The Pennsylvania State University

The Graduate School

Department of Agricultural Economics and Rural Sociology

PAYMENTS FOR ECOSYSTEM SERVICES SCHEMES FOR SPATIALLY COORDINATED LAND MANAGEMENT: AN EXPERIMENTAL STUDY

A Dissertation in

Agricultural, Environmental and Regional Economics

by

Simanti Banerjee

Submitted in Partial Fulfillment
of the Requirements
for the Degree of

Doctor of Philosophy

December 2010

The dissertation of Simanti Banerjee was reviewed and approved* by the following:

James S. Shortle
Distinguished Professor of Agricultural and Environmental Economics
Dissertation Co-advisor
Co-Chair of Committee

Anthony M. Kwasnica
Associate Professor of Business Economics
Dissertation Co-advisor
Co-Chair of Committee

Edward C. Jaenicke
Associate Professor of Agricultural Economics

Robert P. Brooks
Professor of Geography and Ecology

Ann R. Tickamyer
Professor of Rural Sociology
Head of the Department of Agricultural Economics and Rural Sociology

*Signatures are on file in the Graduate School

ABSTRACT

Tackling the problem of ecosystem loss and ecosystem services (ES) degradation on private working landscapes is an important environmental policy challenge. Numerous policy measures have been implemented on these private properties to arrest this degradation. These policies include both economic and non-economic instruments which instruct landowners to change their land uses such that it is beneficial for the protection of ES. The subject matter of this dissertation deals with economic instruments for ES conservation. The key feature of these instruments is that they pay landowners for adopting prescribed pro-conservation land uses on their properties. The Conservation Reserve Program (CRP) is an example of one such economic conservation policy implemented by the USDA. Of these economic payment schemes, of particular interest are those which include market based instruments such as uniform rate payment schemes and auction based schemes. The term Payment for Ecosystem Services (PES) schemes is commonly used for these schemes.

PES schemes can be employed to attain different conservation goals. This dissertation is focused on the study of PES schemes that incentivize landowners to produce spatial patters of conservation land uses on their properties. This objective is not trivial as often degraded habitats exist across multiple property boundaries. Creation of these patterns will require the cooperation of neighboring property owners. The Agglomeration Bonus (AB) subsidy scheme has been proposed in the economic literature on PES schemes to achieve this spatial objective. It is a simple two-component payment scheme that can incentivize spatially coordinated land management by neighboring landowners and hence is ecologically effective.

The ecological effectiveness of the scheme suffers in agricultural landscapes where participants are not certain about their neighbors' conservation attitudes and hence their commitment to participate in the conservation programs. These uncertainties discourage spatially coordinated participation. The first essay in this dissertation initiates an experimental examination of spatial coordination under the AB scheme in a new network setting in the presence of these participation doubts. The experimental methodology provides the means to test the performance of the scheme in big and small networks. For the experiments the AB is structured as a spatial coordination game with subjects arranged around a circular grid whose size varies across experimental sessions. On this grid every subject can coordinate with the same number of neighbors whose identity is different for different individuals. This type of strategic environment is novel to the study of the AB and provides insights that are useful for policy implementation. In line with past experimental predictions spatially coordinated land management is found to be tougher in bigger groups than in smaller ones. This is the key result of the study. When participation in the conservation scheme is characterized by doubts about conservation attitudes, then instances of coordination failure will be much higher within a large group of landowners than a smaller group even if the number of neighbors of the landowners is the same. The second finding from the experiments is that while spatial

coordination is tougher in bigger groups, localized spatial patterns appear on the circular landscape indicating partial policy success.

The second essay in this research presents the structure of a reverse auction for the procurement of spatially coordinated pro-conservation land uses from neighboring landowners. The study of auctions is especially important to the economic performance of PES schemes as these schemes are limited by a fixed budget from which landowner payments have to be made. Thus environmental benefits from spatially coordinated land uses should be procured at the lowest possible cost. Auctions are a popular mechanism to address this cost efficiency objective especially because the conservation agency does not have information about landowners' costs. The second essay presents the structure of a simple iterative descending price auction with full information feedback about results that is designed to select bids from spatially adjacent landowners. The auction structure employs a benefit-cost ratio scoring metric like the CRP to evaluate different combinations of bids to make a final selection. Lab experiments are conducted to test the performance of the auction in settings which vary on the basis of the information available to subjects as well as the cost-benefit parameters associated with the projects for which bids are submitted in the auction. The experimental data provides insights about the ecological effectiveness and economic efficiency of the iterative auction. The chief result of the study is that the ecological effectiveness in the presence of information about the spatial goal is not significantly different from when this information is not present. However cost efficiency of the mechanism is significantly different. Thus when subjects know that their bids relative to their neighbors' bids influence their chances of winning, they submit higher bids. This implies that in the presence of information, procurement of the same amount of environmental benefits is costlier. Since the PES budgets are limited, increase in the costs of conservation indicates a reduction in cost efficiency of the mechanism. The study also provides an analysis of bidding behavior of subjects in the final iteration of the auction. This analysis is relevant to the study of rent seeking in conservation auctions as well as to highlight the difference in bidding behavior of the winners and losers in the auction.

Overall the objective of this dissertation is to address both economic efficiency and ecological effectiveness of PES schemes when spatial patterns of land uses are important for ES conservation. The results of this study have consequence for the performance of PES schemes on real landscapes with landowners who have various economic characteristics. It also presents the need for more research on both auctions and subsidies for spatially coordinated land management.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

The P in my PHD represents all the people with whose guidance, support, assistance, kind words, reminders and sometimes reprimands I was able to complete one of the most challenging and longest journeys of my life.

First, I would like to thank my committee for their guidance and support. I thank Dr. James S. Shortle for teaching me how to pin down the scientific details of my research into a coherent and interesting story. I am especially grateful to him for his patience while I learnt how to transform my verbose and florid writing into a focused and concise scientific writing style. I will also remain indebted to him for helping me develop different aspects of my professional career and always providing financial assitance over the past four years. Next I would like to thank Dr. Anthony M. Kwasnica for guiding and helping me develop my research in many directions hitherto unexplored in this subject area. I remain grateful to him for helping me with coding issues related to Z-Tree, a bottleneck that I could not have resolved on my own and which was one of the toughest hills to climb during my PhD. I thank Dr. Edward C. Jaenicke for always having an open door policy and listening to my concerns about funding, the job market and my research. I consider myself very lucky to have taken AEREC 503 under his instruction where I learnt how to read scientific literature. Finally I would like to thank Dr. Robert P. Brooks for his insight about conservation programs beyond my immediate domain of focus and helping in maintaining the ecological validity of my research. To Dr. Steve S. Smith, an exceptional human being and supportive departmental head who was encouraging off my numerous endeavors. I am also grateful to the College of Agricultural Sciences Seed Grant Program for providing the financial support necessary to conduct the experiments for the dissertation at the LEMA in the Smeal College of Business. To everyone at the Department of Agricultural Economics & Rural Sociology for providing me support over the past 5 years. To Dr. Nick Hanley and Dr. Paul Armsworth for their comments about my research. To Dr. Joyashree Roy and Dr. Silvia Secchi, two amazing researchers and women whose brilliance, tenacity and grit have shaped my professional goals and aspirations.

Second, I am indebted to many friends without whom the PhD would not have been possible. I am indebted to Debanjana and Shama whose support, rebukes, encouragement and honest assessment of my life and work helped me grow as a person and researcher. I am glad to have an elder sister in Shakuntala from whom I have learnt that there can indeed be a method to madness! I am grateful to Savitha my oldest friend for always believing in me even when I did not. I am thankful to Aparajita and Sabyasachi for being amazing catalysts in my life. I am thankful to Nga and Cara for being wonderful friends and collaborators both at the department and at various watering holes we have visited over the years! To Rodrigo, Luis, David, Hernan, Milagro, Veronica and Andrea for trying very unsuccessfully to transform me into a Latina while helping me figure out salsa moves or an econometric equation or a STATA command. To Shonel, Qin and others who did not stop me while I pontificated in the computer lab or outside about the organized chaos that is grad school. To Anna Marie and her amazing family who opened their hearts to me. To Anupama, an amazing roommate and friend without whose support I would not have been able to preserve my sanity in the last few months leading up to the defense. To France and Bryce, exceptional human beings who always believed in me as a person and researcher and taught me how to pay it forward.

I will forever remain indebted to my friends that I met at AID. To Anirban, Archana, Arijit, Piyush, Shiv, Somesh and Vikas for motivating me to work for sustainable development at the grass roots in India, to try to affect structural change in India and run the Philadelphia Half Marathon (2009). To Shak for helping me make sense of my idiosyncrasies and understanding many things which others did not. To Monika for introducing me to AID. To Savitha for teaching me the importance of positivity and faith. To Jayashree di, Neela di, Nagesh and Hemant for being amazing friends and mentors. To Rumi and Rini for their openness and impulsiveness. To Tanushree for keeping the motivation going as we trained for the half-marathon and listening to me when she probably knew all that I was saying anyway. To Swayamjit, for his optimism and selflessness and amazing capacity to help others. To Alodeep and Debalina for welcoming me into their lives. To Raman for helping me figure out issues on econometrics and microeconomics at the drop of a hat. To many others, whose names are not mentioned here but whose presence in my life has helped me get to the place where I am now, Thank you!

Finally I would like to thank my family, my grandma - Minati, parents - Ram and Sushmita, my aunts - Sudeshna, Sudipta and Soma, uncles - Anup, Manas and Amitabh and my sister - Sreya and cousins - Ishita, Sulagna, and Sukanya for their unwavering support, trust and confidence in me while I discovered myself half a globe away.

"No pessimist ever discovered the secret of the stars or sailed an uncharted land, or opened a new doorway for the human spirit." - Helen Keller

"The real voyage of discovery consists not in seeking new landscapes but in having new eyes." - Marcel Proust

"The power of imagination makes us infinite" - John Muir

Chapter 1

Introduction

Tackling the problem of ecosystem and ecosystem services (ES) degradation, is one of the foremost policy challenges at the global level today. An example of this expression of interest in policy circles is the study of the state of the earth's ecosystems and the services produced by them under the Millennium Ecosystem Assessment study, the initiative to create a science-policy interface, termed the Inter-governmental Platform for Biodiversity and Ecosystem Services (IPBES), analogous to the Inter-governmental Panel on Climate Change (IPCC) and the international treaty termed the United Nations Convention on Biological Diversity for the sustainable use and protection of the earth's biological resources.

Public and private sector initiatives to protect and restore ecosystems are now found around the globe. The dissertation focuses on public sector schemes that involve changing land use and land management patterns on private working landscapes where most of the degraded ecosystems are located. For example the US General Accounting Office reported in 1994 that 90% of all species listed as endangered in the United States is located on private lands (GAO 1994). Similarly, in Australia 99% of all endangered ecosystems and 97% of all concerned ecosystems are located on private land (Rolfe et al. 2009).

Public sector initiatives for ecosystem conservation on such private lands include economic incentive schemes that create a market for the ES and hence promote their preservation. By providing monetary compensation, these schemes incentivize self-interested behavior without violating landowners' rights to determine land use practices on their properties. In fact they align private income generating motives with the societal objective of environmental value provision (Brown and Shogren, 1998, Innes et al., 1998, Hahn and Stavins 1992, Stavins 2001). Financial incentive schemes for environmental preservation include market-based instruments, lump sum payment programs and tax incentives schemes that provide landowners tax benefits for transferring their lands into undeveloped preserved states. Market based instruments include auctions and subsidies that are commonly known as Payment for Ecosystem Services (PES) schemes, water & air quality trading programs and conservation banks (Shogren 2005, Shabman et al. 1996, Stavins 2001). Of these schemes, the dissertation focuses on the subsidy and auction based schemes for the protection of ecosystem services on private properties.

Notable auction based schemes include the Conservation Reserve Program (CRP) and the Conservation Reserve Enhancement Program (CREP) in the US, the Ecotender in Australia, the PSA (*Pagos por Servicios Ambientales*) in Costa Rica and the Environmental Stewardship Scheme in the UK. The Single Payment Scheme and the Woodland Grants Scheme in the UK are examples of subsidy schemes. These incentive based programs have achieved considerable success in restoring habitats and environmental quality. For example PES schemes have led to the improvement of stream water quality through reduction of soil erosion and nutrient runoff, grassland restoration in the Prairie Pothole region and improvement in salmon populations through regulation of stream water temperature in the Pacific Northwest U.S. Knop et al. (2006) have documented the environmental benefits of agri-environmental schemes – which PES schemes are often termed in the EU – in Switzerland.

The importance of PES in achieving environmental goals has given rise to an interest in their study in the applied economics literature. This interest has two foci – a policy relevant ecological component and an economic component. The ecological component is focused on designing PES schemes to achieve various conservation goals and deliver a wide variety of ES. The economic focus relates to designing PES schemes that can produce the maximum conservation benefits at the lowest possible costs. Creation of spatially contiguous land use patterns for provision of ES is the chief ecological target of the conservation mechanisms discussed in this dissertation. This spatial goal improves upon the more common coarse filter type (Armsworth et al. 2004) conservation approach of PES schemes that targets the increase in total land area under the conservation program. Under this coarse filter approach land use purchases are largely dictated by proximity, property availability from private landowners and the money available to the participants in the programs. Yet parcels selected in this manner may not lead to effective realization of ecological functions and maximization of ecological benefits. For example coarse filter type conservation can give rise to fragmented land use configurations which often reduces ecosystem sustainability (e.g., increasing amount of "edge" habitat; narrowing wildlife corridors; inefficiently locating riparian buffers etc), compared to optimally shaped reserves and appropriately placed land uses on the geographical landscape (Margules and Pressey 2000). Thus effective PES scheme design requires attention to the location and spatial configuration of land uses.

Next, the economic goal of PES schemes pertains to generating the maximum ES benefits for a given budget. This economic efficiency objective is important as PES policies operate under limited budgets. Economic incentive based PES schemes such as conservation auctions (CA) can attain this goal. The challenge is then to design an auction that leads to the economically efficient outcome while achieving the ecological objective. This dissertation presents two essays which address these design challenges. It deals with two types of PES schemes – a subsidy mechanism and an auction. The subsidy scheme addresses the ecological issue of spatial coordination and the auction addresses the selection of spatially adjacent bids on the landscape in an economically efficient manner.

1.1 Research Objectives and Methods

Spatially coordinated land management is the ecological target of the two PES schemes in this dissertation. This target is achieved by a subsidy mechanism the Agglomeration Bonus (AB) that was first proposed by Parkhurst et al. (2002, 2005 and 2007) and provides incentives for the creation of spatially contiguous land use patterns across multiple property boundaries. The AB research in this study investigates how uncertainty about conservation attitudes of neighboring farmers impacts coordination of land uses for the creation of ecologically effective spatial patterns in circular networks which are representative of actual agricultural landscapes.

The essay on the conservation auction deals with both the economic efficiency and ecological effectiveness of PES schemes. The need for auction design for spatially adjacent bid selection arises since the AB is a uniform rate payment scheme. Thus it does not lead to an economically efficient outcome even if it is ecologically effective. An iterative descending price auction that can be operated to select spatially adjacent selection of bids in an economically efficient manner is presented to achieve the dual objectives.

In both these essays the experimental economic methodology is employed to analyze the ecological and economic performance of the mechanisms. All experiments are conducted under controlled lab settings and enables the comparison of mechanism performance and participant behavior under various treatment conditions. In the first study, spatial coordination of subjects is analyzed in the presence of the AB in big and small networks In the next set of experiments pertaining to the auction, the treatment variables involves varying the information content of the auction and cost-benefit parameters of the projects for which bids are submitted to investigate the impacts on the ecological performance and economic efficiency of the designed iterative auction.

1.2 Importance of Spatial Patterns for Ecological Effectiveness

The main ecological criterion to be achieved by the PES schemes in this dissertation is the creation of spatial patterns of pro-environmental land uses. This feature is important for sustainability of many ecosystem functions. Long term provision of most ES such as maintenance of water quality and temperature, a check on soil erosion and survival of endangered species depends upon the spatial pattern of land uses. For example creation of spatially contiguous areas of riparian buffers have a far greater effect on checking soil erosion and nutrient runoff than if there are gaps between buffered tracts along the length of the streams. It is also universally believed that habitat fragmentation is not conducive to species conservation. Dell et al. (1994) present evidence about the deleterious impacts of habitat fragmentation on biodiversity in the Brazilian Amazon

Negative impacts of lack of spatial patterns are also substantiated by theories on metapopulation dynamics and community complementarity across adjacent habitats. A metapopulation (Levins 1969) is a network of species populations linked by dispersal. In a metapopulation, local populations periodically go extinct with re-colonization occurring through migration of species from other local populations. This re-population is possible if habitats supporting the populations are connected so that if an event causes extinction of some populations, a few others might escape extinction and move to connected habitats. Thus reserve connectivity spreads and reduces the risk of extinction (Gilpin, 1987). Complementarity between communities of native flora and fauna refers to the extent to which an area or set of areas contributes unrepresented ecological features to another area (Vane-Wright et al., 1991, Faith, 1994). If habitats are adjacent to each other, then each area may contribute many species types and high values to each other increasing the ecological diversity and consequently ecological resilience of that area. The theory of bio-geography also attaches considerable importance to the issue of spatial contiguity of habitats. According to this theory bigger, closer and connected reserves are better for species survival (Wilson and Willis, 1975, Diamond, 1975). This is especially true for species such as large carnivores which have large home ranges and are sensitive to fragmented habitats which include forests and the interface of forests and fields. These animals will thrive better in large and connected areas. Fragmented reserves have considerable impacts on bird populations as most of them are either edge or interior species. In a study by Willis (1979), 100% of understory birds that were labeled as edge species were capable of crossing gaps in woodlots compared to only 23% of interior species. Distances between forest fragments and smaller parcels of forest have a significant negative effect on a number of species (Newark, 1991). Bockstael (1996) presents that it not just the total forested land in a region that matters for species abundance and diversity, but its size, shape and the conflicting land uses found along its edges. These factors demonstrate the imperative for incorporating the spatial criterion into the design of PES schemes.

1.3 Outline

Chapter 2 provides context for this study through a review of policy instruments for ecosystem conservation and ecological and economic issues in their design and performance. Chapter 3 provides the description of the experimental methodology. Chapter 4 presents the study on the ecological performance of the AB study in the presence of participation doubts. Chapter 5 deals with the study of the auction for spatially contiguous land management. Chapter 6 provides the conclusion and few words on future research. Appendix A contains instructions which were used in the experiments and description of other notes. Appendix B represents the screen shots of the experiment visible to subjects during the experimental sessions

Chapter 2

Instruments for Ecosystem Preservation

Instruments for ecosystem preservation range from traditional command and control regulations to voluntary policies – economic and non-economic. The latter set is intended to preserve landowner freedom in being able to adopt from a wide variety of land management options and not violate their private property rights. Some or all of these policies involve one or more of the following features – regulatory streamlining, technical assistance, direct funding and tax (property and income) deduction benefits. Each of the policies has pros and cons and is not an all inclusive solution. Their effectiveness depends on factors such as the regulator's objectives, available land, variation in land quality, landowners' dispositions towards conservation activities and information available to the regulator (Shogren 2005). This chapter presents a description of some of the extant approaches to ES preservation and their pros and cons. This discussion provides the policy context within which the discussion of the subsidy and auction mechanism is presented.

2.1 Command and Control Regulations

Command and Control measures include regulatory mandates used by government agencies to implement land use changes on private properties. Historically in the United States, regulation based conservation policy has involved the use of the

Endangered Species Act (ESA), zoning (Parkhurst and Shogren 2005, Miller 1999) and Transferrable Developmental Rights (TDRs), to restrict development on private lands and preserve environmental attributes .

The ESA came into practice in 1973 and is an instrument to prevent takings of endangered and threatened species on private lands. The term *takings* under the Act refers to the act of or the intent to harm any species within an ecosystem designated as critical habitat. The ESA is administered by the US Fish and Wildlife Services (USFWS) and National Oceanographic and Atmospheric Administration (NOAA) and is intended to protect both species and the ecosystems they inhabit (Brown and Shogren 1998). The Act authorizes these agencies to 1) designate species as threatened or endangered, 2) denote the private lands that support them as critical habitat and 3) prevent both the development of critical habitat and takings of the species inhabiting them.

In terms of conservation success, the results of ESA implementation have been mixed (Tear et al. 1993). On one hand many species that were listed as endangered or threatened under the ESA have been delisted over the years. A few examples include the bald eagle and gray wolf. Martin et al. (2005) present a quantitative analysis of the performance of the ESA in the 1990s. They find that in most cases listing a species under the Act led to an increase in its population all through the 1990s. Yet despite this positive outcome, the application and reauthorization of the ESA has been contentious. This is because the regulatory stick of the ESA violates private property rights by removing the landowners' rights to develop their land. Secondly it creates perverse incentives for landowners to preemptively take/destroy species on their lands in fear of future regulation. Such behavior is commonly termed as the shoot and shovel strategy (Brown and Shogren 1998, Bean 1998).

Another regulatory tool is zoning. Public agencies pursue zoning based conservation by designating allowable pro-conservation land uses and imposing legal penalties on land owners in the event of non-compliance with the measures. It is a useful means to achieve conservation goals by targeting specific land use activities on the landscape (Donahue 2005). However, implementation of zoning can be controversial. First, zoning regulations interfere with landowners' rights to choose the pattern of land use on their properties and can give rise to perverse incentives where landowners develop their land a priori in anticipation of a future threat to developmental activities (Miller 1999, Epstein 1996, Boyd et al. 1999). Second, it can result in an unfair distribution of the costs of conservation, inflicting all the costs of ES provision on private entities (Boyd et al. 1999). Third, zoning does not guarantee that the lands with highest benefits to society will be preserved. Fourth, zoning regulations incur high transactions costs (Boyd et al. 1999) and finally zoning ordinances may change with change in political leadership and hence may sometimes be a temporary measure (Parkhurst and Shogren 2005). The concerns with zoning have led to the popularity of Transferable Development Rights (TDRs) regimes that relax some of the inflexibilities associated with it.

TDR programs fix the degree of development within a particular area and then distribute the development rights to landowners. These landowners in turn can sell these rights for development elsewhere. The TDRs create a market for development rights between a selling (sending) area and a buying (receiving) area and provide financial compensation to land owners for the returns from development they forgo for ES provision (Panayotou, 1994, Parkhurst and Shogren 2005). TDRs have been used to pursue conservation goals, in states such as Maryland and Florida. In Maryland the Forest Conservation TDR program has been used to achieve the mandates of the Maryland Forest Conservation Act. The beneficial feature of the TDR scheme is that by creating the market for developmental rights, it allows the preservation of open spaces and other habitats without generating the high social costs that zoning entails. Yet TDRs are not full proof. First, like zoning TDRs are temporary and may be susceptible to changing political leadership. Also site selection under a TDR scheme may be arbitrary and not in accordance with ecological functions (Donahue 2005). Finally there are high transactions costs – enforcement and monitoring costs associated with TDR programs as well.

2.2 Voluntary Economic and Non-economic Approaches

Limitations of command and control regulations have led to policy innovations involving both voluntary economic and non-economic instruments. This class of economic instruments provide monetary rewards and both technical and/or financial assistance to participating landowners for adopting various ecosystem protecting land uses on their properties. The presence of a monetary payment makes these schemes more attractive to landowners and less politically contentious compared to regulatory approaches. Examples of instruments under the category include Habitat Conservation and Stewardship Plans, Conservation Banks and Easements, and PES schemes – auctions and subsidies. This section provides a succinct description of these approaches highlighting how the policy literature has expanded and evolved in the context of ecosystem conservation.

2.2.1 Habitat Conservation and Stewardship Plans

Habitat Conservation Plans (HCP) and Stewardship Plans (SP) are long term conservation agreements between private landowners and government agencies such as USFWS, the Forest Service respectively. HCPs are often used in tandem with the ESA as they allow landowners to pursue developmental activities even if ESA regulations apply as long as they take steps to preserve the vulnerable ecosystems and listed species found on their properties (Kareiva et al. 2005). There are as many as 350 HCPs in the US (Defenders of Wildlife). An example is the Native Fish Habitat Conservation Plan (2000) in Montana. Under this HCP, habitat for eight species of native trout and salmon are protected in over 1,300 miles of fish-bearing streams. SPs on the other hand are agreements between public agencies and private entities that operate independent of any regulations under the ESA. As part of a SP agreement, agencies provide technical assistance, and funding in the form of cost-share assistance, to landowners for pro-environmental land management. The Forest Stewardship Program (FSP) is one of the largest stewardship plans in the U.S. Since being introduced in 1991, it has produced more than 270,000 multi-resource management plans encompassing more than 31 million acres of nonindustrial private forest land. These actively managed forests provide both commercial benefits in the form of timber and non-timber products; conserve wildlife habitat, lead to watershed protection and other environmental benefits. Egan et al. (2001)

evaluate the data for many forest SPs and conclude that the plans have been useful in improving ecosystems and delivery of ES as well as landowners goodwill and interest for sustained ecosystem conservation.

However even though these schemes are more popular than regulatory mandates, they are few limitations. First since, HCPs permit controlled takings; they may result in net loss of habitats and species. Second HCPs may not be based on clear scientific assessment so that ecosystem functions may not be appropriately realized (Hosack et al., 1997; Kaiser, 1997). Kareiva et al. (2005) present a review of 43 HCPs and conclude that the conservation success of HCPs requires inclusion of sound principles of ecosystem science and management.

2.2.2 Conservation Easements

Conservation easements are economic instruments that allow landowners to freeze the developmental rights on their land in exchange for financial rewards. Easements involve legal agreements between public or private entities like land trusts and landowners to freeze the development rights of the lands for subsequent generations. By freezing development easements are used to conserve open spaces, wildlife habitat and water quality. Conservation easements are unique instruments as they can be tailored to the requirements of the landowners creating the easement. Thus they can be used to preserve a wide variety of ecological services. Easements are of two types – Purchased Development Rights (PDR) easements and Donated easements (Parkhurst and Shogren 2005). Both of them involve payments in the form of income and/or property tax breaks as well as one time lump sum payments to the landowners. Typically most donated easements are held by private land trusts like the Nature Conservancy. Kiesecker et al. (2007) present an evaluation of 119 easements of the Nature Conservancy providing a mixed set of results. They suggest that more extensive assessment of ecological outcomes of easements than what exists currently is necessary to draw conclusions about the ecological effectiveness of the scheme,

This necessity to monitor is a key limitation of the tool. Moreover monitoring is not only restricted to evaluation of ecological outcomes. It also entails regular checks on whether current and all future landowners are in compliance with land use and management dictates as noted in the easement agreement. Thus easements incur high costs for the land trust into perpetuity. Hence to sum up, the decision to create an easement is contingent on the flexibility of management and ownership of lands, and the costs associated with maintaining it.

2.2.3 Conservation Banks

Innovations in the field of economic conservation instruments have included institutions such as conservation banks that create a market for ES. These banks are private and government owned environmental institutions that practice ex-ante environmental protection through habitat management such as wetland management, for which they are awarded credits. These credits are marketable and can be purchased by land developers who need to take different species, and or/ destroy and degrade habitat for commercial development (Weems and Cantner 1995, Fox and Nino-Murcia 2005).

Thus conservation banking can improve the condition of ecosystems and the services they produce even before any need for their degradation is felt.

Conservation banking has been prevalent in the US since the 1980s. The Ecosystem Marketplace website reports that currently there are 123 banks in the US preserving 51 types of habitats and 92 species. Initially these banks focused on the wetland preservation but over time have come to include other vulnerable habitats as well. An example is the Southlands Mitigation Bank established in Georgia for the conservation of forests and increase in the number of red cockaded woodpeckers living in them.

An important aspect of conservation banking is that it promotes landscape level conservation. By setting up a bank covering contiguous parcels on a large area, conservation banking minimizes edge effects and creates spatially contiguous habitats (Environmental Defense Fund 2000). Landscape level contiguous bank areas also allow bankers to benefit from economies of scale associated with bank creation (Parkhurst and Shogren 2005). The presence of the credit market incentivizes bank owners to undertake innovations to improve the quality and quantity of their credits as well. The creation of a market and possibilities of financial compensation thus provides a viable method for sustained ES provision.

Yet the advantages of establishing conservation banks have to be weighed against the high costs of bank creation and the need for regulatory foresight. The costs associated with evaluating applications for bank creation, verifying biological assessments of the habitats where the bank is to be set up, evaluating and fixing the quality and quantity of credits that the bank can create and sell, and the money needed for land acquisition and management for creation of habitats can be prohibitive. This high set up cost can be a deterrent for the creation of more banks (Shabman et al. 1998). Thus the success of the conservation banking institution largely depends upon the extent to which public agencies are willing to put regulations into place that will reduce these establishment costs associated with bank creation and market operation and allow bankers to capture the cost savings and benefits from credit generation (Robertson 2006).

2.2.4 Payment for Ecosystem Services (PES) Schemes

PES schemes is a catch all term for schemes comprising of economic instruments such as of auctions and subsidy based schemes that pay landowners for pro-environmental land management actions on private properties out of a fixed budget. These schemes are similar to farm level income support programs (Baylis et al. 2008, Latacz-Lohmann and Hodge 2003) making them easier to comprehend and hence participate in by agricultural landowners. Under these schemes landowners receive payments from public agencies – such as the USFWS, the Natural Resource Conservation Society (NRCS) in the U.S., the Department of Environment, Food and Rural Affairs (DEFRA) in the UK. These agencies in turn procure the land uses from the farmers. For example the DEFRA has introduced many auction based payment schemes as a part of their "Environmental Cross Compliance" initiative. The Single Payment Scheme (EU) and the English Woodlands Grant Scheme (UK) are examples of subsidy schemes. These schemes are also termed agri-environmental (AE) schemes In the EU (Baylis 2008). Such uniform rate subsidy schemes are prevalent in Australia as well (Windle and Rolfe 2008).

Payment rates under these subsidy schemes are calculated on the basis of observable yield and planting histories of farmers. In the US, the Environmental Quality Incentives Program (EQIP), represent a uniform rate payment scheme. Auctions for ecosystem management are common as well as they can be implemented to achieve conservation goals cost efficiently. These auctions are increasingly becoming common in EU nations, Australia and countries such as Costa Rica, Indonesia to name a few This is a very important aspect of PES scheme design given limited policy budgets from which payments are to be made.

The Conservation Reserve Program (CRP) is an example of an auction that enrolls private cropland for reduction of nitrogen content of soil, decrease in soil erosion wetland preservation and wildlife conservation. Since 1985 when the CRP was introduced by the Farm Service Agency (USDA), nearly 36.8 million acres of farmland have been enrolled, 1.8 million acres of wetlands have been restored and erosion of about 450 million tons of soil has been prevented annually. According to Kirwan et al. (2005) the CRP has disbursed about $26 billion in payments to landowners. Under the CRP, cropland and certain marginal pastureland is enrolled during specific periods termed general sign-ups. During this process, bids submitted by landowners are ranked and selected on the basis of the Environmental Benefit Index (EBI).[1] Continuous sign-ups are also encouraged for environmentally desirable land devoted to certain specific conservation practices at any time during the year.[2] The Environmental Stewardship Scheme is an example of an auction based policy for protection of wildlife and

[1] The EBI is a scoring metric that is used for bid ranking and selection during CRP general sign-ups. It includes information on costs and benefits of the land offered for enrollment in the program.
[2] Land offered under continuous sign-ups is not subject to competitive bidding.

biodiversity natural resources, and landscape quality. In Australia, the Bush Tender Trial (BTT) is an example of a field auction in Australia (Stoneham et al. 2003). It was run in the province of Victoria for the conservation of vegetation and other forms of biodiversity on privately owned lands. Like the CRP, a metric similar to the EBI, the Biodiversity Benefit Index (BBI) was used to rank and select bids. The Bush Tender and other pilot field applications indicated that auctions can achieve commensurate ecosystem benefits at a much lower cost than subsidy schemes (Bryan et al. 2005, Gole et al. 2005).

A common feature of most of the above PES schemes has been to increase participation and total protected land area. Yet as newer threats to ecosystems and the services they deliver are revealed, smarter conservation strategies that target additional ecological conservation criteria are required. Spatially contiguous land management as mentioned in Chapter 1 is one such important criterion. In fact the Conservation Reserve Enhancement Program (CREP) in Oregon, another PES scheme under the USDA makes payments to landowners to incentivize the creation of contiguous riparian buffers (Parkhurst and Shogren 2005). This dissertation addresses the design of two payment schemes for the attainment of this new ecological criterion.

Chapter 3

Experimental Economics

The experimental methodology is adopted in this dissertation to analyze the performance and subject behavior under the two PES schemes – the AB and the conservation auction. This chapter provides a primer on the experimental economic methodology and places it in the broader context of behavioral and environmental economics research.

3.1 Behavioral Economics

In economics, the representative agent is fashioned as a rational decision maker who acts selfishly and makes choices on the basis of solutions to explicit optimization exercises. Yet this rationality assumption is limiting as human beings are subject to multiple behavioral limitations (Kahneman 1991, 2003, Thaler 2000). Mullainathan and Thaler (2000) categorize behavioral anomalies into three groups. First economic agents are *boundedly rational* (Simon 1955, 1957, Mazzotta and Opaluch 1995) so that very often they use rules of thumb – heuristics and behavioral biases to make decisions in cognitively complex settings, rather than relying on explicit optimization exercises. Kahneman and Tversky (2000) indicate that reliance on such heuristics and biases can lead to errors in decision making. Second, economic agents are also subject to *bounded willpower* that makes them behave in a manner that is not in their long term interests.

Examples of such behavior include procrastination (Mullainathan and Thaler 2000) and hyperbolic discounting i.e. high impatience for decision making in short time horizons as opposed to exponential discounting where individuals are uniformly impatient throughout the time horizon (Rubinstein 2003). Finally economic agents are often unselfish and exhibit *bounded self-interest* whereby they incur voluntary losses for others' benefits. Bounded self-interest is visible in the case of public good provision (Andreoni 1990). Behavioral economics deals with the study of economic decision making in the scenarios where economic agents are non-rational, non-selfish and non-optimizing.

Behavioral economics employs a combination of psychology and economics to study human decision making in scenarios where the representative exhibits human limitations and complications (Mullainathan and Thaler 2000). The works of Kahneman and Tversky (1982), Tversky and Kahneman (1986, and 1992), Kahneman (1991, 2003), Sunstein and Thaler (2008), Thaler (1985, 1980) represent major contributions to this field. As Thaler (2000) maintains behavioral economics represents the study of the transformation of *Homo economicus* to *Homo sapiens* through the consideration of heterogeneity in preferences, emotions, cognitive difficulties in decision making etc. A considerable portion of behavioral economic research has focused on novel methods such as neuro-economics (Camerer 2008) and experimental economics (Smith 1976) to capture the impact of behavioral anomalies on decision making and mechanism performance. The current research exclusively takes the experimental economics route.

3.2 Experimental Economics

An experiment is a scientific method that entails the variation of an input variable to evaluate its impact on an output variable. In following this procedure the experimenter should keep all other features of the experiment constant so that any change in outcome of the experiment can be attributed to the change in the input variable. Every experiment involves the test of theory and/or hypotheses on the basis of which some propositions can be established. Economic experiments are useful tools to study numerous economic phenomena especially in contexts where theory is very hard to develop and when behavioral issues are important.

