, 1990; Faust and Gillespie, 2006) and compared the self ranking risk method to other risk elicitation methods, including interval and "closing-in" approaches (Thomas, 1987; Schuler and Tierney, 1990; Bard and Barry, 2001; Faust and Gillespie, 2006). The results of these studies are mixed, with some finding a significant correlation between the self-ranking risk preference elicitation method and other methods (Schuler and Tierney, 1990; Thomas, 1987; Fausti and Gillespie, 2006) and others find no significant relationship between the self-ranking method and other methods (Bard and Barry, 2001).

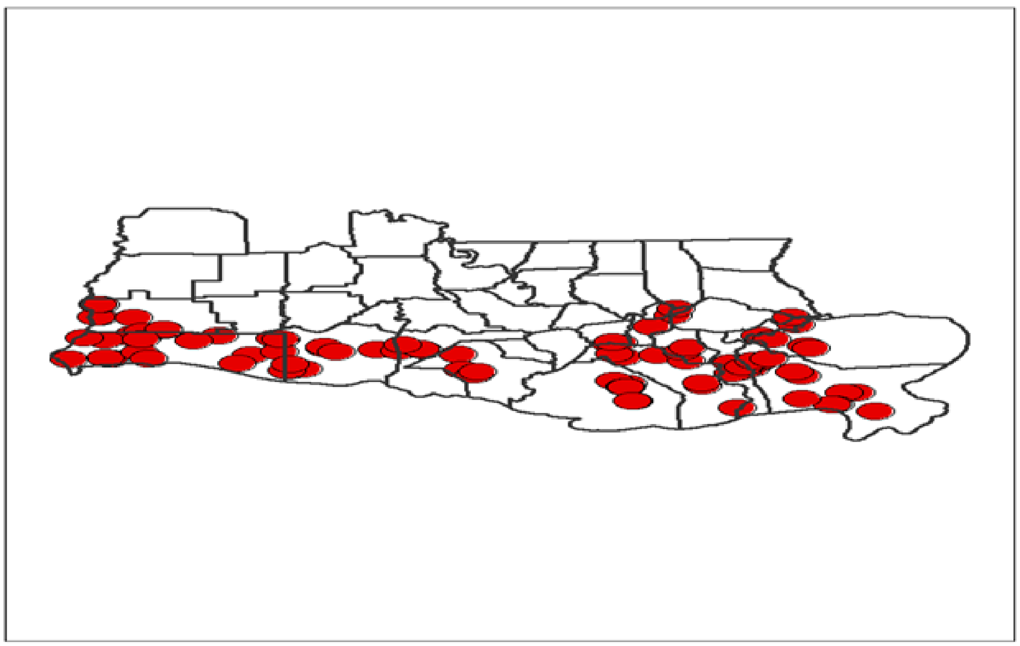

Figure 5.2: Distribution of the survey respondents across Louisiana's Coastal zone.

5.2.2 Multi-item Scale Approach

In the psychological literature, the term "attitudes" refers to clusters of feelings, beliefs, and behavioral tendencies that are not directly observable (Baron and Byrne, 1981). Therefore, risk attitudes are latent variables that can be measured indirectly through a set of indicator variables that are correlated with these latent variables. To measure risk attitudes using a multi-item scale approach, individuals are given a set of questions or items and asked to indicate the degree to which they agree or disagree with each question. This approach was found to perform well in terms of reliability and validity, and it is commonly used to measure the risk preferences of individuals (Penning and Garcia, 2001). For this study, landowners were asked to indicate on scale from 1 (" I strongly disagree") to 5 (" I strongly agree") the extent to which they agreed with a set of statements (Table 5.1) that were selected to 'tap' the domain of the construct as recommended by Churchill (1995). Example applications of the scale approach can be found in the economic literature. Goodwin and Schroeder (1994) measured the risk attitudes of farmers using a binary variable of whether the farmers had preferences for business risk. Penning and Garcia (2001) measured the risk preferences of hog farmers using the multi-scale approach, where the farmers were give seven statements and asked to indicate the degree to which they agreed with each statement. The study found that the risk attitudes measured using the multi-item scale approach were statistically related to risk attitudes measured using the expected utility framework.

5.2.3 Investment Method

The investment method of risk elicitation used in this study closely followed the experimental design developed by Gunjal and Legault (1996) and used the certainty equivalence concept associated with the expected utility model. Table 5.2 presents the basic structure of the experiment. The landowners were given seven investment distributions with various levels of net returns and risks. Each investment distribution had three outcomes (low, average, and high) with equal probability of any of the outcomes occurring. The landowners were asked to select one of the investment distributions as being the most preferred, where the distributions were calculated using the Constant Partial Risk Aversion (CPRA) utility function of the form: $U(x) = (1-\gamma)x^{1-\gamma}$ where x is the certainty equivalent of the risky prospect and γ is the coefficient of risk aversion. The outcomes of the investment distributions were calculated such that two adjacent investment distributions had the same expected utility value. In addition, the investment distributions were generated under the implicit assumption that the majority of landowners are risk averse. Landowners who selected investment options 1 to 4 in Table 5.2 were classified as risk averse. Landowners who selected investment option 5 in Table 5.2 were classified as risk neutral, while landowners who selected investment options 6 and 7 were classified as risk-takers. The upper and the lower limits of the coefficients of the constant partial risk aversion for each distribution are reported in Table 5.2. To investigate the changes in partial risk aversion for each landowner, we increased the level of investment by factors of 4 and 10.

Table 5.1: Statements used to elicit the landowners' risk preference

1. I like taking financial risks
2. I try to avoid investment risks
3. I am willing to take financial risks in order to realize higher returns
4. I prefer to receive a guaranteed return even if it is low
5. It is unlikely that I would invest in a business if it has a chance of failing
6. When making investment decisions I attach equal weight to maximizing long-term returns and minimizing financial risks.
7. I aim to achieve high long-term returns on my investments even if that means taking significant financial risks in the short-run
8. I prefer to receive a guaranteed low return on my investments rather than an uncertain high return

Table 5.2: An example of the basic structure of the investment method experiment using a $25,000 investment level

Investment option	Lowest net return	Average net return	Highest net return	Partial risk aversion interval
1	$2,500	$2,500	$2,500	+infinity to 7.47
2	$2,271	$2,600	$2,930	7.47 to 2
3	$1,989	$2,700	$3,412	2 to 0.85
4	$1,603	$2,800	$3,997	0.85 to 0.32
5	$962	$2,900	$4,838	0.32 to -0.32
6	$372	$2,800	$5,228	-0.32 to -0.45
7	$0	$2,700	$5,400	0.45 to -infinity

5.3 Descriptive Summary of Survey Results

5.3.1 Demographics

Table 5.3 presents a summary of the demographic variables collected from the respondents. The vast majority of the respondents were male (93.15%) and Louisiana residents (92%). The average age for the respondents was just under 62 years, with a range of 22 to 90 years old. The vast majority of the respondents were college graduates (57.53%), with 15.07% of the respondents having some college education and the remaining 27.4% of the respondents having no college education.

Table 5.3: Demographic characteristics of the respondents

Variable	Percent (%)	Cumulative percent (%)
Education attainment		
Some high school (or less)	4.11	4.11
Completed high school or GED	15.07	19.18
Trade or technical school graduate	8.22	27.4
Some college	15.07	42.47
College graduate	57.53	100
Gender		
Female	6.85	6.85
Male	93.15	100
Household total income		
Under $15,000	1.67	1.67
$15,001 to $30,000	8.33	10
$30,001 to $50,000	6.67	16.67
$50,001 to $70,000	6.67	23.33
$70,001 to $100,000	11.67	35
$100,001 to $150,000	23.33	58.33
$150,001 to $200,000	16.67	75
Over $200,000	25	100
Residency		
No Louisiana residence	8.22	8.22
Louisiana residence	91.78	100
Home location		
Does not live on the property	90.41	90.41
Lives on the property	9.59	100

The income question was the most frequently skipped demographic question, with only 60 out of the 75 respondents providing information about income level. As reported in Table 5.3, 35% of the respondents had incomes of $100,000 or less, and 23% of the respondents had incomes in the range of $100,001 to $150,000. In additions, 17% of respondents had incomes in the range of $150,001 to $200,000, and 25% of the respondents reported annual incomes over $200,000, The majority of the landowners (90.41%) reported that they did not live on the properties that were identified in the questionnaire.

5.3.2 Attitudes Toward Wetland Conservation and Various Incentive Programs

Landowners were asked to indicate the extent to which they agreed or disagreed with various statements relating to wetland restoration. First, the landowners were asked, a general question about the importance of wetland restoration to future generations. The majority of the respondents (91%) either strongly agreed or agreed with this statement. Then the landowners were asked more direct questions about the values of wetland restoration. In response to the statement, "Restored wetlands protect wildlife and/or fish habitat," 93% of the respondents strongly agreed or agreed with this statement. Similarly, about 92% of the respondents strongly agreed or agreed with the statement, "Restoring wetlands improves water quality and reduces erosion." Approximately 90% of the respondents strongly agreed or agreed with the statement, "Wetland restoration provides storm and flood protection" (see figure 5.3).

Asked about their awareness of various wetland restoration programs in the coastal zone, 46% of the landowners indicated that they were aware of wetland restoration programs in their area. Out of the group of respondents who were aware of wetland restoration programs in their areas, 47% had enrolled in one or more of the available programs. Landowners were also asked if they would be willing to participate in future programs, with the majority of the respondents (86%) indicating that they were willing to participate.

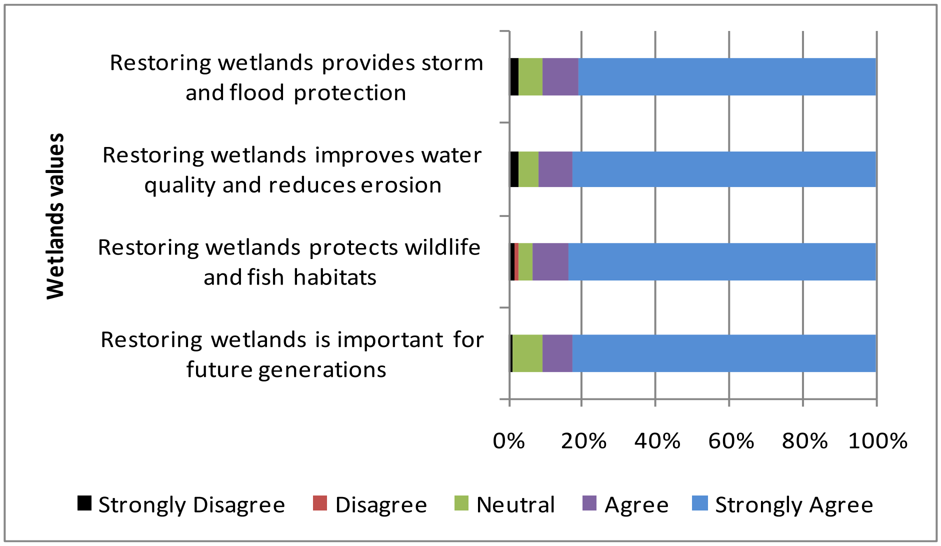

Figure 5.3: Respondents' attitudes concerning the importance of restoring wetlands in coastal Louisiana

Following this question, the landowners who were interested in participation were asked to indicate the importance of the following wetland restoration incentive instruments: 1) tax incentive, 2) cost-sharing assistance, 3) direct grants and subsidies, 4) temporary conservation easement, 5) permanent conservation easement, 6) wetland mitigation banking, and 7) carbon credit program. They were asked to rate (on a 5-point Likert scale) the importance of each of the incentive instruments (see Figure 5.4). The most preferred instrument was direct grants and subsidies (83% of the respondents rated this option as either somewhat important or very important). The second preferred instrument was cost sharing assistance, with 66% of the respondents rating cost sharing as either somewhat important or very important. Tax incentives were also popular, with about 59 % of the respondents indicating that this program was either somewhat important or very important. Somewhat less popular were permanent conservation easements and wetland mitigation banking, but a majority of the respondents (52% and 51 %, respectively) rated these two instruments either somewhat important or very important. Temporary easement and carbon credit instruments received considerably less support, with 35-36 % of the landowners indicating that these programs were somewhat to very important.

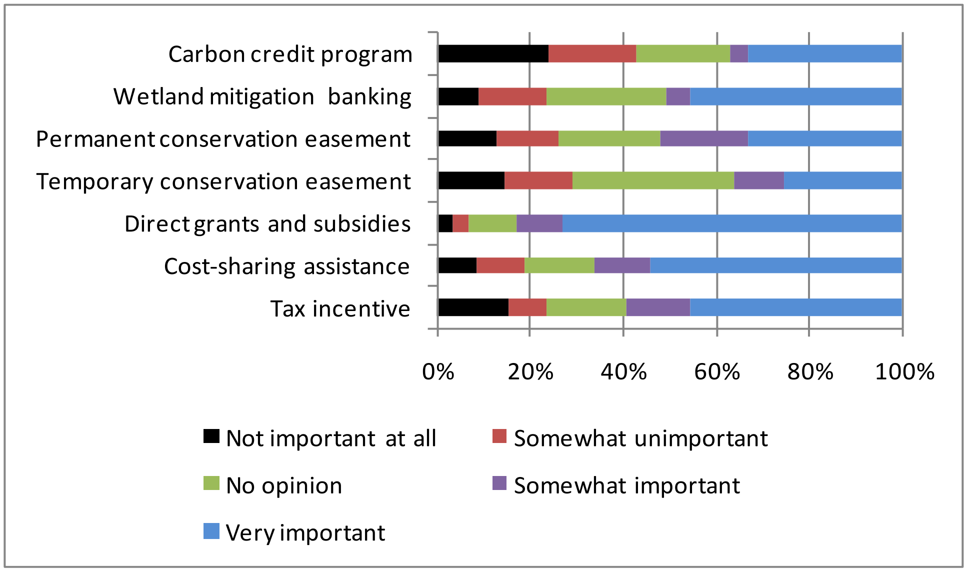

Figure 5.4: Landowners' preferences for various incentive instruments for wetland restoration and maintenance in coastal Louisiana

5.3.3 Characteristics of the Properties

Landowners were asked a group of questions regarding the general characteristics of their landholdings, including property size, percentage of wetland, current land use, ownership type, the time that the property was first acquired, how is it managed, and how much wetland had been loss, the percentage of household income generated from both surface and sub-surface activities, and the expected market value of the property. A statistical summary of the main variables in this section is presented in tables 5.4 and 5.5. The results show that the properties of the landowners who responded to the survey have diverse characteristics. The total acres owned by respondents ranged from 19 to 150,000 acres, with an average of 5,249 acres and standard deviation of 17,892 acres. The average wetland acreage on these properties was 2,764 acres, with a range of 16 to 25,175 acres. In percentage terms, wetlands averaged about 76% of the property acreage of the respondents, ranging from 5% to 100%.

Table 5.4: Statistical summary of the property characteristics for respondents to the landowner survey.

Variable	Mean	Std Dev	Min	Max	Total
Property size	5,249	17,892	19	150,000	393,680
Wetland percent	75.73	28.18	5	100	
Wetland total acres	2,764	4,789	16.4	25,175	193,450
Leased(0,1) dummy variable	0.43	0.50	0	1	
Acres lost	329	1,176	0	800,7	17,417
Leased acres	1,653	4,047	0	25,000	82,635

Table 5.5: Ownership structure and land management

Variable	Percent (%)	Cumulative percent (%)
Ownership type		
Sole ownership	32	32
Joint ownership through a tenants-in- common arrangement	20	52
Joint ownership through a corporation or trust	29.33	81.33
Other ownership	18.67	100
Management type		
Self-managed	60.81	60.81
Managed using hired a service or employees	12.16	72.97
Managed by leaseholder	8.11	81.08

The most common ownership structure among respondents was sole ownership (about 32 % of the properties). The second most common ownership structure was joint ownership through a corporation or trust, with 29% of the respondents choosing this category. The third most common ownership category was joint-ownership through a tenants-in common arrangement, with about 20% of the wetland properties owned in this way. The remaining 19% of the property were owned through some other, generally unspecified structure.