Experiments can be classified into three categories such as lab, field and natural experiments (Roth 2008, Harrison and List 2004, Angrist and Krueger 2001). These experiments differ on the basis of the nature of the participants and the manner in which the treatment is applied to the subjects within the experimental environment. Field experiments involve real decision makers and actual stakeholders who are impacted by the change in the treatment variable. Laboratory controlled experiments on the other hand involve subjects randomly selected from a non-stakeholder group usually a student population. In both field and lab experiments, the experimenter can randomly assign subjects to a treatment and systematically isolate the impact of the treatment variable. Plott (1997) uses the term testbed to define an experimental environment. A testbed is a working prototype of a complex environment which provides a convergence of theory and real life observations. An important feature of the lab experiment is that the experimenter can control different features of the testbed. For example the experimenter can regulate the amount of contextual information about the economic environment of the experiment available to the participants. Context information constitutes specific characteristics of the economic environment within which the impact of the treatment variable is tested. Context incorporates real life scenarios into the testbed and can provide a close correspondence between actions in the testbed and in a real economic setting. Yet contextual information should be included with care as it can also introduce other factors that may influence decision making. For example in the experiments for this dissertation terms such as landowners and parcels were included to inform participants about their roles as landowners. However terms such as ecosystem services, conservation, and environmental benefits were not introduced so that experimental subjects would respond only to the economic features of the environment and not on the basis of other factors such as greater environmental consciousness and conservation motives to mention a few. This attention to control of contextual information ensures that both the generality of the experimental environment and nature of the outcomes obtained in it (Shogren 2001, 2004) are preserved under various circumstances. Thus the challenge of testbed design is to find the "compelling" balance of context and control so that people are motivated for the reasons imagined by the researcher (Shogren, 2004). The ease with which the testbed environment can be controlled sets lab experiments apart from their field counterparts. In field settings with actual decision makers there can be variables other than the treatment that influence decision making and confound outcomes (Davis and Holt 1993).

Finally natural experiments are those where the treatment is applied exogenously. A natural experiment entails the study of the impact of an exogenous variable – the input, on the explanatory variable – the output that in other cases is endogenously related to the outcome of interest (Meyer 1995). The exogenous variation might be via a systematic change in government policy such as investment in school construction in Indonesia that led to an increase in average years of schooling and wages (Duflo 2001) and changes in group actions such as immigration that impacted the wages and employment levels of immigrants (Hunt 1992) to name a few. In these cases the analyzer can only collect data that permits them to make conclusions about the impact of the change.

A key feature of lab and field experiments that distinguishes them from experimental psychology is that participants are provided monetary compensation based upon the decisions they make. This feature has important benefits. First by framing the outcome of participation in monetary terms experimenters are able to reduce variability in outcomes (Davis and Holt). Second the presence of monetary compensation associated with various actions attaches valuations to different actions in the testbed. These valuations allows the experimenter to evaluate subjects' decisions under the assumption of expected utility maximization. This is possible as subjects are assumed make decisions to increase their payoffs and hence expected utilities (Roth 2000, Hertwig and Ortmann 2001). Third monetary compensation can also improve the quality of the data collected by reducing variability in the data. Since actions determine compensation, financial compensation is believed to improve participant concentration and yield statistically reliable and informative data (Fiore 2009).

The data generated during an experiment is used to establish proofs of *concept* and *design consistency*. First, testing proof of concept requires that experiments have both internal and external validity. Internal validity indicates that the outcomes of the experiment were caused by changes in the treatment variable (Meyer 1995, Cook and

Campbell 1975). External validity of experiment necessitates that the results of the experiment be preserved when replicated in similar contexts such as in the field. Second the proof of design consistency requires that theoretically consistent results can be obtained in repeated trials of the experiment (Plott 1997). This feature is important as if the same experiment gives a different set of results in multiple trials, then the results are faulty and of no use at all (Davis and Holt 1993).

Economic experiments have many advantages that often make their use more feasible relative to a theoretical development. For example complex multi-attribute combinatorial auctions (Bichler 2000), while realistic, represent environments that are very hard to model theoretically. The performance of this auction may be more easily examined in an experimental environment where the impact of the treatment variable can be clearly isolated. Moreover since experiments consider real human decision makers laboratory experiments form a useful bridge between simple theories and the full complexity of actual mechanism and policy implementation. Experiments permit wind-tunnel testing of policies prior to final construction and help to establish internal validity of the economic mechanism concerned (Plott 1982, Shogren 2004). As Vernon Smith maintains "the issue is not whether lab experiments can predict outcomes in the field, but whether they allow us to make all the important mistakes at low cost, before field implementation."

Both lab and field experiments can be used to test different types of hypotheses. These include 1) testing behavioral hypotheses, 2) stress testing theory and 3) investigating the presence of behavioral regularity in economic agents (Davis and Holt , Shogren 2001). The elegance of the experimental method is that conclusions from these experiments can not only validate existing theoretical concepts but inform the development of new theory (Crawford 1997, Roth 1988, Samuelson 2005).

The history of the experimental revolution in economics[3] can be traced back to experiments on individual decision making such as experiments to determine an agent's indifference curves by Thurstone (1931) and Rousseas & Hart (1951). This was followed by experiments by Preston and Baratta (1948), Allais (1953) and others which tested various aspects of Expected Utility Theory developed by Von-Neumann and Morgenstern. The experimental methodology also found credence in the study of human behavior in game theoretic settings and performance of various simple and complex market/allocation mechanisms. In terms of game theoretic experiments, a large gamut of experimental research by economists and psychologists focused on Prisoner's Dilemma games all throughout the 1950s and 1960s (Davis and Holt). This experimental agenda gave rise to an interest in experiments studying oligopolistic behavior ushering in experiments in industrial organization. One of the first market level experiments was conducted by Chamberlin (1948). This was followed by other experiments on oligopoly by Hogatt (1959), double auctions by Smith (1962, 1964), and Siegel and Fouraker (1977) and Plott (1982).

The application of the experimental method has become common in many economic fields. Lab experiments are used to test agent behavior and the performance of new mechanisms. Examples include the study of the performance of the Federal Communication Commission (FCC) administered auctions (Plott 1997) and analysis of economic agents' contribution patterns for public good provision. (Andreoni, 1995,

[3] A description of the history is found in Roth (1988, 2009) and Davis and Holt.

Andreoni and Petrie 2004) to mention a few. The first study deals with the design and comparison across multiple formats of auctions for the sale of radio spectrum for the FCC that was not attempted before. The study analyzed how common value elements, presence of complementarities across spectra would impact auction design and behavior. Andreoni (1995) was the first to present experimental results that attributed cooperation in public good experiments to altruism, warm glow effects and kindness. Experiments are also used to study how individuals develop preferences for new commodities. For example Shogren et al. (2000) explore the factors explaining high price premia for new products in the market. Experimental studies have also analyzed the impact of new policies and behavioral biases on decision making. Banerjee et al. (2009) reveal that observational data may not be sufficient to evaluate the performance of developmental programs whose success requires focusing on multiple policy relevant factors. Experiments can be used to control for these determinants. Experiments can also test the impact of socio-demographic factors such as policy making ability of a section of the population for example women policy makers (Duflo and Chattopadhyay, 2004).

3.3 Application of Experimental Economics Environmental Economics Research

Economic experiments as mentioned can be used to analyze human behavior in novel settings and the performance of new mechanisms. These two features make the experimental methodology useful for the study of various problems in the field of environmental economics. For example the study of new markets and market based schemes to address the market failure problem and non-market valuation are some of the areas where experimental examination is common. Economic experiments have been routinely used to analyze the performance of new environmental allocation mechanisms. For example Burtraw et al. (2008) experimentally analyze the collusion resistant properties of multiple auction formats for sale of carbon emission permits. These auctions are similar to the auctions under the Regional Greenhouse Gas Initiative and provide valuable insight about the performance of the mechanisms. Another example includes analysis of relative performance of uniform price and discriminatory price auctions for the sale of non-point source pollution reduction contracts by Cason and Gangadharan (2005).

The study of non-market valuation has also benefited from an experimental examination. This is because non-market valuation is subject to various behavioral biases. For example significant gaps exist between WTP and WTA owing to the endowment effect (Knetsch and Sinden 1984, Knetsch 1989), and PES studies such as forest preservation studies where participants claim lesser amounts of money if they are environmentally motivated than when they are not (Mantymaa et al. 2009). These biases and how they impact valuations of environmental goods can be analyzed through an experimental treatment.

Another pertinent issue mentioned in the previous section is the inherent complexity of new allocation mechanisms that can sometimes make theoretical development intractable. Conservation auctions that form the subject matter of part of this research is a case in point. Theoretical development and Nash Equilibrium determination in the presence of a budget constraint can be quite challenging as the nature of the strategic interactions between different bidders is not known. Thus most of the studies on these auctions have relied on experiments.

Moreover an important feature of lab experiments is that they reveal different properties of the mechanisms and features of human behavior at much lower costs than what would be incurred with actual stakeholder participants. Moreover since the features of an experimental testbed can be controlled by the experimenter, a wide variety of outcomes can be analyzed by varying the experimental parameters and treatments at low costs. This flexibility and affordability of the experimental methodology is especially important for the study of allocation mechanisms that are associated with important polices. Annual conservation auctions by the USDA are an example of policies that implement auctions. When these auctions need to achieve new environmental goals such as spatially contiguous land management, their design needs to be changed. The performance of the new auction design for spatially contiguous land management can then be analyzed in lab settings at low costs before costly policy implementation. All these factors indicate that the study of environmental economics in general and PES schemes in particular will benefit from experimental examinations.

3.4 Critiques of the Experimental Economics Methodology: A discussion

This section presents a discussion about some of the critiques the experimental economic method has been subject to. The first criticism is associated with the issue of subject selection. Most lab experiments use randomly selected subjects from university student populations. Students however may not possess the sophistication necessary to fully comprehend the experimental decision making exercise especially if the experiments are unfamiliar to them. Guillen and Veszteg (2006) and Ball and Cech (1991) provide a review of the literature on subject pool effects. Guillen and Veszteg (2006) indicate that variation in experimental outcomes owing to the nature of the subject populations accounts for only 4% of variation in outcomes. Smith et al. (1988) also provide evidence about the absence of systematic differences between the actions of students and business professionals in experimental asset markets. These studies establish that subject pool variations are not a matter of concern. In fact per Davis and Holt if there is any systematic difference in outcomes in different subject pools, it should be interpreted as a result of a treatment effect rather than as a limitation. Falk and Fehr (2003) maintain that the nature of the difference in experimental outcomes from using different types of subjects is quantitative and not qualitative. Quantitative differences refer to difference in magnitude of effects, and variation in rates of responses while qualitative differences pertain to a complete variation in the nature of effects and responses. An example of quantitative differences is slower learning by businessmen compared to students in auctions (Burns 1985). If qualitative differences appear by considering different subject pools it is probable that some other factor(s) other than the treatment variable in the experiment is influencing outcomes. (Davis and Holt).

A second issue in the application of the experimental methodology is the trade-off between 1) simple experiments and complex theoretical development and 2) the real and hypothetical nature of the testbed. Addressing the first issue, an experimental testbed can be more complex than a theoretical model. But in order to be tractable for the subjects, it has to be much simpler than its real life counterpart. This simplistic representation may however lead to results that are not supported in actual implementation. Davis and Holt however consider such a difference in results as a fault of the underlying theory that is unable to explain the experimental outcomes rather than of the experimental methods.

Third the Wallis and Friedman critique (1942) claims that experimental results are hypothetical given the artificial nature of the testbed environment. Plott (1987) provides comments addressing this critique. He maintains that since experimental economic testbeds always involve payment of real money, any experimental outcome is a result of a real response and not a hypothetical one. As a result the economic environment in the lab or the field is very real. Levitt and List (2006) provide a model that demonstrates that rather than focusing on the issue of the hypothetical nature of the environment, experimental results should be interpreted as providing useful insight about decision making rather than issues related to the theoretical foundations of the testbed. Again Schram (2005) maintains that the severity of the artificiality critique is contingent on the relative importance of internal and external validity. When experiments need to investigate behavioral regularities both in the lab and with actual decision makers, the artificiality critique should be addressed carefully and experiments should be designed so that close correspondence between the testbed and reality can be established.

Finally a common criticism applied to testbeds is that they operate in isolation unlike real economic systems that have linkages to others. Hence conclusions from experiments will not be preserved in real settings. Yet this is a feature of all experiments. As the physical and biological environment cannot be recreated in its entirety in the lab, the economic environment cannot be approximated in entirely in a testbed. This critique is a call for progression from simple testbeds to more complex ones.

Chapter 4
Agglomeration Bonus in Local Networks: Spatial Coordination in the Presence of Participation Doubts

The Agglomeration Bonus (AB) is a simple uniform rate payment scheme that can incentivize spatial coordination on working lands for ES provision. Theoretically it is formulated as a spatial coordination game with the payments structured so that the Nash Equilibrium (NE) outcomes correspond to spatial patterns of land use. For example the Conservation Reserve Program (CREP) in Oregon makes payments resembling the AB to landowners for the creation of contiguous riparian buffers along stream lengths. Two key features of the current AB design is that it does not consider different types strategic interactions between participants that are realistic approximations of inter-farmer relationships on different landscapes and assumes that farmers will always participate in the schemes. Yet in reality this is hardly the case. First, farming landscapes are organized into different types of networks within which strategic interactions are different. These differences in turn have consequences for coordination behavior and hence AB performance. This issue has not been addressed in the prior literature. Second, the literature on analysis of participation in conservation programs (Smith et al. 2007, Lant et al. 1995) indicates that landowners have various reasons for non-participation in these programs which cannot be addressed by increasing the value of compensatory payments of the scheme.

Given this background scenario, this essay examines the performance of AB in a network environment where every participants interact with different neighbors and where players may not choose the strategy for the coordinated outcome even if they are compensated for their action. This particular formulation of the strategic environment is realistic and representative of many working landscapes on which the AB can be implemented. The standard AB game in this new setting is recast as a coordination game with two Pareto Ranked Nash Equilibria where the selection principles of Risk and Payoff Dominance select different strategy profiles. The Payoff Dominant strategy pertains to coordinated performance in the AB and the Risk Dominant strategy captures the non-participation aspect. The analysis of this new game is tested experimentally in sessions with six and twelve players, each of whom play the role of landowners. The experimental results show that in the new local network setting coordination failure is a problem. Furthermore, it is more severe in larger networks than in smaller ones even if the payoffs faced by every player are the same. This group size result corresponds to the result by Van Huyck, et al. (1990, 1991) (VHBB) about the hardness of coordination in groups with more individuals. Finally, while the performance of the AB suffers in bigger networks, coordination behavior is observed in localized areas indicating partial AB effectiveness.

4.1 Agglomeration Bonus: Description and Review of Literature

The AB, first proposed by Parkhurst et al. (2002), consists of two incentive payments. A participation payment is made to landowners who choose to enroll parcels in the program and implement designated conservation practices. This payment is independent of neighbors' actions. The second is the bonus paid to landowners when their enrolled parcels border those enrolled by other participants. The bonus is intended to incentivize landowners to spatially coordinate their actions to create desired patterns in land management. Specifically, the structure of the payments can be adjusted to produce different types of spatial configurations. For example, suppose conservation of an endangered species requires the creation of a regional east-west corridor. Then the bonus can be attached to east and west borders of parcels to incentivize landowners to retire lands in the east-west direction to create the desired corridor.

Parkhurst et al. (2002, 2007) and Warziniack et al (2007) – together PW, use lab experiments to examine how the AB might work in practice. They represent the AB as a repeated coordination game between adjacent landowners. Parkhurst and Shogren (2007) analyze the performance of the AB under different coordination scenarios such as the core, corridor and the cross configurations. Each of these scenarios represents a particular spatial pattern beneficial for biodiversity protection and to which players have to coordinate over multiple interactions in the game. The games in their experiment last for30 periods. Their study findings indicate that the AB performs better for simpler than more complex target patterns. Considering results for the final period of all games, they also find that the corridor configuration is achieved 100% of the time and the core pattern is achieved 76% of the time.

Warziniack et al. investigate the impact of cheap talk (non-binding pre-play communication) on the performance of the payment scheme. The motivation for this treatment comes from the results of Parkhurst et al. (2004) who find that cheap talk increases the instances of coordination failure in games with repeated interactions. In their study, however Warziniack et al. provide evidence that cheap talk in fact enables subjects to coordinate and create the spatial patterns. Both Parkhurst et al. and Warzinak et al. (PW) also indicate that subjects who coordinate in early periods of the experimental sessions are more likely to coordinate throughout the session.

These studies suggest that the AB has merit as an incentive scheme to help achieve ecological goals on working lands when the configurations of land use to be achieved are simple and when program participants have the option to communicate between each other. However, these studies have not considered interactions between players in a network setting nor in scenarios where participation may be a problem. The present research investigates these two issues in an experimental setting.

4.2 Coordination Behavior in Different Networks

The interaction structures in standard games assume that every player interacts with every other player in the game. This form of interaction is termed a *global interaction* structure and all the players in the game together form a *closed neighborhood* or *group* or *network* (Ellison 1993). Yet a closed group interaction is not representative of many economic environments where a player interacts with only a subset of other players in the network. Cassar (2007) lists three types of networks. Random networks include those where individuals are assigned to be neighbors with others on a random basis. An example of random networks is where upon entry into a trading program a new point source can now trade at random with any of the existing point or non-point sources in the watershed. The second type of network is the small world network (Milgram 1967) where every individual player is linked with existing players but also has a positive probability of being linked with others as well owing to their existing connections. Links within social networking websites is a common example of a small world network. Finally another type of network relevant to the current study is local interaction networks. Here every individual is connected to only a subset of players in the entire network. The sub-groups comprising of a player and their opponents together form *open neighborhoods* and the interactions between them are termed *local interactions* (Blume 1993, Kandori et al. 1993, Ellison 1993). A key feature of open neighborhoods is that they overlap so that non-adjacent players share at least one neighbor in common.

Ellison (1993), Berninghaus & Schwalbe (1996), Keser et al. (1998), Berninghaus et al. (2002) and Cassar (2007) have considered coordination games in both closed and open neighborhoods. The key findings in these studies is that in coordination games where selection principles of Payoff Dominance and Risk Dominance select different strategies (Harsanyi and Selten 1988, Straub 1995), Payoff Dominant Nash Equilibrium (PDNE) are more prevalent (VHBB 1990, 1991) in closed networks and in open group coordination games Risk Dominant Nash Equilibria (RDNE) are more common (Keser et al. 1998 and Berninghaus et al. 2002). This outcome provides a foundation for consideration of AB interactions in local network settings for the following reasons. First, the nature of payoff functions associated with AB participation given the strategic environment can be such that the two selection principles indeed select different strategies. Second, the local network set up is characteristic of farmer interactions on agricultural landscapes where, private properties share their borders with different sets of neighboring landowners. In these local settings, creation of spatial patterns across neighboring properties lines will entail a player coordinating with neighbors whose identities vary for every participant. Thus it is appropriate to represent strategic interactions on these landscapes as *local interactions* between sub-groups of players in overlapping *open neighborhoods*. PW in their analysis of the AB have not considered such open interactions explicitly providing an avenue for innovative AB game design

Considering prior research on closed group coordination, an important finding is that in small closed networks PDNE are more common and in bigger closed groups, RDNE are prevalent (VHBB 1990, 2007). In coordination environments with strategic uncertainty, a player may conjecture that 1) others will doubt their commitment to play the PD and that 2) others are not committed to playing the PD as they don't expect their opponents to commit either, so on and so forth. This doubt is much greater in bigger groups than in smaller ones. Thus coordination unravels more often in big groups rather in small ones. In the context of coordination in the AB game, this result is important as working landscapes on which the scheme is to be implemented constitute farming communities of various sizes with variable number of farms. Berninghaus et al. (2002) and Keser et al. (1998) have explored coordination behavior in small and large groups in a local network setting on two local interaction structures – circle and lattice. In their experiments they vary both the total group size and the number of neighbors that each player has under the circular and lattice treatments and obtain similar results – PDNE is more prevalent in closed groups and RDNE in open groups.

This discussion of the implications of *closed* and *open* interactions, and *group size* on NE selection in coordination games with RDNE and PDNE suggest consideration of these factors in the design of experiments on the AB. In conducting this analysis the strategic environment where a player in both big and small groups has the *same* number of neighbors is considered. This treatment allows us to examine 1) the impact of varying the overall group size on coordination tendencies in local networks and 2) assess the impact of direct neighbors' actions within a player's local network on their coordination propensity in small and big groups.

4.3 Participation in Conservation Programs – Consequence for AB

Numerous studies have focused on the factors that determine farmer participation in conservation programs. These include the magnitude of conservation payments, flexibility in adopting conservation practices, government interference in land management as well as conservation attitudes (Smith et al. 2007, Hua et al. 2004, Napier et al.1988). Smith et al. indicate that even if payments over-compensate farmers, they are hesitant to invest in BMPs for the reduction of water pollution owing to the above reasons. Hua et al. suggest that factors such as age and education of the farm operator and their attitudes towards conservation impact participation in adopting conservation tillage practices. They find that younger farmers are more inclined to adopt conservation practices than older ones. This feature is witnessed in the case of species protection as well (Cook and Cable 1996). Also, conservation attitudes have a significant impact on participation. These attitudes include for example, farmers' beliefs about soil erosion being an environmental concern, others' opinions regarding adoption of no-till and their social consciousness . Kingsbury and Boggess (1999) have focused on participation issues related to the CREP. In the context of the current research, their discussion is important as the CREP is the only landscape level conservation program that requires spatially coordinated decision making on the part of the farmers and makes bonus payments. On the basis of a survey of potential and past CREP participants, they list numerous factors that hinder participation. Of these factors of special importance to the current study is that many farmers are disinclined to participate as they are not sure about the conservation attitudes of their neighbors. This uncertainty about participation aligns with the issue of strategic uncertainty in coordination games where players are not sure whether their neighbors will adopt the strategy that will be mutually beneficial and hence end up not choosing the beneficial strategy as well. Given this uncertainty about neighboring farmers' attitudes, farmers interested in obtaining the bonus CREP payments may have to incur costs in finding out about neighbors' environmental attitudes. Higher the number of neighbors with whom coordination is necessary to obtain the CREP payments, greater will be these transaction costs and in turn the obstacles for spatially coordinated land management for ecological value provision. The research on the AB does not consider this issue. Hindrances towards spatial coordination are attributed to landowners' inexperience and unfamiliarity with the payment scheme and spatial coordination. However these issues don't capture participants' doubts about their neighbors' conservation attitudes. Yet this is an important issue and needs to be considered in the context of participation in the AB in particular and conservation programs such as the CREP in general. This research addresses this non-participation issue in a realistic local network setting described in the previous section.

4.4 The Agglomeration Bonus Without Participation Doubts

This section presents the structure of the AB game where such doubts don't exist. This game is the standard PW scenario and provides a baseline scenario to which the new AB game (to be presented in the next section) can be compared to highlight the points of departure. Rather than considering a participation versus non-participation in the AB scenario, let the game be set up such that every player's property has two parcel types denoted by *M* and *K*. Each parcel can be placed in either conventional or conservation land uses. For the conservation uses on both parcels, AB payments can be obtained.

Let the AB game be represented as a symmetric normal form game $\Gamma_N[I, \Sigma, u_i(\cdot)]$ where $I = 1,2, \dots N$ are the players, $\Sigma = \{\phi, M, K\}$ is the strategy set, σ is vector of strategies and $u_i(\sigma_i, \sigma_{-i})$ is the payoff function. In the game $\sigma_i = M$ indicates that player i has opted to place land M in conservation use, $\sigma_i = K$ indicates that player i has opted to place land K in conservation use and $\sigma_i = \phi$ indicates non-participation in the conservation scheme.

Assumption 1: The conservation land use is more profitable for landowners than the conventional land use only when the government payment is available. This assumption implies that farmers will not voluntarily practice ES provision on their lands in the absence of the AB payments.

Assumption 2: The conservation agency can provide AB payments for only one parcel per land owner. This assumption reflects two constraints – one budgetary and the other political. The budgetary constraint indicates that funds are limited so that conservation uses on multiple parcels on the same property is not possible even if it will generate higher benefits than conservation land uses on any one of the parcels alone. The political constraint reflects the agencies' goal to maximize participation in the conservation program and bringing as many farmers under the program as possible

Assumption 3: With the conservation payments, net returns to the landowners are higher than having lands solely in conventional use. This assumption implies that non-participation in the conservation program is a strictly dominated strategy as it is always possible to obtain a higher income by placing any of the lands in conservation use and the other in conventional use.

In this strategic environment a set of neighbors for player i is given by $N_i \subset I$ such that neighborhood membership is symmetric, $j \in N_i$ if and only if $i \in N_j$ and irreflexive – $i \notin N_i$. The cardinality (size) of N_i is denoted by n_i where $n_i \leq N - 1$. Thus a player can interact with everyone in the network or only a few players. This set up is general and incorporates both a closed neighborhood and local network set up. Given a chosen strategy vector σ, define $N_{i\alpha} = \{j \in N_i | \sigma_j = \alpha\}$ for all $\alpha \in \Sigma$ as the set of neighbors of i who have chosen a particular strategy α in the game. Similarly, let $n_{i\alpha}$ be the size of $N_{i\alpha}$. Thus $\sum_{\alpha \in \Sigma} n_{i\alpha} = n_i$.

The conservation authority's AB scheme has two components. The participation component is paid for placing land in the conservation use and is independent of neighbors' actions. Let it be denoted by $s(\alpha)$. The second component is the bonus for each shared border between lands of the same type. The bonus is denoted by $b(\alpha)$. No bonus is paid to neighbors for choosing conservation uses on contiguous parcels of dissimilar types. Let the opportunity cost of enrolling parcels be denoted by $c(\alpha)$. The payoff function for any player i where $-i$ represents the set of neighbors is then represented by

$$u_i(\sigma_i, \sigma_{-i}) = \begin{cases} s(\alpha) + n_{i\alpha} b(\alpha) - c(\alpha) & if\ \sigma_i = \alpha \\ 0 & if\ \sigma_i = \phi \end{cases} \quad (1)$$

Assumption 4: The conservation use on *M* parcels provides higher payoffs than on *K* parcels.

$s(M) - c(M) > s(K) - c(K)$ and $b(M) > b(K)$ for all $i \in I$

This assumption indicates that spatially contiguous conservation is more effective ecologically on type M land than type K. Accordingly, the conservation authority designs AB payment components to reflect this preference by providing landowners greater incentives to choose M in the game.

Proposition: When $n_i = N - 1$ for all *i* $\sigma_i = M$ for all *i* and $\sigma_i = K$ for all *i* are the two Pure Strategy Nash Equilibria (NE).

PROOF: To prove the existence of the two NE we need to demonstrate that unilateral deviation from $\sigma_i = M$ for all i is not profitable, and identify the conditions such that unilateral deviation from $\sigma_i = K$ for all i is not profitable. Consider the payoff for player i from $\sigma_i = M$ when $\sigma_j = M$ for $j \in N_i$,

$$u_i(M, M) = s(M) + n_i b(M) - c(M) \quad (2)$$

The payoff to the i^{th} player from unilateral deviation to the play of strategy K is given by

$$u_i(K, M) = s(K) - c(K) \tag{3}$$

The difference between (2) and (3) is given by

$$u_i(M, M) - u_i(K, M) = [\{s(M) - c(M)\} - \{s(K) - c(K)\}] + n_i b(M)$$

By *Assumption 4*, the difference between the terms in the square brackets is positive. Thus unilateral deviation from $\sigma_i = M$ for all i is not profitable. Hence $\sigma_i = M$ for all i is a Pure Strategy NE of the coordination game.

Next consider the payoff from $\sigma_i = K$ when $\sigma_j = K$ for $j \in N_i$. Then

$$u_i\,(K, K) = s(K) + n_i\, b(K) - c(K) \tag{4}$$

The payoff to the i^{th} player from unilateral deviation to the play of strategy M is given by

$$u_i(M, K) = s(M) - c(M) \tag{5}$$

Now the difference between (4) and (5) is given by

$$u_i(K, K) - u_i(M, K) = [\{s(K) - c(K)\} - \{s(M) - c(M)\}] + n_i b(K)$$

By *Assumption 4*, the difference between the terms in the square brackets is negative. However since placing K lands into conservation uses is ecologically beneficial as well, the conservation authority can fix the magnitude of the bonus $b(K)$ such that the value of the third term is greater than the difference of the first two terms. In that case unilateral deviation from $\sigma_i = K$ for all i is not profitable. Under this condition, $\sigma_i = K$ for all i is a Pure Strategy NE of the coordination game. ■

Numerical Example I: A three player coordination AB game can be used to illustrate the existence of two NE. In this game $n_i = 2\ \forall i = 1,2,3$ and $\Sigma = \{M, K, \phi\}$. By Assumption 3, non-participation is strictly dominated. Let net payments from participation be $s(M) - c(M) = 20$, $b(M) = 20$, $s(K) - c(K) = 15$, and $b(K) = 10$. Table 4.1 represents the payoffs faced by every player according to (1)

.

Neighbors' Actions

Player's actions	Both neighbors chose M	One chooses M &other K	Both neighbors choose K
M	60	40	20
K	15	25	35

Table 4- 1: **Payoff Table Example I**

The payoffs from $\sigma_i = M$ for all i and $\sigma_i = K$ for all i for each player are 60 and 35 respectively. Now given that any 2 players are choosing the same strategy, it is not profitable for player i to unilaterally deviate to another strategy. If $\sigma_j = M$ for all $j \in N_i$, then unilateral deviation to K will cause payoffs to fall to 15, incurring a loss of 45 for the player. Similarly for $\sigma_j = K$ for all $j \in N_i$ a unilateral move from K to M will cause payoffs to reduce to 20, incurring a loss of 15 for the player. Thus in the three player coordination game there are only two pure strategy NE pertaining to everyone managing either parcels M or K. This game is a simplified version of the spatial coordination game considered in the prior AB studies and it can lead to leads to coordination on the high paying outcome in laboratory settings. Also in this game with symmetric payoffs, $\sigma_i = M$ for all i is the Pareto superior NE as it yields higher payoffs for all the players than the outcome $\sigma_i = K$ for all i.

4.5 The Agglomeration Bonus with Participation Doubts and Search Costs

The payoffs in the standard AB environment indicate the existence of two NE of which one is Pareto superior to the other. Since the structure of the payoffs are the similar to that of PW, repeated interactions can lead to ecologically superior payoff dominant outcome. In this section, a modified AB game is considered where players have doubts have their neighbor's conservation attitudes and hence are not sure about their participation and conservation land uses on parcel M or K. Suppose farmers are unsure about neighbors' attitude towards conservation land use on M. As a result let the player incur a cost say T to find out about their neighbor's attitudes towards conserving parcel M. Let this search cost be increasing in the number of neighbors. Since AB payments from choosing K are lower suppose farmers choose to incur the search cost only to investigate attitudes towards management of M parcels only. Assumptions 1 – 4 still hold for the new AB game.

The payoff function is now given by

$$u_i(\sigma_i, \sigma_{-i}) = \begin{cases} s(M) + n_{iM}b(M) - c(M) - n_iT & if\ \sigma_i = M \\ s(K) + n_{iK}b(K) - c(K) & if\ \sigma_i = K \\ 0 & if\ \sigma_i = \phi \end{cases} \quad (6)$$

The next steps is to design the payments so that $\sigma_i = M$ for all i and $\sigma_i = K$ for all i are the two Pure Strategy Nash Equilibrium outcomes in the spatial coordination game with externalities. The payoff from $\sigma_i = M$ with $\sigma_j = M$ for $j \in N_i$ is

$$u_i(M, M) = s(M) + n_ib(M) - c(M) - n_iT \quad (7)$$

The payoff to the i^{th} player from unilateral deviation to the play of strategy K is given by

$$u_i(K, M) = s(K) - c(K) \quad (8)$$

Now the difference between (7) and (8) is given by

$$u_i(M, M) - u_i(K, M) = [\{s(M) - c(M)\} - \{s(K) - c(K)\}] + n_i[b(M) - T]$$

The value of the square brackets in the last expression is positive by Assumption 4. A unilateral deviation will result in a loss if the bonus paid for coordinated conservation use on M parcels is greater than the costs incurred to gather information about neighbors' conservation attitudes about parcel M. Thus the conservation authority has to fix bonus payments such that it compensates participants for the search costs they incur in investigating the conservation attitudes of their neighbors.

Now consider the payoff from $\sigma_i = K$ with $\sigma_j = K$ for $j \in N_i$

$$u_i(K,K) = s(K) + n_i b(K) - c(K) \quad (9)$$

The payoff to the i^{th} player from unilateral deviation to the play of strategy M is given by

$$u_i(M,K) = s(M) - c(M) - n_i T \quad (10)$$

Now the difference between (10) and (9) is

$$u_i(M,K) - u_i(K,K) = [\{s(K) - c(K)\} - \{s(M) - c(M)\}] + n_i(T + b(K))$$

The term in the square brackets in the last expression is positive by Assumption 4. It follows that $\sigma_i = K$ for all i is a Pure Strategy NE if the second term $|n_i(T + b(K))|$in the expression is greater than the first term.

Proposition: In the AB game with externalities $\sigma_i = M$ for all i and $\sigma_i = K$ for all i are Pure Strategy NE if the following conditions are satisfied:

1. $b(M) > T$ implying that for any player the bonus from coordinated management is greater than the cost incurred to investigate neighbor's attitudes.

2. The loss from not earning the bonus $b(K)$ trumps over any net gain that may be available from the higher participatory payments in moving from K to M given that the player has to incur the cost T (increasing in number of neighbors) in moving from K to M.

Numerical Example II: In this example the payoff functions used in Numerical Example I are modified to include the search costs with $T = 10$. Table 4.2 presents the payoffs.

	Neighbors' Actions		
Player's actions	**Both neighbors chose M**	**One chooses M &other K**	**Both neighbors choose K**
M	40	20	0
K	15	25	35

Table 4- 2: **Payoff Table Example – II**

In Table 4.2, the payoffs from $\sigma_i = M$ for all i is 40 and for $\sigma_i = K$ for all i is 35. If $\sigma_j = M$ for all $j \in N_i$, then unilateral deviation to K will incur a loss of 25 for the player. Similarly for $\sigma_j = K$ for all $j \in N_i$ a unilateral move from K to M will incur a loss of 35 for the player. Also the variability of payoffs under M is much higher [from 0 to 40] relative to that under K [from 15 to 35]. Thus in the presence of search costs $\sigma_i = M$ for all i and $\sigma_i = K$ for all i are the two Pure Strategy NE of the AB game.

4.6 Impact of Doubts and Search Costs on Nash Equilibria in Coordination Games

Both sections 4.4 and 4.5 present coordination games with two NE, one associated with coordinated management of parcel M and other parcel K. In both cases the NE in type M strategies is the Pareto Dominant NE (PDNE) because it provides the higher payoff to all players compared to the NE in type K strategies (Cooper et al. 1990). Despite this important common feature, there are strategic differences between the two games that have implications for equilibrium selection and consequently the performance of the AB. This difference pertains to the problem of strategic uncertainty in coordination games as mentioned and the structure of the payoffs in out-of-equilibrium situations.