A majority of the respondents (60.81%) indicated that they self-managed their landholdings (see Table 5.5). The distribution of other management types included the following: 19% of the respondents had their properties managed by government personnel, 12% of the properties were managed by a hired service or employees, and 8% of the properties were not being actively managed.

Landowners were also asked in this section of the questionnaire about wetland loss on their properties and whether they were renting out part of their properties to other landowners. Although only 53 landowners (out of 75 respondents) provided estimates for wetland loss on their properties, these losses averaged 329 acres (standard deviation of 1176 acres), or approximately 14% of the total wetland acres held by the respondents to this question. When the landowners were asked if they leased out part of their properties, only 43% of the respondents indicated that they did, with the average lease size being 1,653 acres (standard deviation of 4,047 acres for the 50 respondents to this question).

Landowners were asked to rate (on a 5-point scale) the importance of each of the following land activities on the tract of land specified in their questionnaire: 1) agriculture production, 2) timber production, 3) fur-trapping, alligator hunting and egg production, 4) waterfowl hunting, 5) fishing, and 6) oil and gas activities. The primary land use was waterfowl hunting, with 57% of the respondents rating this land use option as either important or very important. The second land use option was oil and gas activities, with about 53% of the respondents rating this option as either important or very important. Fur-trapping, alligator hunting and egg production was also a popular land use option, with 40% of the respondents rating it as either somewhat important or very important. About 39% of the respondents rated the fishing land use option as either important or very important. Agricultural activities and timber production were not common in these coastal zone properties, with only 19% and 9% of the respondents rating these options as either somewhat important or very important, respectively. Finally, only 9% of the respondents indicated that they used their landholdings for other types of activities. Figure 5.5 presents a frequency chart of the land use activities.

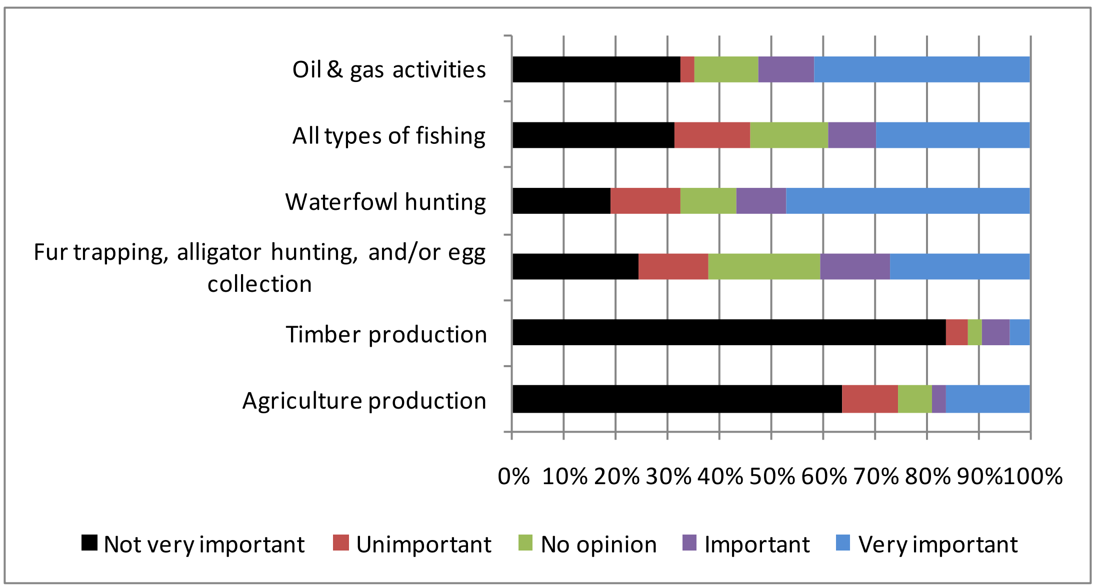

Figure 5.5: Values assigned by the landowners to various land uses activities associated with the current use of the property tract

Landowners were asked about the percentages of their annual incomes derived from surface and subsurface activities on the specific tract of land noted in the questionnaire. The vast majorities of the respondents derived no income from surface (70%) or subsurface activities (72%). For those respondents with income from surface and sub-surface activities, the surface income averaged about 12% of their annual income, ranging from less than 1% to 100%. Similarly, subsurface income averaged about 17% of their annual income, ranging from less than 1% to 88%.

5.3.4. Wetland Investments

Landowners were asked if they made any investment in wetland restoration and maintenance on the property specified in the questionnaire, and how much they privately invested over the last 10 years. Only 35% indicated that they had, with the average total private expenditure over the 10 years period being $31,522 with an associated standard deviation of $93,265 (Table 5.6). Following this question, the landowners who had implemented wetland restoration projects were asked about the type of restoration practices they used. As reported in Table 5.7, the most commonly used practice was the installation of water control structures, with approximately 62% of the respondents using this method .. The second most commonly used practice was vegetative plantings (54% of the respondents), followed closely by sediment, dredge or spoil usage (about 50% of the respondents). Finally, between 20% and 27% of the respondents reported using fresh water inputs, nutrient/sediment traps, or some other wetland restoration practices.

The landowners who invested in wetland restoration projects were asked, using a 5-point Likert scale, to indicate the importance of a set of factors related to their decisions to invest in wetland restoration and maintenance. The most important factor to the respondents was the desire to protect or enhance the ecological functions of their property (Figure 5.6).

Approximately 96% of the respondents rated this factor as either important or very important in their investment decision to. The desire to protect or enhance the property market value was listed as an important or very important reason for investing by 82% of the respondents.

Table 5.6. Statistical summary of the continuous variables in the investment section

Variable	Mean	Std. Dev	Min	Max
Investment level	$31,521.74	$93,265.21	0	$600,000
Invest(0.1) dummy	0.35	0.48	0	1
Uncertainty	5.10	3.68	0	10
Risk attitude	4.90	2.46	1	10

Table 5.7. Type of wetland restoration practices that the respondents used

Name of restoration practice	Restoration practice is used	Restoration practice is not used
Water control structures (gates, weirs, etc.)	61.54%	38.46%
Vegetative plantings (trees or grasses)	53.85%	46.15%
Nutrient/sediment traps (brush fences, terraces, etc.)	20%	80%
Sediment, dredge or spoil usage	50%	50%
Increased fresh water inputs to the property	26.92%	73.08%
Others	24%	76%

The availability of restoration subsidies and the desire to protect or enhance the property's revenue generation ability were listed as important factors by approximately 71% and 75% of the respondents, respectively.

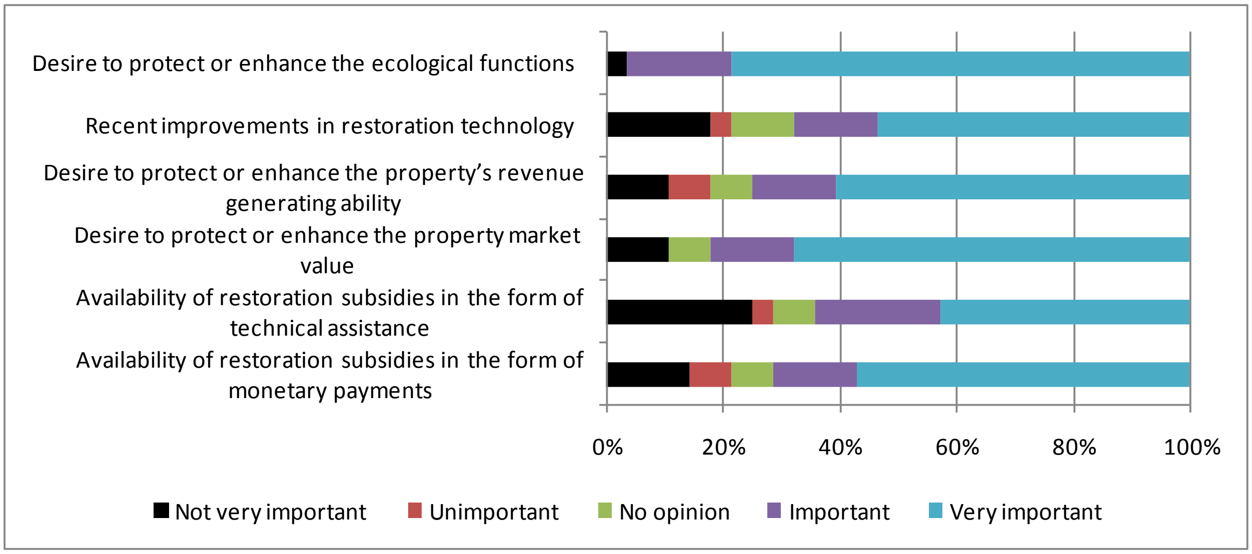

Figure 5.6: Respondents' perceptions about various factors that influence their decisions to invest in wetland restoration and maintenance

Similarly, landowners were asked about the factors that have prevented them, or might prevent them in the future, from investing in wetland restoration (Figure 5.7). Potential respondents were given a list of factors and asked to indicate the importance to each factor using a 5-point Likert scale. Topping the list of these deterrent factors was the high cost of wetland restoration, with 75% of the respondents listing this factor as either important or very important in their decisions not to invest. The second most important factor was insufficient government financial incentives, with about 69% of the respondents rating this factor as important or very important. Uncertainty about future benefits and costs of wetland restoration and the lack of personal financial resources were also important, with about 66% of the respondents ranking these factors as either important or very important. Fifty two percent of the respondents listed the lack of personal economic benefits from wetland restoration as an important or very important impediment to investing. At the bottom of the list of investment impediments was the lack of need for wetland restoration, with only 22% of the respondents reporting this factor as an important deterrent to investment.

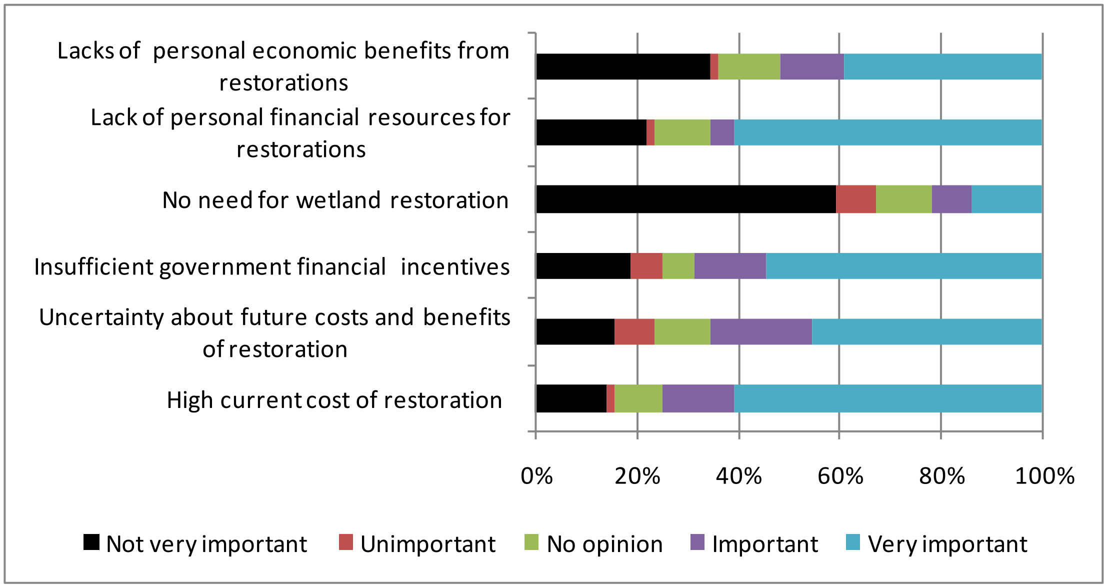

Figure 5.7. Respondents' perceptions about various factors that influence their decisions not to invest in wetland restoration and maintenance

Given the reported importance of uncertainty about future cost and benefits in the investment decision-making process, the landowners were also asked to identify the sources of uncertainty they were facing. Potential respondents were given a selected set of uncertainty sources and were asked to rank them (Figure 5.8). Uncertainty about changing government policies was ranked the number one source of uncertainty, with 50% of the respondents indicating it to be the most important source of uncertainty and 19% of them ranking it second most important source. Another important source of uncertainty, as perceived by the landowners, was shifting environmental conditions, with 58% of the respondents ranking this as either the first or second most important source of uncertainty. Uncertainty about restoration costs and restoration technologies were ranked third and fourth, respectively.

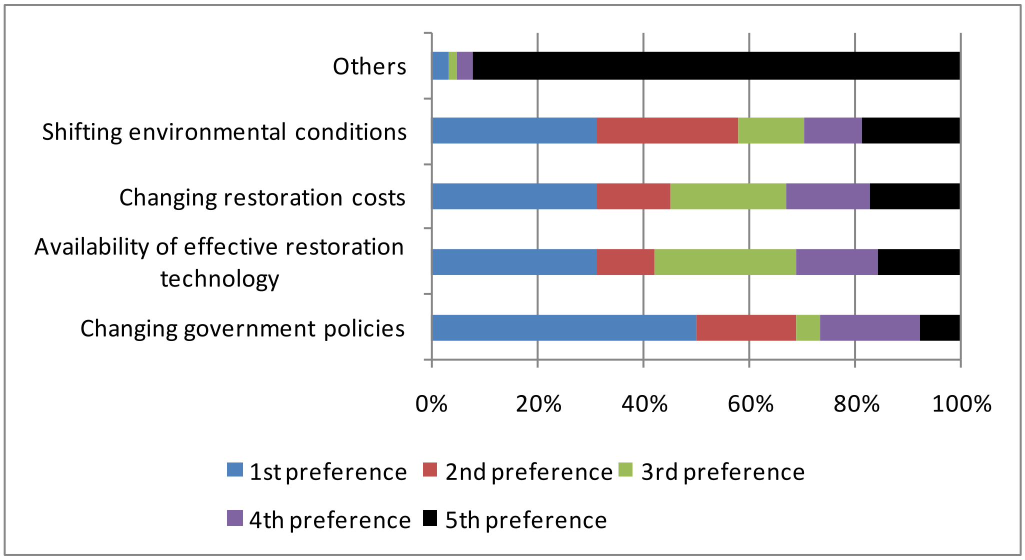

Figure 5.8. Respondents' perceptions about uncertainty sources

Finally, landowners were asked to assess the level of uncertainty associated with making a positive return on investment in wetland restoration and maintenance projects using a 0 to 10 scale, with 0 representing no uncertainty and 10 high uncertainty. On average, the respondents assessed the level of uncertainty to be right in the middle of the range (Table 5.6), with the average score being 5.10 (standard deviation equal to 3.68).

5.3.5 Landowner Risk Preferences

In total, 72 landowners responded to the self-ranking risk question. The responses of the respondents ranged from 1 to 10, with a mean of 4.9 (Table 5.6). The self ranking risk question did not allow for classifying respondents into risk averse and risk taker groups because it did not provide a unique measure of the risk preferences of the respondents (such as the coefficients of the partial risk aversion in the investment method). However, the distribution of the respondents scores reported in Figure 5.9 was used to shed light on how landowners assessed their risk preferences compared to other landowners. For example,

Figure 5.9 shows that 43% of the respondents reported that they avoided taking investment risk compared to a respondent with a score of 5 (the median score). In addition, 38% of the respondents reported that they were willing to take more investment risk than a respondent with a score of 5.

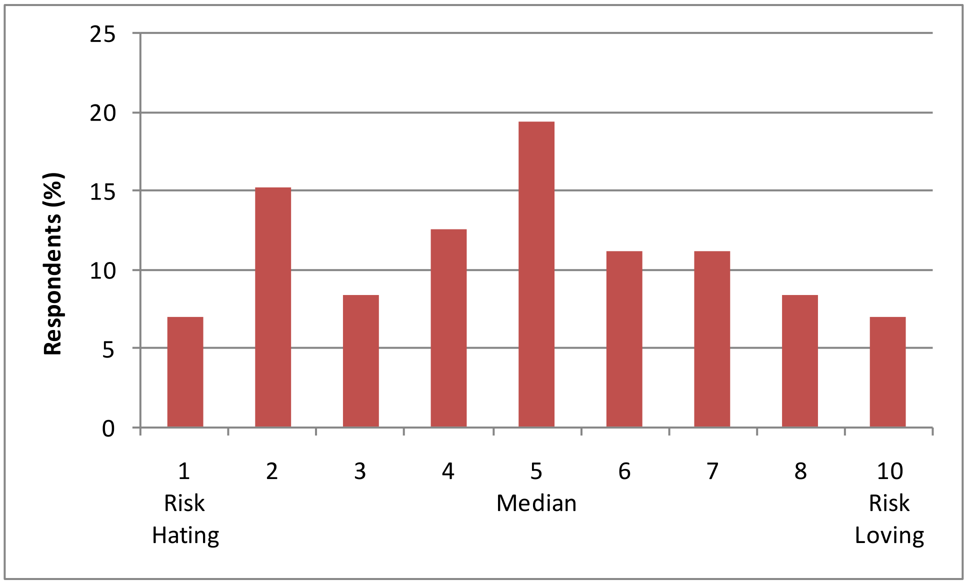

Figure 5.9. Landowners' risk attitude scores based on the self ranking question

Principal component analysis[6] of the multi-item scale approach revealed three important factors that explained about 72% of the total variation in the sample (Table 5.8). The first factor had an eigenvalue of 14.66 and explained about 34.11% of the total variation in the sample, and the second factor had an eigenvalue of 10.31 and explained 24% of the total sample variation. The third factor had an eigenvalue of 5.97 and explained about 14% of the total variation in the sample. Three items (4, 5, and 8) out of the total 8 items reported in Table 5.1 make up the first factor. Since two of these items are related to the return risk, then the first factor appeared to measure the landowners' attitudes toward risk in returns. The

[6] Item# 6 in Table1 was excluded from the principal component analysis due to a small and insignificant loading coefficient.

Table 5.8. Variance matrix of the principal component analysis

Factor	Eigenvalue (variance)	Variance explained (%)	Cumulative variance explained(%)
Factor 1	14.66	34.11%	34.11%
Factor 2	10.31	23.99%	58.10%
Factor 3	5.97	13.89%	71.99%
Factor 4	5.25	12.21%	84.21%
Factor 5	3.51	8.18%	92.38%
Factor 6	1.88	4.37%	96.76%
Factor 7	1.39	3.24%	100%

second factor was represented by two items (1 and 3), and both of them are related to financial risk. Hence, the second factor appeared to be measuring the landowners' attitudes toward the financial risk. Finally, item 2 had significant loadings on the eigenvector of the third factor. The third factor appeared to measure the importance of investment risk (see table 5.9).

The multi-item risk method did not allow for classifying landowners into risk averse, risk neutral, or risk taker groups. However, principal component analysis can be used to calculate the scores of landowners associated with each factor, with these factor scores subsequently used to assess a respondents level of risk preference. Before running the analysis, all items presented in Table 5.9 were rescaled to take on values of -4 ("I strongly disagree") to 4 ("I strongly agree"), with items with negative scores indicating that landowners avoided taking risk and items with positive scores indicating that landowners were willing to take risk. Consequently, respondents with positive factor scores would indicate that they were less willing to take risk than respondents with zero factor scores and respondents with negative factor scores would indicate that they were willing to take more risk than respondents with zero factor scores. As reported in Table 5.10, results of the first factor model showed that 43% of respondents indicated they tend to take less risk than respondents with zero factor scores. However, about 40% of the respondents indicated that they were willing to take more risk than respondents with zero factor scores. Results of the other factor models are presented in Table 5.10.

Table 5.9. Factor loading matrix of the principal component analysis

Item	Factor 1	Factor 2	Factor 3
I like taking financial risks	0.285	**0.597**	0.077
I try to avoid investment risks	0.326	-0.369	**0.777**
I am willing to take financial risks in order to realize higher returns	0.212	**0.598**	0.038
I prefer to receive a guaranteed return even if it is low	**0.535**	-0.155	-0.047
It is unlikely that I would invest in a business if it has a chance of failing	**0.482**	-0.185	-0.459
I aim to achieve high long-term returns on my investments even if that means taking significant financial risks in the short-run	0.232	0.264	0.331
I prefer to receive a guaranteed low return on my investments rather than an uncertain high return	**0.442**	-0.148	-0.257

Note: factors' loadings that are larger than 0.4 are presented in bold. Only the results of the first three factors are reported in this table.

Finally, the distribution of the respondents' answers for the investment method question associated with a $25,000 investment level[7] is reported in Table 5.11. In total, only 52 landowners answered this question. The results showed that the vast majority of the respondents (73%) were classified as risk averse. About 21 % of the landowners were classified as risk neutral, and only 6% of the landowners were classified as risk takers.

Table 5.10. Landowners' risk attitudes based on the multi-item scale approach

Factor	Avoid taking risk	Risk indifferent	Like taking risk
Factor 1	43.28%	16.42%	40.30%
Factor 2	38.81%	23.88%	37.31%
Factor 3	37.31%	29.85%	32.84%

Table 5.11. Landowners' investment distribution choices associated with a $25,000 investment level

Investment option	Percent (%)	Cumulative percent (%)
1	17.31%	17.31%
2	9.62%	26.92%
3	17.31%	44.23%
4	28.85%	73.08%
5	21.15%	94.23%
6	3.85%	98.08%
7	1.92%	100%

[7] Due to large number of missing observations associated with the question regarding the other two investment levels ($100,000 and $250,000), the results of the risk investment question for a $25,000 investment level is discussed.

Taken together, the survey data collected in this study indicated that the majority of landowners were risk averse. About 73% of the respondents were classified as risk averse based on the investment method. The other risk preference elicitation methods did not allow for specific categorizations of the landowners into risk averse and risk taker groups, but they showed that a large number of respondents appeared to avoid taking risk in their investment decisions. A large proportion of landowners placed importance on wetland conservation, with more than 90% of the landowners either strongly agreeing or agreeing with statements related to the importance of wetlands for 1) future generations, 2) wildlife and/or fish habitats, 3) water quality and erosion control, and 4) storm and flood protections. The survey results also provided important information regarding attitudes toward incentive programs for wetland restoration and maintenance. The majority of landowners (86%) indicated that they would be willing to participate in wetland restoration programs. About 83% of these landowners selected direct grants and subsidies as their most preferred incentive instrument. Cost sharing assistance and tax incentives were the second and third most preferable incentive options, respectively.

The primary land uses for respondents to the survey were waterfowl hunting and oil and gas activities. Timber and agricultural production were the least important land-use activities in the sample. The vast majority of landowners (70% or more) derived no income values from their wetland holdings. With regard to investments in wetland restoration and maintenance projects, only 35% of the landowners had made any wetland restoration investments. Costs of wetland restoration, insufficient financial incentives, and uncertainty about future benefits and costs of wetland restoration projects were considered major deterrents to investment. With regard to the uncertainty sources, the majority of the landowners listed uncertainty about changing government policies, and shifting environmental conditions as their chief concerns. The next chapter uses this information, and more, to estimate the empirical models outlined in Chapter 4.

CHAPTER 6

RESULTS OF EMPIRICAL ESTIMATION

Two econometric models to analyze landowner investment decisions were presented in chapter 4 – the Tobit model and the double hurdle model. The Tobit model assumes that landowners make the decisions to invest and the level of investment simultaneously, while the double hurdle model assumes that landowners make these decisions sequentially. To explore the implications of choosing each of these decision making models, this chapter presents empirical results from the estimation of the Tobit and the double hurdle models, comparing the results and testing to see which model best represents the survey data. The material is presented in the chapter as follows. First, a brief summary of the key variables used in the analysis is presented, followed by the results of the Tobit model estimation. Next, the results of the double hurdle model estimation are presented and discussed. Lastly, the two econometric models are compared for their suitability given the collected data.

6.1 Data Summary

Descriptive statistics of the variables selected for the analysis are reported in Table 6.1. Considering the dependent variables, "invest" is a discrete dummy variable that indicates if the landowners made any wetland investment on their property and "invest level" describes the level of private investments that were made over the last 10 years. The descriptive statistics show that majority of landowners did not invest in wetland restoration and maintenance with only 35% of the respondents indicating that they had done so. But, for those who did make private investments, the average total investment over the last 10 years was $31,522 (standard deviation of $93,265).

Table 6.1: Summary statistics for the variables used in the analysis

Variable	Description	Mean	Std. Dev
Invest	=1 if investing in wetland restoration, 0 otherwise	0.35	0.48
Invest level	Total investment expenditure on wetland restoration($)	31,522	93,265
Wetac	Total wetland acres owned or managed	2,764	4,789
Age	Landowner's age, in years	61.94	12.4
Educ	Landowner's level of education	4.07	1.28
Landinc	Total household income related to the property use ($)	8,922	26,828
Sowner	=1 of the landowner is a sole-owner, 0 otherwise	0.32	0.47
Govwetrp	=1 if the landowner is enrolled in government wetland restoration programs, 0 otherwise	0.22	0.41
Pubinv	=1 if public investment is made on the property, 0 otherwise	0.12	0.33
Consatt	An index for the landowners attitudes toward wetland conservation	4.69	0.7
Riskatt	A self reported measure of risk attitude	4.9	2.46
Agruse	=1 if part of the property is used for agricultural production, 0 otherwise	0.19	0.39
LAresid	=1 if the landowner is Louisiana residence, 0 otherwise	0.92	0.28
Distshore	Distance from the shore line(miles)	28.6	17.11
Long	Longitude(miles)	144.87	88.98

6.1.1 Characteristics of Landholdings

A relevant explanatory variable in the decision to invest in wetland restoration and maintenance is the property size, represented here by the total wetland acreages owned or operated. Property size was previously found to have a positive effect on investment in soil conservation (Norris and Batie, 1987; Soule *et al.*, 2000). It was expected that the larger the wetland size, the larger the level of investment in wetland restoration projects. This variable was transformed via natural logarithm to allow for a nonlinear relationship between wetland investments and wetland property size.

Land income ("landinc") was defined as the total household income level[8] derived from the activities that took place on the respondent's wetland property. This variable was created by multiplying the percentage of income derived from the both surface and sub-surface activities with the mid-value of the income range that the respondents reported. A positive relationship between income and the decision to invest was reported in other studies (Norris and Batie, 1987; Romm *et al.*, 1987; Zhang and Flick, 2001). It was expected that landowners with higher incomes from their wetland properties would invest more in wetland restoration and maintenance projects.

Two property location variables were included in the analysis. The first location variable was the distance of the property (in miles) from the shoreline (Distshore). The distance of the property from the shoreline was calculated by overlaying the digitalized property information with the existing GIS map of coastal Louisiana. The distance of the

[8] Out of the total sample (N=75), 60 respondents reported their income earnings. An auxiliary regression was used to impute the missing data. Income was specified as a function of wetland acres (in natural logarithm) and education. The regression R-square was 0.41 and all explanatory variables were highly significant. The predicted incomes from this auxiliary regression were used for the missing observations. The result of this auxiliary regression is presented in Appendix B. Due to missing observations of the explanatory variables in the auxiliary regression model, only 11 out of total 15 income missing observations were generated.

property from the shoreline was calculated by drawing a straight line between the property center and the nearest point on the coastal map, and measuring its length. This variable was included in the model as a proxy for the vulnerability of the wetland property to erosion and other exogenous, weather related forces. It also captured the impact of wetland type on the landowners' investment decision. Properties that are located close to the shoreline are generally dominated by salt marshes, and properties located further from the shoreline are dominated by fresh marshes. It was expected that landowners with wetland properties further inland are more likely to invest, and invest more, in wetland restoration projects. The second location variable was the longitude of the property (Long). This variable was included as a proxy for wetland losses. Historical wetland loss rates and projected losses are concentrated in the eastern part of the State, and then mainly in the lower Terrebonne, Barataria basins and Mississippi basins (Louisiana Department of Natural Resources (LADNR), 1999). As such, the high rate of wetland loss in the eastern part of the state may make investment infeasible and increases investment risk. Therefore, landowners with properties located in the eastern part of the state would be less likely to invest in wetland restoration and maintenance projects. Alternatively, one might argue that the higher the rate of wetland loss in the eastern part of the state may encourage landowners to invest in wetland restoration projects in order to prevent additional wetland losses. Thus, the expected sign of this variable is ambiguous. The Long variable was measured in miles and it increases as the property location moves from west to east.

The use of the property for agricultural production was also hypothesized to influence the decision to invest in wetland restoration and maintenance. To capture this effect, a dummy variable for agriculture land use (Agruse) was included in the analysis. Agruse was assigned a value of 1 if a landowner used part of his/her landholding for agriculture production and 0 otherwise. It was hypothesized that landowners who use part of their properties for agricultural activities were less likely to invest in, wetland restoration projects than other landowners due to diminishing surface and subsurface wetland incomes, time constraints, and changes in operational focus.

6.1.2 Characteristics of the Landowners

Characteristics of the landowners included both demographic variables and attitudes toward risk and wetland conservation issues. The demographic variables included age, education, and residence, and ownership structure. Age was expected to be negatively associated with the dependent variables. Education was expected to have positive impact on the dependent variables. It was hypothesized that landowners who are sole owners and reside in Louisiana have higher chances to invest and invest more in wetland restoration projects.

An index for the landowners' attitudes toward wetland restoration (Consatt) was constructed by averaging the responses of the landowners to four statements regarding the importance of wetland conservation for: 1) future generation, 2) wildlife and fish habitats, 3) water quality and erosion control, and 4) storm and flood protection. All responses were elicited using a Likert scale (1= strongly disagree, 2=disagree, 3= neutral, 4=agree, and 5=strongly agree). It was hypothesized that the higher the score of the Consatt variable, the higher the likelihood and the level of wetland investments. A landowner's attitudes toward risk were elicited using the self-ranking risk question. They were given a 1 to 10 scale (1 being risk hating, and 10 being risk loving) and asked to rate their risk preferences. Risk attitude was expected to have a negative relationship with the decision to invest in wetland restoration and maintenance projects.

6.1.3 Influence of Government Programs

Participation in government wetland restoration programs (Govwetrp) is expected to influence a landowner's decision to invest in wetland restoration and maintenance projects. The Govwetrp variable is measured as a dichotomous variable, indicating whether a landowner is a participant in any wetland restoration programs. It was hypothesized that landowners who were enrolled in government-sponsored wetland restoration programs would be more likely to invest, and invest more, in wetland restoration and maintenance projects. Hence, the expected sign of the Govwetrp variable is positive.

The decision to invest in wetland restoration and maintenance projects was also expected to be influenced by the level of public investment (Pubinv) made on the property. Pubinv is a dummy variable equal to 1 if a landowner received cost sharing assistance or direct subsidies to conduct wetland restoration projects, and 0 otherwise. The expected sign of this variable is an empirical question.

6.2 Results of the Tobit Model

All parameter estimates and marginal effects of the Tobit model were generated using Stata version 11 (StataCorp, 2009). The parameter estimates for the Tobit model and their associate standard errors are reported in Table 6.2. The standard errors associated with the parameter estimates of the Tobit model were made robust to some kinds of error misspecification, including non-normality and hetroskedasticity,[9] using the subroutine "*Vce (robust)*" in Stata (Cameron and Trivedi, 2009). The marginal effects for the variables that are used in the model, and their associated standard errors, are presented in Table 6.3. Two

[9] Tests for both non-normality and heteroskedasticity were conducted using the regression version of the Lagrange Multiplier (L test outlined in Wooldridge (2002) page 534. The result of the LM test failed to reject the null hypothesis of homoskedasticity (LM test of 0.427 with a p-value equal to 0.808). However, the LM test rejected the null hypothesis that the error terms are normally distributed. The value of the LM statistic is 43.803, and it has a p-value that less than 0.001.

types of marginal effects are reported . The conditional average marginal effects are the partial effects averaged across the sample observations and obtained using the "*margeff*" command in Stata. The conditional marginal effects at the means are the partial effects estimated at the sample means of explanatory variables and obtained using the "*mfx*" command in Stata (Cameron and Trivedi, 2009). The two marginal effects can have significantly different values in nonlinear models. In addition, the average marginal effects are preferable for nonlinear models and models and in the case of discrete variables (Wooldridge, 2002, Papke and Wooldridge, 2008). Unless otherwise stated, therefore, the conditional marginal effects we refer to in the discussion section are the conditional average marginal effects. Overall, the Tobit model fit the data well, with an overall model likelihood ratio statistic of 30.77 (significant at 1% level).