Owing to the doubts that a player has about their neighbors' attitude to coordinate they incur the search costs for which the bonus will compensate if neighbors participate and choose M as well. In this setting, if some players still have doubts that others will not coordinate and choose the ecological beneficial outcome, then this doubt "reverberates" into a much bigger doubt that spreads to every player in the environment (Morris and Shin 2002). This doubt turns the possibility that no one will participate and coordinate into the reality of coordination failure. In the current setting of strategic uncertainty, the presence of search costs greatly increases the losses to a player if their neighbors choose the other strategy K. Possibility of this heavy loss is not present in the standard AB setting where players only lose out on the bonus if neighbors don't participate. The loss from lack of neighbor participation according to expression (6) is increasing in the number of neighbors. Thus the presence of this upfront cost causes the deviation loss associated with strategy K to be much higher compared to strategy M. As a result that PDNE and RDNE are not associated with the same strategy profile any more

Harsanyi and Selten has proposed that players by virtue of their collective rationality are able to coordinate to the PDNE solving the problem of coordinate failure in coordination games with Pareto ranked NE. Yet Straub produced experimental evidence that coordination to the PDNE is possible when the PDNE and RDNE coincide. Otherwise, risk dominance guides equilibrium selection to the low paying RDNE. Experiments by VHBB (1990, 1989), Battalio et al. (2001) and Goeree and Holt (2005) with coordination games where the PDNE and RDNE don't coincide indicate that individuals choose the RD strategy more often than the PD strategy. The selection of the RD strategy manifests as coordination failure (Devetag and Ortmann 2007). Since in the current game the PDNE and RDNE are different, presence of search costs imply that spatially coordinated outcome may not be attained in this new AB setting.

The numerical example from Sections 4.3 and 4.4 can be used to illustrate this outcome. In Example I the deviation loss for the strategy $\sigma_i = K$ for all i is 15. The corresponding value for $\sigma_i = M$ for all i is 45. Thus the loss to a player if their commitment to play M is not supported by others is much higher than the loss from strategy K. Thus the strategy profile $\sigma_i = M$ for all i generates both higher payoffs on selection and higher losses from unilateral deviation than $\sigma_i = K$ for all i. Moreover regardless of the neighbors' choices, there is not a big difference in the variation of payoffs betweenstrategy choices M and K. Thus in the absence of search costs, according to Harsanyi and Selten and Straub risk dominance and Pareto dominance selects the same NE, $\sigma_i = M$ for all i .

Consider the case of the $\sigma_i = K$ for all i NE in Example II. Here, the deviation loss for strategy *K* is 35 compared to 25 for strategy M. Hence the Nash Product for deviation from *K* is greater than the same for *M*. The loss to players if their tendency to coordinate to *M* is not supported by neighbors (who all choose *K*) is much higher here than when the search cost is not incurred. Noting the variability between payoffs for any particular strategy, the variation in payoffs from a M choice is much higher than that from a K choice. Thus K is less risky than M. Thus in the new AB game risk dominance selects $\sigma_i = K$ for all i and payoff dominance selects $\sigma_i = M$ for all i. Here if a player believes that neighbors don't have the conservation attitudes which will make them conserve and that they will choose K even if M pays a higher payoff, this strategic uncertainty may cause coordination to unravel and move the game to the RDNE, $\sigma_i = K$ for all i.

In terms of the game presented in Section 4.4, in order for $\sigma_i = M$ for all i to be the PDNE and $\sigma_i = K$ for all i to be the RDNE

1. $u_i(M, M) > u_i(K, K)$ for all i
2. The value if the deviation loss for K should be greater than that for M –

$$[u_i(K, K) - u_i(M, K)] \quad > [u_i(M, M) - u_i(K, M)]$$

$$\Rightarrow [s(K) - c(K) + n_i b(K) - s(M) + c(M) + n_i T]$$

$$> [s(M) - c(M) + n_i b(M) - s(K) + c(K) - n_i T]$$

Thus in a 3 player coordination AB game, in the presence of the search costs, we can demonstrate that equilibrium selection principles of risk and payoff dominance selects two different strategy profiles. Also as mentioned earlier, the experimental evidence indicates that in local interaction settings, with both RDNE and PDNE, repeated interactions leads to the RD outcome. Thus if the AB were to be implemented in real landscapes which are arranged in the form of local networks, then participation doubts may cause the policy to fail. The experimental literature on conservation schemes to date has not investigated coordination and equilibrium selection in the AB setting in different sized networks (representing small and large farming communities) when the immediate local neighborhood of players are the same. The experimental treatment in this essay achieves this objective.

4.7 Experimental Design

Experiments were conducted at the Laboratory of Economics, Management and Auctions (LEMA) at the Smeal College of Business at Penn State University. All subjects were selected from Penn State's student population. The experiments were conducted between March and April 2009. In all experiments subjects played the game presented in Table 4.3. Using the notation presented in Section 4.4 and 4.5, the size of the neighborhood given the local interactions structure is $n_i < N - 1$. All other notation is the same as in Sections 4.4 and 4.5. The treatment variable for these experiments was the total number of players on the landscape. Experiments were conducted with six and twelve player groups. Let the 6 player sessions be termed SMALL and the 12 player sessions be termed LARGE. These numbers were chosen so that variation in sizes of the groups is large enough to give rise to differences in coordination patterns.

4.7.1 The Spatial Grid

Strategic interactions between players take place on a one-dimensional circular grid. The choice of this shape is motivated by support from past research on coordination games with local interactions such as Berninghaus et al. (2006), theoretical models of infectious disease management on farmland (Hennessey 2007) and studies on socio-economic networks (Jackson and Wollinsky 1996). An example of an actual geographical area that fits the circular set up is found in the Peak District (UK). Here land with high conservation potential is found atop hills and is surrounded by intensively cultivated parcels that have lower conservation values.

On this circle for any player $i = 2, 3, \ldots\ldots N - 1$, the set of neighbors is given by $N_i \in \{i - 1, i + 1\}$. For $i = 1, N_1 \in \{N, 2\}$ is the set of neighbors and for $i = N$, $N_N \in \{N - 1, 1\}$ represent the set neighbors. This type of neighbor specification follows (Berninghaus and Schwalbe 1996). Figure 4.1 represents this circular spatial grid. The hole in the centre of the grid indicates that a players situated opposite a player are not the player's neighbors. In this local interaction environment, any three consecutive players on the spatial grid nests the same coordination game in Table 4.3. An annularslice on the circle represents the property boundaries. Every property has two parcels. The interior parcel near the centre of the circle is the *M* and the outer parcel is the *K* parcel. Conservation land use on *M* generates higher ecological value than the same on *K* parcels but in order to earn the bonus the search cost needs to be incurred as well.

4.7.2 Experimental Procedure

Table 4.4 presents the experimental design.[4] Players were given a diagram at the beginning of experiments showing their position on the circle and an ID. This ID identified who were their neighbors during the experiment. Players were instructed about the number of participants in the game and how neighbors' actions would affect their payoffs. Instructions explicitly stated that a player's payoffs could be directly influenced by neighboring players' actions only. Each experimental session had twenty periods.[5] The payoff table was visible to each player whenever they made a decision in any period. At the end of a period players were able to view the choices of their neighbors but not the choices of non-neighbors. Information about neighbors' choices from all past periods was available in a history table that was displayed at the end of every period.

The experiment adopted a fixed matching scheme. Under this scheme the identity and consequently the location of the neighbors of a player remained the same all throughout the session. By fixing the location of players in the game repeated interactions was used to promote learning from past play and to facilitate reputation building. None of the experiments used the same set of subjects and someone who participated in one treatment was not permitted to partake in a session under the other treatment.[6]

In every session players were informed about their role as a landowner whose actions would determine a land use outcome. However all other contextual terminology

---

[4] Instructions for the experiments are included in Appendix A.

[5] A session or trial refers to an interaction between individuals in an experimental environment with a fixed set of experimental conditions (Roth 1994). Each session is made up of single or multiple periods. A period refers to the time during which subjects make a decision. At the end of a period, the experiment restarts with the same or new set of parameters.

[6] This protocol is referred to as the "between" subjects treatment implying that every subject is exposed to a single treatment only

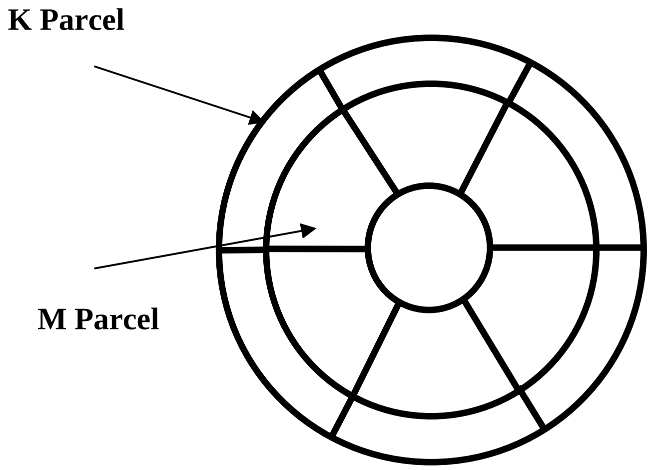


Figure 4- 1: **Spatial Grid**

	Neighbors' choices		
Player's actions	**Both neighbors chose M**	**One chooses M &other K**	**Both neighbors choose K**
M	36	18	0
K	27	24	21

Table 4- 3: **Payoff Table for Experimental Sessions**

	Treatment	
	SMALL	**LARGE**
Number of sessions	8	8
Number of players in a session	6	12
Number of periods per session	20	20
Payment structure	$5 show up fee Exchange rate – 40 experimental dollars for every US $	

Table 4- 4: **Experimental Design**

related to ES provision such as environmental conservation, endangered species and biodiversity were excluded from the instructions. This context free environment ensures that subjects are not influenced by biases such as environmental consciousness, altruism and warm-glow effects while making their decisions. Mitigating the influence of contextual information is important as it permits participants to respond solely to financial incentives provided by the AB. This in turn reduces the possibilities of confounding of results by other variables and facilitates isolation of the impact of the treatment variable – group size.

The instructions also did not mention explicitly that land use activity on *M* parcels is more profitable than on *K* parcels. The payoff table indicated this ranking and players were expected to figure this out by observation and strategy choice over the multiple periods of the game. Players in every session were provided with a quiz before they started the first period in order to ensure that all instructions have been understood.

Every participant was paid a show up fee of $5 and whatever money they made during the experiment. The experimental currency was converted into actual currency at the rate of 40 experimental dollars to one real dollar at the end of the session. The software Z-Tree (Fischbacher 2007) was employed to run the experiments.[7]

4.8 Results

The key findings of this study are that (1) with search costs, players often fail to coordinate to the PDNE, and that (2) coordination to the PDNE occurs more often in

[7] The screen shots of the experiment that subjects saw in the sessions are included in Appendix B.

SMALL than in LARGE even if the size of the player's immediate strategic environment determined by the number of direct neighbors is the same. These results raise questions about reasons behind the divergence of behavior across treatments. In the context of the AB, the frequent convergence to the PDNE in small groups imply that a conservation policy is more likely to be ecologically effective in creating spatial patterns in landscapes with fewer farmers. These results are elaborated below.

4.8.1 Impact of overall Group Size on Performance of Agglomeration Bonus

The results of the experiments establish the generality of VHBB's findings on coordination failure in bigger groups for the current open neighborhood setup. Players in the smaller group are able to coordinate to the PDNE more often than in larger groups. Figure 4.2, a plot of the percentage of M decisions by period for both the treatments indicates this outcome. Considering subjects' choices over time obtains a detailed view of the difference in outcomes by treatment. The percentage of M decisions in the first period (see Table 4.7) is similar in both the treatments – 66.67% in the SMALL treatment and 62.5% in the LARGE treatment. A chi-squared test indicates no significant difference in the first period decisions between treatments. This result indicates that with no experience in the game subjects start off by responding only to the value of payoffs that are the same in both treatments. Over time however the graphs start diverging. In the final period the percentage of M decisions is 64.58% in the SMALL treatment but 33.33% in the LARGE. The value of the chi-squared statistic for the final period is significant at 1% level of significance. Thus, systematic behavioral differences emerge over multiple periods with subjects choosing more M decisions in the SMALL treatments than in the LARGE. In the context of the AB, smaller landscapes with fewer farmers imply a lower degree of strategic uncertainty which in turn causes fewer instances of coordination failure. Thus there is a predominance of M choices translating into greater instances of spatial coordination to the ecologically superior outcome in SMALL. The effect of group size and experience with coordination in the dynamic AB game along with other variables can be examined statistically by regression analysis. The regression equation for the dependent variable *y* representing the probability of a M choice can be specified by

$$y_{it} = D + \gamma y_{it-1} + \beta t + \delta t^{*} y_{it-1} + \varepsilon_{it} \qquad (11)$$

$$\varepsilon_{it} = \propto_i + u_{it}$$

$$(i = 1,2, \dots \dots .144; t = 1,2, \dots \dots 20)$$

The binary dependent variable y_{it} takes a value of 1 for every M choice and a 0 for every K choice by subjects. Then the probability of a M choice can be expressed as a function of own lagged value y_{it-1}, vector of independent variables x_{it} including , the dummy to capture the treatment effect, the Period variable to account for experience and an interaction between the Period variable and the past period action variable and the error term ε_{it} comprising of the component $\propto_i$ which is the time invariant unobserved heterogeneity associated with every subject *i* uncorrelated with the independent variables in the model and the component u_{it}. .

The following reasons motivate these variable choices. First, one's own decision from the past period is expected to explain part of the variability in the choice of M in the current period. Secondly, choice of strategy M depends on the player's experience with coordination in the game that is captured by the period variable. An interaction term between Period and action in past period is also included to capture the impact of variation in one's own pattern of past play with increasing experience, on actions in the present period. One difference between the current set of variables and those included by Berninghaus et al.(who have considered subject choices in open neighborhood coordination games in circular grids) is that the variable representing number of M decisions by neighbors' from the preceding period in not included in the analysis. The explanation for this exclusion is as follows. On the basis of the myopic best response assumption (See Appendix A), both direct and indirect impacts of neighbors' and non-neighbors' actions in the open neighborhood are captured by the variable representing neighbors' actions in the past period. In the current experiments, the differences in overall group size implies that the direct and indirect impact of neighbors and non-neighbors' choices respectively are different in both groups. In the analysis the dummy is introduced to pick up this effect and so the variable representing neighbors' past choices is left out of the analysis.

No interaction terms between the dummy and other independent variables are included in the analysis as1) the impact of one's own past response on strategy choices in the current period is not contingent on whether the subject belongs to the big or small group and 2) the experimental data indicates (see Figure 4.2) that experience does not have an appreciable impact on choices in SMALL In all periods of the game, the percentage of M decisions are near the 60% mark indicating that in the smaller open groups subjects are able to retain a coordinated outcome (in this case on M) once they have attained it. This starting point effect on coordination has been observed in studies by VHBB, Berninhaus et al. and Devetag and Ortmann as well.

Given the set of independent variables, the estimation of expression (11) in this study is novel for the following reasons. First, the presence of the unobserved individual specific heterogeneity $\propto_i$uncorrelated with the independent variables (specifically the dummy since subjects are randomly assigned to the treatment) implies a random effects specification. Second, the lagged value of the dependent variable on the right hand side indicates the presence of state dependence implying that the estimation needs to consider an autoregressive model. Moreover the presence of the unobserved heterogeneity $\propto_i$ indicates that the error term ε_{it} is correlated across cross sectional units (Maddala 1987, Stewart 2006). Hence with this autoregressive structure and random effects specification, a dynamic random effects probit model according to Stewart (2006) is estimated. The probit specification is chosen over the logit for the following reasons. First, the presence of two choices M and K indicate that a probit can be estimated with ease. Second, given the random effects structure of the data a probit specification provides flexibility of estimation since it does not put restrictions on the value of correlations between the errors. Stewart (2006) provides a maximum simulated likelihood technique for the estimation of a dynamic random effects probit model that generates consistent estimates. This estimation technique is adopted in this study.

The results of the estimation are presented in Table 4.5. Of particular interest is that the parameter for the dummy is the negative and significant (at 1% level). The negative sign indicates that in bigger open neighborhoods the probability of choosing M are lower than in smaller ones. The negative and significant constant term (at 5%)

indicates that probability of playing M are lower than playing K in SMALL as well. This is to be expected as the effect of the search cost and strategic uncertainty is extant in SMALL sessions as well.

The estimated parameter for "own action" in the past period is positive and significant at 1% level of significance implying that the previous period's choice of the M significantly increases the probability of choosing the M in the current period. This finding is consistent with Warziniack et al. where past behavior is found to be the strongest determinant of strategy choice in the present period. The estimate for the Period variable is negative and significant (1% level) indicating that as play progresses, subjects' probability of choosing M decreases. Over time in the game players learn about the risk associated with choosing M and the loss from trying to coordinate to M by deviating from K. These two effects cause an increase in percentage of K choices as time passes. The general result in this context is that increasing experience in the game focuses actions to the RDNE through an increase in the percentage of RD in the latter periods of the games. The negative trend in LARGE session in Figure 4.2 confirms this claim.

The estimate for the interaction term between Period and "own action' in the preceding period is positive and significant at 1% level. The positive value of the estimate implies that in latter periods of the game, players' choice of M in the preceding period has a positive impact on the probability of choosing M in the current period. Thus if a player chooses M in the latter periods of the game they have a greater tendency to stick to that response in the very next period if not longer. This behavior exists is regardless of an increase in the propensity to choose K and supports subjects' inclination to build up reputation for play of M and signal neighbors to coordinate to M as well.

To sum up, these results indicate that coordination failure is higher and instances of spatial coordination are lower on working landscapes with many farms. This outcome varies with experience. With low levels of experience overall group size matters less and players are able to coordinate to the ecologically superior M outcome. This is true in both large and small farming landscapes. However in large groups where over time most subjects end up coordinating to the ecologically inferior K configuration.

4.8.2 Impact of Local Neighborhood Size on Performance of Agglomeration Bonus

Of particular interest to the study of coordination failure is the impact of an individual's immediate local neighborhood on their propensity to coordinate. In the initial periods of the game, there is very little difference in the percentage of M decisions (See Table 4.7). Treatment specific differences start appearing only after Period 10 by which time subjects have gathered enough experience in the game to understand the impact of the overall group size. This result contrasts with the findings of VHBB. In their studies the treatment effect takes hold from the very beginning of the game and choices diverge sharply from the very onset. This difference in behavior with VHBB is a consequence of keeping the size of the local neighborhood the same in the current study. Here, a player plays the same game under both treatments. In VHBB however the games faced by a layer in both treatments are different since the number of opponents is different. Hence their behavior is different from the onset as well. Thus in the current study the percentage of M responses is similar and the impact of the local neighborhood is stronger than the impact of the overall group size in the earlier half of the game. with time however

Dependent Variable	**Probability of Choosing M**
Independent Variable	**Estimate (Standard Error)**
Constant	-.2455** (.1027)
Own Action in the Past Period	1.231* (.1254)
Period	-.0485* (.0079)
Own Action × Period	.0646* (.0107)*
Dummy	-.2480* (.0622)
# of Observations	2736
# of Groups	144

* represents 1% level of significance
** represents 5% level of significance

Table 4- 5: **Estimates of Dynamic Random Effects Probit Regression**

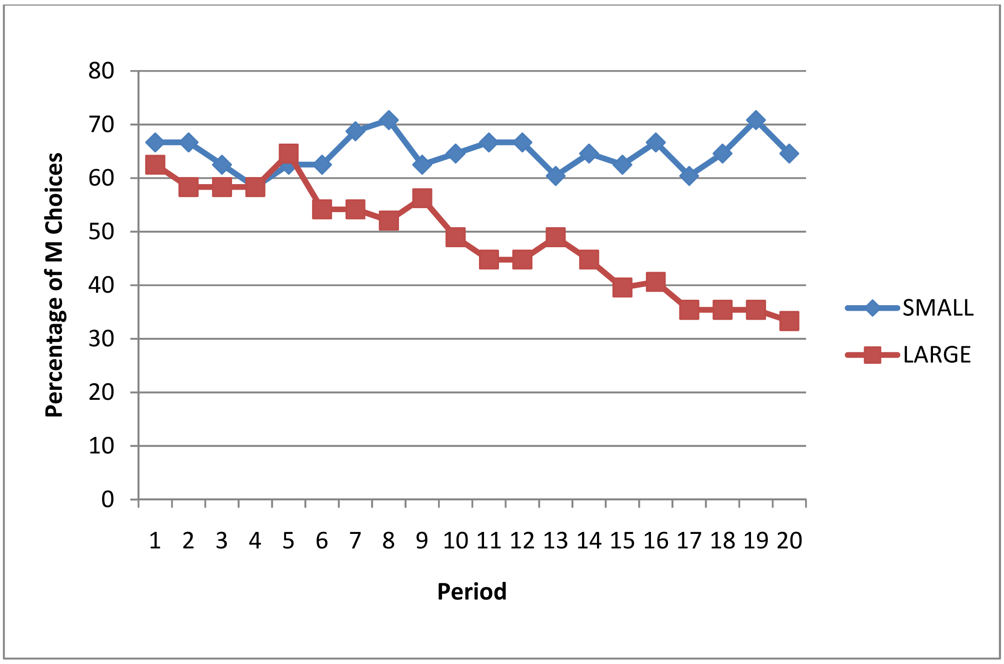


Figure 4- 2: **Percentage of M Choices**

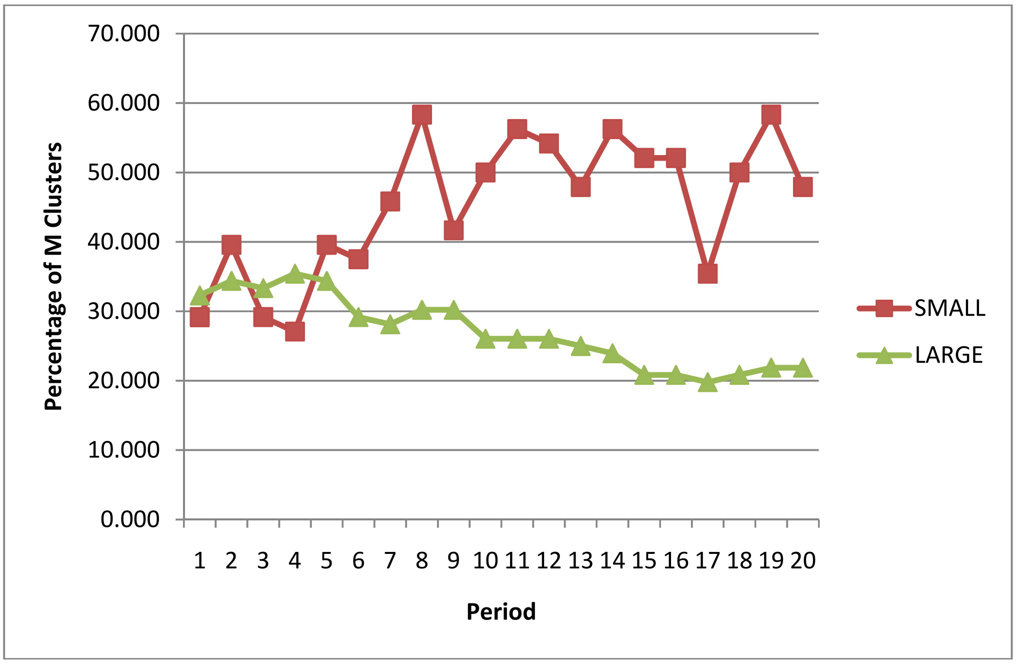


Figure 4- 3: **Percentage of M Clusters**

divergence occurs. This result indicates that while subjects might be able to coordinate on the basis of their immediate neighbors' choices initially, coordination starts to unravel eventually and more often in bigger groups than smaller ones since the overall strategic environment is different in both treatments. Another key result of this study pertains to variation in the final period's choices. Theoretically in local interaction games on a one dimensional circle multiple strategy choices are not possible (Berninghaus and Schwalbe). Yet players are found to choose both M and K in the final period in the current study. This coexistence of M and K decisions imply that many players make sub-optimal out of equilibrium choices in the final period.

In order to explain this coexistence of choices, define a *cluster* as a player and their direct neighbors in their local neighborhood. The neighborhood structure determines the number of players included in a cluster. In this research, a cluster comprises of any three contiguous players on the grid. There are a total of six clusters in the SMALL and twelve clusters in the LARGE games. Every individual is at the centre of one cluster and at the periphery of two others. When all players in a cluster choose the same strategy a *Local Nash Equilibrium* (LNE) is obtained. Let M-LNE denote clusters where all players are choosing M and K-LNE denote those choosing K.

For any LNE, the player at the centre of the cluster is earning payoffs associated with a NE. They can be considered to be in a *Nash Equilibrium state* as unilateral deviation is not beneficial for them in the next period under the assumption that their neighbors will not change their choices in the next period as well. This player's neighbors on both sides however may or may not be in a NE state. This is because they may not be at the centre of a LNE. This possibility of a sub-optimal state for the peripheral player is a consequence of the overlapping open neighborhood structure.

Figure 4.3 shows the percentage of M-LNE across periods. The closer the percentage is to 100% the greater is the frequency of coordination to M by the entire group. The outcome that the percentage of M-LNE in both treatments is similar in the initial periods of the game (established by a chi-sq test) corresponds to the similarity in percentage of M decisions in these initial periods. Beyond Period 5 however, the percentages start diverging and the value is consistently higher in SMALL.

In the final period of the SMALL games there are 47.91% M-LNE and 18.75% K-LNE compared to 22.91% M-LNE and 53.12% K-LNE in LARGE (the figures don’t add up to 100% since some players at the centre of clusters are in a sub-optimal state with both their neighbors choosing different strategies). The difference in percentage of M-LNE between treatments is significant at 1% level of significance on the basis of a chi-sq test. This result indicates that there are greater chances of coordination to the ecologically superior outcome by players in a cluster in SMALL. Conversely impact of overall group size is higher in LARGE. Greater percentage of M-LNE in SMALL also implies that coordination on M from the local neighborhood spreads out to the other parts of the landscape.

Co-existence of both M-LNE and K-LNE especially in LARGE also has significance for performance of the AB. Consider the percentage of M-LNE and K-LNE and the percentage of M decisions in Period 20. Since none of these percentages are near 100%, it is clear that regardless of the size, strategic uncertainty and the local interaction network causes coordination failure as well as mis-coordination in both games with the incidence significantly higher in LARGE. Taken together these metrics imply that both the choice of M in the final period and where this choice is made – at the centre of a cluster or at a periphery are to be considered while drawing conclusions about the ecological effectiveness of the AB in agricultural network communities

For a clearer picture of mis-coordination, the number of shared borders between players choosing M is considered as a percentage of the maximum number of shared borders in SMALL and LARGE. The maximum for SMALL is 6 and that for LARGE is 12. The shared border metric allows us to consider a situation where some players have made isolated M choices whereby no shared borders exist and hence their choice is neither ecologically nor economically beneficial. Table 4.6 represents the percentage of shared borders by treatment in the final period. A value of 1 indicates coordination to a M-NE where everyone chooses strategy M and a 0 indicates a K-LE where everyone chooses K.

	Session 1	**Session 2**	**Session 3**	**Session 4**	**Session 5**	**Session 6**	**Session 7**	**Session 8**
SMALL	0.5	0.5	0.33	0	1	1	0.16	1
LARGE	0	0.5	0.33	0.08	0.33	0	0	1

Table 4- 6: Percentage of Shared Borders

Table 4.6 indicates that of 8 sessions in both treatments, there are four each that attain a Nash Equilibrium state (a value of 1 or 0). In the case of SMALL, in three sessions all players are able to coordinate to the payoff superior and ecologically beneficial outcome while in LARGE, players coordinate to the low risk low paying ecologically inferior outcome in three sessions. In both SMALL and LARGE treatments there is one session each where a K-NE and M-NE is reached. For SMALL this indicates that since doubts about conservation attitudes exist strategic uncertainty causes coordination failure in SMALL groups. The presence of a M-NE in LARGE indicates that in some cases players in big farming communities with local networks can obtain enough knowledge about others' conservation attitudes to be able to coordinate to the ecologically desirable outcome.

Observing the remaining four sessions for each treatment, considerable heterogeneity of choices are visible. In three of the remaining four SMALL sessions there is one session with 33% and two sessions with 50% shared M borders. This outcome indicates a modest level of coordination while in the final session there are only two adjacent players choosing M so that there is a single shared M border and a low percentage value of 16%. In the LARGE sessions, there are two sessions with 33% shared M borders and one session with 50%. These numbers represent the localized areas of coordinated behavior as represented by the non-zero value of M-LNE in the final period of the LARGE sessions. In the final session only 8% of shared borders are found. This low value is owing to fragmented and isolated participation where there are only two adjacent players who choose M and one isolated player who is caught with a M choice in between neighbors who both choose K.

The percentage of M-LNE in the intermediate periods (Figure 4.3) in both the treatments can also provide some valuable insight about subjects' choices within a cluster. Since the percentage of M-LNE is always less than 100%, it implies that many players at the periphery of clusters are in sub-optimal state all throughout the game. The choice of M in the current period in response to M and K choices of neighbors in the preceding period is sub-optimal. This type of choice pattern indicates that 1) players don't practice best response behavior (choosing K when both neighbors' have chosen different strategies in the past) and 2) undergo losses voluntarily and delay switching to K. Such behavior is observed in multiple periods. This loss making behavior reflects players' tendency to influence their neighbors to choose M so that they can reach the centre of a M-LNE.[8] However such behavior is exhibited by players who are caught in between two neighbors choosing M and K only. If both neighbors continue choosing K, the coordination inducing player switches to K as well. In fact considering final period choices there are only 3 out of 96 individuals in LARGE caught in the centre of a cluster choosing M, when both their neighbors are choosing K. No similar instances exist in SMALL This is because 1) players are averse to continuously earning zero payoffs and 2) they doubt that they will be able to make both their neighbors switch from K to M. However sub-optimal economic behavior bodes well for ES provision as localized coordination represented by the M-LNE translates as partial policy success.

4.9 Conclusion

The current research presents an exploration of coordination issues in an conservation setting in a network environment. In the presence of doubts about

[8] Note from Table 4.4 that the difference in payoffs between M and K when neighbors are choosing different strategies is 6. This loss is small and will be trumped by the gains that will accrue to the loss maker if they get to the centre of a M-LNE in any period and are able to stay there henceforth. Thus the magnitude of these payoffs impacts loss making tendencies. It may be that the strategic environment and NE payoffs remaining the same, loss making will not be practiced if the difference is a much larger number than 6.

coordination, overall size of the farming landscape and the choices of a farm's immediate neighbors are explored. The experiments indicate that there is a predominance of PDNE in smaller groups reiterating VHBB's proposition about coordination being easier in small groups. At the same time, localized coordination with the co-existence of both M and K clusters is found in the final periods of the game. Such a scenario reflects possibilities on real geographical landscapes where some people participate in the AB and others don't. In actual settings whether sustained existence of such localized spatial patterns will spread to the whole landscape can be investigated on the basis of field studies. The most common way to avert this failure is to enable landowners to learn about the conservation attitudes of their neighbors. Regular meetings of watershed groups within which a lot of conservation decisions are made especially with respect to water quality trading and reduction in nutrient runoff can be used to solve this coordination failure (Hua et al.). University extension educators have an important role to play in promoting conservation attitudes as well. Finally, over time with sustained participation of one farmer, their neighbor's attitudes towards conservation may be changed so that we can revert back to the old AB environment where search costs need not be incurred any more. To conclude, the AB can lead to spatially contiguous land management. However in its existing form, it assumes that landowners base their AB participation decisions on the payoff magnitudes and don't have other factors dictating that their participation and strategy choices. The present essay addresses this limitation in an environment that is both geographically realistic and also in tandem with social norms that represent localized farmer relationships.

	% M Choices		% M-LNE	
Period	**SMALL**	**LARGE**	**SMALL**	**LARGE**
1	66.7	62.5	29.2	32.3
2	66.7	58.3	39.6	34.4
3	62.5	58.3	29.2	33.3
4	58.3	58.3	27.1	35.4
5	62.5	64.6	39.6	34.4
6	62.5	54.2	37.5	29.2
7	68.8	54.2	45.8	28.1
8	70.8	52.1	58.3	30.2
9	62.5	56.3	41.7	30.2
10	64.6	49.0	50.0	26.0
11	66.7	44.8	56.3	26.0
12	66.7	44.8	54.2	26.0
13	60.4	49.0	47.9	25.0
14	64.6	44.8	56.3	24.0
15	62.5	39.6	52.1	20.8
16	66.7	40.6	52.1	20.8
17	60.4	35.4	35.4	19.8
18	64.6	35.4	50.0	20.8
19	70.8	35.4	58.3	21.9
20	64.6	33.3	47.9	21.9

Table 4- 7: **Percentage of M Decisions, M-LNE and Groups Earnings**

Chapter 5

Conservation Auctions for Spatially Contiguous Land Management

Limited budgets for PES programs require that the funds be expended efficiently to maximize conservation impact. This efficiency objective leads to an interest in auctions based PES. Auctions are routinely used for government procurement. Examples include procurement of highway construction contracts (Porter and Zona 1993), milk supplies by school districts (Porter and Zona 1999) and pro-conservation land use patterns from farmers (Kirwan et al.). Examples of auction based PES policies are the Conservation Reserve Program (CRP), the Stewardship Scheme in the UK, and the auctions under the Australian Land Recovery Program.

This essay presents the structure of an iterative descending-price procurement auction, for the selection of spatially adjacent pro-conservation land uses cost efficiently, given limited fixed budget. This spatial objective is imperative for the achievement of various ecological and ecosystem preserving functions as noted in Chapter 1. Two key features of this conservation auction (CA) are that it procures a heterogeneous set of objects representing land use contracts from private properties and evaluates combinations of bids for spatially adjacent and non-adjacent projects before making a selection. Both the ecological and economic performance of this CA can be examined in a controlled laboratory setting. This experimental approach is essential to the study of CA as it is an affordable means to wind-tunnel test the performance of the new mechanism with real human subjects under different settings that resemble scenarios observed in field.

In this study, experimental sessions consider two treatment variables. The first is the information about the spatial goal of the auctioneer and the second is the value of environmental benefit and land management cost parameters used for every subject in the experiments. The spatial information treatment is useful in analyzing whether knowledge about the auctioneer's conservation objective influences bidding patterns and achievement of the spatial and economic efficiency goals. The parameter variation treatment provides insights about the performance of the CA in landscapes which vary by participants' cost structures and the magnitude of environmental benefits their land management activities produce.

There are three main impacts of the two treatments on auction performance. First, per the parameter variation treatment, auction performance is sensitive to the cost and benefit features of the land management projects as well as where they are located on the landscape. Second, knowledge about the auctioneer's conservation goals is found to have a significant negative impact on the economic efficiency of the CA. This is because every unit of conservation benefit that can be procured in the CA is more expensive when subjects have the spatial information than when this information is not explicitly provided. The increase in expense is a result of higher bid submissions by subjects. Surprisingly enough the ecological performance of the auction is not significantly different when this bit of information is available to auction participants. Finally, the results also suggest a significant difference between the behavior of winning and losing bidders. At the end of the auction winning bidders' markups are significantly different and higher than the markups of losing bidders. This outcome implies that when the auction ends, winners bids are much higher than their costs compared to losers' bids. This result is a feature of the auction format and is true across all sessions regardless of treatment specifications. These results are discussed elaborately in subsequent sections.

5.1 Conservation Auctions Policy

In the US, the United States Department of Agriculture (USDA) runs CA separately in the 50 states at various times during the year. The CRP is the notable land retirement auction for procurement of conservation benefits in the US. As mentioned in Chapter 2, it has to date disbursed $26 billion (Kirwan et al.) to preserve nearly 1.8 million acres of wetlands and retire nearly 36.8 million acres of farmland and reduce soil erosion. Classen et al. (2001) estimated a loss of nearly 220 million tons of soil erosion per year if the CRP were to be terminated. Most of the CRP land is found in the Northern Great Plains, Prairie Gateway and the Heartland (USDA). In the CRP, landowners submit bids indicating what compensation they would accept to enroll lands into the program. This period of bid submission is termed a signup. In order to be eligible for CRP payments, farmers have to commit to specific set of land management practices prescribed by the scheme. Once the bids are in, The CRP administers a competitive auction that evaluates all submitted bids on the basis of a scoring metric termed the Environmental Benefit Index (EBI). The EBI is a benefit cost ratio. The benefits involve quantified values of ecosystem benefits from different land uses and the cost is the bids submitted. The EBI penalizes high bids and favors lower ones. On the basis of the EBI scores, all bids are ranked in decreasing order of magnitude. Then, starting with the highest score, bids are progressively selected and the money is paid out until the budget is exhausted. The use of such benefit cost scores for selection of bids or conservation contracts is termed benefit cost targeting (Classen et al. 2008). The structure of the CRP was adopted by conservation agencies in Australia under the Bush Tender pilot trials (Stoneham et al. 2003) and the Auction for Landscape Recovery pilot (Gole et al. 2005). These auctions trials used a similar index – the Biodiversity Benefit Index (BBI) and the EBI respectively to evaluate bids.

A key factor for ecosystem sustainability and effective environmental conservation is the creation of spatially contiguous areas of managed habitat on working landscapes. Such spatial adjacency reduces habitat fragmentation and edge effects between habitats and promotes sustainable ecosystem preservation. To date neither the CRP nor other auctions have addressed this spatial criterion. Selection of projects has been focused only on increasing total farmer participation and areas enrolled under the scheme. Advancement of the conservation policy literature thus needs to consider the design of CAs which incorporate this spatial criteria for maximum ecological effectiveness. Simultaneously, innovation in auction design for cost efficient budget spending is important. An experimental iterative descending price auction with two rounds piloted under the Wetland Reserve Program (another land retirement program) in 2006 substantiates in this claim. Under this new format farmers were able to resubmit lower bids in a second round if they judged that their score was lower than other participants' scores indicating a smaller chance of selection. This double round auction generated cost savings of nearly $820,000 in Fiscal Year 2006 (USDA). Such cost savings demonstrate a need for the improvement of the design of CAs for cost-efficient spending of the budget. This research addresses both these ecological and economic goals of conservation policy by presenting the design of a multi-round iterative auction for the selection of spatially adjacent bids.

5.2 Economic Literature on Conservation Auctions

The economic research on CAs is organized around three different themes. The first theme involves the analysis of performance of CA relative to uniform rate payment schemes. Empirical studies which have analyzed the performance of CA such as the CRP are part of the second theme. Finally, part of the literature on CA is devoted to experimental exploration of auction performance and bidding behavior in multiple economic and conservation settings.

The study by Latacz-Lohmann and Van der Hamsvoort (1997) was the first to present a comparative performance analysis of a simulated CA for the purchase of soil conservation practices relative to uniform rate payment schemes. Their results suggested that competitive bidding in auctions reduces the costs associated with purchase of pro-environmental land uses. Similar results have been obtained in studies using laboratory data (Schilizzi and Latacz-Lohmann 2007), data from field trials (Stoneham et al. 2003, Windle and Rolfe 2008) and data from agent based simulation exercises (Hailu and Schilizzi 2004). Akey finding of this efficiency analysis is that cost-efficiency of CAs are preserved only in the one shot setting. Over multiple periods the CA loses its advantage over the fixed payment schemes. Subjects gain experience and familiarity with the auction. With an increase in this familiarity over multiple periods, they are able to figure out how their bids are evaluated in the auction. On the basis of this information they are able to submit higher bids and earn more rents. Such rent seeking is a problem given the budget as it leads to purchase of lower conservation benefits.

Evaluation of bidding behavior and program performance using actual CA data forms the focus of the second theme. Reichelderfer and Boggess (1988) and Osborn et al. (1990) provide evidence indicating that over successive signups of the CRP, the mean value of bids submitted went up. Kirwan et al. present a comprehensive analysis of rent seeking behavior using CRP data. Their conclusions are similar to those obtained with experimental and simulated data. Over time as farmers gain more experience with CRP participation, they submit higher bids and are able to retain more rents when they are accepted into the scheme. The authors also provide estimates which indicate that bids increased over time with the rents constituting nearly 10% to 40% of the CRP's rental pay-outs under sign ups 20 and 26.

These findings about performance of CAs develop a research agenda for the design and performance analysis of the CA under various in various economic environments and for the attainment of multiple ecological goals. The experimental methodology proves invaluable in this regard. Both lab and field experiments are routinely used to test the performance of multiple CAs as well as evaluate the nature of bidding under various treatment conditions.

Studies by Said and Thoyer (2007) have used lab experiments to compare the economic efficiency of three auction formats. The formats include a sequential auction, a simultaneous bid auction and combinatorial auction for the purchase of conservation contracts which exhibit cost synergies. This set up is important for the study of CA as projects for the achievement of one environmental goal often reduces the costs of attaining other environmental goals as well. For example, creation of riparian buffers for the reduction of soil erosion reduces the costs of decreasing nutrient runoffs for the farmers. If the conservation authority has both soil erosion and non-point source pollution reduction goals then procuring contracts from the same individual may be cheaper. Given the budget, this low cost outcome implies greater cost efficiency. Their experiments provide insightful results about the relative performance of the three auction formats. For example, the sequential auction is found to perform better relative to the simultaneous and combinatorial auctions from the perspective of rent seeking. The combinatorial auction is, however, found to be more cost-efficient compared to the other two formats.

The study of CA formats has also focused on the use of iterative multi-round/iteration auctions and single round auctions. Rolfe et al. (2009) provide evidence indicating that compared to single round formats iterative descending price auctions improve efficiency owing to bid reductions, increased information flows between rounds and the bidders' ability to learn how to bid and avoid making mistakes in bid submission. Cason et al. (2003) find similar results with their iterative auction as well. Their results imply that the efficiency of the auction rises over multiple iterations. The importance of the iterative format has also been demonstrated in the cost savings under the Wetland Reserve Program in 2006 as mentioned in Section 5.1.

Cason and Gangadharan (2004) present comparative results of sealed bid uniform price and discriminatory price auctions for nutrient reduction contracts. These studies indicate that the discriminatory price auction performs better relative to the uniform price auction despite rent seeking. Burtraw et al. (2008) have evaluated sealed bid discriminatory and uniform price auctions and a sequential clock auctions for the sale of carbon emission permits in the presence of communication between participants. Their experiments imply that the first two auctions produce significantly higher revenues compared to the third format both in the presence and absence of communication. Additionally, collusion affects the performance of the clock auction more than the other two formats.

Cason et al. (2003) have also conducted experiments by varying the features of the testbed. They consider an iterative auction for non-point source pollution reduction procurement. In their auction, a limited information feedback structure exists about auction results. As part of the feedback mechanism every participant is only informed about whether they win a round or not. Given this setup, the treatment variable in their auction involves informing bidders about the environmental benefit associated with their projects in some sessions and leaving this information out in remaining sessions. This treatment on variation in the information available to participants has received attention in both theoretical and experimental auction research. Milgrom and Weber (1982) present a theoretical model that indicates that revenue rises in auctions when the auctioneer provides information about the value of the goods to the bidders. This is because the knowledge about the valuations reduces the amount of private information held my each bidder and consequently reduces rent seeking. In the Cason et al. auction, a potential reduction in rent seeking owing to revelation of information about the valuation of environmental projects to bidders is of significance. Since conservation budgets are limited, lower rents leave less money on the table and more money for conservation procurement. Yet the results of their study indicate that both ecological effectiveness and economic efficiency of the auction is negatively affected by the presence of this information. When bidders know the environmental benefits, they exploit this advantage to earn higher rents. Thus, the results of impact of information revelation on auction performance are dependent on the features of the strategic environment.

The description of the above studies demonstrates that the performance of CAs is sensitive to both the economic and ecological attributes of the conservation problem. This underscores the need for extensive research on the design and performance of the mechanism under multiple settings. One such scenario is the design and analysis of CA for the selection of spatially adjacent bids.

5.3 Auctions for Spatial Contiguity

The experimental studies by Rolfe et al. (2005) and Reeson et al. (2008) have considered a CA addressing the spatial agglomeration issue. These studies evaluate the performance of auctions for the creation of landscape corridors and linkages between core areas of habitat. Rolfe et al. consider both sealed bid and iterative auction experiments with actual landowners. These individuals submit bids for the creation of various spatial patterns on a simulated landscape. The use of different types of scoring metrics which value various parcels on the landscape differently permit the creation of these multiple spatial patterns. Their iterative format considers limited information feedback about auction results. Here, landowners are able to view the location of the winners on the landscape at the end of every round. This information allows them to revise bids in the next iteration if they have not won in the current iteration. The chief result of these experiments is that the iterative auction format leads to spatial patterns more cost efficiently than the sealed bid format. Under the sealed bid format subjects are permitted to communicate and submit bids for their management projects. This communication in turn intensifies rent seeking reducing the amount of conservation benefits procured.

Reeson et al. address the corridor creation goal in controlled laboratory settings with a non-stakeholder group of participants. They also consider an iterative auction with limited information feedback about auction results at the end of each round. The feedback information includes knowledge about winners on the experimental landscape as well. The auction experiments provide insightful results about: 1) the impact of knowledge of total number of rounds and 2) the possibility to improve bids submitted across multiple rounds on rent seeking in the CA's ability to create spatial patterns. The efficiency of the auction in terms of rent seeking for spatially contiguous project selection is found to be significantly higher when number of rounds is unknown and when subjects don't have the ability to revise bids in the next rounds. Rent seeking is also mitigated under scenarios where provisional winners in a round are unable to submit bids in future rounds. These outcomes are important as they highlight scenarios where the auctioneer is able to create landscape corridors cost effectively on the basis of the money available.

Given this literature, enhanced understanding of CA for spatial coordination will benefit from design variations which: 1) involve iterative auctions with full information feedback about auction results, 2) explore the sensitivity of auction outcomes to different features of the geographical landscape and 3) which consider the impact of knowledge of the auctioneer's spatial objective on auction performance.

5.4 Objectives of the Current Research

This essay presents the structure of an iterative descending price auction for the selection of a spatially adjacent set of land management projects. This iterative format is similar to existing CAs which have focused on the spatial goal. Choice of this format also reflects the interest within policy circles for the design of iterative auctions for cost savings in conservation procurement. Variation in auction design is brought about by the inclusion of a full information feedback mechanism about auction results across multiple rounds of the CA. The information provided via feedback includes both the magnitude and location of all bids – winning and losing, in an auction round. The reason for considering this particular feedback format is two-fold. From the perspective of conservation policy, a full feedback auction approximates real life scenarios where it is always possible for participating farmers within a region to know who were selected in the auction and how much money they were paid. Moreover, given the complex spatial goal, knowledge about others' bids and location of winners may also improve the performance of the auction. From an economic perspective, full information feedback is of interest as it affords the study of a new auction design that has not been considered in the context of CAs.

In line with past experimental research, within the full information feedback format, the knowledge about the auctioneer's spatial objective is considered as a treatment. This treatment addresses both a policy and an economic goal. First, in terms of the policy goal, conservation policy to date has not considered an auction for the attainment of the spatial contiguity objective. Thus, the spatial conservation objective may be hard for farmers to understand. Hence, they may benefit from knowing the auctioneer's objective. Rolfe et al. have considered experiments where they inform participants about the spatial goal by providing them information about the scoring metric. They however don't consider this as an explicit treatment across multiple treatments. The current study addresses this gap. In the lab the subjects are informed about the positive impact of neighbors' wins on their own chances of winning and hence the spatial objective in a few sessions while in others this information is suppressed. Second, from an economic standpoint, this treatment is of interest as the impact of increased information on auction performance is different in different settings. Moreover, a common agenda in experimental research is to stress test the performance of allocation mechanisms in different economic environments. In this essay, the full information feedback structure indicates subjects already possess all information about the auction outcomes. In this setting, it is useful to test whether revealing the spatial goal will improve performance. Results of this analysis are important in understanding the sensitivity of the current auction design to changes in informational content of the testbed. They also provide insights about whether the auctioneer's spatial goals need to be revealed to the bidders in field studies.

Another treatment considers CA performance under multiple scenarios where every project has a different cost and environmental benefit value. This treatment is it informs the implementation of actual CAs in different regions where both the costs of conservation procurement and the total conservation value possible are different.

To sum up, the current research presents the structure of a new iterative auction and considers two treatment specifications that enable analysis of auction performance and bidding behavior under multiple economic environments This research agenda produces results that contribute to both the conservation policy and the economic literature.

5.5 The Conservation Auction Model

Let $I = \{1,2, \ldots N\}$ be the set of N participants in the auction. The opportunity cost of shifting land into conservation uses for participant i is defined as a nonnegative real number θ_i . All land owners are assumed to be symmetric, risk neutral, have independent private values and incur no transactions costs from participating in the bidding exercise.[9] Thus bidders maximize utility and submit bids that are dependent on their private costs θ_i. Each bid represents the amount of financial compensation bidders are willing to accept for conservation land uses on their property. For simplicity let every bidder can submit a single bid only so that the total number of bids is equal to the number of participants. Let $b = (b_1, \ldots . b_N)$ represent a vector of submitted bids. The auction is a discriminatory price auction where every winning bidder is paid the value of the bid

[9] Symmetric bidders imply that they have types that are randomly drawn from the same distribution. Risk neutral bidders imply that they maximize net benefits from participation rather than expected utility. Finally presence of independent private values implies that bidders valuations and hence their bids are not contingent on others' valuations i.e. all bidders' bids are determined by types which are independent draws from the type distribution.

submitted at the end of the auction. Let $x \in \{0,1\}^N$ be the vector defining an allocation representing the set of winning and losing bidders in the auction. Every element $x_i = 1$in the vector *x* represents a bidder i who has been accepted to partake in the conservation activity and an element $x_i = 0$ represents bidder i who are rejected from doing so. The utility function is presented in linear form as

$$u_i(b_i, \theta_i, x_i) = x_i(b_i - \theta_i) \quad (1)$$

The auctioneer has information about both the intrinsic ecological benefits from conservation land uses on the *N* properties and the benefits generated when any two spatially adjacent properties are placed in the conservation program. Let the intrinsic benefits be represented by the vector $v = (v_1 \dots v_N)$.

Let matrix **B** be a $N \times N$ matrix where each element (i, j) represents the agglomeration benefit from selecting bids for the i^{th} and j^{th} parcels. All diagonal elements of the matrix are zero since a project is not its own neighbor and there are no agglomeration benefits from selection of the same. Also if any off-diagonal element is zero, it indicates that the projects i and j are not contiguous to each other or there is no environmental benefit from accepting these projects into the program. In order to count the benefits from contiguous participation only once in the value function, matrix **B** is taken to be a triangular matrix. The value of the elements in matrix **B** depends upon the spatial configuration of the projects on the landscape that determines which project is contiguous to the other.

Two examples of spatial configurations include linear and circular configurations. A linear configuration is appropriate for a landscape with farms arranged along a line such as a stream. Along this stream, all except the properties at the extremities of the stream or at the edge of the jurisdiction of the program agency have two neighbors – upstream and downstream and hence two shared borders. Additionally, the neighbors of any given property cannot also be neighbors of each other. A conservation project on this linear landscape may constitute riparian buffer creation along the length of the stream for reduction of nutrient runoff, regulation of water temperature and storm water flow. Contiguous management for the provision of these ES may involve the creation of non-fragmented riparian buffer all along the length of the stream.[10] The circular configuration is a simplistic representation of landscapes where every property has the same number of neighbors. A representative example can be found in the Peak District in the UK. Here, the land is intensively managed for agriculture while being suitable habitat for birds of conservation concern. On this landscape contiguous management of neighboring properties will improve bird habitat and their populations.

Let the general form of the auctioneer's value function when spatial patterns matter be represented as

$$V(x) = x'v + x'Bx \qquad (2)$$

The first term in (2) is the total intrinsic benefits from conservation land uses of the properties selected in the auction and the second term represents the spatial benefits

[10] The Conservation Reserve Enhancement Program in Oregon makes AB payments to farms arranged along the length of streams.

from selecting adjacent projects. For this study the agglomeration benefit from parcels is identical and represented by a factor d . The general form of the environmental value function (2) for the linear configuration is represented as

$$V(x) = \sum_{i=1}^{N} x_i v_i + d \sum_{i=1}^{N-1} x_i x_{i+1}$$

(3)

The expression for the value function for the circular configuration is

$$V(x) = \sum_{i=1}^{N} x_i v_i + d \left(\sum_{i=1}^{N-1} x_i x_{i+1} + x_N x_1 \right)$$

(4)

5.6 The Auctioneer's Problem

The CA in the study is an iterative descending price auction with multiple rounds $t = 1,2, \ldots..T$ where T is the maximum possible rounds in the auction. In each round bidders submit a single bid. The auctioneer selects the winning allocation x_t^* for that round on the basis of the bids. For a circular neighborhood the winning allocation, x_t^*, is the solution to the following budget constrained optimization problem:

$$\max_{x_t^*} V(x) = \sum_{i=1}^{N} x_{it} v_i + d \left(\sum_{i=1}^{N-1} x_{it} x_{(i+1)t} + x_{Nt} x_{1t} \right)$$

Subject to $\sum_{i=1}^{N} x_{it} b_{it} \leq M$ (5)

The x_t^* is the provisionally winning allocation for round *t*. In the presence of the budget constraint and costs and benefits associated with every property, the current optimization takes the form of a knapsack problem (Kellerer et al.2004). In this problem a greedy algorithm is used to obtain the solution that maximizes the net benefits associated with every project given the budget. The greedy algorithm is a local optima generating algorithm. It starts with an initial set of winning bidders (who are associated with particular projects) and replaces them with other non-selected objects until an allocation x_t^* is reached that maximizes the value function. This solution corresponds to a set of projects which maximize environmental benefits and generates a spatial pattern on the landscape in any round.

In this study the optimization problem to select the set of projects x_t^* can be reformulated as

$$\max_{x_t^*} \sum_{i=2}^{N-1} \frac{v_i x_i + dx_{it}(x_{(i+1)t} + x_{(i-1)t})}{b_{it}} + \frac{v_N x_N + dx_{Nt}(x_{1t} + x_{(N-1)t})}{b_{Nt}} + \frac{v_1 x_1 + dx_{1t}(x_{2t} + x_{Nt})}{b_{1t}}$$

$$\text{Subject to } \sum_{i=1}^{N} x_{it} b_{it} \leq M \qquad (6)$$

This knapsack problem formulation is different from the standard approach as it select x_t^* that maximizes the sum of benefits per unit costs (Hajkowicz et al. 2007). The structure of the optimization problem is such that the objective of spatially contiguous bid selection is incorporated into the winner determination exercise. In this auction bids for spatially adjacent projects are automatically given a higher score owing to the presence of the factor d and hence have a higher chance of being selected.[11] Once the provisionally winning allocation x_t^* is determined it is announced to the bidders and the auction proceeds to round $(t+1)$ where the process is repeated and provisionally winning bidders are determined again along with the new provisionally winning allocation $x_{(t+1)}^*$.

In iterative auctions, often participants may not bid in the early rounds of the auction. They may instead prefer to observe the outcome at the end of the first few rounds and obtain information about winners and their bids (if revealed). On the basis of this information they can submit bids in future rounds. Such waiting prolongs the auction and provides waiting bidders an opportunity to game the auction. An activity rule in the iterative auction prevents such waiting and gaming by forcing all bidders to bid in a round to be able to bid in subsequent rounds. Activity rules are have been used in the FCC auctions (Plott 1997), power auctions (Wilson 1997), and airwaves auctions (McAfee and McMillan 1996). The activity rule for the current study is implicit within the auction procedure. In the auction bids from the past round are automatically submitted in the current round and are restricted to be less than or equal to the past round bids. In this setting subjects are always compelled to bid rather than wait as if a subject waits then their bid for that round is zero. Since bids are restricted to be positive, and are decreasing between rounds, they cannot improve on their zero bid in the next round and essentially lose the opportunity to participate in the auction.

---

[11] The reason for the benefit-cost ratio formulation is that policies implementing CA adopt this benefit-cost ratio method, to select projects. For example the EBI used by the CRP is a benefit-cost ratio score. The use of this score for project selection in the CA is termed benefit-cost targeting (Classen et al.).

Once the bids are submitted, then provisional winners are determined and the auction proceeds to the next round. This process is repeated until the stopping rule is satisfied. The stopping rule also ensures that the iterative auction does not continue indefinitely. The stopping rules are as follows.

1. $\bar{t} \leq t \leq T$ where $\bar{t}$ represents the minimum number of rounds.
2. $V(x_t^*) = V(x_{t-1}^*)\ \forall t < T$.

Condition 1 indicates that for a round t to be final the auction has to go through a minimum of $\bar{t}$ iterations prior to ending. The minimum rounds ensure that bidders gain familiarity with bidding in the auction. The second condition implies that for a round t to be final the winning score from selecting the projects in round $(t-1)$ should be the same as the score generated from selecting the projects in round *t*. If for any round $\bar{t} \leq t < T$ both conditions I and II hold then the auction ends. When $t = T$ the maximum possible rounds have been played and the auction ends automatically.

On the basis of the above stopping rules, x_t^* is selected as the winning allocation in the iterative auction and b_t^* the winning bid vector at the end of final round *t*.

5.7 Experimental Design

5.7.1 The Information Content of the Auctions

The iterative auction in the study considers full information feedback about auction results in all sessions. At the beginning of the auction, every subject knows their own cost and the value of the budget to be spent. As part of the full information feedback, at the end of every auction round, the information about the identity of winners, the value of their scores, and the value of all bids submitted are provided to every subject. This information is common to all subjects in the experiment.

In this setting a key experimental objective is to evaluate the ecological and economic performance of the mechanism when subjects have knowledge about the spatial objective of the auctioneer. In the experiments in 6 sessions, knowledge of the spatial objective is provided up front by informing bidders about the format and components of the scoring metric. These sessions are termed SCORE sessions. In the remaining 6 sessions termed NO-SCORE sessions, the information about the scoring metric is not provided to the subjects.

The metric is a benefit cost ratio like the EBI. For any project, the environmental benefit from the project depends upon its intrinsic project benefit and the benefit from spatial contiguity. The benefit from spatial contiguity depends upon the number of winning neighbors. Higher the number of winning neighbors, higher is the magnitude of benefits generated and the score. Higher scores in turn indicate a greater likelihood of selection. When subjects know the metric format and that spatial patterns are important and that their scores are higher if their bids are chosen along with their neighbors, they may be able to bid in a spatially coordinated fashion to improve their chances of winning in the auction. Selection of spatially adjacent players in turn improves the ecological performance of the auction. Such systematic classification of sessions permits isolation of the effect of the spatial information treatment.

5.7.2 Auction Performance Metrics

Three different metrics are used to analyze the economic efficiency, competitiveness and ecological effectiveness of the auction. The specific metrics are based on the metrics developed in Cason et al. (2003). Since explicit theoretical development of an auction solution is not provided in this research, the allocation selected in the auction when bidders bid at cost is used as a reference point. Let this solution (given the costs and benefits associated with different projects) be represented by x^{max} . Here participants receive only their minimum willingness to accept (i.e., their cost). This solution obtained at costs is the complete information solution.

The ecological effectiveness (EE) of the auction is then measured as the ratio of environmental benefits received from auction outcome x^* to the environmental benefit that can be obtained from allocation x^{max}. Thus using expression (4)

$$EE(x^*; x^{max}) = \frac{V(x^*)}{V(x^{max})}$$

The value of EE indicates how far the auction solution is from the first best allocation. The projects pertaining to allocation x^{max} may also be selected in the auction when bidders are not bidding at cost. In this scenario even if the auction is ecological effective, its cost efficiency differs since individual conservation units are dearer than when they are procured at costs. The EE metric does not pick up this difference. So another metric that explicitly considers the cost efficiency of the auction is required.

The economic efficiency of the auction is measured on the basis of the actual environmental benefits per unit expenditure in the auction relative to that which can be generated when bidders bid at cost. Economic efficiency (CE) is measured as a ratio of two ratios. The numerator represents the actual environmental benefit obtained from an allocation x^* in the auction per unit money spent in procuring the projects included in it. The denominator is the environmental benefit obtained from allocation x^{max} per unit money spent in procuring the projects associated with x^{max}. Thus CE is represented as

$$CE(x^*; x^{max}) = \frac{\dfrac{\sum_{i=1}^{N-1} v_i x_i^* + dx_i^* x_{(i+1)}^* + \ v_N x_N^* + dx_N^* x_1^*}{\sum_{i=1}^{N} b_i^* x_i^*}}{\dfrac{\sum_{i=1}^{N-1} v_i x_i^{max} + dx_i^{max} x_{i+1}^{max} + v_N x_N^{max} + dx_N^{max} x_1^{max}}{\sum_{i=1}^{N} \theta_i x_i^{max}}}$$

The value of the denominator for a given set of cost and benefit parameters is fixed. Consider the ratio in the numerator. For any allocation x^* the value of the numerator representing the total environmental benefit generated in the auction is fixed. Then lower values of bids associated with x^* indicates that a given amount of conservation benefit can be procured cheaply compared to when procurement costs are higher. As a result, the overall value of CE is higher. Greater cost efficiency of the auction is associated with higher values of CE. A value of CE equal to 1 indicates that bids submitted equal costs. Also as different amounts are disbursed in the auction depending upon bids submitted, money left over from the budget is different as well. The CE metric picks up the effect of the unspent budgets left over after winners are paid in the auction. This is important as the money left over can have some alternative use. One caveat in the interpretation of the CE metric is that owing to the budget constraint, a situation may arise where very little conservation is purchased and a lot of the budget is left over after paying off the bidders since the bids submitted by losing bidders are very high. In this case, the value of the CE can be greater than 1. This scenario however represents a highly inefficient outcome. However the likelihood of it occurring in the current iterative auction where bidders get multiple chances to submit bids in order to improve their chances of getting into the winning allocation is low relative to a one shot auction where the winners are chosen on the basis of single bid submissions.

Finally on the side of the bidders, the Information Rents within a session or seller profits are calculated as the difference between winning bids and costs. Rents measure the total money in excess of costs paid by the auctioneer to procure a set of projects and represents the “money left on the table”. This metric also captures the degree of competitiveness of the auction since competition between bidders across multiple rounds is expected to reduce the value of submitted bids It is represented as

$$Rents = \sum_{i=1}^{N} b_i^* x_i^*$$

These performance metrics can be employed to consider different scenarios within which the auction can operate. These scenarios are represented with the help of the cost and benefits associated with projects discussed in the next section.

5.7.3 Experimental Parameters in the Auction

The CA can be implemented in different landscapes which vary on the basis of the cost-benefit profiles of conservation projects as well as on the basis of relative position of projects vis-a-vis their neighbors. It is then of interest to investigate the variability in CA performance across these multiple landscapes whose features are such as to give rise to different levels of ecological effectiveness and economic efficiency of the mechanism and different types of spatial patterns. The costs and environmental benefit parameters associated with every project in the experiment can be varied across multiple periods such that groups of players at various locations on the circular grid have chances of winning in the auction.

Four sets of parameters are considered for the twelve periods in the experiment. Each set consists of costs and environmental benefit values for the 6 auction participants who are arranged around a circle. Let G1 represent parameter set 1 and G2 the set 2 so on and so forth. Since the theoretical features of the Nash Equilibrium outcome of the game is not developed here, the values of the parameters are chosen on the basis of the performance of the CA expected at a allocation that can be supported as a stable auction solution. At this stable allocation no bidder has any incentive to change their behavior. This is true when the following criteria apply for the losing and winning bidders. For the losers, at the stable allocation, bids are equal to costs so that it is not in their interest to reduce their bids to improve their likelihood of winning. For the winners, their bids are greater than or equal to costs so that rents are non-negative. However they don't have any incentive to submit higher bids to earn more rents as that will remove them from the winning allocation. On the basis of these features of a stable solution, parameters are chosen such that varying degrees of ecological effectiveness and economic efficiency can be potentially generated in the auction under each parameter regime. In addition to different potential values of the performance metrics, the costs and benefits are assigned to the six projects in a way that the potential solution can have two other features.

1) If bidders submit bids equal to cost, x_{max} for each parameter set corresponds to a different number of projects. Thus with the cost and benefit parameters

pertaining to G1, G3 and G4 the auction selects four out of the six projects. In case of G2, three projects can be selected.

2) If bidders submit bids equal to cost, under every regime the auction produces a different spatial configuration. Under G1 and G4, four adjacent projects can make up the stable solution. With set G2, of the three selected projects only two are adjacent to each other and under regime G3 three of the four projects can be adjacent to each other.

The total value of the budget is the same for all periods and is equal to 350 experimental dollars. The value of environmental benefit from selecting any two adjacent projects on the spatial grid is 50. The numerical example below explains how the parameter selections are made on the basis of a candidate stable allocation. Let Table 5.1 represent the costs and benefits values for the six projects.

Bidder	Benefit	Cost	Bids	If 3 raises bids	If 4 raises bids	If 5 raises bids
1	241	100	100	100	**100**	**100**
2	280	**137**	137	137	137	**137**
3	235	**51**	**96**	*107*	96	**96**
4	277	**69**	**115**	**115**	*130*	115
5	252	**87**	**93**	**93**	**93**	*126*
6	269	124	124	**124**	**124**	124

Table 5- 1: Example of Parameters Choice at Stable Allocation

On the basis of the optimization problem in section 5.6, projects 2,3,4 and 5 constitutes allocation x_{max}. Then with the bids listed in column (4) of Table 5.1, projects 3, 4 and 5 generates the highest value for the objective function at 9.49 and can be a potential solution of the auction if it has the properties of a stable allocation. Considering the bidders, 1,2 and 6, they have bids equal to their costs and hence have no incentive to lower their bids. Also bidders in the allocation have no incentive to change their behavior as an increase will remove them from the winning allocation. Thus if bidder 3 increases their bids from 96 to 107, the value of the objective function becomes 9.189 which is less than 9.201 corresponding to the allocation of projects 4,5 and 6 (which is then chosen). Thus winner 3 is removed from the winning allocation which now changes to include projects 4,5 and 6. Similarly if bidder 4 raises bids from 115 to 130, then they are removed from the winning allocation in favor of allocation 1,5 and 6 for which the value of objective function is 9.13 as opposed to 8.87 for projects 3,4 and 5. Finally if 5 increases the value of their bids from 93 to 126, then the value of the objective function drops to 8.2 and the allocation cannot be supported by the budget of 350 anymore. In this scenario the allocation consisting of projects 1,2 and 3 are selected in the auction generating a value of 8.53 for the objective function. Thus allocation comprising of projects 3,4 and 5 is a stable allocation which can be achieved in the auction with the cost benefit parameters listen in Table 5.1. On the basis of the defined performance metrics, at this stable solution the value of EE is 0.72, and for the given set of bids the value of CE is 0.8 and the value of seller profits earned is 101. This parameter set confirms to set G4 used in the auction sessions. In a similar fashion, parameters corresponding to sets G1, G2 and G3 are obtained. These are listed in Table 5.2. For regime G1 and G2, a value of EE equal to 1, and for G3 a value equal to 0.84 respectively can be obtained at a stable solution. The value of CE for sets G1 and G2 for a given set of stable final bids can be 0.89 and 0.9 respectively and the same for G3 can be 0.78. Finally the value of total rents possible for G1, G2 and G3 is 35, 33 and 35 respectively. In the actual experiments however different values of all the three metrics than those listed above on the basis of which parameter selections are made may be obtained. This is because the stable allocation is not a Nash Equilibrium outcome of the auction and multiple stable allocations are possible.

A point of interest in the study of the current CA is that besides the cost and benefit associated with the project, its location on the landscape relative to their neighbors determines its own chances and its neighbors' chances of being selected in the auction. In the auction combinations of projects are considered together by evaluating every project with a score that is dependent on the winning status of their neighbors. Thus if projects have low costs and high benefits and are adjacent to other low cost and high benefit projects, they have a greater likelihood of being accepted in the auction as opposed to a situation where they are at a location surrounded by one or both high cost (high or low benefit) projects. Similarly, the low cost and high benefit projects themselves improve their neighbors' chances of winning as they have a higher chance of acceptance owing to their intrinsic high values and low costs. Thus in the current auction, there is reciprocity between a project and its neighbors with each generating an externality for the other on the basis of which their chances of being selected in the auction are impacted. In other words, projects adjacent to each other have varying degrees of influence on their own and their neighbors' chances and can be considered to be pivotal to the selection of a combination of spatially adjacent projects. Also a project's capacity to be pivotal increases if they are adjacent to projects with lower costs than to those with higher ones. Thus in the current study a project can contribute different degrees of benefits depending upon which combination it is a part of. This feature sets the CA in this study from that presented in the earlier research such as that by Cason et al. In this auction, whether a project is pivotal or not can be determined by evaluating the degree to which the value of the objective function (sum of benefit per unit cost) drops if that project is no longer included in the CA. Greater the fall in the value of the objective function, greater is the pivotalness of the project. For example, if bidders submit bids equal to costs for set G4, the value of the objective function from selecting projects 2,3,4 and 5 is 17.91. Now if project 4 with cost of 69 and benefit of 277 is removed from the auction, then projects 1,2, and 3 are selected as they maximize the value of (6). As a result the value of the objective function drops by 6.64. This value drop is higher than the drop of 6.55 obtained if project 3 (with benefits equal to 235 and cost equal to 51) and not 4 is excluded from the allocation. Thus project 4 is more pivotal than project 3. Of special interest is the fact that project 4 is more pivotal than project 3 despite having a higher cost. This is because it has a higher benefit and is in a location where it is flanked by two low cost neighbors (project 5 with a cost of 87 and project 3 which have a higher likelihood of selection as well) compared to project 3 which is adjacent to project 4 and project 2 which has a high cost of 137 and not that high a benefit. Here Project 3 is ranked second in pivotalness owing to its low cost and because it improves both its neighbors chances of selection. Since Projects 2 and 5 are at the edge of the selection they don't contribute a large amount to the environmental benefit of the allocation and hence are low on the pivotal chart. Hence, it is evident that besides own costs and benefits, the location of a project relative to neighbors plays a role in determining whether it has a greater likelihood of selection and accordingly whether it improves its adjacent projects' selection chances as well. This feature is utilized to choose parameters for the auction in a way that bidders holding projects at different points on the landscape have varying degrees of coordination capability and influence for their own and their neighbors' selection. Regardless of location, since the score is a benefit cost ratio, projects at isolated positions may be accepted in the auction if their benefits are high enough and/or cost is low enough. This is true for G2 where the two adjacent projects 3 and 4 along with the isolated project 6 constitute x_{max} since project 6 has a very high benefit of 349 compared to projects 5 or 2 which have benefits of 204 and 295 respectively. Finally, in the current auction environment, it may be expected, that players with pivotal projects will be able to exploit this comparative advantage to try to earn higher rents if they are selected in the auction. Thus at the stable allocation in Table 5.1, at which the performance measures are evaluated, the bidder for project 4 earns the highest rent of 46 compared to 45 for project 3 followed by project 5, the remaining winner. Table 5.3 represents the degree of pivotalness of each of the projects comprising x_{max} for G1, G2, G3 and G4. It presents the value of the change in the objective function from the removal of a project and the movement to another allocation and the pivotal rank of different projects For both G1 and G2, the lowest cost project is most pivotal and is at the centre of other selected projects (G1) or has at least one neighbor (G2). For G3 and G4, while the pivotal projects don't have the lowest cost they rank very high on the benefit scale (G4).