The results in Table 6.2 reveal that property size is an important factor explaining a landowner's investment decisions. The coefficient of the variable representing wetland property size (Lnwetac) is positive and statistically significant at the 5% level, indicating that the larger the wetland property size, the higher the probability of investment and level of investment in wetland restoration and maintenance. The conditional marginal effect[10] reported in Table 6.2 suggests that a 1% increase in wetland property size will increase private investment by approximately $299 for those landowners who had already decided to invest. This result is consistent with the finding of other studies. Norris and Batie (1987) found a positive relationship between farm size and the soil conservation expenditures, while Soule et al. (2000) found farm size to be positively related to the adoption of conservation practices.

[10] The unconditional marginal effect s and the probability marginal effects were excluded from Table 6.3 for simplicity reasons and the absence of statistically significant marginal effects.

Dhakal *et al.* (2008) found that property size was positively related to the probability of investing in a forestry plantation.

Table 6.2. Parameter estimates of the Tobit model

Variable	**Coefficient**	**Robust standard error**
Constant	-2214273*	1097693
Lnwetac	29918.81**	14152.73
Riskatt	11767.48	13237.41
Sowner	154632***	55871.96
Govwetrp	160479.8	116596.9
Pubinv	-91670.31	111136.6
Landinc	-0.93	2.04
Agruse	-211311.2*	119070.9
Long	-894.36*	471.51
Distshore	6444.99*	3377.71
Consatt	383296.2*	216603.3
Age	431.1981	2868.953
Educ	6474.37	20378.67
LAresid	-163196.9	114810.9
Log-Likelihood	-222.05	
Likelihood ratio statistics	30.77	
Prob>chi-square	0.0036	
Sample size	58	

***,**,* denotes that the corresponding parameters are significant at 1%,5% and 10% respectively

Table 6.3. Marginal effects for the Tobit model

Variable	Conditional marginal effect	Conditional marginal effect (evaluated at the mean level)
Lnwetac	29919**	3903**
	(14153)	(1952)
Riskatt	11767	1535
	(13237)	(1762)
Sowner	154632***	22994**
	(55872)	(8928)
Govwetrp	160480	26680
	(116597)	(21084)
Pubinv	-91670	-10483
	(111137)	(10839)
Landinc	-0.93	-0.12
	(2.04)	(0.27)
Agruse	-211311*	-22067**
	(119071)	(10486)
Long	-894.36*	-116.67**
	(471.51)	(51.47)
Distshore	6444.99*	840.76**
	(3377.71)	(371)
Consatt	383296*	50001**
	(216603)	(13483)
Age	431.20	56.25
	(2868.95)	(371.64)
Educ	6474	845
	(20379)	(2792)
LAresid	-163197	-29321
	(114811)	(22927)

Note: Standard errors are in parentheses ***,**,* denotes that the corresponding parameters are significant at 1%,5% and 10% respectively,

Other Tobit results indicate that ownership structure plays an important role in the investment decision. The coefficient of ownership dummy variable (Sowner) is positive and highly significant at the 1% level. As expected, landowners who were sole-owners were more likely to invest, and invest more, in wetland restoration and maintenance projects. Conditional on investing in wetland restoration and maintenance, landowners with a sole ownership structure invested $154,632 more than other landowners. Ownership structure was previously found to be an important factor influencing the decisions to invest in soil conservation (Soule et al. (2000); Featherstone and Goodwin (1993); Norris and Batie (1987)), invest in forest improvement (Dhakal *et al. (*2008)), and participate in government forestry assistance programs (Nagubadi *et al.* 1996).

The estimated coefficient for Agruse dummy variable was negative and significant at the 10% level, suggesting that landowners who use part of their properties for agricultural production are less likely to invest, and make smaller investments if they do, in wetland restoration projects. This negative correlation between agricultural land use and the decision to invest was expected for several reasons. First, the survey data showed that the majority of landowners (more than 70%) derived no income values from their wetland properties. Hence, the presence of wetlands on agricultural production properties might impose extra costs on the landowners with farming activities because landowners cannot use these wetland areas for agricultural production purposes. Gelso et al.(2008) investigated the costs associated with the presence of wetland areas in cropland for Kansas producers. They found that the presence of wetlands imposed inconvenience costs on producers, especially the more dispersed these wetlands. Second, one can argue that investment in wetland restoration is not very appealing for landowners engaged in agricultural activities for reasons such as time constraints, competition for private capital between agriculture and wetlands operations, and changes in operational focus. Royer (1987) investigated the reforestation behavior of southern private landowners and found a negative relationship between farming and reforestation investments. The conditional marginal effect shows that landowners who had invested in wetland restoration projects and used their properties for agricultural production invested $211,311 less on wetland restoration and maintenance than other landowners.

The coefficient of the longitude variable (Long) was negative and statistically significant at 10% level in the Tobit model. Thus, landowners with wetland properties in the eastern part of the state were less likely to invest in wetland restoration and maintenance than landowners in the western part of the state. This negative and significant correlation between the longitude of the property and the decision to invest was not unexpected. First, the majority of wetland losses in coastal Louisiana are concentrated in the eastern part of the State. Second, the vast majorities of these wetlands are relatively unproductive (from an ecological perspective) salt marshes, at least compared to the coastal freshwater marshes in the western part of the state. This combination of high wetlands losses and relatively low productivity makes investments in properties located in the eastern part of the state less attractive to private landowners. The conditional marginal effect of the Long variable shows that investment in wetland restoration and maintenance decreased by $894 as the property location moved 1 mile west to east.

The distance of the property from the shore line (Distshore) had positive and significant coefficient at the 10% level, indicating that the probability of investment and the level of investment increases in relation to distance from the coast. This positive relationship between Distshore variable and investment was expected for several reasons. First, it is generally true that the further a tract is from the coastal boundary between land and open sea, the less vulnerable it is to the damaging effects of hurricane wind, storm water surges, and other weather related factors. This, in return, lowers the risk associated with the decision to invest in restoration projects and may increase the likelihood of investing in such projects. Second, freshwater marshes tend to dominate the wetland properties that are furthest from the coastal boundary, and the expected return on an investment in freshwater wetlands is generally higher than for salt marshes. As reported in Table 6.3, the conditional marginal effect shows that the level of investment increased by $6,445 as the distance of the property from the shore line increased by 1 mile (evaluated at the mean distance of 28.6 miles, the conditional marginal effect was equal to $841).

Attitudes toward wetland restoration and maintenance were found to be important factors in the investment decision. The coefficient of the variable that captured the landowner's attitudes toward wetland conservation (Consatt) was positive and statistically significant at the 10% level, indicating that landowners who sympathize with wetland conservation objectives were more likely to invest, and invest more, in coastal wetland restoration projects. Conditional on investing, an additional unit increase in the conservation attitude index (Consatt) increased the level of investment by approximately $383,296. Langpap (2004) found conservation attitudes to be an important factor in private landowners' decisions to participate in incentives programs for habitat protection of endangered species. However, Ervin and Ervin (1982) did not find statistical evidence that conservation attitudes influenced the decision to invest in soil conservation.

Unexpectedly, the coefficient of the risk attitude variable (Riskatt) was not statistically significant given that. survey results indicated that landowners considered uncertainty an important impediment factor in their investment decisions. About 66 % of the respondents rated uncertainty about future benefits and costs of wetland restoration as either an important or very important impediment factor. The insignificant effect of risk aversion may be attributed to the failure of the Tobit model to treat the decision about whether to invest and the decision about how much to invest separately. The role of risk aversion in the two decision processes is still an empirical question in the literature. Saha *et al.* (1994) demonstrated that that risk aversion played an important role only in the level of adoption decision but not the decision to adopt. However, Koundouri *et al.* (2006) showed that risk aversion played an important role in the decision to adopt irrigation technology. In addition, another surprising result of the Tobit model was that none of the typical explanatory variables were statistically significant in the decision process, including age, land income (Landinc), education (educ), residency (LAresid), participation in government wetland restoration program (Govwetrp), and public investment(Pubinv)

6.3 Results of the Double Hurdle Model

The double hurdle model was estimated using Stata version 11 (StataCorp, 2009). Given that in most cases theory does not give clear guidance concerning allocation of explanatory variables between the first and second hurdles, an *ad hoc* method for selecting variables for each hurdle is used (Carroll *et al*, 2005). Specifically, the allocation of explanatory variables in the two hurdle equations was explored through a lengthy selection procedure that involved an iterative series of estimations. First, a preliminary probit model was estimated using all potential explanatory variables. Then, a preliminary Tobit model was estimated using all potential explanatory variables. Only explanatory variables that were statistically significant at the 10% level (or greater) in either a probit model or a Tobit model were selected to start the estimation of the double hurdle model. Initially, all of these significant variables were included in both the first and second hurdle equations, but statistically insignificant variables were gradually removed from the model. In some ways, this procedure sought to mimic reverse stepwise regression, both to focus on the variables that had the most explanatory power and to conserve degrees of freedom in the estimations.

The maximum likelihood parameter estimates for the double hurdle model and the marginal effects for the variables were obtained using the *Craggit* command in Stata (described in Burke (2009). The parameter estimates and the associated standard errors are reported in Table 6.4, with marginal effects for the variables that are used in the model and their associated standard errors presented in Table 6.5. The marginal effects referred to here are the partial effects averaged across the sample observation. The standard errors for the marginal effects were calculated using the delta method and the *nlcom* command in Stata. The standard errors associated with the parameter estimates of the double hurdle model were made robust to some kinds of error misspecification, including non-normality and heteroskedasticity,[11] using the command *Vce (robust)* in Stata(Cameron and Trivedi, 2009).

As in the Tobit model, the estimated coefficient of the Longitude variable (Long) is negative and statistically significant at the 1% level of significance. Thus, wetland restoration and maintenance investments by private landowners were more likely to occur as one moves in a westerly direction. In other words, landowners facing high wetland losses (east) are less likely to invest in wetland restoration and maintenance, perhaps due to the risk of investment failure and the higher cost of restoration activities in areas where wetland loss is rapidly occurring. The probability marginal effect of the Long variable is statistically significant at 1%. It shows that the probability of investment in wetland restoration and maintenance will decrease by 0.2% as the property location moves west to east by 1 mile. The unconditional marginal effect of Long variable, which is positive and significant at the 1% level, indicates

[11] Similarly to the Tobit model case, we test for both non-normality and heteroskedasticity of the error term in the second hurdle equation using the regression version of the Lagrange Multiplier (LM) test (Wooldridge, 2002). The result of the LM test failed to reject the null hypothesis that the error terms are homoskedastic (value of the LM test is 1.09 with a p-value equal to 0.58). However, the LM test rejected the null hypothesis that the error terms are normally distributed (value of the LM statistic is 19.1 with a p-value less than 0.001).

that expected investment in wetland restoration and maintenance decreases by $271 as the property location moves 1 miles to the east.

Table 6.4. Parameter estimates of the double hurdle model

Variable	Coefficient	Robust standard error
First hurdle equation		
Constant	-13.744**	5.712
Sowner	1.113**	0.535
Agruse	-1.990**	0.844
Govwetrp	1.457***	0.556
Consatt	2.656**	1.146
Long	-0.008***	0.003
Distshore	0.029*	0.016
Second hurdle equation		
Constant	-1358299***	273779
Lnwetac	81295***	16212
Riskatt	69165***	16048
Sowner	400376***	99277
Govwetrp	298995***	56834
Pubinv	-510153***	73807
Landinc	27.920***	9.901
Educ	46987	32953
Sigma	59335***	14248
Log-likelihood	-205.4	
Sample size	59	

***,**,* denotes that the corresponding parameters are significant at 1%,5% and 10% respectively

Similarly, the estimated coefficient of the variable Distshore is positive and statistically significant at 10% level in the first hurdle equation, indicating that the greater the distance of the property from the shoreline, the higher the probability of investment in wetland restoration and maintenance projects. As discussed earlier, the further a tract is from the coastal boundary, the less vulnerable it is to the damaging effects of hurricane wind, storm water surges, and other weather related factors. This, in turn, lowers the risk associated with the decision to invest and may increase the likelihood of investing in such projects. Furthermore, tracts that are located close to the shore line are generally dominated by salt marshes and they are less productive than tracts located further from the shore, which are dominated by fresh marshes, perhaps making them less attractive as investment candidates. The marginal effect of this variable is positive and significant at the 1% level. It shows that the probability of investment increases by 0.6% as the property's distance from the shore increases by 1 mile. The unconditional marginal effect shows that investment in wetland restoration and maintenance will increase by $1,067 as the property distance from the shore increases by 1 mile.

Past studies have found ownership structure to be a significant influence on the decision to invest in soil conservation (Soule *et al.,* 2000); Featherstone and Goodwin, 1993; Norris and Batie, 1987), forestry improvements (Dhakal *et al.,*2008), and decisions to participate in government forestry assistance programs (Nagubadi *et al.*, 1996). In this study, the impact of the ownership structure was captured using a dummy variable (Sowner) that was equal one if the landowner was a sole-owner and 0 otherwise. The estimated coefficient of this variable was positive and significant at the 5% level in the first hurdle, implying that landowners who are sole-owners are more likely to invest in wetland restoration and maintenance than other landowners. The marginal effect of this variable indicates that sole-owners are 23% more likely to invest privately in wetland restoration and maintenance. In addition, the coefficient of Sowner is positive and significant at the 1% level in the second hurdle equation, implying that landowners who are sole-owners are not only more likely to invest, but they also invest more than owners with other types of ownership structures. The unconditional marginal effect indicates that sole-owners privately invest $103,405 more in wetland restoration and maintenance activities than other landowners. Conditional on the investment decision, sole-owners are found to invest $155,356 more in wetland restoration and maintenance than other landowners.

Table 6.5. Marginal Effects for the Double Hurdle Model

Variable	Probability	Conditional Investment	Unconditional Investment
Lnwetac		25094***	9454***
		(5708.48)	(345.21)
Riskatt		21350***	8043***
		(5651.14)	(341.74)
Sowner	0.228	155356	103405
	n/a	n/a	n/a
Agruse	-0.290		-63139
	n/a		n/a
Govwetrp	0.332	125968	136470
	n/a	n/a	n/a
Consatt	0.545***		96528***
	(0.1374)		(7172)
Long	-0.0015***		-271.28***
	(0.00034)		(18.24)
Distshore	0.006***		1067.4***
	(0.00194)		(84.4)
Pubinv		-121865	-61375
		n/a	n/a
Landinc		8.620**	3.25***
		(3.359)	(0.203)
Educ		14504	5464***
		(10998.5)	(665.11)

Note: Standard errors are in parentheses
***,**,* denotes that the corresponding parameters are significant at 1%,5% and 10% respectively,

The estimated coefficient for landowner attitudes toward wetland restoration and maintenance (Consatt) was positive and statistically significant at the 5% level in the first hurdle equation, indicating that landowners who value wetland restoration issues are more likely to invest in coastal wetland restoration. The marginal impact of this variable suggests that a 1 unit increase in the conservation attitude index increases the probability of investment by 55% and increases the expected level of investment by approximately $96,528. Langpap (2004) found conservation attitudes to be an important factor in private landowner decisions to participate in incentives programs. Gelso *et al.* (2008) also found that farmer attitudes toward conservation and environmental regulation have a significant impact on the perceived costs associated with the presence of wetland areas on their farmlands. However, Ervin and Ervin (1982) found no statistical evidence that conservation attitudes influence the decision to invest in soil conservation.