Budget – $350 Environmental Benefit from Two Adjacent Projects – 50								Periods in which used
G1	Benefit Cost	245 100	150 40	215 90	209 95	195 85	285 112	2, 4, 10
G2	Benefit Cost	204 112	349 105	213 89	295 146	363 95	271 110	3, 5, 11
G3	Benefit Cost	210 140	215 95	220 103	265 85	145 130	145 60	6, 8, 12
G4	Benefit Cost	252 87	269 124	241 100	280 137	235 51	277 69	7, 9, 13

Table 5- 2: Parameters for Experiments

Set	Winning Project	Change in Value of Objective Function	Pivotal Rank
G1	3	0.2	IV
	4	1	II
	5	6.36	I
	6	0.86	III
G2	3	1.12	I
	4	0.07	III
	6	0.36	II
G3	1	3.17	II
	2	3.17	II
	3	4.57	I
	5	2.41	III
G4	2	0.24	IV
	3	6.55	II
	4	6.64	I
	5	3	III

Table 5- 3: Pivotalness of Winning Projects by Parameter Regime

	Treatment	
	SCORE	**NO-SCORE**
Number of sessions	6	:6
Number of players in a session	6	6
Number of periods per session	13 (one practice period)	13 (one practice period)
Maximum number of rounds	10	10
Minimum number of rounds played	5	5
Payment structure	$7 show up fee Exchange rate – 15 experimental dollars for every US $	

Table 5- 4: Experimental Design

Once the parameter selections are made on the basis of the pivotalness of projects and potential auction performance at a stable allocation, they are assigned to the 12 periods of the auction experiment. In doing this, it is ensured that if everyone places bids equal to their cost, every bidder wins three times across the twelve periods. Also these parameter values are assigned to different periods on an ad-hoc basis to eliminate order effects across the treatment. Finally at the beginning of every auction session a training period is conducted in order to demonstrate to the participants how the auction works. For this period, a different set of numbers is selected on an ad-hoc basis.

5.7.4 Description of Experimental Procedure

All participants were randomly selected from Penn State's student population. The experimental sessions where conducted at the Laboratory for Economics, Management and Auctions (LEMA) at the Smeal College of Business at Penn State in April 2010. The sessions lasted between an hour and an hour and a half. Subjects were paid a show-up payment of $7 as well as the money they made during the course of the experimental session. The exchange rate to convert experimental dollars to actual dollars was 15 experimental dollars per real dollar. Neutral terminology was used during the experiments and the use of economic jargon was kept at a minimum. The term QUALITY was used to refer to the environmental value and the term ITEM was used to denote a land management project.

Twelve experimental sessions (6 each varying by informational content) were conducted. Every session had 6 players.[12] Players in a session interacted in the lab through software interface programmed in Z-Tree (Fischbacher 2007).[13] The iterative auction was run for 13 periods with the first period being a practice non-paying period. Every period (except the practice period) had a minimum of 5 and a maximum of 10 rounds during which bidders placed bids over the computerized interface. After all players submitted bids in a round, the computer displayed a results screen showing the submitted bids and the identity of provisional winners. In addition, all players saw their own score for the current round, the bids from the current and past rounds, their costs figures and the number of neighbors selected in the current round. The cost and past

---

[12] The terms players, subjects, participants have the same meaning.
[13] The instructions for the experiments are included in Appendix A and screenshots are included in Appendix B

round were visible to the subjects whenever they submitted a bid. The bids submitted in any round were restricted to be always above the costs. The bid from a past round was automatically submitted in the next round by Z-Tree (Fischbacher 2007). Subject could however decrease bid value by a minimum decrement of 50 cents (experimental). The provisional winners in a round became final winners of a period if the stopping rule was satisfied or 10 rounds were played.[14] During a session, the identity and location of players on the circular landscape remained unchanged.

5.8 Results

The results in this study can be divided into two categories. The first part deals with market performance analysis. The second deals with the analysis of markups from the final round of every period.

5.8.1 Analysis of Market Performance

Data from the final round of every auction period from multiple sessions is used for the analysis of market performance.[15] This is because the final round is the binding round and determines the outcome of the auction in any period. Let the equation to be estimated for the performance metrics be represented by

[14] Henceforth selection of bids or selection of projects or selection of participants will have identical meaning.

[15] Data is recorded for all the 12 periods of all the NO-SCORE sessions and 3 SCORE sessions. For the remaining 3 SCORE sessions, the last period is lost owing to software error. Also in some periods, the stopping rule is violated owing to a glitch in program. Here the stopping rule is forcefully applied to end the auction and data from subsequent rounds are eliminated.

$$y_{it} = x_{it}^{'}\beta + \alpha_i + u_{it} \quad (7)$$

For the purpose of regression analysis the dependent variable is the value of the performance metric for the final round of a period. This value is recorded for all twelve periods of the experiment.

In this expression, $i = 1,2, \dots .12$ denotes the session number and $t = 1,2, \dots .12$ the time periods for which the performance metrics y_{it} are computed. The set x_{it} represents the value of set of independent variables for the i^{th} session for the time period t. For both the models the treatment dummy, the Period variable the round variable and parameter dummies representing different cost benefit regimes are included as the independent variables. The Information Dummy captures the impact of varying the information content of the CA and the parameter dummies pick up the impact of varying the costs and benefits of the subjects in multiple periods. The constant term represents the effect of the omitted parameter category and the NO-SCORE sessions. The Period variable captures the impact of experience with bidding on auction performance. Similarly the round variable is included to estimate how performance of the auction varies within a period. In the analysis both period and round variables are considered in log formats so that estimated coefficients can have growth rate and elasticity interpretations. The current estimation, however, does not include any interaction terms between the treatment and parameter dummies, and the period and round variables. This choice can be explained as follows.

First, in the current iterative CA, knowledge of the importance of spatial patterns is not expected to influence how experience with bidding has an impact on the performance of the mechanism. Thus an interaction term between the Period variable and

Information Dummy is not included in the analysis. Second, since in the iterative format regardless of the information content, bids would always be decreasing an interaction between the Final Round variable and Information Dummy is not included. . Interactions between the parameter dummies and the other variables are not included in the analysis as well. Since the parameter groups are assigned to periods on an ad-hoc basis to minimize ordering effects, interactions between Period and G1, G2, and G3 are excluded. An interaction term between Round and parameter dummy is excluded for the following reason. The round variable represents how efficiency changes within a period with a change in the number of rounds. Since bids are falling, both CE and EE will rise over successive rounds. This is true for all periods. As a result the positive impact of rounds on performance of the mechanism can be captured by the round variable without considering the interaction with the parameter dummies. Also even if subjects were bidding differently across rounds in different periods, if they were never chosen or were chosen very few times, their impact on the performance of the mechanism will not show up in the results and the interaction terms will not be significant.

In the estimation of expression (7) the error u_{it} is the normal, identically and independently distributed error term and α_i is the time invariant unobserved heterogeneity associated with every session *i,* that is uncorrelated with the independent variables in the model. Thus, a random effects specification for the estimation exercise is appropriate. In addition to estimate the equation for the metrics EE a random effects Tobit specification is considered since value of EE cannot exceed 1. For the CE metric, a simple random effects specification is used. If the bidders bid at their costs in the auction, value of CE as per the form of the metric will be equal to one. Yet given the budget constraint, there may be a scenario where the magnitude of losing bids are so high that very little conservation is purchased and a lot of the budget is left over. In this case, the value of CE may be greater than 1. A summary of the data reveals that this is in fact true as there is one observation for which the value of CE is at 1.02 and of the total experimental budget of 350 experimental dollars, only 243 is spent. Given the iterative format, chances of such an inefficient outcome are however low since losing bidders always have a chance in the next round to reduce their bids in to improve their likelihood of winning in the auction. For the information rents regression a log form for rents is used as the dependent variable in a random effects regression model. The log specification gives a double log form to the estimation function and elasticity interpretations for the estimates.

Table 5.5 presents the regression results for the three metrics. The insightful result from the analysis is that in an iterative auction with full information feedback, the significant impact of increased information content is only felt on the economic efficiency of the mechanism; the total conservation purchased is not significantly different. The signs of the estimate indicate that in the presence of information about the scoring metric, the average economic efficiency is significantly lower (at 5% level). This reduction in cost efficiency means that given the budget all purchased conservation units are more expensive in the presence of information about the spatial goal. The significant estimate (at 5%) for the dummy in the rents regression implies that when subjects know the spatial objective, they successfully exploit their locational and cost advantages to submit and earn higher rents (on winning). Figures 5.1 – 5.3 provide visual proofs of these results. Comparing between treatments, the value of CE is greater for all SCORE sessions except in two periods (5 and 12). Again, in Figure 5.2 the plot of average markups per session in SCORE sessions is greater than those in NO-SCORE. Finally no significant difference in the percentage ecological benefits is observed across treatments for multiple periods in Figure 5.3.

The nature of the impact of experience in the auction is captured by the Period variable. The estimate for the log of Period is significant at 5% for the CE and at 1% in the rents and significant at 10% in the EE regression. The negative sign of the estimate in the CE and EE regressions indicates that with increasing experience and familiarity with the CA, the performance of the mechanism suffers. The negative trend in the graphs in figure 5.1 demonstrates the negative impact of experience on economic efficiency. This adverse impact of experience and familiarity of auction performance has significance for actual policy implementation. Government run CAs are implemented a number of times within a year as well as over a period of multiple years. Here farmers' repeated participation in the mechanism increases familiarity and promotes learning about the structure of the scheme that can enable them to submit bids that are much higher than costs and earn high rents. A real policy based example of this phenomenon is the increase in bids submitted (and hence reduction in conservation purchased) in CRP signups in the past (Kirwan et al.). Submission of high bids is also statistically validated in the current model by the positive and significant (at 1%) estimate for Log of Period in the rents regression and the positive trend in the markup graph presented in Figure 5.2. The inelastic nature of the impact can be attributed to the iterative format. Within a period bidding takes place in multiple rounds where successively lower bids are submitted. So

Dependent Variable	Economic Efficiency	Log of Rents	Ecological Effectiveness
Estimate (Standard Error)	**Random Effects**	**Random Effects**	**Random Effects Tobit**
Constant	.8060* (.046)	4.8873* (.230)	.5703* (.059)
Information Dummy	-.0422* (.014)	.1981** (.079)	-.0415 (.028)
Ln(Period)	-.0227** (.009)	.1781* (.047)	-.0207*** (.011)
Ln(Final Round)	.0380*** (.022)	-.3989* (.111)	.1114* (.028)
G1	-.0179 (.019)	-.5380* (.096)	.0039 (.023)
G2	.0201 (.017)	-.7717* (.086)	.1702* (.021)
G3	-.0011 (.016)	-.5137 * (.081)	.0766* (.019)
Number of observations		141	
Number of groups		12	
Panel Variable		Session	

*** represents significance at 10% level of significance
** represents significance at 5% level of significance
*represents significance at 1% level of significance

Table 5- 5: Regression Results for Market Performance

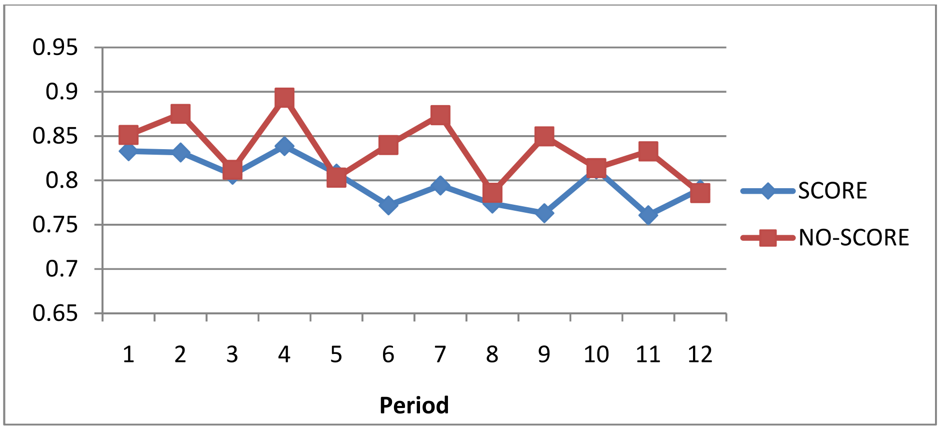


Figure 5-1: Average Cost Efficiency by Period

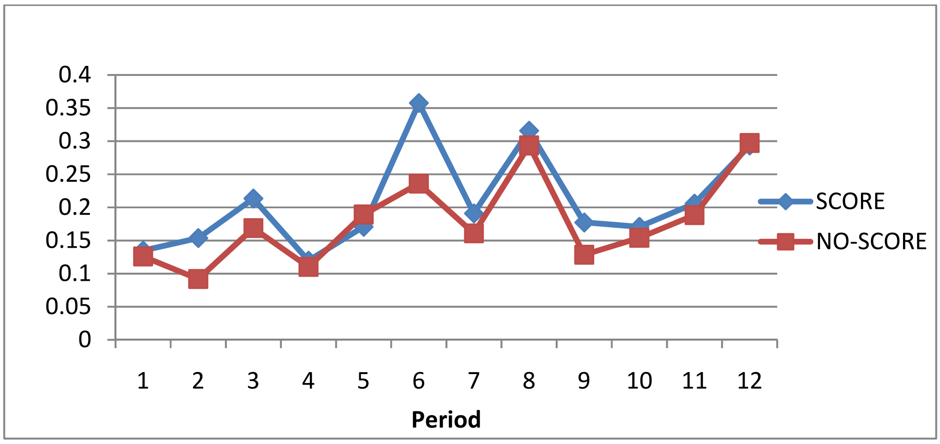


Figure 5-2: Average Markup by Periods

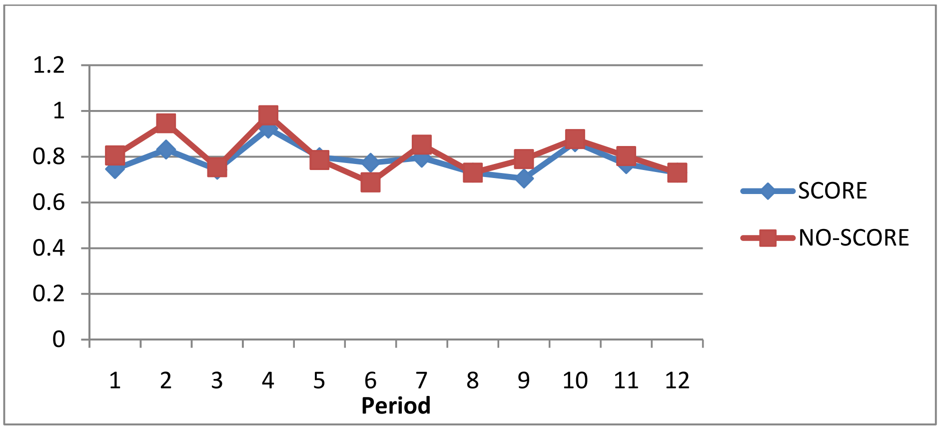


Figure 5-3: Average Ecological Effectiveness by Period

		Number of Observations	Mean	Standard Deviation	Minimum Value	Maximum Value	Stable Allocation
Ecological Effectiveness	G1	36	0.757	0.09	0.55	0.92	1
	G2	36	0.903	0.12	0.59	1	1
	G3	36	0.8	0.08	0.58	0.94	0.84
	G4	33	0.723	0.06	0.47	0.95	0.72
Economic Cost Efficiency	G1	36	0.819	0.05	0.63	0.91	0.9
	G2	36	0.844	0.07	0.68	0.94	0.78
	G3	36	0.812	0.08	0.66	0.96	0.8
	G4	33	0.812	0.07	0.7	1.02	0.8
Total Information Rents	G1	36	52.12	27.56	7	160.5	35
	G2	36	44.34	18.85	17.5	111	33
	G3	36	59.54	15.65	33	101	35
	G4	33	101.57	25.26	36	141	101

Table 5-6: Summary of Performance Metrics in Auction by Parameter Group

even if higher rents are earned over time, reduction in bids within a period reduces the magnitude of this experience induced rent seeking. Finally, pertinent to the current study is the impact of experience on ecological effectiveness of the mechanism. The estimate is significant at 10% and has a negative value indicating that regardless of the quantity of information available to a group of people, with full information feedback conservation units get more expensive over time so that fewer units can be purchased with the funds available. The impact is, however, weak as evinced by the very flat slope of the graph in Figure 5.3.

The log of Round is significant at 10% level of significance in the CE model and at 1% for the rents and EE models. The sign of the estimate is negative for the rents regression and positive for the other two. The sign of the estimate in the three regressions is a consequence of the iterative format under which bids submitted are decreasing over multiple rounds. In addition, the elasticity estimate in the rents regression is less than one indicating that within a period, bidders always try to retain as much rent as possible as they reduce the value of bids submitted from one round to the other. This result is true regardless of the information content of the auction.[16]

In the current research the parameter dummies represent a secondary within treatment that every subject is exposed to. For the analysis of market performance parameters are chosen on the basis of expected performance levels and pivotalness of projects in x_{max} at a potential stable allocation in the auction. Table 5.6 provides a summary of the performance metrics by parameter regimes along with metric values for the candidate stable solution that served as the reference point for the parameter choices. Relative to the value of the metrics at the stable allocation used to fix the parameter values, their mean values attained in the auction is different. This indicates that subjects are able to exploit the private information they have and their location characteristics to earn higher rents. This higher rent seeking as mentioned makes every unit of conservation benefit dearer. In current regression, G4 is considered to be the omitted category and the

[16]Models were estimated using interaction terms between the dummy and explanatory variables. However they led to poor model estimates and reduced the significance of existing estimates.

positive constant term picks up the impact of being under set G4 on auction performance. This choice is made as the total information rents that can be earned by winners at the candidate/potential stable solution is the highest. In addition, the expected EE at this stable solution is the lowest as well. Now considering the results in both Tables 5.5 and 5.6, the estimates for G2 and G3 are significantly different from zero implying that environmental performance under these regimes are significantly different. The positive estimate indicates that environmental performance of the auction in these regimes is significantly higher relative to G4. One outcome of interest is that while an allocation with an EE value of 1 can be supported as the stable solution in the auction under G1 and G2, the mean EE value under G1 never reaches 1. In fact the mean EE under G1 is very near the same obtained in G4 (Table 5.6) and is equal to 0.75. Thus relative to G4, there is a very high degree of rent seeking going on in the periods under this regime that causes the EE to plummet. This high degree of rent seeking reduces the difference in CE across parameter groups. This is seen from the mean values of the metrics in the summary table and the lack of significance for the G1, G2 and G3 estimates in the CE regression. Rent seeking also causes significant differences in performance between regimes in the rents regression as evinced from the significant and positive estimates in the log of total rents regression. All the estimates are positive and significant indicating that rent seeking tendencies of all regimes are significantly different from that under G4. The negative sign of the estimates indicate that relative to G4, under all other regimes there is significantly less money left under the table. These signs and magnitudes of the parameter estimates indicate that auction performance is sensitive to parameter choices. In the context of actual policy based CA, a significant impact indicates that the performance of the CA will vary with the variation in the costs and benefits of conservation land uses and where they are located on the different working landscapes.

5.8.2 Analysis of Bidding Behavior in the Final Round

The descending price format of the iterative CA implies that over successive rounds, subjects bid down towards their costs. A round is declared final in this auction when after the minimum rounds have been played, total score in the round is equal to that from the past round. The score remains the same from one round to the other if neither provisional winners bid down further nor losers decrease their bids as they are already at costs. This feature of the bidders in the final round of a period as mentioned represents a stable allocation in the auction at which deviating from ones current state is not profitable for a bidder. In order to statistically assess whether the behavior of winners and losers at the end of an auction period, corresponds to a theoretically stable allocation, a regression is conducted with the value of average markup of bid over costs for every bidder in the final round of all the periods as the dependent variable. The markup is the differences between bids submitted and costs as a ratio of the bidders' cost. Regression results provide insight about the variables that explain how close or far bidders' bids are from costs when the auction ends. We expect that for a winner this markup will be higher than costs and for losers it will be lower and very near to zero or equal to it. Near zero markups also indicate high levels of competition between players. Let the dependent variable y_{it} represent the value of markup for subject $i = 1,2, \dots .72$ in the final round for period $t = 1,2, \dots .12$. The markup function to be estimated is

$$y_{it} = x_{it}^{'}\beta + \alpha_i + u_{it} \tag{8}$$

The x_{it} represents the vector of independent variables for the i^{th} individual for the time period t, u_{it} is the normally distributed error term and α_i is the time invariant unobserved heterogeneity associated with subject i. A total of 846 observations for 72 subjects are used for this analysis. The set of independent variables include the Information Dummy, the reciprocal of the period variable that represents Learning that takes place for every individual over time, the Final Round variable to capture if there is any difference in behavior within a period across multiple periods and the parameter dummies G1, G2 and G3. Finally a dummy is included to capture the winning or losing status of a player in any period. Let this variable be termed Winner. Typically the status of a player in the final round of a period would be included. However this will give rise to the problem of endogeneity. This is because bids (and hence markups) determine the winning or losing status of a player. Thus higher the bids, lower the likelihood of selection. However in keeping with the theoretical properties of a stable solution, for a winner, the markup should be different from zero while for a loser the markup should be at zero. Given this problem of endogeneity, the status of a player from the past round is used as an instrument for the Winner dummy. The correlation coefficient between the Winner variable for the final round and the penultimate round in a period is approximately 0.82. Moreover markups demanded in the current round don't influence the likelihood of selection in the preceding round. Let this variable be termed the Lag Winner. An interaction term between the Information Dummy and the Lag Winner variable is also included in order to capture the fact that having upfront information about spatial benefits impacts how winning in the penultimate round influences final round markups. Next, since different parameter regimes are assigned to periods on an ad-hoc basis to minimize ordering effects, no interactions between the parameter dummies and the experience variable are included in the analysis. According to a similar reason, interactions between Round and parameter dummies are not included as well. An interaction term between the Experience and the Information Dummy variable is not included as we don't expect upfront information about spatial benefits to impact how experience with bidding impacts markups. The presence of agent learning indicates that experience gained in the past may have an impact on future behavior. A test by Wooldridge (2002) for no serial correlation in the errors rejects the null hypothesis at 1% level of significance indicating that the errors are serially correlated. Thus a random effects regression model is estimated with AR(1) disturbances.

Table 5.7 represents the set of estimated coefficients for this model. The positive and significant constant term (at 1%) indicates markups for all subjects are significantly different from zero at the end of the auction. In addition, the Information Dummy is positive and significant (at 5% level) indicating that information provided upfront in SCORE sessions allows bidders to earn higher markups than in NO-SCORE sessions where this information is not provided.

The estimates for G1, G2 and G3 are all negative and significantly different from the constant term that picks up the effect of set G4. As mentioned earlier, rents earned by subjects are significantly different across parameter regimes. Also at the potential stable solution used to fix the values of the parameters, the total rents that winners could expect to earn was the highest under G4 relative to other regimes. Thus the negative sign of the estimates for each of G1, G2 and G3 indicate that the markups earned by players are less and they are closer to costs under these regimes which in turn is in keeping with the final stable solution of the auction.

Of special interest to the study of markup behavior are the estimates for the Lag Winner and the interaction between Lag Winner and Information Dummy variables. The positive and significant estimate for the Lag Winner variable (at 1%) indicates that winning bidders' markups at the end of the auction are higher than losing bidders' values. This outcome is in line with the properties of bids of winners and losers at a stable solution of the auction. However, the interaction term between Lag Winner and the Information Dummy is not significant. Thus, the entire impact of information on markups in SCORE is captured by a level shift represented by the significant and positive dummy estimate. Having this extra information in SCORE sessions does not influence how winners demand higher markups.

The estimate for Leaning is negative and significant (at 5%) indicating that in latter periods, by which time, agents are familiar and have learnt to bid in the auction, markups demanded and earned are higher than in the initial periods where experience and familiarity with bidding is low and bidders are still learning how to bid to their best advantage. The trends in the average markup graphs for both SCORE and NO-SCORE in Figure 5.4 substantiate this claim. This result corresponds to higher and significant rent seeking in the auction in latter periods as established in the analysis of auction performance. Finally, the sign of the estimate for the Round variable is negative and significant (at 1%). This result indicates that a greater number of iterations within a period reduce markup values.

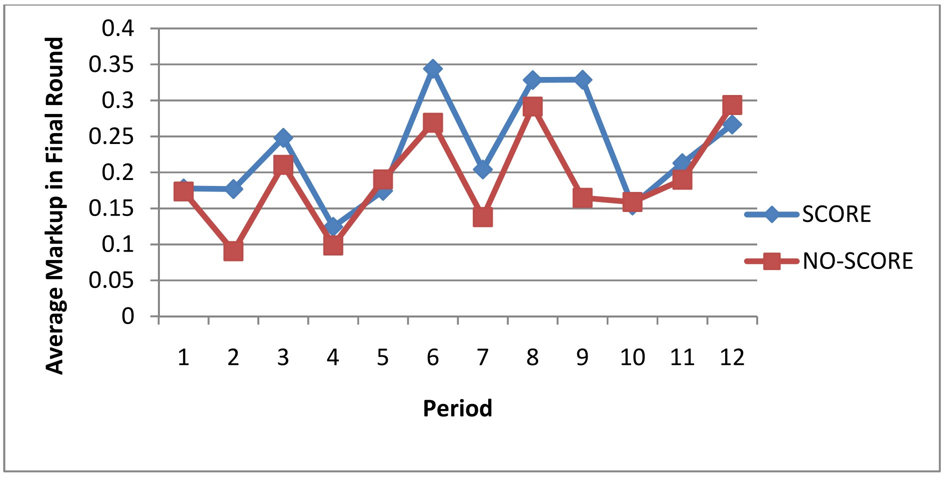


Figure 5- 4: Markup in Final Round

Dependent Variable : Markup over costs in Final Round of Period	
Dummy	.0621868** (.026)
Lag Winner	.1553713* (.021)
Learning (1/Period)	-.0993517** (.039)
Final Round	-.0221124* (.004)
Dummy*Lag Winner	.0062591 (.031)
G1	-.050062*** (.025)
G2	-.1575812* (.023)
G3	-.1150897* (.021)
Constant	.3699381* (.037)
Number of Observation	846
Number of Groups	72
Unit of Observation	Individual Subject

*** represents estimate is significant at 10% level of significance
** represents estimate is significant at 5% level of significance
* represents estimate is significant at 1% level of significance

Table 5- 7: Estimates (Standard Error) for Average Markup for Final Round

The analysis of final round markups presented in this section provides valuable insight about subjects' behavior at the end of the auction. Higher markup values for winners indicate that winners bids are above their costs and are significantly higher compared to losers who may have bid at costs and so cannot lower bids anymore. The relative magnitude of markups across winning and losing bidders provides support for the stability properties of the auction solution. Once the solution is reached in the final round, none of the bidders have any incentive to deviate from their decisions and so the auction ends. The negative sign for the Learning variable also indicates the rent seeking taking place for agents over time in these auctions.

5.9 Conclusion

The dual objective of ecological and economic efficiency that needs to be pursued given fixed budgets has led to the development of an extensive literature on conservation auctions. A substantial portion of this research is devoted to the analysis of auctions for the achievement of various conservation goals in a laboratory setting. The current study follows this research path. It considers the structure of an iterative auction for the selection of bids for projects adjacent to each other on a circular grid. The key result of the study is that auction performance is sensitive to information available to subjects and the value of costs and benefit associated with each project. When subjects have more information the economic performance of the auction suffers. However, there is no significant impact of the knowledge about auctioneer's spatial objective conservation benefits produced in the auction. Thus, added information serves to only make conservation units more expensive for the auctioneer. Second, the rent seeking and environmental effectiveness of the auction is significantly different across different parameter groups. Thus, CA implementation will lead to variable degrees of competition between participants and produce varying levels of performance in different landscapes, which have different cost benefit features and where projects at various locations are pivotal. Finally the analysis of individual bid values across multiple auction periods indicate that at the end of the auction, bids submitted by both winners and losers are significantly different from their costs and that winners submit significantly higher bids than losers. This learning across periods reflects the reality of conservation auction policy performance and is a matter of concern. The decrease in performance indicates that innovation in auction design for spatially contiguous land management is necessary to ensure that conservation units can be procured cheaply and that auctions can still perform cost efficient conservation procurement.

The results of the current auction research add to the growing body of work focusing on the performance of auctions in various conservation settings. The auction structure is simple and similar to actual policy based CAs implemented in practice (such as the CRP auctions) so that results obtained can be directly translated to policy settings. While the study provides valuable insight about how the auction would fare in achieving spatial coordination, more complicated scenarios need to be considered for enhanced understanding of auctions in this spatial setting. Complicated and realistic scenarios can include the consideration of how collusive bidding will impact auction performance and when every bidder can submit multiple bids in a round.

As threats for ES increase, incentive based mechanisms to promote voluntary conservation of natural resources is necessary. Additionally, with limited budgets, economic efficiency of the incentive mechanisms is a central objective. Thus, policy making needs to focus on mechanisms that target various ecological criteria. The current interest in both research and policy circles are to explicitly incorporate the spatial criterion into the auctions so that it can be attained in an economically efficient manner. This essay contributes to this policy making exercise.

Chapter 6

Conclusions and Future Research

A majority of the ES are found on intensively managed working landscapes where protection incurs high opportunity cost. Alavalapati et al. (2005) estimate that the opportunity cost of adopting prescribed burning, invasive species control, increasing streamside management zone width, and delaying timber harvesting is nearly $33 per acre per year. This positive number implies that in the absence of an external policy support, a majority of landowners are less likely to adopt these practices. PES incentives hold much promise in this respect. They make payments to landowners for adopting conservation friendly land uses and ensure sustained provision of ES. Uniform rate subsidies and auction based payments are the two types of PES schemes in both developed and developing nations (Engel et al. 2008). This dissertation presents the structure of two PES schemes to achieve the ecological objective of spatially coordinated land use management as well as cost efficient allocation of conservation budgets.

Kleijn et al. (2006) present evidence supporting the positive impacts of EU agri-environmental schemes on various species of farmland biodiversity such as vascular plants, birds and grasshoppers in five European countries. They also present that schemes impact various species differently. Thus rather than a standard one size fits all approach of transferring as much land area as possible into conservation, PES schemes should target different types of ecological criteria. As mentioned spatial targeting of conservation efforts for reconnection of biodiversity reserves, reduction of reserve fragmentation and creation of spatial patterns of land use conducive to species conservation and sustained flow of other ES is the targeted ecological effectiveness criterion. Spatial targeting is important as ecological processes depend both on the nature of land use change and where it occurs. For example Merckx et al. (2009) present that landscape level contiguous management generates substantial biodiversity gains through improvement of moth populations. Second conservation benefits purchasable by the scheme are limited by the budget indicating a call to the economic research of PES schemes that are both economically efficient and ecologically effective. Instruments targeting the spatial criteria have been studied by Wunscher et al. (2008), Reeson et al. (2007) and PW (2002, 2007). This dissertation focuses on the AB and the CA for the attainment of the spatial criterion. In addition the CA is also important to the achievement of the economic efficiency goal.

The first study considers the case of doubts about participation in conservation programs and how that can impact participation in the AB scheme. The second study considers a iterative auction with full information feedback for the selection of spatially adjacent bids. Given the policy relevant nature of PES scheme research, both essays present empirical analyses of the mechanisms in different controlled laboratory environments that represent features of real landscapes and actual conservation policies. The experimental methodology affords the investigation of human behavior and mechanism performance by varying two pertinent features – the size of coordinating group in the AB study and availability of information about conservation authority's spatial objective to the participants in the CA study.

The conclusions of this dissertation produces results that promote greater understanding of the structure of the PES schemes, identify performance issues in multiple economic environments and highlight behavioral issues related to subject participation in these schemes. By virtue of the tools used to study the two PES schemes, this research extends the use of 1) the theory of coordination games and interaction structures in the study of PES schemes, 2) application of mechanism design to the design and analysis of the conservation auction and 3) use of economic experiments to study human behavior in controlled lab settings which allow affordable means to test the mechanisms before costly field implementation. These methodological innovations advance the field of PES scheme research as a whole by adding to both its theoretical and empirical richness.

6.1 Study Conclusions

Agglomeration Bonus, Participation Doubts and Ecological Effectiveness

In Chapter 4, the payoff functions and numerical examples demonstrate that spatial coordination in the AB game can be conceptualized within a coordination game environment with Pareto ranked NE. Innovation in the study of the AB scheme is brought about by considering strategic interactions between participants in a network environment that is consistent with inter-farmer interactions on real agricultural landscapes. In this new strategic environment, the format of the game is transformed by incorporating the issue of doubts about neighbors' participation within the strategic environment. given these participation doubts, participants are assumed to incur costs in finding out about their neighbors' attitudes towards conservation programs. These doubts and the attendant costs increase the riskiness associated with coordination. In the standard AB game that does not consider these participation issues, coordination to the high paying NE – the PDNE is possible even if strategic uncertainty and hence risks of coordination failure exist. According to Harsanyi and Selten players are able to collectively reach the high paying ecologically superior outcome in the game – the PDNE. On the contrary in the presence of the costs to ascertain participation attitudes of neighbors, doubts that others will not coordinate magnify causing them to choose the RD strategy leading the entire game to the RDNE.

The theoretical discussion of the greater incidence of coordination failure in the presence of participation doubts is tested experimentally in a network setting. These experiments test whether the theoretical predictions of the game are achieved in the lab with human subjects. These experiments consider a network neighborhood which is open and where the number of opponents of each player is kept fixed at two and variation is brought about in the size of the experimental landscape. Observational data, statistical tests and regression analysis on the basis of the experimental data provide valuable results. Non-parametric chi-squared tests indicate the presence of systematic differences between players' responses across groups. In smaller groups in the presence of the costs of doubt reduction, the PDNE is much more common than in larger groups. This study thus provides experimental evidence establishing the generality of the group size effect of Van Huyck et al. in local interaction networks where the overall group size varies but the number of opponents remain the same. It is also found that not only is coordination rarer, it is much harder to sustain in larger groups as well. If any player in large groups starts choosing the RD, their neighbors switch from PD to RD as well and this phenomenon spreads to other players in the group causing coordination to unravel. Coordination failure is however not absent in small groups – there are many RD in SMALL sessions. This is because the game played by subjects is the same in both treatments.

The overall results of the study provide results that align with existing research on participation and effectiveness of conservation programs. When doubts about participation exist as is the case on most agricultural landscapes and which has been witnessed in the implementation of the CREP, the performance of the AB suffers. This problem is more intense in larger open networks than in smaller ones. A panacea for policy failure in this current setting is to address the conservation attitudes of farmers and improve their knowledge base about these programs that will increase their willingness to participate in these schemes.

Conservation Auctions, Spatial Contiguity and Economic Efficiency

The second essay is concerned with the economic efficiency of PES schemes. It presents the structure of a simple iterative descending price auction with full information feedback for selection of bids for spatially adjacent projects on a circular landscape. Experimental examination of this new mechanism is conducted to assess its ecological effectiveness, economic efficiency and ability to generate competitiveness (by mitigating rent seeking) in when subjects are specifically informed about the spatial objective of the auctioneer and under scenarios that pertain to different levels of ecological effectiveness.