The double hurdle estimation shows that landowners who are using part of their properties for agricultural activities are less likely to invest in wetland restoration projects, with the coefficient of the dummy variable (Agruse) being negative and significant at the 5% level in the first hurdle equation. As discussed with respect to the Tobit model, this negative relationship between the use of a land tract for agricultural production and the probability of wetland investment is not surprising. Several factors can explain this negative correlation, including the lack of farming income from wetland areas, competition for private capital between agriculture production and wetland restoration, and the costs involved in changing operational focus. The results of this study are similar to the findings of Royer (1987), where engagement in farming activities was negatively related to reforestation investment. The marginal effect value of this variable implies that landowners who are using their properties for agricultural production have, on average, a 29% smaller chances of investing in wetland restoration and maintenance than other landowners, *ceteris paribus*. The unconditional marginal effect shows that landowners who use part of their landholdings for agriculture production invest $63,139 less on wetland restoration and maintenance than other landowners.

In contrast to the Tobit model results, participation in government-sponsored wetland restoration programs (Govwetrp) had a positive effect on the probability of investment and the level of investment in the double hurdle model, with the estimated coefficient of Govwetrp being positive and statistically significant at the 1% level in both hurdles. This result supports the hypothesis that government wetland restoration programs have stimulated at least some private wetland investment in coastal Louisiana. The marginal effect indicates that landowners enrolled in wetland restoration programs have a 33% higher probability of investing in wetland restoration and maintenance. The unconditional marginal effect shows that landowners who were enrolled in wetland restoration programs invested $136,470 more, on average, than other landowners. Conditional on having made the decision to invest, landowners who are enrolled in wetland restoration programs invest $125,968 more than other landowners. These results are similar to those found in other studies. For example, Hagos and Holden (2006) studied the influence of public programs on the household's investment in soil conservation in northern Ethiopia, and found that participation in public programs stimulated investment in soil conservation. In another instance, Featherstone and Goodwin (1993) used a Tobit model and found that participation in government programs had a positive effect on farmer decisions to invest in soil conservation.

The estimated coefficient of the public investment dummy variable (Pubinv) was negative and highly significant in the second hurdle equation, indicating that receiving public financial assistance results in lower private investment, thus signaling a substitution relationship between public and private capital. The marginal effects show that landowners who use public investments to conduct wetland restoration and maintenance activities invest $61,375 less than landowners who did not receive public investments. Conditional on investing, landowners who use public investment invest $121,865 less on wetland restoration and maintenance than other private landowners. This result is similar to Zhang and Flick (2001), who found that forest landowners receiving cost sharing subsidies invested less of their own capital in forest replanting. These authors also concluded that there was a substitution effect between public funds and private capital.

Risk attitude was found to play an important role in the level of private investment made by the landowner. The coefficient of this variable (Riskatt) was positive and statistically significant at the 1% level, implying that the more risk averse the landowners, the lower the investments will be in wetland restoration and maintenance. Both the conditional and unconditional marginal effects for the risk attitude variable were statistically significant at the 5% level (see Table 6.5). The unconditional marginal effect indicates that a 1 unit increase in the risk attitude score (in other words, becoming less risk averse) leads to an $8,043 increase in the level of private investment. The conditional marginal effect of this variable shows that a 1 unit increase in the risk attitude score leads to $21,350 increase in the level of investments for the landowners who have already made the investment decision. Figure 6.1 presents the predicted wetland investments for various levels of risk aversion, holding all other variables constant at their means. The predicted wetland investment ranges from $1,703 for a highly risk averse landowner to $46,573 for a highly risk taking landowner. Therefore, risk aversion decreases the expected level of wetland investment. This negative relationship between risk aversion and investment has been documented in other studies that examined similar decision making problems (Ervin and Ervin, 1982; Shapiro, 1992; Hagos and Holden, 2006; Benitez *el* *al*., 2006; Goldstein *et al*., 2006; Stordal *et al.*, 2007; Abadi Ghadim *et al.*, 2005; Isik and Khanna, 2003).

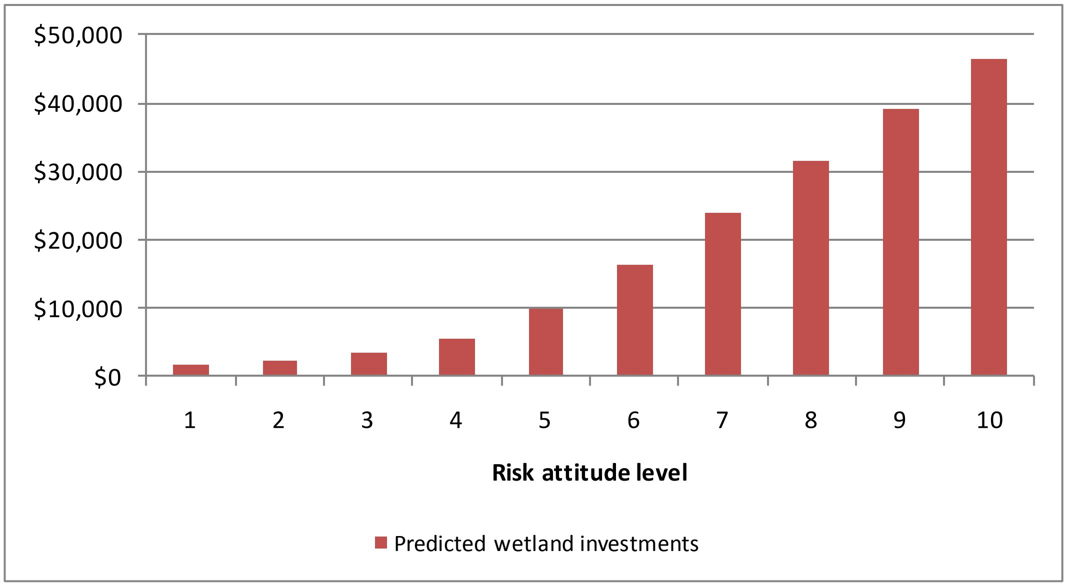

Figure 6.1 Predicted wetland investments associated with various levels of risk attitudes.

The coefficient of the wetland property size (lnwetac) was positive and statistically significant in determining the level of investment (the second hurdle equation), indicating that larger wetland properties generally experience higher levels of investment. Furthermore, the coefficient of the wetland property size variable in the Tobit model was approximately 64% lower than the estimated coefficient of wetland size in the double hurdle model. This divergence between the two models exemplifies the degree of bias that can arise when an intrinsically two-stage decision process is modeled as a single process. The conditional marginal effect of wetland size suggests that a 1% increase in property size will lead to a $250 increase in the level of investment in restoration and maintenance, while the conditional marginal effect for the Tobit model shows that a 1% increase in size increases the level of investment by $299 (or approximately 20% more than the corresponding conditional marginal effect reported for the double hurdle model). As a comparison, the literature reported mixed results regarding the relationship between investment and the property size. Some studies found that property size had significant positive effects on investment decisions (Norris and Batie, 1987; Soule *et al.*, 2000); Dhakal *et al.*, 2008). Other studies, however, found no significant relationship between property size and investment decisions (Ervin and Ervin, 1982; Featherstone and Goodwin, 1993; Romm *et at*., 1987; Hagos and Holden, 2006; Zhang and Flick, 2001). The result of double hurdle estimation in this study, however, clearly indicates that property size has positive effects on the investment decisions for private landowners.

The coefficient of the land income variable (Landinc) was positive and statistically significant in the second hurdle equation, indicating that landowner income plays an important role in determining the level of private investment in wetland restoration and maintenance, with more productive properties (in terms of income) receiving higher levels of private investment. This positive relationship between income and investment was reported in a number of other studies (Norris and Batie, 1987; Romm *et al.*, 1987; Zhang and Flick, 2001), but Featherstone and Goodwin (1993) did not find a relationship between total farm income and soil conservation investments. The marginal effects reported in Table 6.5 show that a $1 increase in income from wetland-based activities resulted in a $3.25 increase in the level of investment for all landowners, and a $8.62 increase for those landowners who had already made previous investments.

Finally, the estimated coefficient of the education variable (educ) was positive but statistically insignificant. The unconditional marginal effect was significant and shows that a move from one education category to the next highest category would lead to a $5,464 increase in the level of investment. For example, a respondent who has completed college will invest $5,464 more in wetland restoration projects if he/ she has some college education (but never completed it). On the other hand, the conditional marginal effect was larger in magnitude, but not statistically significant. Previous studies have found education to be a significantly positive influence on the level of investment in technology adoption (Saha *et al.*, 1994) and soil conservation (Ervin and Ervin, 1982; Norris and Batie, 1987; Hagos and Holden, 2006).

One way of interpreting the estimated double hurdle model is by categorizing landowners into two groups. The first group, landowners who do not cross the first hurdle equation, may never invest in wetland restoration and maintenance under any circumstances. The second group, landowners who pass the first hurdle, are potential investors. This second group has two choices: a) invest in wetland restoration and maintenance (positive value of the dependent variable) or b) do not invest in wetland restoration and maintenance (zero value of the dependent variable). Therefore, the estimated double hurdle model can be used to predict the probability that an individual landowner would fall in one of the two categories. Consequently, looking at the common characteristics of the landowners in each category may be of interest when it comes to discussing the policy implications of landowner behavior. The probability that a landowner will not invest in wetland restoration and maintenance can be expressed as follows:

$$P(y_i = 0/z_i) = 1 - P(y_i > 0/z_i) = 1 - \Phi(z_i'\hat{\alpha}) \quad (50)$$

where $\hat{\alpha}$ is a vector of the estimated parameters of the variables that are included in the first hurdle equation. Equation (50) was estimated for all the landowners who did not invest in wetland restoration and maintenance at the time the survey was taken. The predictive results (see Figure 6.2) show that most landowners have a high probability of never investing in wetland restoration projects. More specifically, the histogram shows that 85% of the landowners who did not invest in wetland restoration projects at the time of the survey have probabilities in excess of 0.5 that they will never invest in wetland restoration projects. The results also show that, on average, the probability that a landowner in this group would never invest in wetland restoration and maintenance was 0.81.

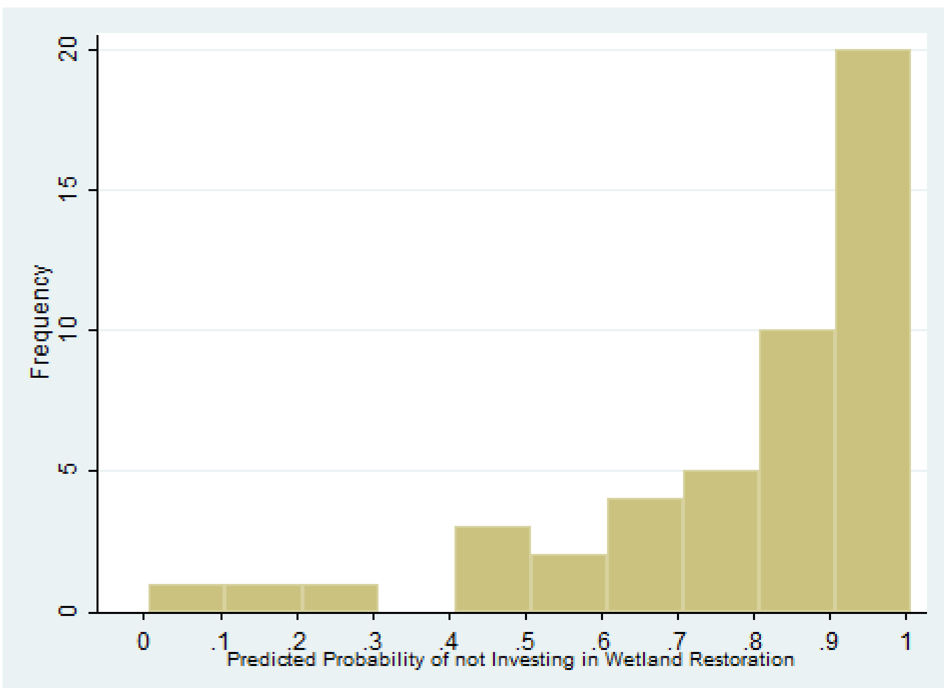

Figure 6.2: Histogram of predicted probability of no investment in wetland restoration and maintenance

Similarly, we can use the double hurdle model to look at probability distributions for landowners who are potential investors. The probability that a landowner will invest in wetland restoration and maintenance is:

$$P(y_i = 1/z_i) = \Phi(z_i^{'}\hat{\alpha}) \tag{50}$$

where $\hat{\alpha}$ is the vector of the estimated parameters of the variables that are included in the first hurdle equation. Equation (50) was estimated for all landowners in the sample who reported investing in wetland restoration projects at the time of the survey, and a frequency histogram of the results is presented in Figure 6.3. The results indicate that only 46% of the landowners who are potential investors have probabilities of investment higher than 50%. Put another way, the majority of the landowners in the group of potential investors have probabilities of investment lower than 50% based on the estimated double hurdle coefficients.

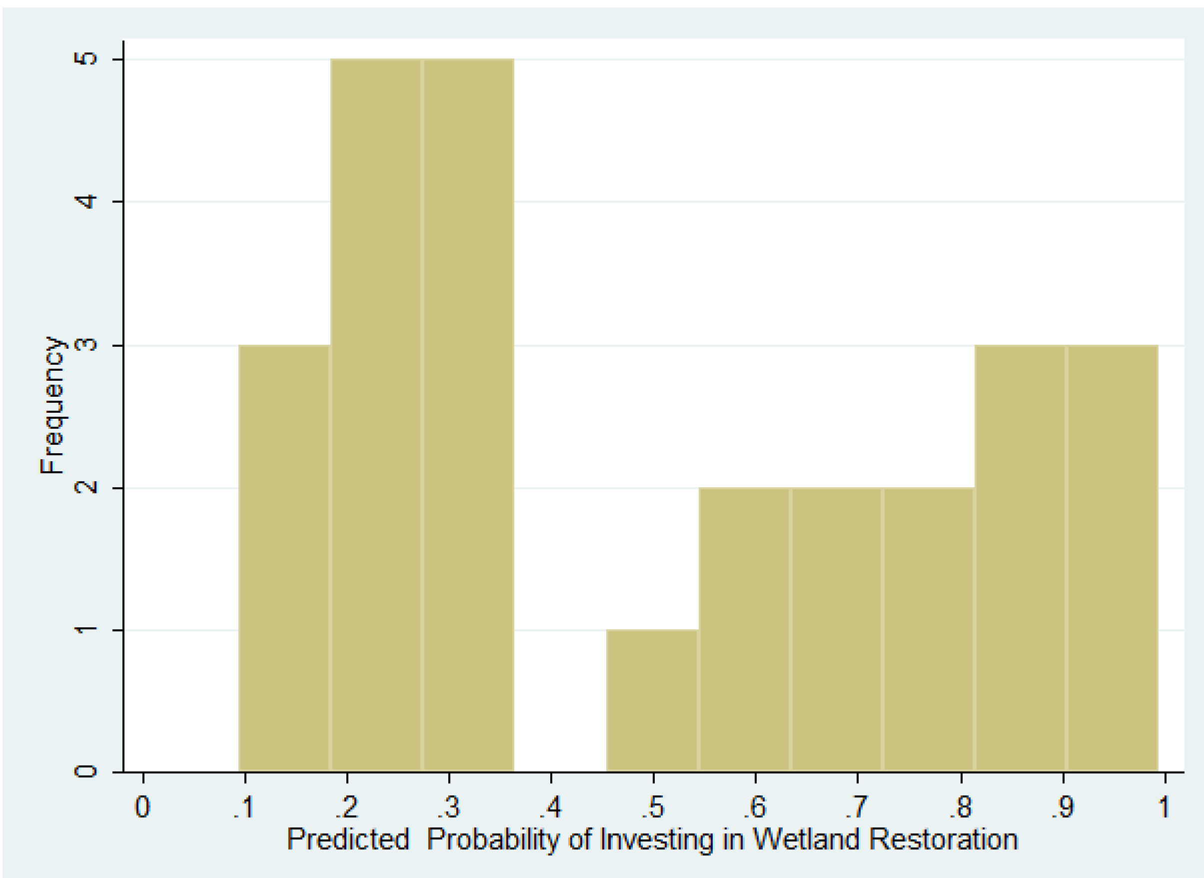

Figure 6.3: Histogram of predicted probability of investment in wetland restoration and maintenance

6.4 Model Selection

The results of the Tobit and double hurdle models presented in the previous sections show that both models adequately represented the collected data. However, comparisons of the two models suggest that the double hurdle model might better explain the data (compared to the Tobit model) due to a larger number of significant parameters. This hypothesis can be tested by: a) estimating a Tobit model with only the variables found in the second hurdle of the double hurdle model (the result of this restricted Tobit model is presented in Appendix C) using a likelihood ratio test for the null hypothesis that the univariate Tobit is superior to the double hurdle model. The resulting likelihood ratio statistic was 2(229.5-205.4)=48.2 with a chi-square distribution and 7 degrees of freedom. This result indicates that the Tobit model specification can be rejected in favor of the double hurdle model specification at the 5% level of significance, or that landowners make private wetland restoration and maintenance investment decisions in a sequential manner by first deciding whether to invest and then deciding how much to invest.

While the Likelihood ratio (LR) test shows that the double hurdle model outperforms the Tobit model, the double hurdle model is preferable to the Tobit model for other reasons, too. For example, several variables, including risk attitude (Riskatt), are not statistically significant in the Tobit model, but they are significant in the double hurdle model. In part, this leads to the double hurdle model's better explanatory power.

Existing literature suggests that risk attitude plays an important role in investment decisions (Ervin and Ervin, 1982; Shapiro, 1992; Hagos and Holden, 2006; Benitez *el al.*, 2006; Goldstein *et al.*, 2006; Stordal *et al.*, 2007; Abadi Ghadim *et al.*, 2005; Isik and Khanna, 2003; Saha *et al.*, 1994; Koundouri *et al.*, 2006). The majority of these studies found a negative relationship between risk aversion and the level of investment. Results of the double hurdle estimation are in line with these findings. The result of the Tobit model, however, did not show that risk aversion significantly influenced the landowner's investment decision.

Previous findings on the role of income on investment decisions are inconsistent. Some studies found income to be an important factor in the investment decision (Norris and Batie, 1987; Zhang and Flick, 2001; Romm *et al.,* 1987), while others studies did not (Featherstone and Goodwin, 1993). The result of the double hurdle model suggests that income significantly influences the level of investment decision. This result is in line with the results of most previous studies, and lends support to the double hurdle model as the best fit to the data. On the other hand, the results of the Tobit model do not show that income affects investment decisions of the landowners.

Participation in government programs has been found to influence the farmers' decisions to invest in soil conservation (Featherstone and Goodwin, 1993) and reforestation investment (Zhang and Flick, 2001). Two variables were used to capture the participation decisions of the landowners in this study – Govwetrp and Pubinv. The coefficients of these two variables are statistically significant in the double hurdle model, but not in the Tobit model. This is additional evidence that the double hurdle model outperforms that Tobit model, which in return emphasizes the importance of the first hurdle in the decision process.

It was hypothesized that the more positive the attitudes toward wetland restoration issues, the more likely that landowners would invest in wetland restoration and maintenance. This hypothesis is supported by both the estimated double hurdle model and the Tobit model.

The coefficient of the Consatt variable is positive and significant at 1% and 10% levels of significance respectively. The result of the double hurdle model shows that landowners' attitudes toward wetland restoration influence only the landowners' decisions about whether to invest but not the level of investment. This is the reason for including this variable only in the first hurdle equation. Our findings are in line with the results of the study by Langpap (2004).

In summary, the double hurdle model statistically outperformed the Tobit model, was a better explainer of the collected data, and conformed to the majority of findings in related research areas. The next, and final, chapter uses the results from the double hurdle model in support of a discussion examining the implications of the modeling for efforts to promote the use of private investment in coastal wetland restoration and maintenance.

CHAPTER 7

CONCLUSIONS AND POLICY IMPLICATIONS

Encouraging private wetland landowners to invest in wetland restoration and maintenance activities can be a challenging task. First, any decision to invest in restoration and maintenance is subject to a high level of uncertainty associated with climate change, changes in wetland regulatory policy, and changes in restoration technologies, Second, the majority of the benefits associated with wetland restoration and maintenance activities are enjoyed by the public rather than private landowners themselves, thereby presenting, at least partly, a public goods barrier to individual action. This dissertation developed a theoretical model of the landowner's decision making process in the face of uncertainty and relatively high wetland restoration costs. The conditions under which landowners would invest were derived under assumptions of risk aversion and relatively high fixed and variable costs. The validity of the theoretical model was tested using survey responses from 75 private wetland landowners in coastal Louisiana. Two econometric models (Tobit and double hurdle) were estimated to determine the importance of various factors, including risk aversion, on the probability and the level of private coastal wetland investments.

The results of the survey data showed that the vast majority of landowners considered the costs of wetland restoration and the uncertainty surrounding future benefits and costs of wetland restoration projects as the major factors deterring wetland restoration in coastal Louisiana. The survey respondents considered changing government policies and shifting environmental conditions as major sources of uncertainty. Overall, the majority of landowners were found to be risk averse, an observation that partly explains the respondent's focus on uncertainty and highlights the fact that uncertainty and restoration costs play important roles in the decision to invest in wetland restoration and maintenance activities.

The Likelihood Ratio (LR) test was employed to test the null hypothesis that the Tobit was superior to the double hurdle model. The result of the LR test indicates that the Tobit model specification can be rejected in favor of the double hurdle model specification, thus suggesting that landowners make their investment decisions in a sequential, two-step process. First, landowners decide whether to invest in wetland restoration and maintenance, and second, they decide on how much to invest. The double hurdle model conformed closely to both the theoretical expectations and previous empirical research concerning the importance of various factors in the decision to invest in wetland restoration and maintenance. For example, several variables, including risk attitudes of the landowners and land income were not statistically significant in the Tobit model, but they were highly significant in the double hurdle model.

The role of risk in landowner decisions was shown to arise from at least two sources: the varying risk attitudes among landowners and the physical risk factors associated with the location of the wetland property. More specifically, risk aversion decreased the expected level of restoration and maintenance, and the physical risk factors associated with the location of the wetland property, and high restoration costs, decreased the likelihood of investment. These relationships are evident in the geographic dispersion of investments, where landowners who own/manage properties that are located in the eastern part of the state and located close to the shore line (highly vulnerable areas) being less likely to invest in wetland restoration and maintenance projects than other landowners.

Wetland property size was also an important factor that helped determine whether a landowner would invest in wetland restoration and maintenance. Landowners with larger wetland properties invested more in wetland restoration and maintenance activities than other landowners. The results also indicated that landowners who used at least part of their properties for agriculture production were less likely to invest in restoration projects. A couple of reasons can be proposed for this finding, including the potential for lost farm incomes due to wetlands – either because of direct resource-use competition or competition for scarce fixed and variable cost capital – or the diversion of managerial focus from production to preservation. The results also show that landowners who are sole-owners are not only more likely to invest in wetland restoration and maintenance, but they also invest more in these projects. Landowner's attitudes toward wetland conservation had a positive influence on the decisions to invest in wetland restoration and maintenance, with positive attitudes toward wetland conservation increasing the probability of investment.

Participation in government-sponsored wetland restoration programs was a very important determinant of a landowner's investment decisions. Landowners who participate in government-sponsored wetland restoration programs have higher probabilities of privately investing in wetland restoration and they make larger investments than other landowners. At the same time, private investment expenditures in wetland restoration projects are lower for landowners receiving public financial assistance, which suggests a substitution effect between public and private capital.

Finally, the results of the double hurdle model showed that income is also important determinants of a landowner's decision to invest in wetland restoration and maintenance. Total household income derived from activities on the wetland property had a positive influence on the investment decision, with higher income households having higher levels of investment. Education also had a positive effect on the landowner's decision regarding the level of wetland investment but it was statistically insignificant at 10% level of significance,.

The result of this modeling effort also highlighted the difference between the marginal effects obtained by averaging the partial effects across the sample (average marginal effects) and the marginal effects obtained at the sample means. In general, average marginal effects for the Tobit model were approximately 7 to 8 times more than the marginal effects computed at the sample mean. This result raises a serious question about which marginal effect should be used in an analysis. For example, if the average marginal effects across the sample are the correct ones, then using the marginal effects at the sample means can seriously underestimate the effects of the explanatory variables and lead to erroneous conclusions. The opposite is true if the marginal effects at the sample mean are the correct ones. While the literature contains only limited discussions of this topic, and is still inconclusive about which type of marginal effects should be used, several authors have advocated the use of average marginal effects for nonlinear models and models with discrete variables (Greene 2003,Wooldridge 2002, Papke and Wooldridge 2008, Bartus 2005). Therefore, only the average marginal effects for the double hurdle model were reported, and all the discussions of the model results were done in terms of the average marginal effects.

Once estimated, the double hurdle model was used to predict the probability of zero future investments in wetland restoration and maintenance projects for all landowners in the sample who did not undertake any wetland restoration projects. The results indicate that 85% of the landowners who did not invest in wetland restoration projects at the time of the survey have probabilities in excess of 0.5 that they will never invest in wetland restoration projects.

This finding supports the anecdotal evidence that the vast majorities of landowners are not only not planning to invest in wetland restoration and maintenance, but that the idea of doing so does not even occur to them.

The results presented in this dissertation have potentially important implications for the design of policy instruments to encourage private wetland restoration efforts in coastal Louisiana. First, policies need to consider the effects of risk aversion, and uncertainty on a landowner's decisions to invest in wetland restoration projects. Failure to do so will not only lead to overestimating the participation rates in a program, but it will also lead to underestimating the size of the needed incentive payments for participation and the expected costs of the policy instruments. Therefore, incorporating the effects of risk aversion, and uncertainty into the benefit-cost analysis of the proposed policy may provide more realistic assessment of how a wetland restoration policy will perform in the future.

Another result with strong policy implications concerns the current and future role of publically-funded restoration programs. Landowners who participate in government-sponsored wetland restoration programs are more likely to invest in wetland restoration and maintenance and make more private investments than landowners who have no experience with the government programs. This suggests that the existing programs in the coastal zone such as Wetlands Planning, Protection and Restoration Act (CWPPRA), and Coastal Wetland Reserve Program (CWRP) have been effective in introducing restoration technology to landowners and in encouraging them to take a more active role in the stewardship of their land. Coupled with the result that a landowner's attitudes toward wetland conservation have a positive influence on the probability of investing, an argument can be made in favor of expanded education programs concerning the benefits of wetland conservation and restoration activities. At the same time, however, there was a distinct public-for-private capital substitution effect when examining landowners who received some form of financial assistance in conducting restoration projects. While this substitution effect is not surprising, it does imply that the size of, and rules governing, financial assistance programs needs to be closely considered so that they do not have the perverse effect of reducing overall private investment.

The results of the modeling effort clearly showed a competitive relationship between agricultural production and wetland restoration. While policies similar to the Wetland Reserve Program – which provides financial and technical support for landowners to protect and restore wetland areas on their properties – would be one way to reduce this competition, other avenues need to be explored to increase the revenue generating capability of wetlands, particularly those in agricultural areas. In fact, because the total amount of household income derived from activities on the wetland property was found to have positive influence on the level wetland investment, one could expect wetland owners to welcome that enhance the income generation capability of wetland properties. For example, under the North American Wetlands Conservation Act (NAWCA), landowners can receive financial support to undertake waterfowl habitat improvement projects. The survey data shows that waterfowl hunting was the primary land use among the survey respondents. Therefore, the expansion of programs such as NAWCA should provide additional incentives for private restoration activities in the coastal zone.

Variations in wetland investments across the characteristics of the landowners and their landholdings have policy implications with regard to the design and implementation of wetland restoration programs that seek to encourage private actions. For example, results of the double hurdle model suggests that any program will be more effective if it targets landowners who are more educated, own large wetland properties, are sole-ownership organized, are not engaged in agricultural production, and have properties that are located inland and in the western part of state. Such a policy, if correctly structured and implemented, could lead to high participation rates and significant private investments. For example, we used the parameter estimates of the double hurdle model to estimate the total amount of private investment that has been expended by all landowners in the analysis. We find that the estimated total level of investment for all 59 landowners over the last ten years is approximately $2,629,991. On average, each landowner invests about $44,576 in wetland restoration and maintenance activities over the last ten years. Extrapolating that level of investment to all landowners in the sample frame, the expected level of private investment in wetland restoration and maintenance is $7,481,258 for the ten year period.

In the absence of targeted wetland restoration programs, wetland investments might not occur in coastal areas where wetland restoration projects are thought to be needed the most (i.e., areas with high wetland loss rate). If the objective of the wetland policy is to maximize investments in high-risk areas, then publicly-funded projects may be a better approach. Alternatively, it may be possible to design a program, or separate programs, that would address the unique characteristics of the wetland restoration problems on the opposite sides of the state.

Given the magnitude and scope of the problem in coastal Louisiana, the best strategies for addressing wetland loss should include cooperation between all interested parties, jncluding private landowners, local communities and their citizens, and government officials. Private landowners control the vast majority of wetlands in the coastal zone, but they have very limited private capital and their investment decisions have limited effects in the absence of existing large scale public restoration projects. Similarly, there are limited public funds to completely address the issue of wetland loss in Louisiana's coastal zone, and the majority of public restoration projects will either affect or be implemented on private properties. As a result, the cooperation of private landowners, and the coordination of their private investment decisions with public restoration projects, are necessary for any successful wetland restoration effort. Wetland restoration programs can be more effective if they target the participation of private landowners in areas that are actively being addressed by public restoration projects. Furthermore, these wetland restoration programs will be most effective if they are designed to encourage greater coordination of investment decisions of adjacent landowners and landowners in close geographic areas.

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REFERENCES

Abadi Ghadim, A.K., D.J. Panell., and M.P. Burton. 2005. Risk, uncertainty, and learning in adoption of a crop innovation. *Agricultural Economics* 33:1-9.

Alig, R.J. 1986. Econometric analysis of the factors influencing forestry acreage trends in the Southeast. *Forestry Science*, 32(1):119-134.

Amemiya, T. 1984. “Tobit models: A survey.” *Journal of Econometrics* 24: 3-61.

Antle, J.M. 1983. Incorporating risk in production analysis. *American Journal of Agricultural Economics* 65:1099–1106

Arabmazer, A., and P. Schmidt. 1982.An investigation into the robustness of the Tobit estimator to nonnormality. *Econometrica* 50:1055-1063

Arabmazer, A., and P. Schmidt. 1981.Further evidence on the robustness of the Tobit estimator to hetroskedasticity. *Journal of Econometrics* 17:253-258

Arrow, K.J. and A.C. Fisher. 1974. Environmental preservation, uncertainty, and irreversibility.” *Quarterly Journal of Economics* 88:312-319.

Arrow, K.J. 1971. Essays in the theory of risk bearing. Chicago: Markham Publishing.

Bard, S.K., and P.J. Barry. 2001.Assessing farmers’ attitudes toward risk using ‘closin-In’ Methods. *Journal of agricultural and resource Economics* 26:248-260.

Baron, R. A., and Byrne, D. (1981). Social psychology: Understanding human interaction (3rd ed.). Boston: Allyn & Bacon.

Barras, J.A., Bernier, J.C., and Morton, R.A., 2008, Land area change in coastal Louisiana--A multidecadal perspective (from 1956 to 2006): U.S. Geological Survey Scientific Investigations Map 3019, scale 1:250,000, 14 p. pamphlet

Bartus, T. 2005. Estimation of marginal effects using margeff. *The Stata Journal* 5(3):309-329

Benitez, P. C., T. Kuosmanen., R. Olschewski., and G.C. Van Kooten. 2006. Conservation payments under risk: A stochastic dominance approach. *American Journal of Agricultural Economics* 88:1-15.

Blundell, R., and C. Meghir. 1987. Bivariate alternatives to the univariate Tobit model. *Journal of Econometrics* 34:179-200.

Boesch, D.F., M.N. Josselyn, A.J. Mehta, J.T. Morris, W.K. Nuttle, C.A. Simenstad, and D.J.P. Swift. 1994. Scientific assessment of coastal wetland loss, restoration and management in Louisiana. *Journal of Coastal Research* 20:1-103

Burke, W.J. 2009. Fitting and interpreting Cragg's Tobit alternative using Stata. *The Stata Journal* 9(4):584-592

Bulte, E., D.P.Van Soest., G.C. Van Kooten., and R. A. Schipper. 2002. Forest conservation in Costa Rica when nonuse benefits are uncertain but rising. *American Journal of Agricultural Economics* 84(1):150–160.