The experiment produces mixed results. In contrast to existing conservation auction studies, information about the scoring metric has no significant impact on the amount of conservation benefits that the auction can purchase. Market efficiency metrics on the other hand indicate a significant influence of information. Cost efficiency of the auction is significantly higher in the absence of information. Information rents which are a metric of the severity of the asymmetric information problem is significantly lower in the absence of information as well. Thus in the presence of more information the auction purchases less conservation benefits and is also subject to intensified rent seeking. Thus if an iterative English auction were to be implemented for spatially contiguous land management, better economic outcomes can be expected if the information content of the auction is restricted to only the benefit cost nature of the scoring metric (as in the baseline sessions) rather than explicitly describing the form of the scoring metric that indicates the importance of neighbors and hence the spatial criterion.

Another important finding in the current study is the sensitivity of auction performance to variation in auction parameters. This variation has significance for policy implementation. Working landscapes in different regions have different cost patterns and generate different magnitudes of environmental benefits. Significant performance differences across multiple parameter regimes in the lab imply that the same may be true in the field as well. In scenarios where potential ecological effectiveness achievable owing to the cost structure of the participants is low, performance of the auction will suffer. Such variation in auction performance is a key finding for policy makers. While deciding on implementation, the conservation authority should try to obtain some information about the cost structure of the participants on the landscape so that a decision can be made about implementation.

Analysis of markup of bids over costs from final rounds of every period provides insightful results about bidding behavior and stability of an allocation obtained at the end of the auction. Theoretically a winning allocation qualifies as stable if winners are bidding very near and have no incentive to change their behavior and losers have bid down to costs and cannot bid down further in order to improve their chances of winning. The regressions results suggest that at the end of the auction this is the case. We find that there is a significant difference between average bid markups between winners and losers at the end of the auction. The estimate is positive for both the dummy variable representing the winners and the losers implying that at the end of the auction winners are further away from costs than losers. This statistical result provides empirical evidence about the theoretical properties of the auction solution.

To sum up the results, iterative descending price auctions for spatially contiguous land management are susceptible to rent seeking if subjects are explicitly notified about the form of the scoring metric that represents the spatial objective of the auctioneer. Thus from a purely cost-efficiency standpoint, the iterative auctions can be operated without providing any information about the scoring metric to the bidders. The bidding in the descending price auction will provide the information necessary to reach the ecologically effective outcome in a more cost-effective manner than when more information such as that about the scoring metric is available.

6.2 Future Research

The research on incentives for spatially contiguous land management can be extended in many directions. the current study is one of the very first to consider coordination between participants in a network environment in a conservation setting. Experiments dealing with a simple one dimensional open network provides insightful results about participation and behavior of agents. These results provide the basis for the consideration of more complex networks to reflect different types of strategic and geographical (spatial) relationships between the AB participants. This research agenda will not only expand the study of conservation schemes in a network setting which has not been attempted before but is also policy relevant in considering realistic landowner dynamics within the structure of the scheme.

The results from the second study on the iterative auction provide many avenues along which conservation auction research can progress. First the reduction in auction efficiency (a finding consistent with existing research) indicates the need for innovation of the iterative auction format during the lifetime of implementation of the auction so that experience induced rent seeking can be staved off. This objective is important given the fixed policy budgets and the necessity of cost effective spending of the same.

It is also of interest, to test investigate how resilient the mechanism is to bidder collusion given the issue of spatial coordination. Owing to the iterative nature of the auction and full information feedback about results at the end of every round, it is possible for bidders to signal collusive strategies to each other via their bids. Given the importance of spatial coordination, such collusive tendencies are more likely to be observed than not. While collusion was not observed in the current CA, it will be useful to design an experiment where nature of the cost and benefit parameters and pivotalness of subjects is such that collusion may occur. One method to do so would be to introduce the possibilities of communication between bidders. Cason et al. found the incidence of collusion in their auctions in the presence of limited information feedback with communication. Since farmers in a region know each other and communicate, testing for collusion between participants in the presence of communication in the iterative auction of this study will provide policy relevant conclusions as well.

The future research agenda presented above contribute to the policy relevant study of the PES schemes as well as the expansion of the experimental research on the same. One aspect of the entire research literature on PES auction design is the limited attention on developing a theoretical model to explain the strategic interactions between agents and identify the necessary and sufficient conditions for the existence of Nash Equilibrium solutions for the auction. In this research, the results on the markup regressions from the final round provide statistical evidence for the features of a stable auction allocation. Using these features of the auction as a starting point, it will be insightful to theoretically represent the nature of the strategic environment, the bid functions and the Nash Equilibrium outcomes. With an increasing interest in the study of PES schemes especially auctions to address various aspects of ecological effectiveness, the importance of developing theory for these budget constraint auctions s is important. Such theoretical development will provide comprehensive understanding of PES schemes under various economic and ecological settings.

Bibliography

Alavalapati, J., J. Matta, and G. Tanner. 2005. National commission on science for sustainable forestry.

Allais, M. 1953. Le comportement de l'homme rationnel devant le risque: Critique des postulats et axiomes de l'école américaine. *Econometrica: Journal of the Econometric Society* 21 (4): 503-46.

Andreoni, J. 1995. Cooperation in public-goods experiments: Kindness or confusion? *The American Economic Review* 85 (4): 891-904.

Andreoni, J. 1990. Impure altruism and donations to public goods: A theory of warm-glow giving. *The Economic Journal* 100 (401): 464-77.

Andreoni, J., and R. Petrie. 2004. Public goods experiments without confidentiality: A glimpse into fund-raising. *Journal of Public Economics* 88 (7-8): 1605-23.

Angrist, J. D., and A. B. Krueger. 2001. Instrumental variables and the search for identification: From supply and demand to natural experiments. *Journal of Economic Perspectives* 15 (4): 69-85.

Armsworth, P. R., B. E. Kendall, and F. W. Davis. 2004. An introduction to biodiversity concepts for environmental economists. *Resource and Energy Economics* 26 (2): 115-36.

Ball, Sheryl B., and Paula A. Cech. 1991. The what, when, and why of picking a subject pool. (0003), http://econpapers.repec.org/RePEc:feb:artefa:0003.

Banerjee, A. V., and E. Duflo. 2009. The experimental approach to development economics.

Bateman , I.J and K. G. Willis, ed. 1999. Valuing environmental preferences: Theory and practice of the contingent valuation method in the US, EU, and developing countries. New York: Oxford University Press.

Battalio, R., L. Samuelson, and J. Van Huyck. 2001. Optimization incentives and coordination failure in laboratory stag hunt games. *Econometrica* 69 (3): 749-64.

Baylis, K., S. Peplow, G. Rausser, and L. Simon. 2008. Agri-environmental policies in the EU and united states: A comparison. *Ecological Economics* 65 (4): 753-64.

Bean, M. J. 1998. The endangered species act and private land: Four lessons learned from the past quarter century. *Environmental Law Reporter News and Analysis* 28 : 10701-10.

Berninghaus, S. K., K. M. Ehrhart, and C. Keser. 2002. Conventions and local interaction structures: Experimental evidence* 1. *Games and Economic Behavior* 39 (2): 177-205.

Berninghaus, S. K., and U. Schwalbe. 1996. Conventions, local interaction, and automata networks. *Journal of Evolutionary Economics* 6 (3): 297-312.

Bianchi, F., C. J. H. Booij, and T. Tscharntke. 2006. Sustainable pest regulation in agricultural landscapes: A review on landscape composition, biodiversity and natural pest control. Paper presented at Proc. R. Soc. B.

Bichler, M. 2000. An experimental analysis of multi-attribute auctions. *Decision Support Systems* 29 (3): 249-68.

Blume Lawrence, E. 1993. The statistical mechanics of strategic interaction. *Games and Economic Behavior* 5 (3): 387-424.

Bockstael, N. E. 1996. Modeling economics and ecology: The importance of a spatial perspective. *American Journal of Agricultural Economics* 78 (5): 1168.

Boyd, J, K. Caballero and R.D. Simpson. 1999. The law and economics of habitat conservation.: Lessons from an analysis of easement acquisitions. Discussion paper 99-32. Resources for the Future.

Boylan R, T., and A. El-Gamal Mahmoud. 1993. Fictitious play: A statistical study of multiple economic experiments. *Games and Economic Behavior* 5 (2): 205-22.

Brandts, J., and D. J. Cooper. 2006. Observability and overcoming coordination failure in organizations: An experimental study. *Experimental Economics* 9 (4): 407-23.

Brown Jr, G. M., and J. F. Shogren. 1998. Economics of the endangered species act. *The Journal of Economic Perspectives* 12 (3): 3-20.

Bryan, B., Gatti, S., Connor, J., Garrod, M. and King, D. 2005. A NAP Market-Based Instrument Pilot Project (CSIRO Land and Water and the Onkaparinga Catchment Water Management Board).

Burns, Penny. 1985. "Experience and Decision Making: A Comparison of Students and Businessmen in a Simulated Progressive Auction," in *Research in Experimental Economics,* Vol. 3. V. L. Smith, ed. Greenwich, CT: JAI Press.

Burtraw, D., J. Goeree, C. A. Holt, E. Myers, K. Palmer, and W. Shobe. 2008. Collusion in auctions for emission permits.

Camerer, C.F. 2008. The potential of neuroeconomics. *Economics and Philosophy* 24: 369-79.

Cason, T. N., L. Gangadharan, and C. Duke. 2003. A laboratory study of auctions for reducing non-point source pollution. *Journal of Environmental Economics and Management* 46 (3): 446-71.

Cason, T. N., and L. Gangadharan. 2004. Auction design for voluntary conservation programs. *American Journal of Agricultural Economics* 86 (5): 1211.

Cassar, A. 2007. Coordination and cooperation in local, random and small world networks: Experimental evidence. *Games and Economic Behavior* 58 (2): 209-30.

Chamberlin, E. H. 1948. An experimental imperfect market. *The Journal of Political Economy*: 95-108.

Chattopadhyay. R and E. Duflo. 2004. Women as Policy Makers: Evidence from a Randomized Policy Experiment in India. Econometrica 72(5): 1409-43

Claassen, R., L. Hansen, M. Peters, V. Brenneman, M. Weinberg and others. Agri-Environmental Policy at the Crossroads: Guideposts on a Changing Landscape. AER 794, January 2001.

Claassen, R., A. Cattaneo, and R. Johansson. 2008. Cost-effective design of agri-environmental payment programs: US experience in theory and practice. *Ecological Economics* 65 (4): 737-52.

Cook, T. D., D. T. Campbell, and A. Day. 1979. *Quasi-experimentation: Design & analysis issues for field settings.* Houghton Mifflin Boston.

Cooper, R. W., D. V. DeJong, R. Forsythe, and T. W. Ross. 1990. Selection criteria in coordination games: Some experimental results. *The American Economic Review*: 218-33.

Davis, D.D. and C.A. Holt. 1993. Experimental Economics. Princeton University Press.

Devetag. G and A. Ortmann. 2007. When and why? A critical survey on coordination failure in the laboratory. *Experimental Economics* 10:331-44

Diamond, J. M. (1975). The island dilemma: lessons of modern biogeographic studies for the design of natural reserves. *Biological. Conservation* 7:129.

Dobbs, T. L., and J. N. Pretty. 2004. Agri-environmental stewardship schemes and" multifunctionality". *Applied Economic Perspectives and Policy* 26 (2): 220.

Donahue, D. (2005). The Endangered Species Act and Its Current set of Incentive Tools for Species Protection, in *Species at Risk: Using Economic Incentives to Shelter Endangered Species on Private Lands*, ed. J. F. Shogren, pp. 25. University of Texas Press, Austin.

Drukker, D. M. 2003. Testing for serial correlation in linear panel-data models. *Stata Journal* 3 (2): 168-77.

Duflo, E. 2001. Schooling and labor market consequences of school construction in indonesia: Evidence from an unusual policy experiment. *American Economic Review* 91 (4): 795-813.

Egan, A., D. Gibson, and R. Whipkey. 2001. Evaluating the effectiveness of the forest stewardship program in West Virginia. *Journal of Forestry* 99 (3): 31-6.

Ellison, G. 1993. Learning, local interaction and coordination. *Econometrica* 61: 1047.

Engel, S., S. Pagiola, and S. Wunder. 2008. Designing payments for environmental services in theory and practice: An overview of the issues. *Ecological Economics* 65 (4): 663-74.

Epstein, R.A. 1996. A conceptual approach to zoning. What's wrong with Euclid? *NYU Environmental Law Journal* 5: 277-91.

Faith, D. P. (1994). Phylogenetic pattern and the quantification of organismal biodiversity. *Phil. Trans. R.Soc. Lond. B* Vol. 345, pp. 45.

Falk, A., and E. Fehr. 2003. Why labor market experiments? *Labor Economics* 10 (4): 399-406.

Fiore, A. 2009. Experimental economics: Some methodological notes.

Fox, J., and A. Nino-Murcia. 2005. Status of species conservation banking in the united states. *Conservation Biology* 19 (4): 996-1007.

Gilpin, M. E. in *Viable Populations for Conservation* (ed. Soulé, M. E.) pp. 126 (Cambridge Univ. Press, New York, 1987).

Goeree, J. K., & Holt, C. A. (2005). An experimental study of costly coordination. *Games and Economic Behavior*, *51*, 349–364.

Gole, C., Burton, M., Williams, K.J., Clayton, F., Faith, D.P., White, B., Huggett, A. and Margules, C. (2005). *Auction for Landscape Recovery: ID 21 Final report, September 2005*. Commonwealth Market Based Instruments program, WWF Australia. Available from URL: http://www.napswq.gov.au/mbi/round1/project21.html [accessed 18 Aug 2006].

Hailu, A., and S. Schilizzi. 2004. Are auctions more efficient than fixed price schemes when bidders learn? *Australian Journal of Management* 29 (2): 147.

Hajkowicz, S., A. Higgins, K. Williams, D. P. Faith, and M. Burton. 2007. Optimisation and the selection of conservation contracts*. *Australian Journal of Agricultural and Resource Economics* 51 (1): 39-56.

Harrison, G. W., and J. A. List. 2004. Field experiments. *Journal of Economic Literature* 42 (4): 1009-55.

Harsanyi, J. C., and R. Selten. 1988. A general theory of equilibrium selection in games. *MIT Press Books* 1.

Hennessy, D. A. 2007. Biosecurity and spread of an infectious animal disease. *American Journal of Agricultural Economics* 89 (5): 1226.

Hertwig, R., and A. Ortmann. 2001. Experimental practices in economics: A methodological challenge for psychologists? *Behavioral and Brain Sciences* 24 (03): 383-403.

Hoggatt, A. C. 1959. An experimental business game. *Behavioral Science* 4 (3): 192-203.

Hua, W., C. Zulauf, and B. Sohngen. 2004. To adopt or not to adopt: Conservation decisions and participation in watershed groups. Paper presented at Selected Paper for Presentation at the American Agricultural Economics Association Annual Meeting, .

Hunt, J. 1992. The impact of the 1962 repatriates from Algeria on the French labor market. *Industrial and Labor Relations Review* 45 (3): 556-72.

Innes, R., S. Polasky, and J. Tschirhart. 1998. Takings, compensation and endangered species protection on private lands. *The Journal of Economic Perspectives* 12 (3): 35-52.

Jackson, M. O., and A. Wolinsky. 1996. A strategic model of social and economic networks. *Journal of Economic Theory* 71 (1): 44-74.

Kahneman, D. 1991. Judgment and decision making: A personal view. *Psychological Science* 2 (3): 142-5.

Kahneman, Daniel. 2003. Maps of bounded rationality: Psychology for behavioral economics. *The American Economic Review* 93 (5) (Dec.): 1449-75

Kahneman, D., and A. Tversky. 1982. The psychology of preferences. *Scientific American* 246 (1): 160-73.

Kahneman, D., and A. Tversky. 2000. *Choices, values, and frames.* Cambridge University Press.

Kandori, M., G. J. Mailath, and R. Rob. 1993. Learning, mutation, and long run equilibria in games. *Econometrica: Journal of the Econometric Society* 61 (1): 29-56.

Kareiva, P., S. Andelman, D. Doak, B. Elderd, M. Groom, J. Hoekstra, L. Hood, F. James, J. Lamoreux, and G. LeBuhn. 2005. Using science in habitat conservation plans. NCAEAS and American Institute of Biological Sciences

Kellerer, H., U. Pferschy, and D. Pisinger. 2004. *Knapsack problems*Springer Verlag.

Keser, C., K. M. Ehrhart, and S. K. Berninghaus. 1998. Coordination and local interaction: Experimental evidence. *Economics Letters* 58 (3): 269-75.

Kiesecker, J. M., T. Comendant, T. Grandmason, E. Gray, C. Hall, R. Hilsenbeck, P. Kareiva, L. Lozier, P. Naehu, and A. Rissman. 2007. Conservation easements in context: A quantitative analysis of their use by the nature conservancy. *Frontiers in Ecology and the Environment* 5 (3): 125-30.

Kingsbury, L., and W. Boggess. 1999. An economic analysis of riparian landowners' willingness to participate in Oregon's conservation reserve enhancement program. *Oregon State University Master's Thesis*.

Kirwan, B., R. N. Lubowski, and M. J. Roberts. 2005. How cost-effective are land retirement auctions? estimating the difference between payments and willingness to accept in the conservation reserve program. *American Journal of Agricultural Economics* 87 (5): 1239.

Kleijn, D., R. A. Baquero, Y. Clough, M. Diaz, J. Esteban, F. Fernández, D. Gabriel, F. Herzog, A. Holzschuh, and R. Jöhl. 2006. Mixed biodiversity benefits of agri-environment schemes in five european countries. *Ecology Letters* 9 (3): 243-54.

Kleijn, D., and W. J. Sutherland. 2003. How effective are european agri-environment schemes in conserving and promoting biodiversity? *Journal of Applied Ecology* 40 (6): 947-69.

Knetsch, J. L. 1989. The endowment effect and evidence of nonreversible indifference curves. *The American Economic Review* 79 (5): 1277-84.

Knetsch, J. L., and J. A. Sinden. 1984. Willingness to pay and compensation demanded: Experimental evidence of an unexpected disparity in measures of value. *The Quarterly Journal of Economics* 99 (3): 507-21.

Knop, E., D. Kleijn, F. Herzog, and B. Schmid. 2006. Effectiveness of the swiss agri-environment scheme in promoting biodiversity. *Journal of Applied Ecology* 43 (1): 120-7.

Lant, C.L.; Kraft, S.E.; Gillman, K.R. 1995. Enrollment of filter strips and recharge areas in the CRP and USDA easement programs. *Journal of Soil and Water Conservation* 50(2): 193.

Latacz-Lohmann, U., and I. Hodge. 2003. European agri-environmental policy for the 21st century. *Australian Journal of Agricultural and Resource Economics* 47 (1): 123-39.

Lecocq, S., T. Magnac, M. C. Pichery, and M. Visser. 2005. The impact of information on wine auction prices: Results of an experiment. *Annales d'Economie Et De Statistique*: 37-57.

Levitt, S., and J. List. 2007. What do laboratory experiments tell us about the real world? *Journal of Economic Perspectives* 21 (2): 153-74.

Levins, R. (1969). Some demographic and genetic consequences of environmental heterogeneity for biological control. *Bulletin of. Entomological. Society. America.* Vol. 15, pp**.** 237.

Loewenstein, George. 1999. Experimental economics from the vantage-point of behavioural economics. *The Economic Journal* 109 (453, Features) (Feb.): F25-34, http://www.jstor.org/stable/2565583.

Maddala, G.S. 1987. Limited dependent variables including panel data. The Journal of Human Resources 22(3): 307-38.

Mäntymaa, E., A. Juutinen, M. Mönkkönen, and R. Svento. 2009. Participation and compensation claims in voluntary forest conservation: A case of privately owned forests in finland. *Forest Policy and Economics* 11 (7): 498-507.

Margules, C. R., and R. L. Pressey. 2000. Systematic conservation planning. *Nature* 405 (6783): 243-53.

McAfee, R. P., and J. McMillan. 1996. Analyzing the airwaves auction. *Journal of Economic Perspectives* 10(1): 159-175.

Merckx, T., R. E. Feber, R. L. Dulieu, M. C. Townsend, M. S. Parsons, N. A. D. Bourn, P. Riordan, and D. W. Macdonald. 2009. Effect of field margins on moths depends on species mobility: Field-based evidence for landscape-scale conservation. *Agriculture, Ecosystems & Environment* 129 (1-3): 302-9.

Meyer, B. D. 1995. Natural and quasi-experiments in economics. *Journal of Business & Economic Statistics* 13 (2): 151-61.

Milgram, S. 1967. The small world problem. *Psychology Today* 2 (1): 60-7.

Milgrom, P. R., and R. J. Weber. 1982. A theory of auctions and competitive bidding. *Econometrica: Journal of the Econometric Society* 50 (5): 1089-122.

Miller, A.J. 1999. Transferable Development Rights in the constitutional landscape: Has Penn Central failed to weather the storm. *Natural Resources Journal* 39: 459-516.

Morris, S., C. Foundation, H. S. Shin, and H. Street. 2002. Measuring strategic uncertainty.

Mullainathan, S., and R. H. Thaler. 2000. Behavioral economics. *NBER Working Paper*.

Napier, T. L., C. S. Thraen, and S. M. Camboni. 1988. Willingness of land operators to participate in government-sponsored soil erosion control programs. *Journal of Rural Studies* 4 (4): 339-47.

Newark, W.D., (1987). A land-bridge island perspective on mammalian extinctions in western North American park. *Nature* Vol. 325, pp. 430.

Osborn, C. T., F. Llacuna, and M. Linsenbigler. 1990. The Conservation Reserve Program. Enrollment Statistics for Signup Periods 1-9 and Fiscal Year 1989. Washington DC: U.S. Department of Agriculture, ERS Statist. Bull. 811, 1990.

Panayotou, T. 1994. Conservation of biodiversity and economic development: The concept of transferable development rights. *Environmental and Resource Economics* 4 (1): 91-110.

Parkhurst, G. M., J. F. Shogren, C. Bastian, P. Kivi, J. Donner, and R. B. W. Smith. 2002. Agglomeration bonus: An incentive mechanism to reunite fragmented habitat for biodiversity conservation. *Ecological Economics* 41 (2): 305-28.

Parkhurst, G.M., J.F. Shogren (2005). An Economic Review of Incentive Mechanisms to Protect Species on Private Lands, in *Species at Risk: Using Economic Incentives to Shelter Endangered Species on Private Lands*, ed. J. F. Shogren, pp. 65. University of Texas Press, Austin.

Parkhurst, G.M., J.F. Shogren (2007). Spatial incentives to coordinate contiguous habitat. *Ecological Economics*, Vol: 64(2), pp.344.

Plott, C. R. 1982. Industrial organization theory and experimental economics. *Journal of Economic Literature*: 1485-527.

Plott, C. R. 1997. Laboratory experimental testbeds: Application to the PCS auction. *Journal of Economics & Management Strategy* 6 (3): 605-38.

Porter, Robert. H and J. Douglas Zona. 1999. Ohio school milk markets: An analysis of bidding. *The Rand Journal of Economics* 30 (2): 263.

Porter, Robert. H. and J. Douglas Zona. 1993. Detection of bid rigging in procurement auctions. *The Journal of Political Economy* 101 (3): 518.

Preston, M. G., and P. Baratta. 1948. An experimental study of the auction-value of an uncertain outcome. *The American Journal of Psychology* 61 (2): 183-93.

Reichelderfer, K., and W. G. Boggess. 1988. Government decision making and program performance: The case of the conservation reserve program. *American Journal of Agricultural Economics* 70 (1): 1.

Robertson, M. M. 2006. Emerging ecosystem service markets: Trends in a decade of entrepreneurial wetland banking. *Frontiers in Ecology and the Environment* 4 (6): 297-302.

Rolfe, J., and J. Windle. 2006. Using field experiments to explore the use of multiple bidding rounds in conservation auctions. *Canadian Journal of Agricultural Economics*.

Rolfe, J., J. Windle, and J. McCosker. 2009. Testing and implementing the use of multiple bidding rounds in conservation auctions: A case study application. *Canadian Journal of Agricultural Economics/Revue Canadienne d'Agroeconomie* 57 (3): 287-303.

Roth, A. E. 1988. Laboratory experimentation in economics: a methodological overview. *The Economic Journal* 98 (393): 974-1031.

Roth, A. 1993. The early history of experimental economics. *Journal of the History of Economic Thought* 15 (02): 184-209.

Roth, A. E. 1994. Lets keep the con out of experimental a methodological note. *Empirical Economics* 19 (2): 279-89.

Rousseas, S. W., and A. G. Hart. 1951. Experimental verification of a composite indifference map. *The Journal of Political Economy* 59 (4): 288-318.

Rubinstein, A. 2003. " Economics and psychology"? the case of hyperbolic discounting*. *International Economic Review* 44 (4): 1207-16.

Saïd, S., and S. Thoyer. 2007. Agri-environmental auctions with synergies. *LAMETA DR2007-07, University of Montpellier*.

Samuelson, L. 2005. Economic theory and experimental economics. *Journal of Economic Literature* 43 (1): 65-107.

Schram, A. 2005. Artificiality: The tension between internal and external validity in economic experiments. Journal of Economic Methodology 12(2): 225-37

Shabman, L., P. Scodari, and D. King. 1996. Wetland mitigation banking markets. *Mitigation Banking: Theory and Practice*: 109–138.

Shabman, L., K. Stephenson, and P. Scodari. 1998. Wetland credit sales as a strategy for achieving no-net-loss: The limitations of regulatory conditions. *Wetlands* 18 (3): 471-81.

Shogren, J. F. 2004. Incentive mechanism testbeds: Discussion. *American Journal of Agricultural Economics* 86 (5): 1218.

Shogren, J. F. 2005. *Species at risk: Using economic incentives to shelter endangered species on private lands*Univ of Texas Pr.

Shogren, J. F., J. A. List, and D. J. Hayes. 2000. Preference learning in consecutive experimental auctions. *American Journal of Agricultural Economics* 82 (4): 1016-21.

Siegel, S., and L. E. Fouraker. 1977. *Bargaining and group decision making: Experiments in bilateral monopoly.* Greenwood-Heinemann Publishing.

Simon, H. A. 1955. A behavioral model of rational choice. *The Quarterly Journal of Economics* 69 (1): 99-118.

Smith, C. M., J. M. Peterson, and J. C. Leatherman. 2007. Attitudes of great plains producers about best management practices, conservation programs, and water quality. *Journal of Soil and Water Conservation* 62 (5): 97A.

Smith, V. L. 1976. Experimental economics: Induced value theory. *The American Economic Review* 66 (2): 274-9.

Smith, V. L. 1964. Effect of market organization on competitive equilibrium. *The Quarterly Journal of Economics* 78 (2): 182-201.

Smith, V. L. 1962. An experimental study of competitive market behavior. *The Journal of Political Economy* 70 (2): 111-37.

Smith, V. L., G. L. Suchanek, and A. W. Williams. 1988. Bubbles, crashes, and endogenous expectations in experimental spot asset markets. *Econometrica: Journal of the Econometric Society*: 1119-51.

Stavins, R. N. 2003. Experience with market-based environmental policy instruments. *Handbook of Environmental Economics* 1 : 355-435.

Stewart, M. B. 2006. Maximum simulated likelihood estimation of random-effects dynamic probit models with autocorrelated errors. *Stata Journal* 6 (2): 256.

Stoneham, G., V. Chaudhri, A. Ha, and L. Strappazzon. 2003. Auctions for conservation contracts: An empirical examination of victoria's BushTender trial. *Australian Journal of Agricultural and Resource Economics* 47 (4): 477-500.

Straub, P. G. 1995. Risk dominance and coordination failures in static games. *The Quarterly Review of Economics and Finance* 35 (4): 339-63.

Thaler, R. H. and C. R. Sunstein. 2008. Nudge, Improving Decisions about Health, Wealth and Happiness.

Tear, T.H., Scott, J.M. Hayward, P.H. and B. Griffith. 1993. Status and prospects for success of the Endangered Species Act: a look at recovery plans. *Science* 262(5136): 976

Thaler, R. 1985. Mental accounting and consumer choice. *Marketing Science* 4 (3): 199-214.

Thaler, R. 1980. Toward a positive theory of consumer choice. *Journal of Economic Behavior & Organization* 1 (1): 39-60.

Thaler, R. H. 2000. From homo economicus to homo sapiens. *The Journal of Economic Perspectives* 14 (1): 133-41.

Thurstone, L. L. 1931. The indifference function. *Journal of Social Psychology* 2 (13): 167.

Tversky, A., and D. Kahneman. 1992. Advances in prospect theory: Cumulative representation of uncertainty. *Journal of Risk and Uncertainty* 5 (4): 297-323.

Tversky, A., and D. Kahneman. 1974. Judgment under Uncertainty. Heuristics and Biases. Science 185(4157): pp. 1124-1131.

Tversky, A., and D. Kahneman. 1986. Rational choice and the framing of decisions. *Journal of Business* 59 (S4).

Van Huyck, J. B., R. C. Battalio, and R. O. Beil. 1991. Strategic uncertainty, equilibrium selection, and coordination failure in average opinion games. *The Quarterly Journal of Economics* 106 (3): 885-910.

Van Huyck, J. B., R. C. Battalio, and R. O. Beil. 1990. Tacit coordination games, strategic uncertainty, and coordination failure. *The American Economic Review*: 234-48.

Van Huyck, J. B., R. C. Battalio, and F. W. Rankin. 2007. Evidence on learning in coordination games. *Experimental Economics* 10 (3): 205-20.

Vane-Wright, R. I., C. J. Humphries, and P. H. Williams. 1991. What to protect?--systematics and the agony of choice. *Biological Conservation* 55 (3): 235-54.

Wallis, W. Allen and Milton Friedman. 1942. "The Empirical Derivation of Indifference Functions," in Studies in Mathematical Economics and Econometrics in memory of Henry Schultz, O. Lange, F. McIntyre, and T.O. Yntema, editors, Chicago, University of Chicago Press, 175-189.

Warziniack, T., J. F. Shogren, and G. Parkhurst. 2007. Creating contiguous forest habitat: An experimental examination on incentives and communication. *Journal of Forest Economics* 13 (2-3): 191-207.

Weems, WA, and L. W. Canter. 1995. Planning and operational guidelines for mitigation banking for wetland impacts. *Environmental Impact Assessment Review* 15 (3): 197-218.

Willis, E.O. (1979). The composition of avian communities in luminescent woodlots in southern Brazil. *Papeis Avulsos de Zoologia*, Sao Paulo 33, 1–25.

Wilson, E. O. & Willis, E. O. in *Ecology and Evolution of Communities* (eds Cody, M. L. & Diamond, J. M.) pp. 522 (Belknap, Cambridge, MA, 1975).

Windle, J., and J. Rolfe. 2008. Exploring the efficiencies of using competitive tenders over fixed price grants to protect biodiversity in Australian rangelands. *Land use Policy* 25 (3): 388-98.

Wooldridge, J. M. 2002. *Econometric analysis of cross section and panel data*The MIT press.

Wünscher, T., S. Engel, and S. Wunder. 2008. Spatial targeting of payments for environmental services: A tool for boosting conservation benefits. *Ecological Economics* 65 (4): 822-33.

Appendix A

Experimental Instructions

I. Agglomeration Bonus Study

Thank you for participating in today's experiment. You have been provided with a sheet which has your unique participant number for this experiment. This is your ID. This number is private and should not be shared with anyone. Please enter your ID before continuing. Please enter the number exactly as it appears on your sheet.

General Information:

This is an experiment in decision making. In today's experiment you will participate in a group decision task which involves choosing between **two actions**. In addition to a $5 participation fee, you will be paid the money you accumulate from your choices which will be described to you in a moment. Upon the completion of the experiment, your earnings will be added up and you will be paid privately, in cash. The exact amount you will receive will be determined during the experiment and will depend on your decisions and the decisions of others. From this point forward all units of account will be in **experimental dollars**. At the end of the experiment, experimental dollars will be converted to U.S. dollars at the rate of 1 U.S. dollars for every 35 experimental dollars. If you have any questions during the experiment, please raise your hand and wait for the experimenter to come to you. Please do not talk, exclaim, or try to communicate with other participants during the experiment. Participants intentionally violating the rules may be asked to leave the experiment and may not be paid.

Group Decision Task

The experiment will have **twenty periods**. In each period you will be in a group with **11** other participants. During this experiment each of you will assume the role of a landowner who has two kinds of parcels on their property denoted by **M** and **K**. You will receive payoffs from managing the land on any of these parcels. All the players including you are arranged around a circular grid which is shown in the handout that you have been provided. This grid represents the landscape on which your properties are located. On this grid every parcel is marked by **M** or **K**. The number attached to both M and K denotes subject ID. Thus if your ID is **8**, then parcels **M8** and **K8** constitute your property.

On this grid you have two neighbors, one on each side. The hole in the centre indicates that the player diametrically opposite to you is not your neighbor. Your neighbors will be the **same** in all periods. You will never know the identity of your neighbors. Your ID will determine who your neighbors are. Please keep in mind that every player has a **different** set of neighbors. Thus if you are player **11** then your neighbors are players **10** and **12**. Player **12** has **you** and player **1** as neighbors.

In each period, each one of you will make a choice between managing **parcel M** and **parcel K**. You will each receive money based on your choice and the choices of your neighbors. In a moment we will give you a detailed description of your choices and how your payment will be determined. Please raise your hand if there are any questions otherwise click "Continue"

Your Payment from Group Decision Task:

In each period of the experiment, the computer will display the table shown below. This table is the same for everyone and is the same for all periods of this experiment. The amounts shown in the table reflect the possible payments you might receive for that period, based on your choice and the choices of your neighbors. Each number in the table corresponds to a payment (**in experimental dollars**) resulting from a possible combination of your choice (row) and your neighbors' choices (column). Your choice of strategy M corresponds to your position on the grid on the parcel marked by **M and your ID**. Your choice of strategy K corresponds to your position on the parcel marked by **K and your ID**. Please take a moment to look over the table. Whenever you are making a choice, you will be able to see this table. Your payoff depends upon your management decision **(M or K)** and that of your two neighbors. In general, your payoff increases when you manage the same parcels.

Making a choice in a period:

Once the period starts, each of you will choose a strategy **(M or K)** by clicking on one of the buttons that will appear on the right of your screen. You may change your choice as often as you like, but once you click on **OK** your choice for that period is final. Note that when you are making your choice, you will not know the choices of others. Also, remember that you will never know the identity of anyone else in your group, meaning that all choices are confidential and that no one will ever know what choices you make.

At the end of each period, your screen will display your strategy and the choices of other players, your payment for the current period, your neighbors' payments and your accumulated payment through the current period. At the end of the experiment, you will receive the sum of your payments from all twenty periods. This will be paid to you privately in cash. We are now ready to begin the experiment. On the next screen you will participate in a quiz. Please note that this is a non-paying period and your answers in this quiz will not influence your payoffs at the end of the experiment.

Quiz (non-paying period)

Before we begin the experiment, we would like you participate in the quiz below. Your answers should be based on the payoff table shown. Please raise your hand if you are having trouble answering any of the questions. Once you are finished please click "Continue".

1. Suppose one of your neighbors plays strategy M and the other plays strategy K. Then your payoff from playing strategy M is? 18
2. My neighbor has the same neighbors as I do. FALSE
3. Your neighbors change in every period. FALSE
4. What is your payoff when you chose K and all your neighbors chose M? 27

We are now ready to begin the experiment. On the next screen you will be able to see the payoff table. Please make a choice. You will be paid on the basis of all the choices you make henceforth.

How to read the Results Table

On the next screen you will be able to see two tables. The first table records your and your neighbors' choices for **the present period**. Your choice is in the cell at the centre of the table. Your neighbors' choices are recorded in cells on your left and right. The second table is the **History Table** and records your choices and those of your neighbors for **all periods** of this experiment. It also shows your profit for the present period as well as your total profit across all periods. Please raise your hand if there are any questions otherwise click "Continue"

II. Scoring Auctions

General Information

This is an experiment in decision making. In today's experiment you will participate in an auction. In addition to a $5 participation fee, you will be paid the money you accumulate during the auction which will be described to you in a moment. Upon the completion of the experiment, your earnings will be added up and you will be paid privately, in cash. The exact amount you will receive will be determined during the experiment and will depend on your decisions and the decisions of others. From this stage onwards all units of account will be in \b experimental dollars\b0. At the end of the experiment, experimental dollars will be converted to U.S. dollars at the rate of 1 U.S. dollar for 40 experimental dollars.

If you have any questions during the experiment, please raise your hand and wait for the experimenter to come to you. Please do not talk, exclaim, or try to communicate with other participants during the experiment. Participants intentionally violating the rules may be asked to leave the experiment and may not be paid. Once you are ready, please press Continue.

Description of the player environment:

In this experiment, you will participate in series of auction periods where you will bid to sell your item to a **single buyer**. In each auction period you will be in a group with **5** other participants. All of you will be arranged around a **circular grid**. On this grid you have two neighbors, one on each side. Your neighbors will be the **SAME** in all periods. Your Subject ID determines who your neighbors are. For example, if you are player \b 5 \b0 then your neighbors are players **4** and **6** and player **6** has you and player **1** as neighbors. During each auction period you will submit offers to sell your item. You have a cost associated with selling the item, which will be known to you at the time you bid in the auction. You make money by selling the item above your cost. For example if your cost is 50 this period, and you sell the item for 100, then your profits this period would be (100-50) or 50. If you do not sell the item, you do not pay the cost and receive your offer so that your profits for that period are zero. Your costs may also change from period to period, and they may be different from the costs of other participants.

Your item also has a **QUALITY** that is known and valued by the buyer. Your quality levels may change from one period to another period, and may be different from the quality levels of other participants.

The computer will play the role of the buyer in the auction. Each auction period will have **multiple rounds** during which you will be able to submit an offer for your item. The value of your offer, the quality of your item and the quality and offers of others' items will determine whether you will win in the auction or not. If you win and your item is selected, you will be able to sell your item and obtain your offer.

Notice that if you sell your item for a price that is less than its cost, then you lose money on that sale. The quality of your item will play an important role in determining the winners in the auction. Higher the quality of your item; higher are your chances of winning. Also while you cannot influence the quality of your item, you can choose the value of your offer to improve your chances of winning. High offer values increase your earnings if you win in the auction but may have a negative impact on your chances of winning. Please raise your hand if there are any questions otherwise click "Continue"

Description of auction environment:

Every auction period will have multiple rounds. In each round you will submit an offer that indicates the amount you wish to receive for your item. After everyone submits their offers, the computer will evaluate the total quality and the costs (on the basis of offers submitted) of different **combinations** of items. We will describe this process in more detail shortly.

Once all possible combinations have been evaluated, the computer will compute a SCORE – sum of ratios of total quality (to be defined later) and cost – for each combination and rank them in decreasing order of magnitude. It will then choose the combination of items that has the highest rank, spending all or a part of the fixed and constant **budget** that is available in the auction. In the case of a **tie**, between two or more combinations, where the computer cannot purchase both, it will randomly determine which combination to select.

Description of bidding across rounds:

In any auction period there are multiple rounds. You will have multiple chances to submit offers in these rounds. If you are not selected in a round, you can submit a different offer in the next round. If you have not won in the current round, you can improve your chances of winning in the next round by submitting a different offer. Please note that the computer wants to buy items from you and 5 other players - your opponents, spending the least amount of money. Thus if your offer has not been accepted in the current round an increase in your offer will not improve your chances of winning. However reducing your offer may improve your chances of being chosen in the next round. Please raise your hand if there are any questions otherwise click "Continue"

Information available to you after your have made an offer:

At the end of every auction round, you will see a results screen. On this screen you will be informed whether your offer has been accepted in the current round, which other participants have been accepted in the current round and your SCORE in the current round. Your SCORE in a round depends on your **total quality and your offer**.

The total quality of your item is calculated on the basis of the quality of your item, a constant term B and the number of selected neighbors. Thus

$$\text{Total Quality} = \text{Quality} + N*B$$

N represents the number of your neighbors that are selected. Since every player has two neighbors, N can either be 2 or 1. If N = 0, this implies that none of your neighbors are selected.

Please remember that once the computer has chosen a combination of offers, this will determine the SCORE for the winning combination along with a set of sellers who are the **provisional winners** in a round. If this of winning score increases in the next round, then the auction period will continue into the next round. The final offer round will be announced only after it is completed, and which round is final may vary from auction period to period. A round qualifies as a final round if the SCORE of the provisionally winning combination in the current round is higher than that obtained in the preceding round AND at least 5 rounds have been played. When the auction period ends the provisional winners will become the winners of the current period and will be paid the amount of their offers. Please raise your hand if there are any questions otherwise click "Continue"

Example of how winners are determined in an auction period

Let us consider an example of how winners are determined in the auction. Suppose there are four participants arranged around the circular grid. The table below contains their items' cost, quality and the offers they submit. Let the total budget be $20 and B = 5. Let there be two rounds in the auction. **Please note that in the actual auction, you will not know the total number or final round, your quality as well as the quality levels or the cost levels of others participants' items**.

Once the offers have been made in Round 1, the computer calculates the SCORE – a sum of ratio of total quality and cost of all items in a combination. Please note that in order to evaluate a combination, the sum of offers must be less than or equal to the budget $20. In this example with a budget of $20 and offers in Round 1, the combinations of items (1, 2), (2, 3) and (3, 1) can be bought. Now the computer evaluates the scores for these combinations and it finds that both (1, 2) and (2, 3) has the same score of 4.625. Since the computer cannot purchase all the three items, suppose it picks combination (2, 3) at random. Thus participants 2 and 3 are chosen as the **provisional winners** in the current round.

This information is announced to all participants. The auction then proceeds to the next round. Suppose every losing participant must reduce their offers by an amount at least equal to 50 experimental cents if not more. As a result, we get a new set of offers in Round 2 as represented in the table. Please note that since participants 2 and 3 win in the preceding round they have no incentive to change their offers in the current round 2.

With the new set of offers the computer repeats the same procedure and combination (1, 2) has the highest score of 4.758. Thus in the current round participants 1 and 2 are selected to be provisionally winning. Now since the SCORE has gone up from 4.625 to 4.758 and the auction has 2 rounds, the period ends and participants 1 and 2 become the winners of the auction in the current period. They are then paid the value of their offers. There will be a practice round in the beginning of the experiment to give you an idea about how the auction will proceed.

Quiz:

1. Your neighbors are the same in all periods of the auction TRUE
2. Your costs and benefits can change from auction period to period TRUE
3. Your earnings depend on your costs and your bids TRUE
4. You are part of the winning combination if the provisionally winning combination in the current round is unchanged in the next round TRUE
5. If the cost of your item is $100 and your offer is $150 and you are a winner in the auction, your earnings are? $50

Please raise your hand if there are any questions otherwise click "OK" to participate in the auction.

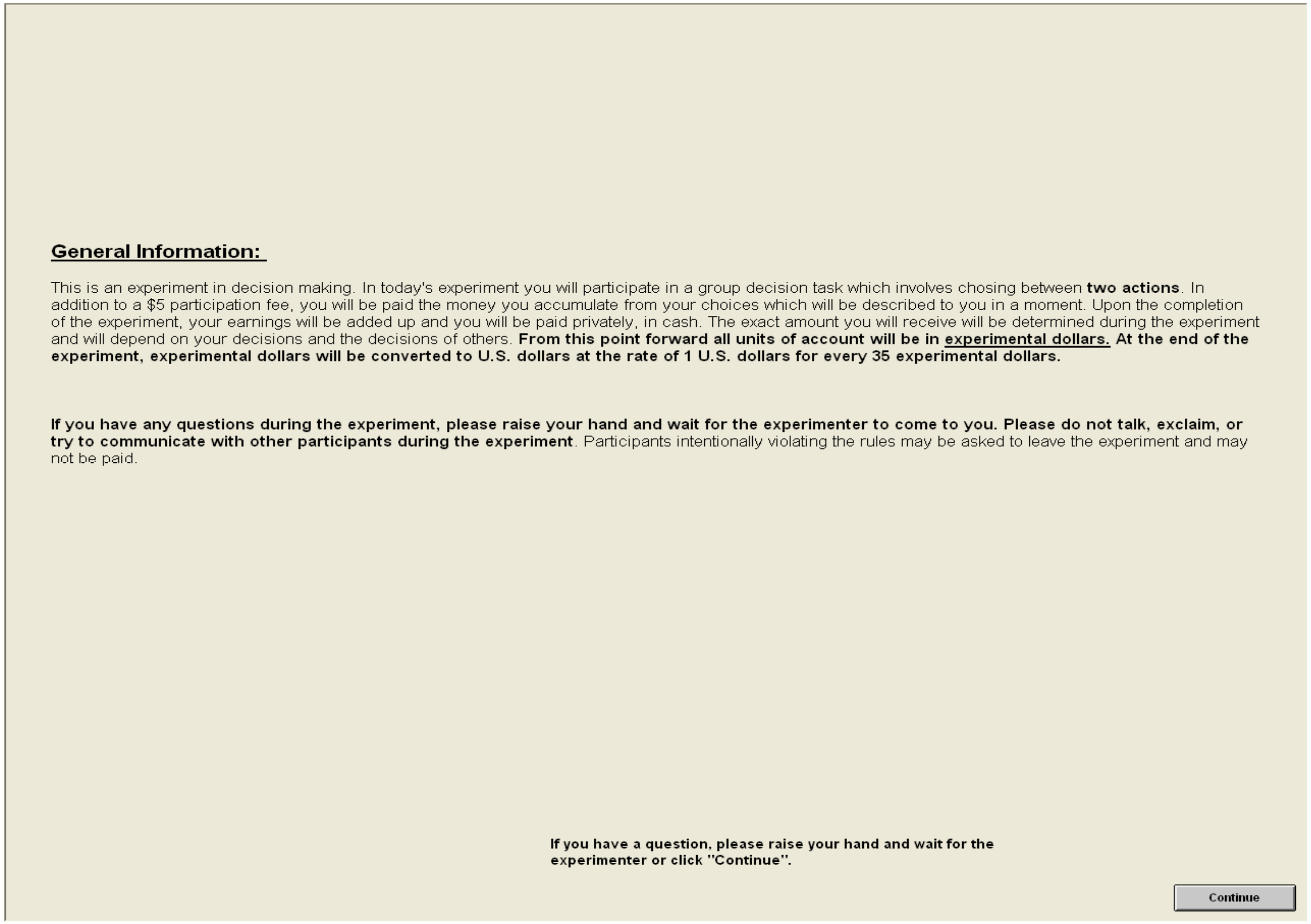
III Myopic Best Response and Individual Behavior

In the study of strategic interactions in overlapping open neighborhoods an important aspect of agent behavior in local interaction settings is the manner in which other players' actions in the group impact actions of each player. This is especially important given the overlapping interaction structure in the open neighborhood. There are different types of theories that explain how agents learn from their neighbors' actions in local interaction networks. These include belief reinforcement models (Boylan and El-Gamal, 1993) and myopic best response (Berninghaus and Schwalbe, Berninghaus et al.). Myopic Best Response or Local Best Response assumes that subjects make decisions on the basis of their neighbors' responses *only*. This is a simplification of the complex strategic interactions in the open neighborhood where neighborhoods are overlapping and even non-neighbors impact a player's actions and payoffs. This myopic best response assumption captures two aspects of agent behavior. First, it captures the rationality of agents whereby their actions depend on their neighbors' actions. Second, it represents their myopic response that does not consider the overlapping nature of the strategic interactions in the open neighborhoods whereby non-neighbors influence actions as well (Berninghaus and Schwalbe 1996).

This assumption is a simplification may be considered objectionable. Yet, experimental evidence on choices indicates that players respond on the basis of neighbors' choices from the past period (Berninghaus and Schwalbe, Berninghaus et al.). Second, for an overlapping interaction structure like a circle, including non-neighbor's choices as explaining a player's choices without having any theoretical formulation supporting this inclusion is undesirable. Moreover indirect impacts may not be very strong and even if considered may not contribute appreciably to the explanatory power of the model. Finally, in real landscapes with many stakeholders, it is not possible to base one's own decision on actions of landowners geographically situated far away from oneself even if an indirect influence can exist. Given these factors, the regression analysis in this research considers the impact of the direct neighbors only and does not include any second or higher order term to represent actions of non-neighbors

Appendix B Screen Shots

Figure B- 1: Screen 1(AB)



General Information:

This is an experiment in decision making. In today's experiment you will participate in a group decision task which involves chosing between **two actions**. In addition to a $5 participation fee, you will be paid the money you accumulate from your choices which will be described to you in a moment. Upon the completion of the experiment, your earnings will be added up and you will be paid privately, in cash. The exact amount you will receive will be determined during the experiment and will depend on your decisions and the decisions of others. **From this point forward all units of account will be in experimental dollars. At the end of the experiment, experimental dollars will be converted to U.S. dollars at the rate of 1 U.S. dollars for every 35 experimental dollars.**

If you have any questions during the experiment, please raise your hand and wait for the experimenter to come to you. Please do not talk, exclaim, or try to communicate with other participants during the experiment. Participants intentionally violating the rules may be asked to leave the experiment and may not be paid.

If you have a question, please raise your hand and wait for the experimenter or click "Continue".

Continue

Figure B- 2: Screen 2(AB)

Group Decision Task:

The experiment will have **twenty periods**. In each period you will be in a group with **11** other participants. During this experiment each of you will assume the role of a landowner who has two kinds of parcels on their property denoted by **M** and **K** . You will receive payoffs from managing the land on any of these parcels.

All the players including you are arranged around a circular grid which is shown in the handout that you have been provided. This grid represents the landscape on which your properties are located. On this grid every parcel is marked by **M** or **K**. The number attached to both M and K denotes subject ID. Thus if your ID is 8, then parcels **M8** and **K8** constitute your property.

On this grid you have two neighbors, one on each side. The hole in the centre indicates that the player diametrically opposite to you is not your neighbor. Your neighbors will be the **same** in all periods. You will never know the identity of your neighbors.

Your ID will determine who your neighbors are. Please keep in mind that every player has a **different** set of neighbors. Thus if you are player **11** then your neighbors are players **10** and **12**. Player **12** has **you** and player **1** as neighbors.

In each period, each one of you will make a choice between managing **parcel M** and **parcel K**. You will each receive money based on your choice and the choices of your neighbors. In a moment we will give you a detailed description of your choices and how your payment will be determined.

Please raise your hand if there are any questions otherwise click "Continue".

Continue

Figure B- 3: Screen 3(AB)

Your Payment from Group Decision Task:

In each period of the experiment, the computer will display the table shown below. This table is the same for everyone and is the same for all periods of this experiment. The amounts shown in the table reflect the possible payments you might receive for that period, based on your choice and the choices of your neighbors. Each number in the table corresponds to a payment (**in experimental dollars**) resulting from a possible combination of your choice (row) and your neighbors' choices (column). Your choice of strategy M corresponds to your position on the grid on the parcel marked by **M and your ID**. Your choice of strategy K corresponds to your position on the parcel marked by **K and your ID**.

Please take a moment to look over the table. Whenever you are making a choice, you will be able to see this table. Your payoff depends upon your management decision (M or K) and that of your two neighbors. In general, your payoff increases when you manage the same parcels.

Payoff Table

Strategy Chosen by My Neighbors

		Both Manage M	One M & Other K	Both Manage K
My Strategy	Manage M	36	18	0
	Manage K	27	24	21

Continue

Figure B- 4: Screen 4(AB)

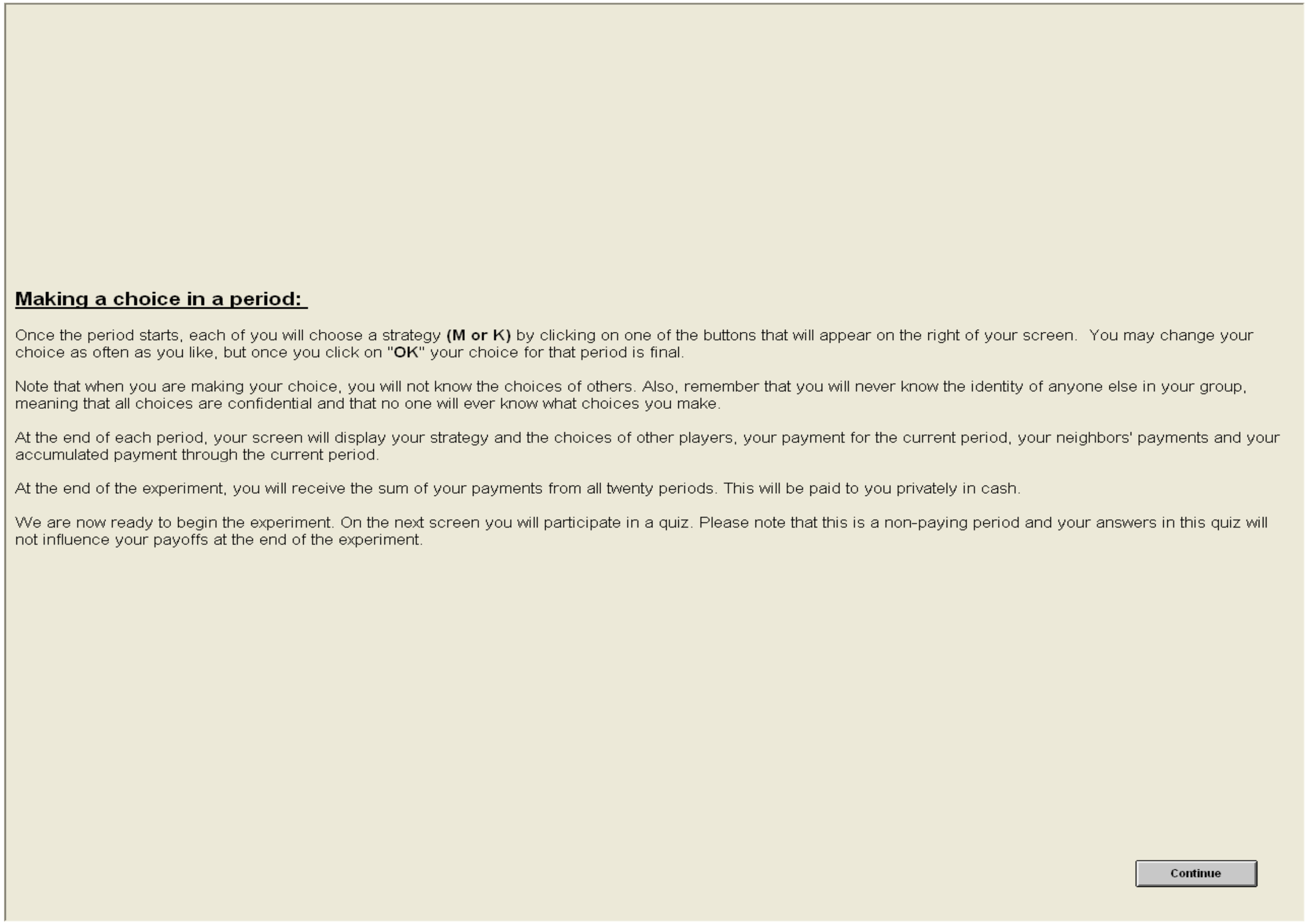
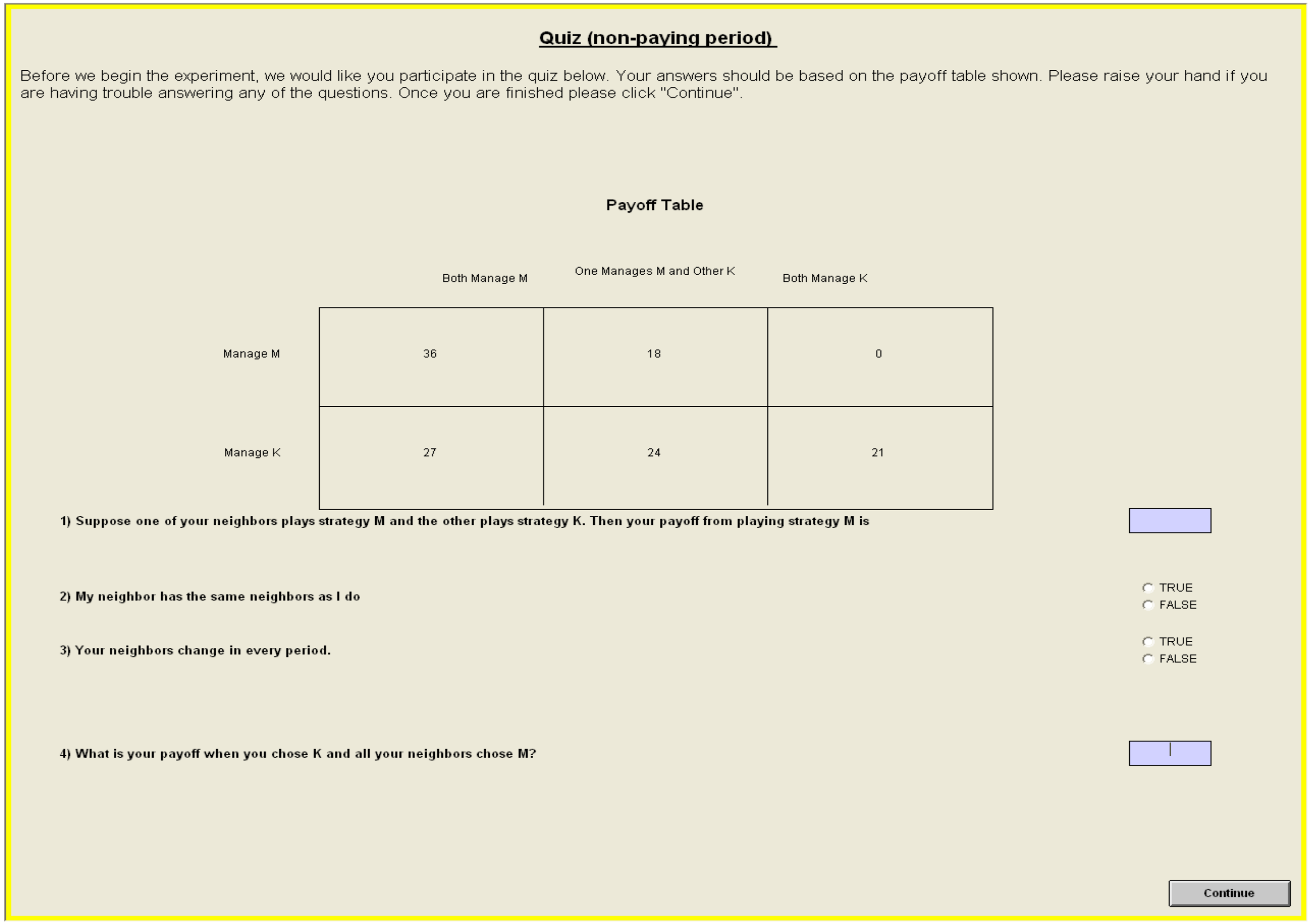


Figure B- 5: Screen 5(AB)



Quiz (non-paying period)

Before we begin the experiment, we would like you participate in the quiz below. Your answers should be based on the payoff table shown. Please raise your hand if you are having trouble answering any of the questions. Once you are finished please click "Continue".

Payoff Table

	Both Manage M	One Manages M and Other K	Both Manage K
Manage M	36	18	0
Manage K	27	24	21

1) Suppose one of your neighbors plays strategy M and the other plays strategy K. Then your payoff from playing strategy M is

2) My neighbor has the same neighbors as I do

TRUE

FALSE

3) Your neighbors change in every period.

TRUE

FALSE

4) What is your payoff when you chose K and all your neighbors chose M?

Continue

Figure B- 6: Screen 6(AB)

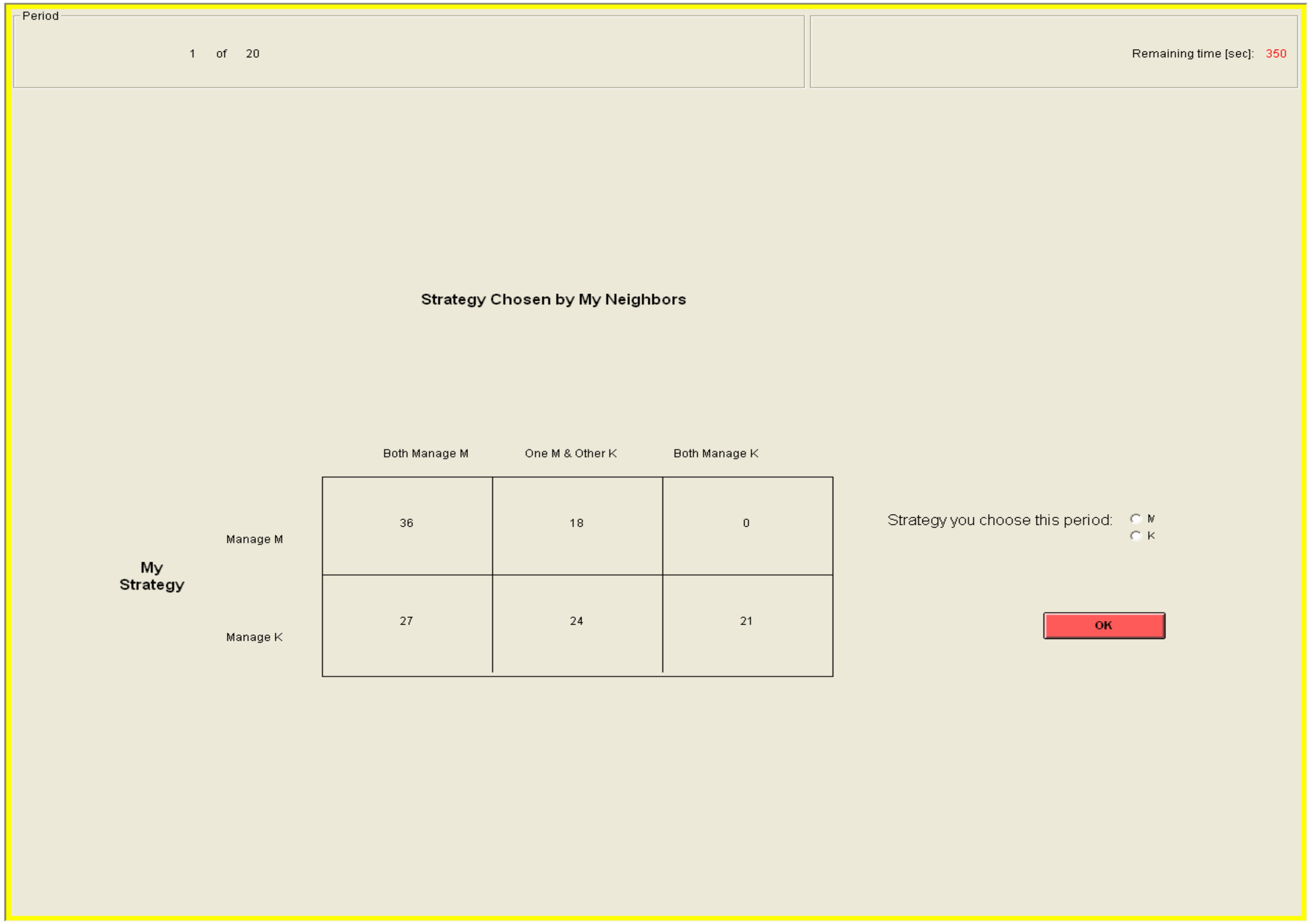


Figure B- 7: Screen 7(AB)

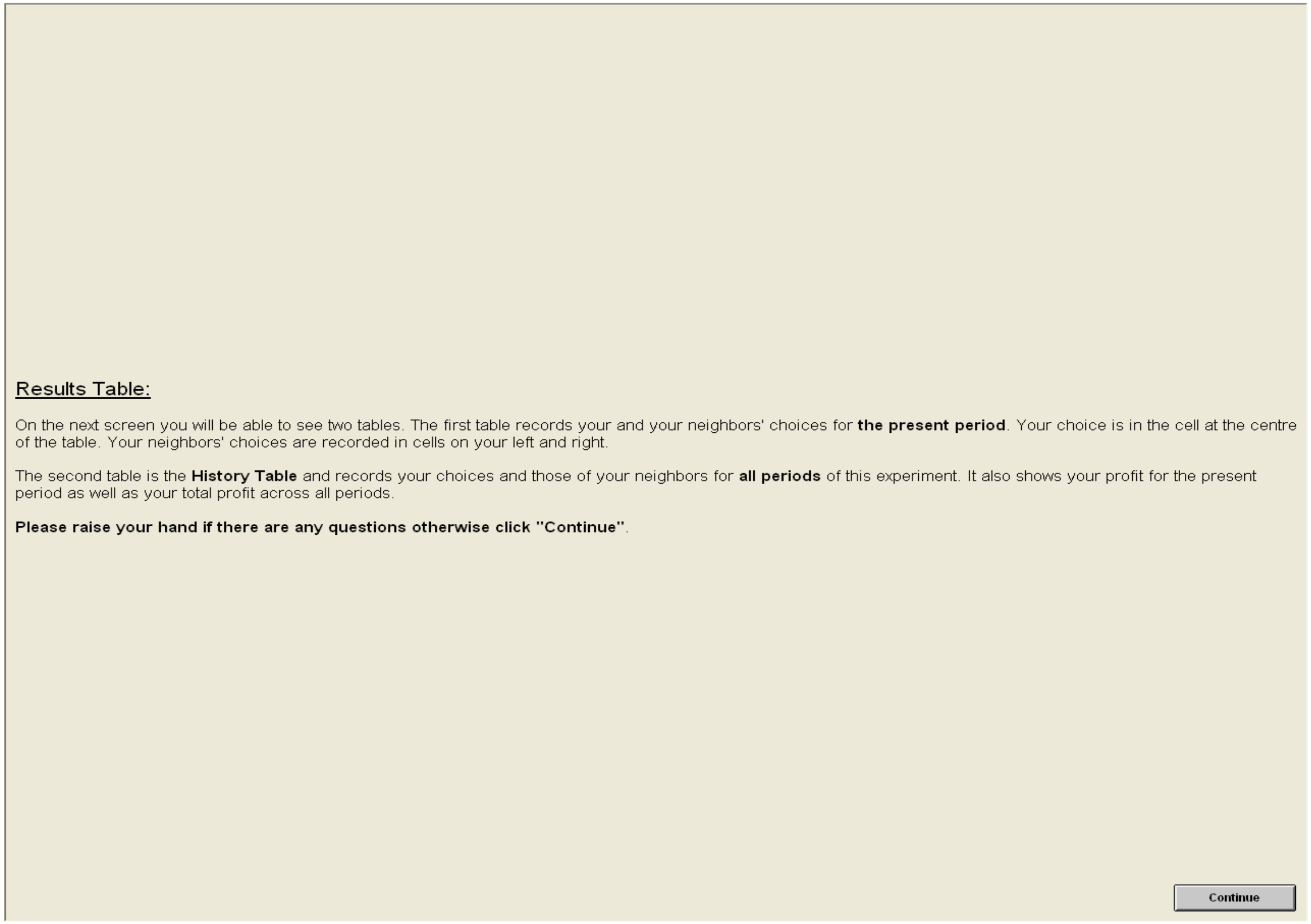


Figure B- 8: Screen 8 (AB)

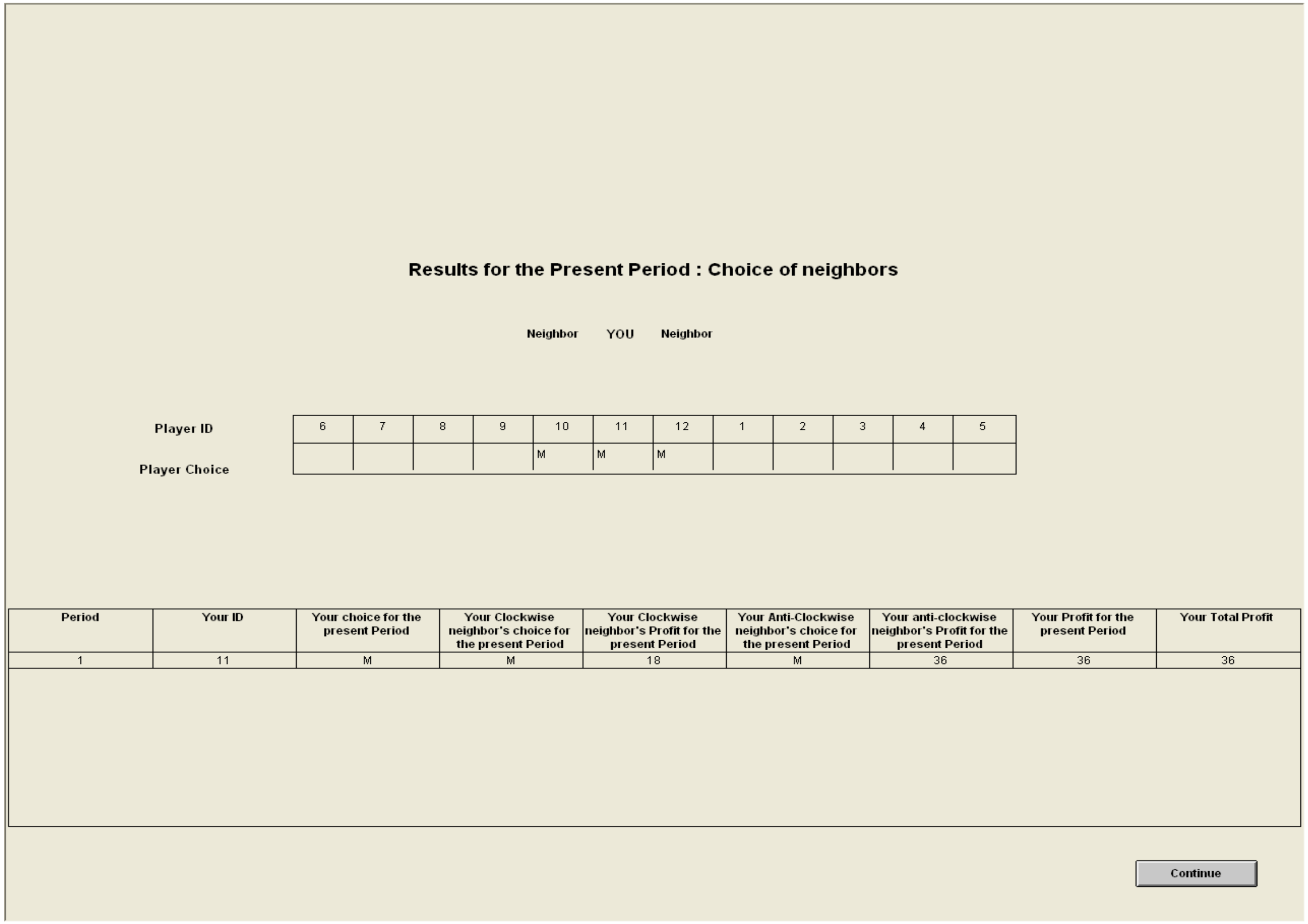


Figure B- 9: Screen 9(AB)