Caffey, R.H. and M. Shexnayder. 2003. Coastal Louisiana and south Florida: A comparative wetland inventory. Draft Fact Sheet. Louisiana State University.

Caffey, R.H. 2005. Why is Louisiana losing its coastal wetlands and how much have been lost? Louisiana sea grant hurricane resources recovery website, FAQ,

Capozza, D.R. and Y. Li. 1994. The intensity and timing of investment: the case of land. *American Economic Review* 84(4):889-904.

Cameron, A.C., and P.K. Trivedi.2009. Microeconometrics using Stata. College Station, TX: Stata Press.

Capozza, D.R. and G.A. Sick. 1994. The Risk structure of land markets. *Journal of Urban Economics* 35:297-319.

Capozza, D.R. and R. Helsley. 1990. The Stochastic city. *Journal of Urban Economics* 28:187-203

Capozza, D.R. and Y. Li. 1994. "The intensity and timing of investment: The Case of Land." *American Economic Review* 84(4):889-904.

Capozza, D.R. and G.A. Sick. 1994. The Risk structure of land markets. *Journal of Urban Economics* 35:297-319.

Cardona, H. 1999. Analysis of policy alternatives in implementation of coastal nonpoint pollution control program for agriculture, PhD Thesis, Department of Agricultural Economics and Agribusiness, Louisiana State University, Baton Rouge.

Carey.J M; and D. Zilberman.2002. A model of investment under uncertainty : Modern Irrigation technology and emerging markets in water. *American Journal of agricultural economics* 84: 171-183

Carroll, J., S.McCarthy., and C. Newman.2005. An econometric analysis of charitable donations in the republic of Ireland. *The Economic and Social Review* 36(3):229-249.

Churchill, G.A. 1995.Marketing research: methodological foundations. Chicago: The Dryden Press.

Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA). 2006. A response to Louisiana's land loss.

Coastal Protection and Restoration Authority(CPRA). 2007. Fiscal year 2008 annual plan: ecosystem restoration and hurricane protection in coastal Louisiana.

Cragg, J.G. 1971. Some statistical models for limited dependent variables with application to the demand for durable goods. *Econometrica* 39(5): 829-844

Dhakal, B., H. Bigsby.,and R. Cullen. 2008. Determinants of forestry investment and extent of forestry expansion by smallholders in New Zealand. *Review of Applied Economics* 4:65-76.

Day, J. W., Jr., J. Barras., E. Clairain, J. Johnston, D. Justic, G. P. Kemp, J.-Y. Ko, R. Lane, W. J. Mitsch,G. Steyer, P. Templet, and A. Yañez-Arancibia. 2005. Implications of global climatic change and energy cost and availability for the restoration of the Mississippi delta. *Ecological Engineering* 24:253-265.

Dillman, D. 1978. Mail and telephone surveys: The total design method. New York: John Wiley and Sons.

Dixit, A.K. and R.S. Pindyck. 1994. *Investment under uncertainty.* Princeton, NJ: Princeton University Press.

Epstein,L.G.1980. Decision making and the temporal resolution of uncertainty. *International Economic Review* 21(2):269-283.

Ervin, C A. and D. E. Ervin. 1982. Factors affecting the use of soil conservation practices: hypotheses, evidence and policy. *Land Economics* 58(3):277-292

Fausti, S and J. Gillespie. 2006. Measuring risk attitude of agricultural producers using a mail survey : how consistent are the methods. The Australian journal of agricultural and resource economics, 50:171-188.

Featherstone, A.M. and B.K. Goodwin. 1993. Factors influencing a farmer's decision to Invest in long-term conservation improvements. *Land Economics* 69(1):67-81.

Feder,G., R.E. Just., and D. Zilberman.1985. Adoption of agricultural innovation in developing countries: A survey. *Economic Development and Cultural Change* 33:255-298.

Fisher, A. C., and W.M. Hanemann. 1990. "Option value: theory and measurement", *European. Review of Agricultural Economics* 7(2): 167-180

Fisher, A.C., J.V. Krutilla and C.J. Cicchetti. 1972. The economics of environmental preservation: A theoretical and empirical analysis. *American Economic Review* 62:605-619.

Galloway, G., D. Boesch, and R. R. Twilley. 2009. Restoring and protecting coastal Louisiana. Issues in Science and Technology, Winter 2009:29–38.

Gelso, B.R., J.A. Fox.,and J.M. Peterson. 2008. Farmers' perceived costs of wetland: effects of wetland size, hydration, and dispersion. *American Journal of Agricultural Economics* 90(1):172-185.

Geltner, D., T. Riddiough, and S. Stojanovic. 1996. Insights on the effect of land use choice: The perpetual option on the best of two underlying assets. *Journal of Urban Economics* 39:20–50.

Goldstein , J.H . G.C Daily. J. B. Friday. P.A, Matson.R. L, Naylor. and P,Vitousek. (2006). Business strategies for conservation on private lands: Koa forestry as a case study. *Proceedings of the National Academy of Sciences* 103: 10140-45.

Goodwin, B.K., and T.C. Schroeder.1994. Human capital, producer education programs, and the adoption of forward pricing methods. *American Journal of Agricultural Economics* 76:936-947

Greene, W.H. 2003. Econometric analysis. 5th ed. Upper Saddle River, NJ: Prentice Hall

Gunjal,K., and B. Legault. 1994. Risk preferences of dairy and hog producers in Quebec. *Canadian Journal of Agricultural Economics* 43: 23-36.

Jenson, H.H., and S. T. Yen. 1996. Food expenditures away from home by type of meal. *Canadian Journal of Agricultural Economics* 44:67-80.

Hagos,F. and S. Holden. 2006. Tenure security, resource poverty, public programs and household plot level conservation investments in the highlands of north Ethiopia. *Agricultural Economics* 34:183-196

Heimlich, R.E., K.D. Weibe., R. Claassen., D. Gadsy.,and R.M. House. 1998. Wetlands and agriculture: Private interests and public benefits. Resource Economics Division, E.R.S., USDA, agricultural economic report 765.10.

Henderson,J.E. 2007. Liability, institutions, and determinants of landowner access policies for fee-based recreation on private lands. Ph.D. Dissertation, Department of Agricultural Economics and Agribusiness, Louisiana State University, Baton Rouge.

Henry, C. 1974. Investment decisions under uncertainty: The irreversibility effect, *The American Economic Review*, 64(6):1006-1012.

Hurd, M. 1979. Estimation in truncated samples when there is hetroskedasticity. *Journal of Econometrics* 11:247-258

Isik, M., and W. Yang. 2004. An analysis of the effects of uncertainty and irreversibility on farmer participation in the conservation reserve program. *Journal of Agricultural and Resource Economics* 29(2):242-259

IsiK, M. and, M . Khanna.(2003) Stochastic technology, risk preferences and adoption of site-specific technologies. *American Journal of Agricultural Economics* 85:305-317.

Isik, M., M. Khanna, and A. Winter-Nelson. 2001. Sequential investment in site-specific crop management under output price uncertainty.*Journal of Agricultural and Resource Economics* 26: 212–29.

Jones, D., C. Cocklin and M. Cutting. 1995. Institutional and landowner perspectives on wetland management in New Zealand. *Journal of Environmental Management* 45:143-161.

Koundouri, P., C. Nauges., and V. Tzouvelekas.2006. Technology adoption under production uncertainty: theory and application to irrigation technology. *American Journal of Agricultural Economics* 88(3):657-670.

Kim, K., and J.P. Chavas. 2003. Technological change and risk management: An application to the economics of corn production. *Agricultural Economics* 29:125-42.

Kline, J.,R.J. Alig., and R.L. Johnson. 2000. Fostering the production of non-timber services among forest owners with heterogeneous objectives. *Forest Science* 46:302-311.

Knapp, K.C., and L.J. Olson.1996. Dynamic resource management: intertemporal substitution and risk aversion. *American Journal of Agricultural Economics* 78:1004–1014.

Layva, J.C., J.A. Franco Martinez., and M.C. Gonzalez Roa. 2007. Analysis of the adoption of soil conservation practices in olive groves: the case of mountainous areas in southern Spain. *Spanish Journal of Agricultural Research* 5(3):249-258.

LaDNR.1999. Coast 2050: Toward a sustainable coastal louisiana, Louisiana Coastal Wetlands Conservation and Restoration Task Force, La Dept. of Natural Resources. Baton Rouge, LA.

Lipton, D.W., K. Wellman., I.C. Sheifer., and R .F. Weiher. 1995.Economic evaluation of natural resources: A handbook for coastal resource policymakers.NOAA coastal ocean program decision analysis series No. 5. NOAA coastal ocean office, Silver Spring, MD.

Maddala,G.,and F. Nelson. 1975. Specification errors in limited dependent variable models. Working paper 96, National Bureau of Economic Research. Cambridge, Mass.

McDonald, J.F., and R.A. Moffitt.1980. The uses of Tobit analysis. *Review of Economics and Statistics 62:318-321.*

Moffatt, PG.2005. Hurdle models of loan default. *Journal of Operation Research Society* 56:1063-1071.

Nagubadi,V. K.T. McNamara.,W. L. Hoover., and W.L. Mills, Jr. 1996. Programs participation behavior of nonindustrial forest landowners: A probit model. *Journal of Agricultural and Applied Economics* 28(2):323-336

Norris, P. E., and S. S. Batie. 1987. Virginia farmers' soil conservation decisions: An application of Tobit analysis. *Southern Journal of Agricultural Economics* 19(1):79-90.

Penning, M.E., and P. Garcia. 2001. Measuring producers' risk preference: a global risk-attitude construct. *American Journal of Agricultural Economics* 83(4):993-1009

Papke,L.E., and J.M. Wooldridge. 2008. Panel data methods for fractional response variables with an application to test pass rates. *Journal of econometrics* 145:121-133

Parks, P. J., and Kramer.1995. A policy simulation of wetlands reserve program. *Journal of Environmental Economics and Management* 28:223-240

Parks, P. 1993. Explaining Irrational land use: Risk aversion and marginal agricultural land. Journal of environmental economics and management 28:34-47

Paulsen,S. 2007. Investment in wetlands for pollution abatement under uncertainty. PhD Dissertation. Department of Economics, Swedish University of Agricultural Sciences (SLU), Uppsala.

Plantinga. A.J., R.N. Lubowski., and R.N. Stavins. 2002. Effects of potential land development on agricultural land prices. *Journal of Urban Economics* 52:561-581

Pratt, J. 1964. Risk aversion in the small and in the large. *Econometrica* 32: 122-136.

Purvis, A., W.G. Boggess, C.B. Moss, and J. Holt. 1995. Technology adoption decisions under irreversibility and uncertainty: An *ex ante* approach." *American Journal of Agricultural Economics* 77:541–551.

Quigg, L.1993. Empirical testing of real option-pricing models. *Journal of Finance* 48(2):621-640.

Romm, J., R. Tuazon.,C. Whashburn. 1987. Relating forestry investment to the characteristics of nonindustrial private forestland owners in northern California. *Forest Science* 331:197-209

Royer, J.P. 1987. Determinants of reforestation behavior among southern landowners. *Forest Science* 33(3):654-667

Ryan, M., and C.D. Susman. 2003. Wetlands conservation in Louisiana: Voluntary incentives and other alternatives, *Journal of Environmental Law and Litigation* 17: 441-495.

Saha, A., H.A. Love and R. Schwart. 1994. Adoption of emerging technologies under output uncertainty. *American Journal of Agricultural Economics* 76:836-846.

Schatzki, T. 2003. Options, uncertainty and sunk costs: an empirical analysis of the land use change. *Journal of Environmental economics and management* 46:86-105.

Schurle, B., and Tierney, W.I. 1990. A comparison of risk preference measurements with implications for extension programming, staff paper no. 91-6. Department of Agricultural Economics, Kansas State University, Monhattan.

Soderqvist, T. 2003. Are farmers prosocial? determinants of willingness to participate in Swedish catchment-based wetland creation program. *Ecological Economics* 47:105-120.

Soule, M., A. Tegene and K.D. Wiere. 2000. Land tenure and the adoption of conservation practices. *American Journal of Agricultural Economics* 82(4):993-1005.

Straka,T.J., H.W. Wisdom.,and J.E. Moak. 1984. Size of forest holding and investment behavior of non-industrial private owners. *The Journal of Forestry* 82(8):495-496.

Stordal, G. L,. J.B. Hardaker., and L.J. Asheim. 2007. Risk aversion and optimal forest replanting : A stochastic efficiency Study. *European journal of Operational Research* 181:1584-92.

StataCorp. 2009. *Stata Statistical Software: Release 11*. College Station, TX: StataCorp LP.

Su, S-J. B., and S. T. Yen. 1996. Microeconometric models of infrequency purchased goods: An application to household pork consumption. *Empirical. Economics* 21: 513-533.

Tengene, A,. K.Wiebe., and B. Kuhn. 1999. Irreversible investment under uncertainty : conservation easements and option to develop agricultural land. *Journal of Agricultural Economics* 50:203-219.

Thomas, A.C. 1987. Risk attitudes measured by the interval approach: a case study of Kansas Farmers . *American Journal of Agricultural Economics*, 69:1101-1105.

Tobin,J.1958. Estimation of relationships for limited dependent variables. *Econometrica* 26(1):24-36.

Torkamani, J., and S. Shajari. 2008. Adoption of new irrigation technology under production risk. *Water Resources Management* 22:229-237.

Winter-Nelson, A., and K. Amegbeto. 1998. Option values to construction and agricultural price policy: application to terrace construction in Kenya. *American Journal of Agricultural Economics* 80:409–418.

Wiemers, E. and Behan, J. 2004. Farm forestry investment in Ireland under uncertainty. *The Economic and Social Review* 35:305-320.

Wooldridge, J.M. 2002. Econometric analysis of cross section and panel data. Cambridge, MA: MIT Press.

Zhang, D., and W.A.Flick.2001. Sticks, carrots, and reforestation investment. *Land Economics* 77(3):444-455

Zhao, J. and D. Zilberman. 1999. Irreversibility and restoration in natural resource development. *Oxford Economic Papers* 51(July):559-573.

APPENDIX-A

WETLAND INVESTMENT SURVEY QUESTIONNAIRE

Enclosed with this questionnaire are a number of maps, each one showing a property tract in the coastal zone. Later in this questionnaire we are going to ask you to focus on just one of these tracts of land, but for the first few questions (1 through 5) we would like you to answer with respect to all of the properties you own or manage.

1. How many **total acres of land (wetlands and uplands)** do you own (by yourself, jointly, or as a corporation) and into how many separate tracts is it divided?

   ________ acres divided among ________ tracts

Wetlands can be defined as areas having wet soils supporting water-loving plants for at least part of the year and/or areas covered by shallow water at some time during the year.

2. Given this definition, what percent of the total acreage from question 1 **is wetland**?
   ________ percent (**If zero**, you do not have to finish the survey – please mail back the questionnaire in the envelope provided).
3. Do you know that various government-sponsored wetland restoration and maintenance programs exist?
   - O No
   - O Yes – If yes, how many acres do you currently have in each of the following programs?
     - ________ Wetlands Reserve Program (WRP)
     - ________ Coastal Wetlands Reserve Program (CWRP)
     - ________ Coastal Protection and Restoration Authority (CPRA)
     - ________ Coastal Wetlands Planning, Preservation & Restoration Act (CWPPRA)
     - ________ Other (Please explain below)

     ____

4. Would you be willing to participate in future government-sponsored wetland restoration and maintenance programs?
   - O No, not under any circumstances (If no, please skip **question 5**).
   - O Yes, given the right incentives and conditions.

5. Please indicate (by circling a number) the level of importance each potential incentive would have in convincing you to participate in future government-sponsored wetland restoration and maintenance programs.

	Not Important	**Very Important**

General tax breaks	1--------2--------3--------4--------5
Cost-sharing assistance	1--------2--------3--------4--------5
Direct grants and subsidies	1--------2--------3--------4--------5
Temporary conservation easements	1--------2--------3--------4--------5
Permanent conservation easements	1--------2--------3--------4--------5
Expanded opportunities to use wetlands in mitigation banking (development offset)	1--------2--------3--------4--------5
Use of wetlands in carbon credit programs	1--------2--------3--------4--------5
Other incentives (please explain)	1--------2--------3--------4--------5

____

The next section of the questionnaire (questions 6 through 24) seeks information about one of the property tracts that you own. If you look at the property maps, you will notice that each is labeled with a letter at the top. Please choose the property tract that you have invested the most in with respect to wetlands restoration/maintenance and answer the following questions with that specific property in mind. If you have not invested in any of the property tracts, please choose the largest tract and answer the remaining questions.

I am going to be answering the following questions with respect to property

- O Tract A
- O Tract B

6. Do you still maintain ownership (solely, jointly, or other) in the tract?
   - O Yes – If yes, in what year did your ownership start? ________
   - O No – If no, what year did you stop owning the property? _______

IF YOU NO LONGER HAVE OWNERSHIP, PLEASE SKIP TO QUESTION 25.

7. How do you own the specific property tract?
   - O Sole ownership
   - O Joint ownership through a tenants-in-common arrangement
   - O Joint ownership through a corporation or trust
   - O Other (please explain)

   ____

8. If you maintain joint ownership of the property, what percent of the tract do you own?

   _________ percent

9. What percent of your total 2008 household income came from surface (non-oil & gas) activities taking place on the tract?

_________ percent

10. What percent of your total 2008 household income came from sub-surface (oil & gas) activities taking place on the tract?

_________ percent

11. How many wetland acres have been lost on this tract of land due to erosion, storms, or other environmental factors during the time you have owned it? ________ acres
12. How would you describe the overall condition of the wetlands within the tract?
    - O Poor
    - O Good
    - O Excellent
    - O I don't know

13. Please indicate (by circling a number) the level of importance each of the listed activities has in the way the property tract is currently used.

	Not Important ... **Very Important**
Agriculture production	1--------2--------3--------4--------5
Timber production	1--------2--------3--------4--------5
Fur trapping, alligator hunting, and/or egg collection	1--------2--------3--------4--------5
Waterfowl hunting	1--------2--------3--------4--------5
All types of fishing	1--------2--------3--------4--------5
Oil & gas activities	1--------2--------3--------4--------5
Other (please explain)	1--------2--------3--------4--------5

14. Is any part of this tract being leased out for activities in question 13?
    O No O Yes – If yes, how many acres are leased out? _______ acres

15. Which of the following best describes the current management of this property?
    - O Self-managed
    - O Managed using a hired service or employees
    - O Managed by a leaseholder
    - O Not being actively managed
    - O Managed by government personnel

16. If you were to sell the property tract today, what price do you think you might receive?

$ ____________

17. Have any wetland maintenance or restoration activities ever been attempted on this tract of land?
   - O No, not to my knowledge (please skip to **question 22)**
   - O Yes – If yes, what year did they start? _______ year

   Please estimate the total number of wetland acres that have been restored or maintained on this tract of land over the last 10 years _______acres

18. What practices were used to restore or maintain the wetlands on this tract of land? (Please check all that apply)
   - O Water control structures (gates, weirs, etc.)
   - O Vegetative plantings (trees or grasses)
   - O Nutrient/sediment traps (brush fences, terraces, etc.)
   - O Sediment, dredge or spoil usage
   - O Increased fresh water inputs to the property
   - O Other (please explain below)
     ____

19. If you were involved in the decision to undertake restoration and maintenance activities on this tract of land, please indicate (by circling a number) the level of importance each of the listed reason was to your decision.

	Not Important ... **Very Important**
Availability of restoration subsidies in the form of monetary payments	1--------2--------3--------4--------5
Availability of restoration subsidies in the form of technical assistance	1--------2--------3--------4--------5
Desire to protect or enhance the property market value	1--------2--------3--------4--------5
Desire to protect or enhance the property's revenue generating ability	1--------2--------3--------4--------5
Recent improvements in restoration technology	1--------2--------3--------4--------5
Desire to protect or enhance the ecological functions	1--------2--------3--------4--------5
Other (please explain below)	1--------2--------3--------4--------5

20. Over the last 10 years that you had ownership in the property, what level of private investment expenditures were made on wetland restoration and maintenance activities? Please do not include expenditures that were paid for by non-private parties, such as government agencies or programs.

    $ ___________

21. Over the last 10 years that you had ownership in the property, what level of public (i.e., governmental agency or program) investment expenditures were made on wetland restoration and maintenance activities (if you only know the government's cost share, please provide that information)?

    $ ___________ or __________ percent cost share

    O Public investments were made, but I do not know how much.

22. If no restoration or maintenance activities have been attempted on the tract of land, or if you would not consider future restoration activities, please indicate (by circling a number) the level of importance each of the listed reason was to this decision.

	Not Important ... **Very Important**
High current cost of restoration	1---------2---------3---------4---------5
Uncertainty about future costs and benefits of restoration	1---------2---------3---------4---------5
Insufficient government financial incentives	1---------2---------3---------4---------5
No need for wetland restoration	1---------2---------3---------4---------5
Lack of personal financial resources for restorations	1---------2---------3---------4---------5
Lacks of personal economic benefits from restorations	1---------2---------3---------4---------5

23. Uncertainty can sometimes be an important factor when making decisions. With respect to your wetland investment decision, please rank the following sources of uncertainty in terms of their importance to you, with 1 being the most important, 2 the next most important, etc.

    ____ Changing government policies

    ____ Availability of effective restoration technology

    ____ Changing restoration costs

____ Shifting environmental conditions

____ Others (please specify_______________________________________)

24. If you consider uncertainty an important factor in your wetland investment decision, please indicate your level of uncertainty in whether your investment will yield a positive payoff by circling the appropriate number?

0--------1--------2-------3-------4--------5--------6-------7--------8--------9-------10
No uncertainty ←——————————————→ High uncertainty

This next question seeks information that will help us better understand your attitudes concerning coastal wetlands restoration.

25. Please indicate how much you disagree or agree with each of the statements by circling the appropriate number using the given scale:

	Strongly Disagree ... **Strongly Agree**
Restoration is important to future generations	1---------2---------3---------4---------5
Restored wetlands protect wildlife and/or fish habitat	1---------2---------3---------4---------5
Restoring wetlands improves water quality and reduces erosion	1---------2---------3---------4---------5
Restored wetlands provide storm and flood protection	1---------2---------3---------4---------5
Restoring wetlands is a waste of time and money given the predicted increases in sea level	1---------2---------3---------4---------5

In this next section we ask questions that will allow us to categorize your responses with other survey participants.

26. How old are you? _______

27. What is the highest level of education that you have attained?
   - O Some high school (or less)
   - O Completed high school or GED
   - O Trade or technical school graduate
   - O Some college
   - O College graduate

28. What is your gender?
    - O Male
    - O Female

29. Which of the following best describes your total household pre-tax 2008 income?
    - O Under $15,000
    - O $15,001 to $30,000
    - O $30,001 to $50,000
    - O $50,001 to $70,000
    - O $70,001 to $100,000
    - O $100,001 to $150,000
    - O $150,001 to $200,000
    - O Over $200,000

30. Are you a legal resident of the State of Louisiana?
    - O Yes
    - O No

31. Do you live on the tract of land indicated on the map included in this survey package?
    - O Yes
    - O No

This last section of the questionnaire is designed to help us measure your attitudes towards risk and how those attitudes might affect your decision making regarding wetlands conservation and restoration.

32. Compared to other landowners, how would you rate your willingness to undertake risky investments? (please circle the appropriate number

    1--------2--------3--------4--------5--------6--------7--------8--------9--------10

    Risk Hating ←→ Risk Loving

33. Please indicate how much you disagree or agree with each of the following statements by circulating the appropriate number.

	Strongly Disagree — **Strongly Agree**
I like taking financial risks	1--------2--------3--------4--------5
I try to avoid investment risks	1--------2--------3--------4--------5
I am willing to take financial risks in order to realize higher returns	1--------2--------3--------4--------5
I prefer to receive a guaranteed return even if it is low	1--------2--------3--------4--------5
It is unlikely that I would invest in a	1--------2--------3--------4--------5

business if it has a chance of failing

When making investment decisions I attach equal weight to maximizing long-term returns and minimizing financial risks. 1--------2--------3--------4--------5

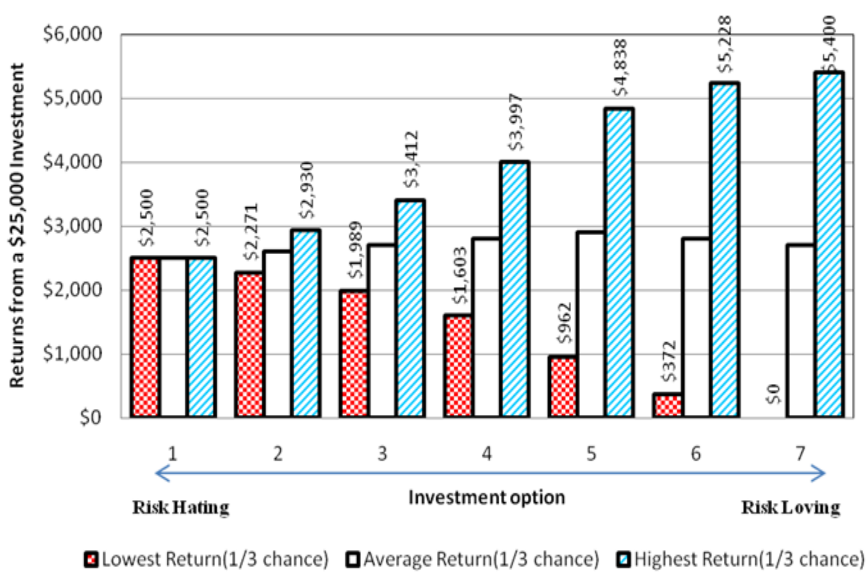
I aim to achieve high long-term returns on my investments even if that means taking significant financial risks in the short-run 1--------2--------3--------4--------5

I prefer to receive a guaranteed low return on my investments rather than an uncertain high return 1--------2--------3--------4--------5

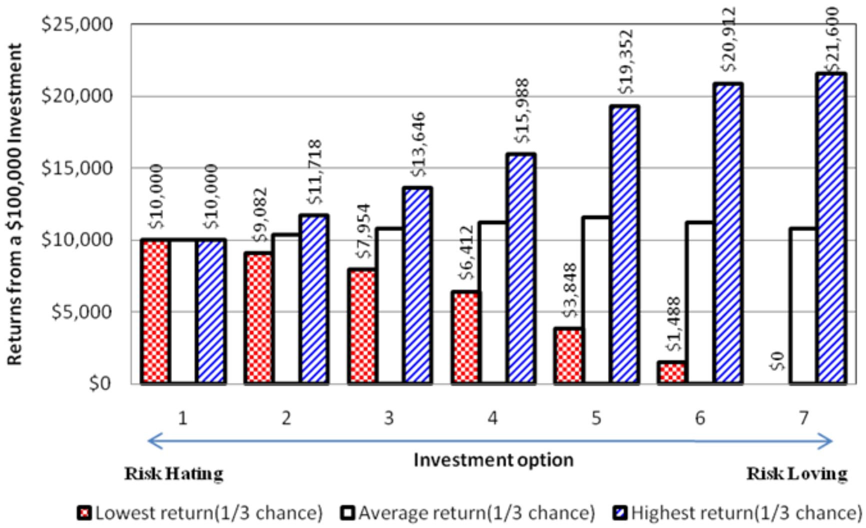
Another way to measure your attitudes towards risk is to ask you to choose from a group of potential investments where you know the possible outcomes of each choice.

34. Suppose that you are given **$25,000** to invest, and you have seven investment options to choose from (see graph below). Each investment option will yield one of 3 levels of net returns, with a 1 in 3 chance of each level occurring. These investment options are designed such that the level of risk you face increases as you move from left to right on the graph.

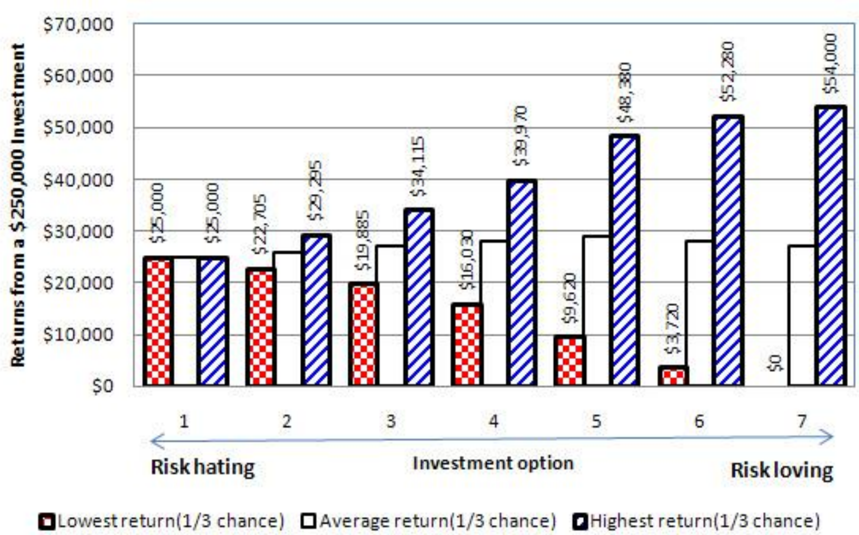
For example, by choosing investment #1 you are guaranteed to receive an **annual net return of $2,500.** However, if you choose investment #7 you have a 1 in 3 chance of doubling your return compared to #1, but you also have a 1 in 3 chance of losing all the guaranteed return you would have received under investment #1. Please examine the likely ***annual* net *returns*** from the 7 potential investment options and circle the number of the option you would prefer to have.



35. Now assume that your investment level has been **increased** from **$25,000 to $100,000.** Please examine the likely ***annual* net *returns*** from the 7 potential investment options and circle the number of the option you would prefer to have.



36. Now assume your investment level has been **increased** from **$25,000 to $250,000**. Please examine the likely ***annual* net *returns*** from the 7 potential investment options and circle the number of the option you would prefer to have.



37. Please use the space below to provide us with other comments or suggestions you might have concerning the incentives and programs that could be used to encourage private investment in coastal wetland restoration and maintenance

Thank you for completing the survey.

Please mail the questionnaire back in the envelope provided.

APPENDIX-B

RESULTS OF THE AUXILIARY REGRESSION MODEL

Table B1. Prediction of the total household income

Variable	Coefficient	Standard error
Intercept	1.168	0.788
Lnwetac	0.365***	0.118
Educ	0.570***	0.179
R-Square	0.41	

***, denotes that the corresponding parameters are significant at 1%

APPENDIX-C

RESULTS OF THE RESTRICTED TOBIT MODEL

Table C1. Parameter estimates of the restricted Tobit model

Variable	Coefficient	Robust standard error
Constant	-582377**	237994.8
lnwetacr	36147.34	22993.89
Riskatt	23563.67	15714.18
Sowner	120062*	64970.49
Govwetrp	94710.88	143271.3
Pubinv	-8900.84	141251.1
Landinc	-1.66	1.12
Educ	15403.04	23442.78
Log-Likelihood	-229.5	
Likelihood ratio statistics	16.47	
Prob>chi-square	0.02	
Sample size	59	

***,**,* denotes that the corresponding parameters are significant at 1%,5% and 10% respectively

VITA

Cheikhna Dedah graduated from Nouakchott University of Economics in 2000. He received a Bachelor of Science in Economics with concentration on business administration and management. In Fall 2002, he enrolled in the graduate school at Louisiana State University. He graduated with a Master of Science degree in environmental sciences in the Summer of 2005. In Spring 2005, he entered the doctoral program at the Department of Agricultural Economics & Agribusiness at Louisiana State University. He also pursued a dual Master of Science degree in the Department of Experimental Statistics at Louisiana State University. He obtained a Master of Science in Applied Statistics in the Fall of 2007. Mr. Dedah is currently a doctoral candidate at the Department of Agricultural Economics & Agribusiness, and he is scheduled to graduate in the Fall of 2010.