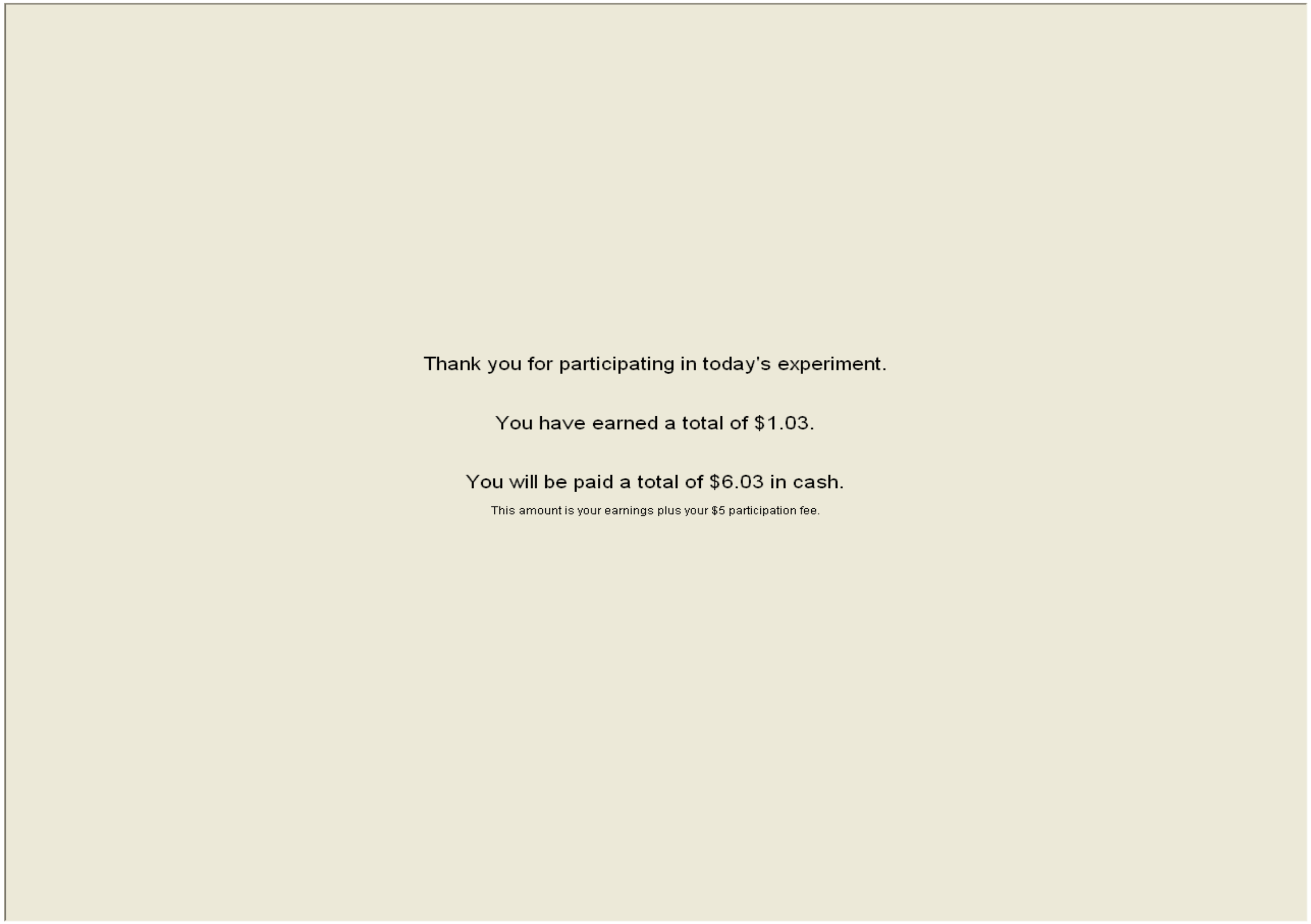


Figure B- 10: Screen 10(AB)

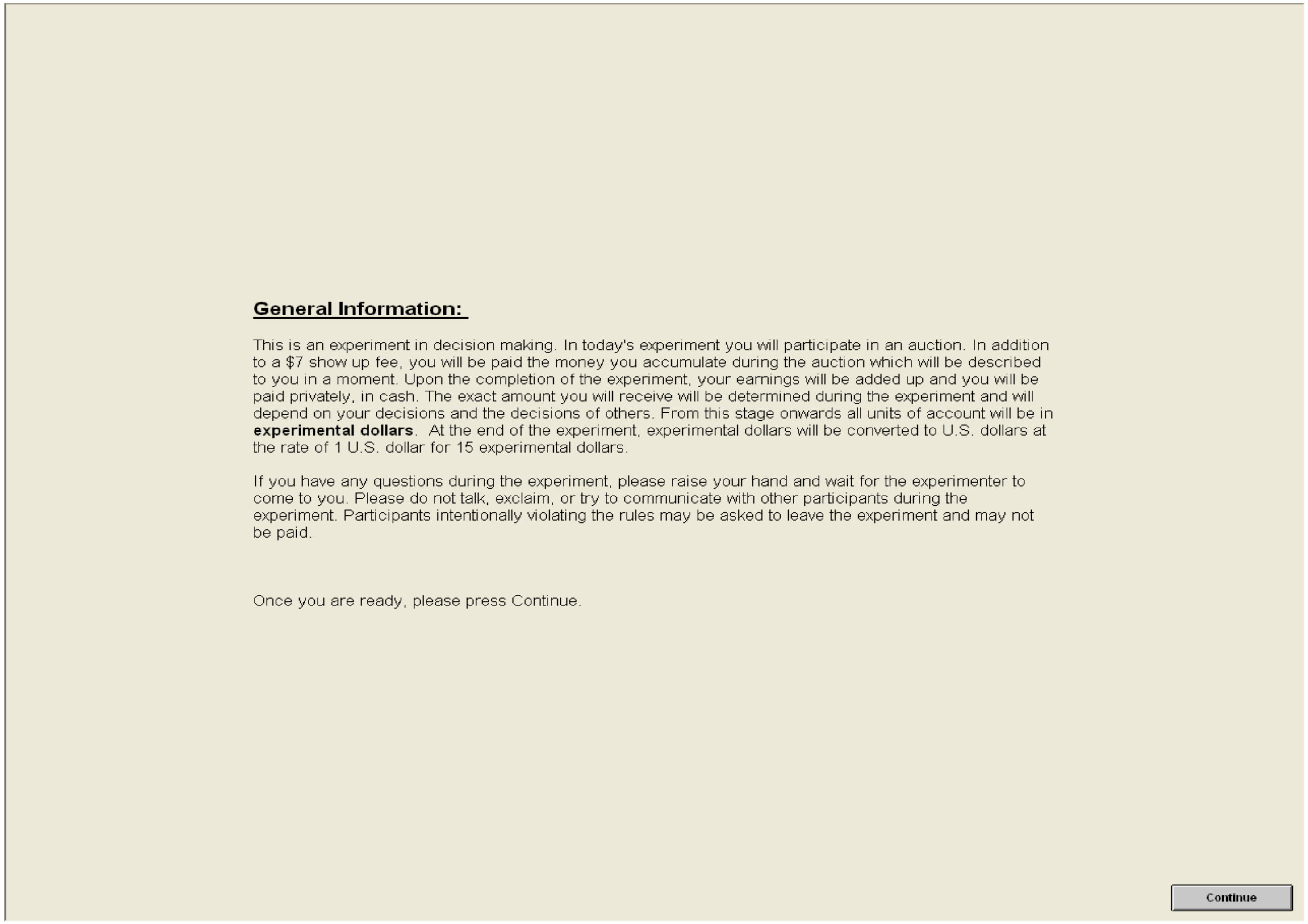


Figure B- 11: Screen 1(Auction)

Description of the player environment:

In this experiment, you will participate in 13 auction periods where you will bid to sell your item to a **single buyer** .

In each auction period you will be in a group with **5** other participants. All of you will be arranged around a **circular grid** . On this grid you have two neighbors, one on each side. Your neighbors will be the **SAME** in all periods. Your Subject ID determines who your neighbors are. For example, if you are player **5** then your neighbors are players **4** and **6** and player **6** has you and player **1** as neighbors.

During each auction period you will submit offers to sell your item. You have a cost associated with selling the item, which will be known to you at the time you bid in the auction. You make money by selling the item above your cost i.e.

Profits = Selling Price - Cost

For example, if your cost is 50 this period, and you sell the item for 100, then your profits this period would be (100-50) or 50. If you do not sell the item, you do not pay the cost and don't receive your offer so that your profits for that period are zero. Your costs may also change from period to period, and they may be different from the costs of other participants.

Your item also has a **QUALITY** that is known and valued by the buyer. Your quality levels may change from one period to another period, and may be different from the quality levels of other participants.

The computer will play the role of the buyer in the auction. Each auction period will have **multiple rounds** during which you will be able to submit an offer for your item. The value of your offer, the quality of your item and the quality and offers of others' items will determine whether you will win in the auction or not. If you win and your item is selected, you will be able to sell your item and obtain the value of your offer.

Notice that if you sell your item for a price that is less than its cost, then you lose money on that sale. The quality of your item will play an important role in determining the winners in the auction. Higher the quality of your item; higher are your chances of winning. Also while you cannot influence the quality of your item, you can choose the value of your offer to improve your chances of winning. High offer values increase your earnings if you win in the auction but may have a negative impact on your chances of winning.

Please raise your hand if there are any questions otherwise click "Continue"

Continue

Figure B- 12: Screen 2(Auction)

Description of auction:

Every auction period will have multiple rounds. In each round you will submit an offer that indicates the amount you wish to receive for your item. After everyone submits their offers, the computer will evaluate the quality and the costs (on the basis of offers submitted) of different **combinations** of items. We will describe this process in more detail shortly.

Once all possible combinations have been evaluated, the computer will compute a SCORE - a ratio based on the quality and cost of each item in the combination and rank them in decreasing order of magnitude. It will then choose the combination of items that has the highest SCORE, spending all or a part of the fixed and constant **budget** that is available in the auction. In the case of a **tie**, between two or more combinations, where the computer cannot purchase both, it will randomly determine which combination to select.

Description of bidding across rounds:

In any auction period there are multiple rounds. You will have multiple chances to submit offers in these rounds. If you are not selected in a round, you can submit a different offer in the next round. If you have not won in the current round, you can improve your chances of winning in the next round by submitting a different offer. Please note that the computer wants to buy items from you and 5 other players - your opponents, spending the least amount of money. Thus if your offer has not been accepted in the current round a decrease in your offer may improve your chances of winning in the next round.

Please raise your hand if there are any questions otherwise click "Continue"

Continue

Figure B- 13: Screen 3(Auction)

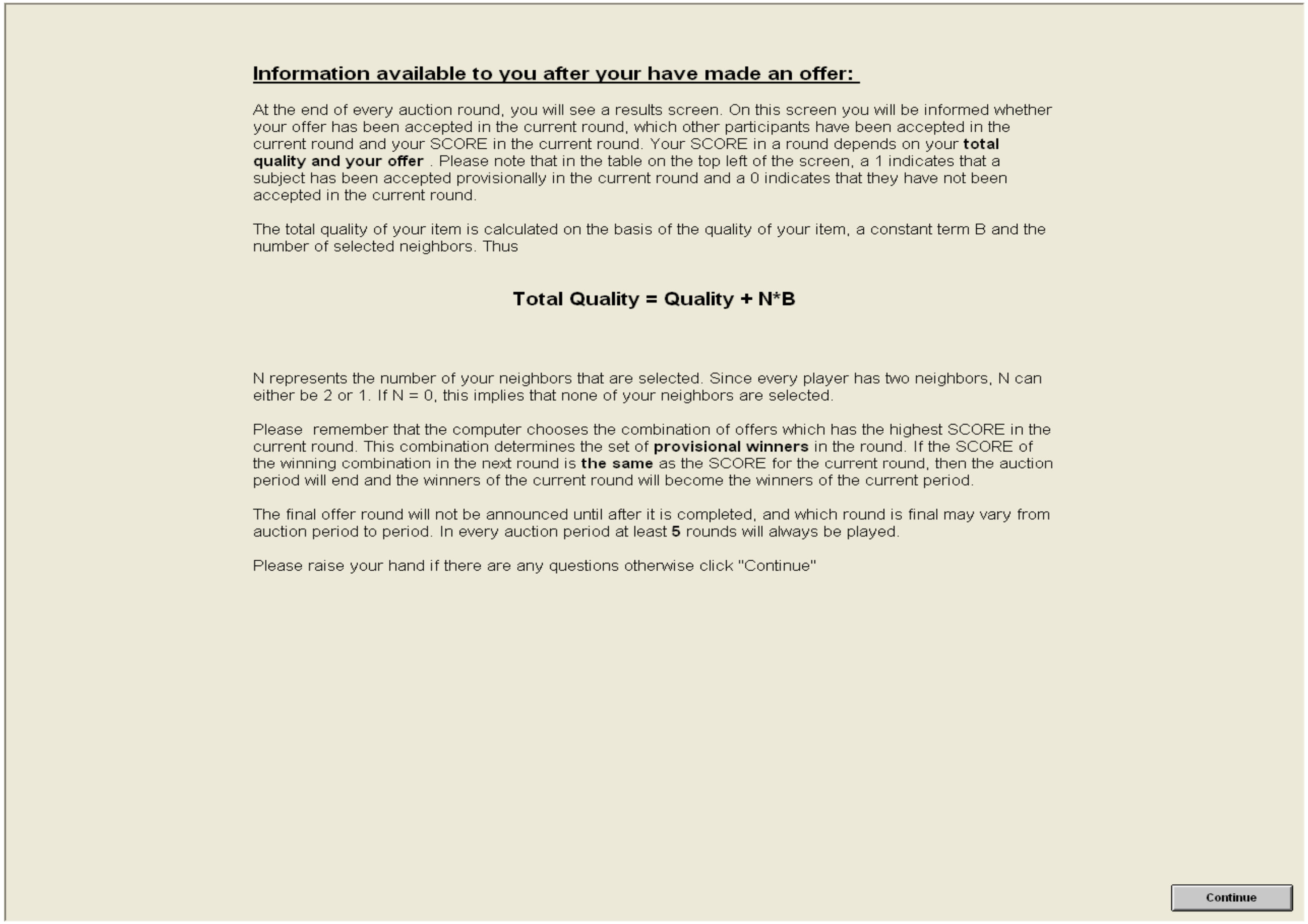
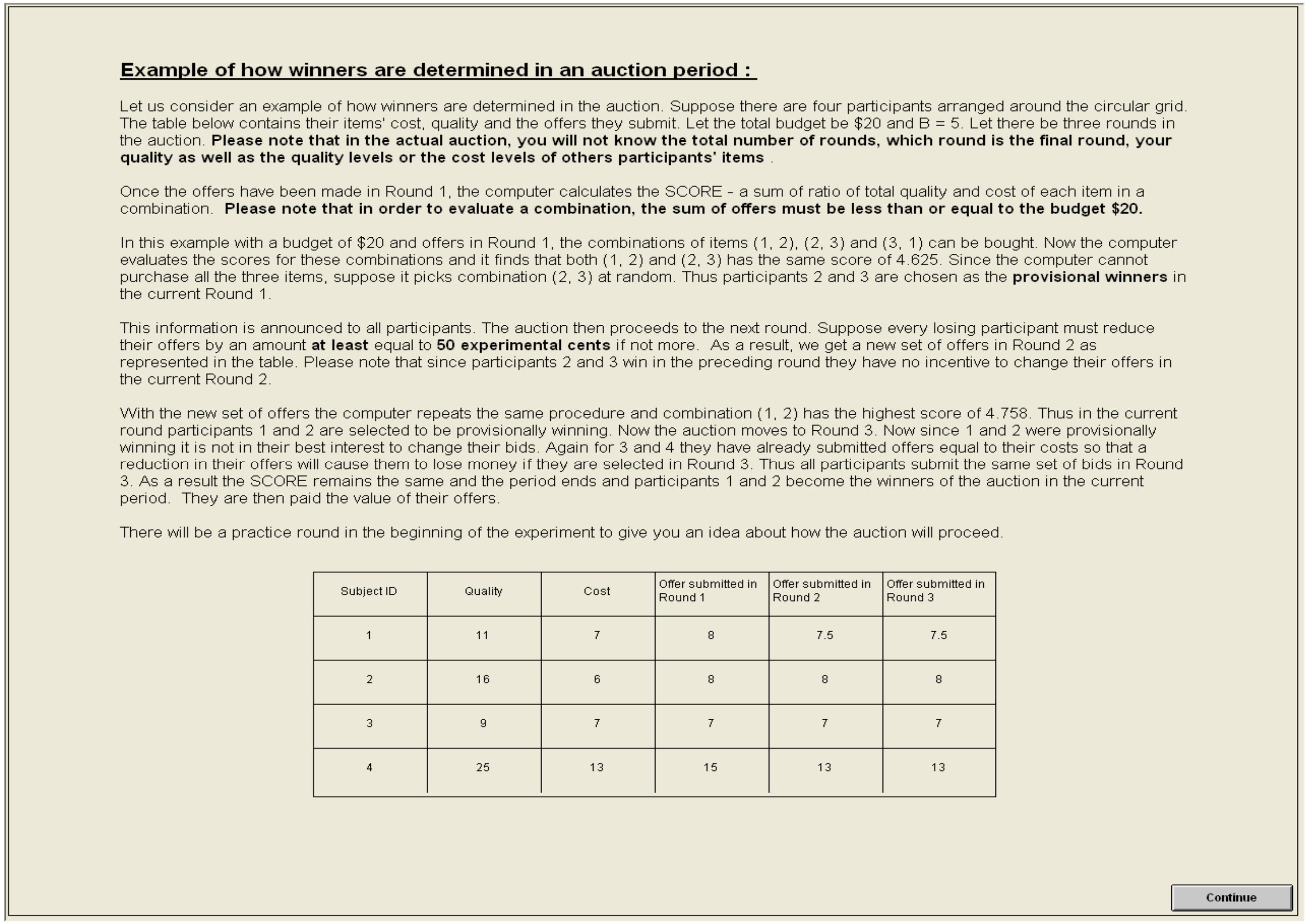


Figure B- 14: Screen 4(Auction)



Example of how winners are determined in an auction period :

Let us consider an example of how winners are determined in the auction. Suppose there are four participants arranged around the circular grid. The table below contains their items' cost, quality and the offers they submit. Let the total budget be $20 and B = 5. Let there be three rounds in the auction. **Please note that in the actual auction, you will not know the total number of rounds, which round is the final round, your quality as well as the quality levels or the cost levels of others participants' items** .

Once the offers have been made in Round 1, the computer calculates the SCORE - a sum of ratio of total quality and cost of each item in a combination. **Please note that in order to evaluate a combination, the sum of offers must be less than or equal to the budget $20.**

In this example with a budget of $20 and offers in Round 1, the combinations of items (1, 2), (2, 3) and (3, 1) can be bought. Now the computer evaluates the scores for these combinations and it finds that both (1, 2) and (2, 3) has the same score of 4.625. Since the computer cannot purchase all the three items, suppose it picks combination (2, 3) at random. Thus participants 2 and 3 are chosen as the **provisional winners** in the current Round 1.

This information is announced to all participants. The auction then proceeds to the next round. Suppose every losing participant must reduce their offers by an amount **at least** equal to **50 experimental cents** if not more. As a result, we get a new set of offers in Round 2 as represented in the table. Please note that since participants 2 and 3 win in the preceding round they have no incentive to change their offers in the current Round 2.

With the new set of offers the computer repeats the same procedure and combination (1, 2) has the highest score of 4.758. Thus in the current round participants 1 and 2 are selected to be provisionally winning. Now the auction moves to Round 3. Now since 1 and 2 were provisionally winning it is not in their best interest to change their bids. Again for 3 and 4 they have already submitted offers equal to their costs so that a reduction in their offers will cause them to lose money if they are selected in Round 3. Thus all participants submit the same set of bids in Round 3. As a result the SCORE remains the same and the period ends and participants 1 and 2 become the winners of the auction in the current period. They are then paid the value of their offers.

There will be a practice round in the beginning of the experiment to give you an idea about how the auction will proceed.

Subject ID	Quality	Cost	Offer submitted in Round 1	Offer submitted in Round 2	Offer submitted in Round 3
1	11	7	8	7.5	7.5
2	16	6	8	8	8
3	9	7	7	7	7
4	25	13	15	13	13

Continue

Figure B- 15: Screen 5(Auction)

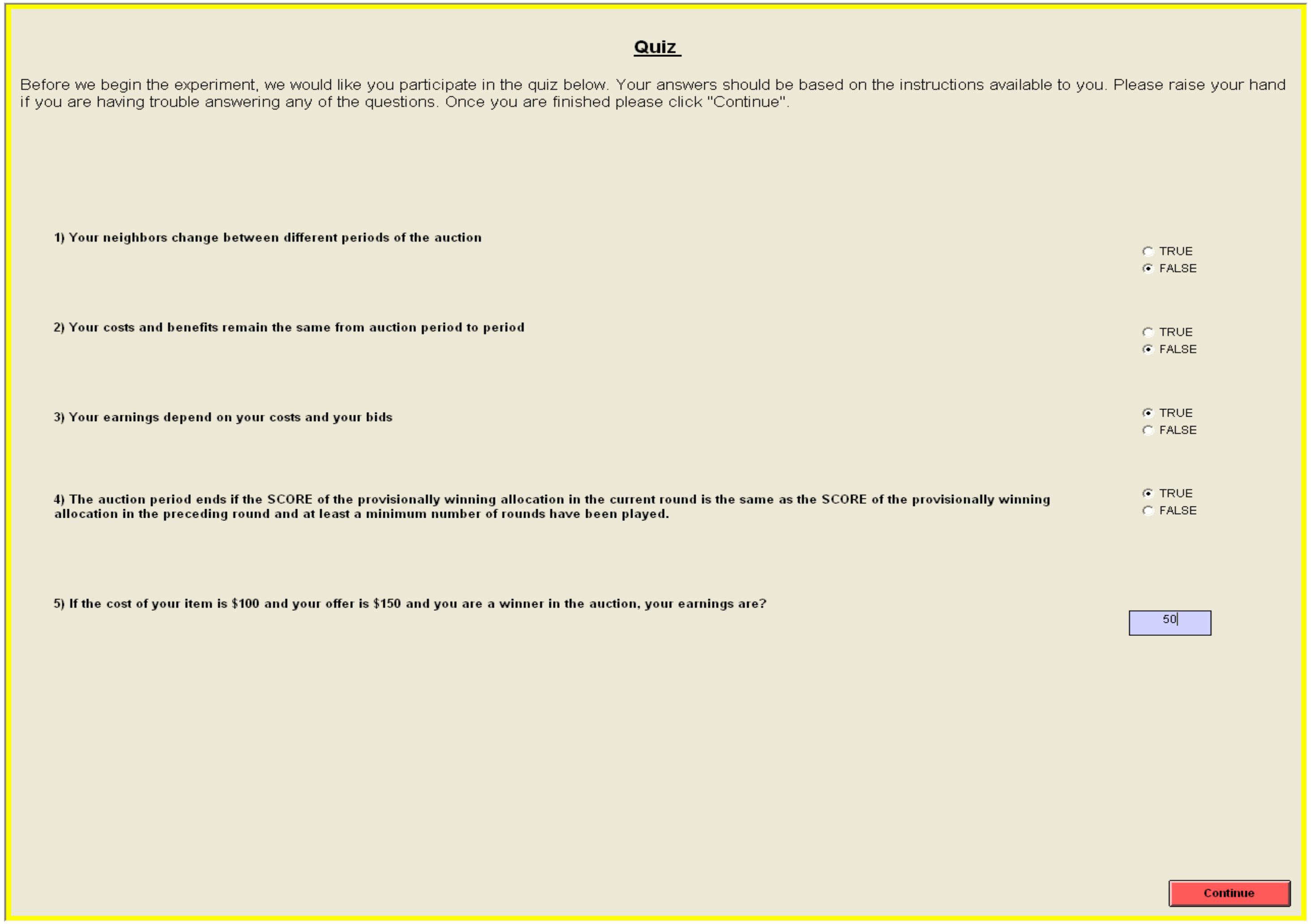


Figure B- 16: Screen 6(Auction)

Figure B- 17: Screen 7(Auction)

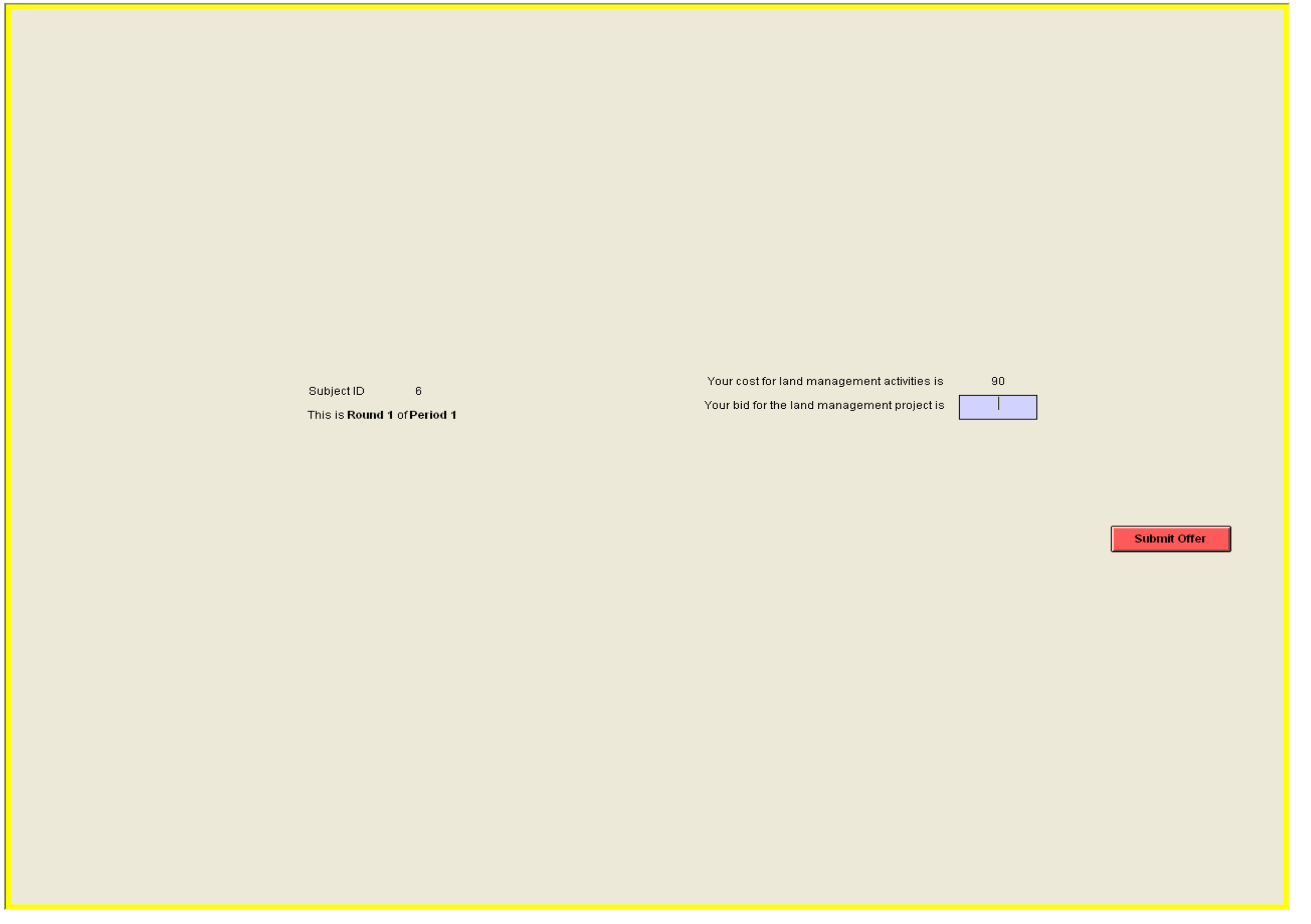


Figure B- 18: Screen 8(Auction)

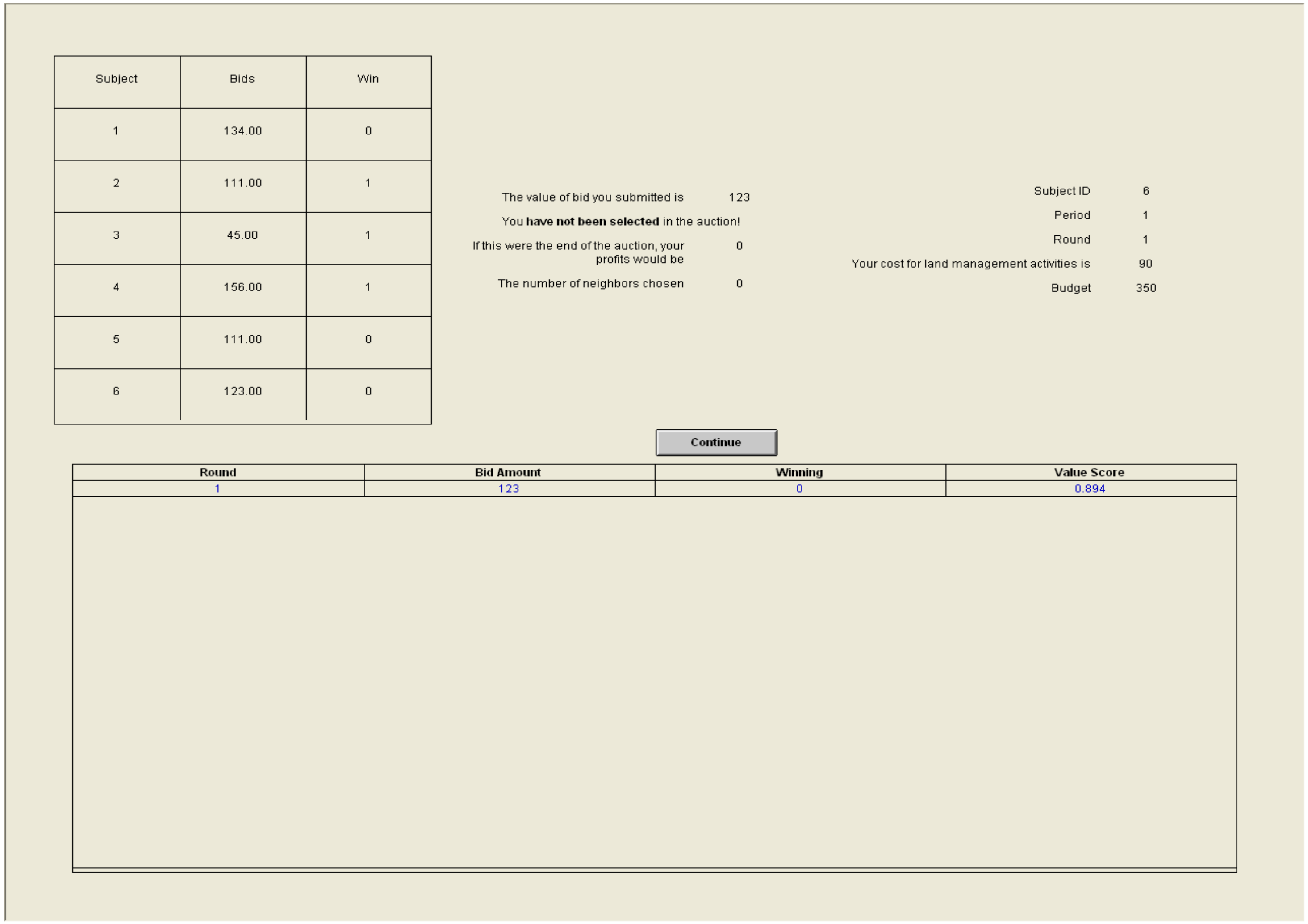


Figure B- 19: Screen 9(Auction)

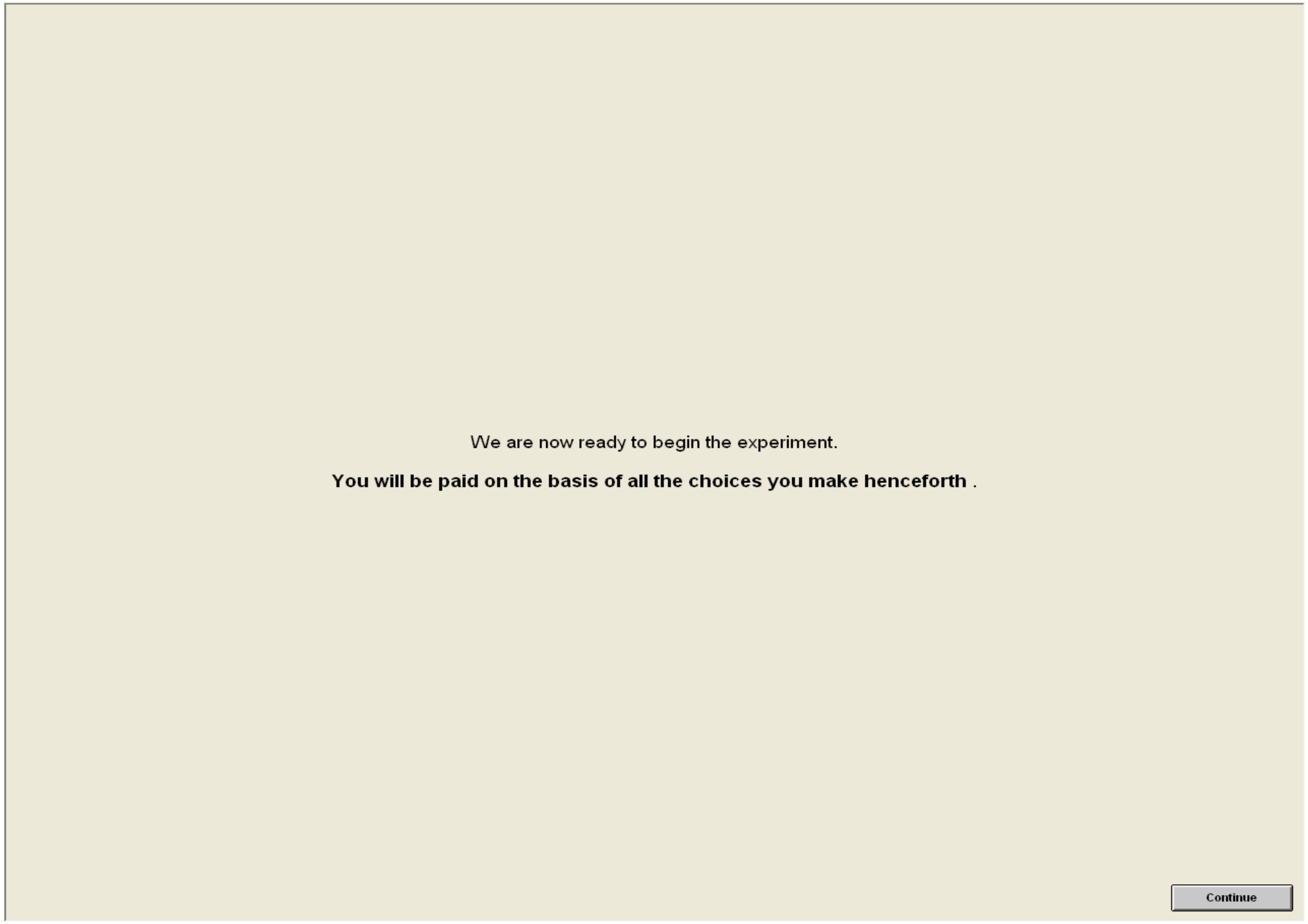


Figure B- 20: Screen 10 (Auction)

Figure B- 21: Screen 11 (Auction)

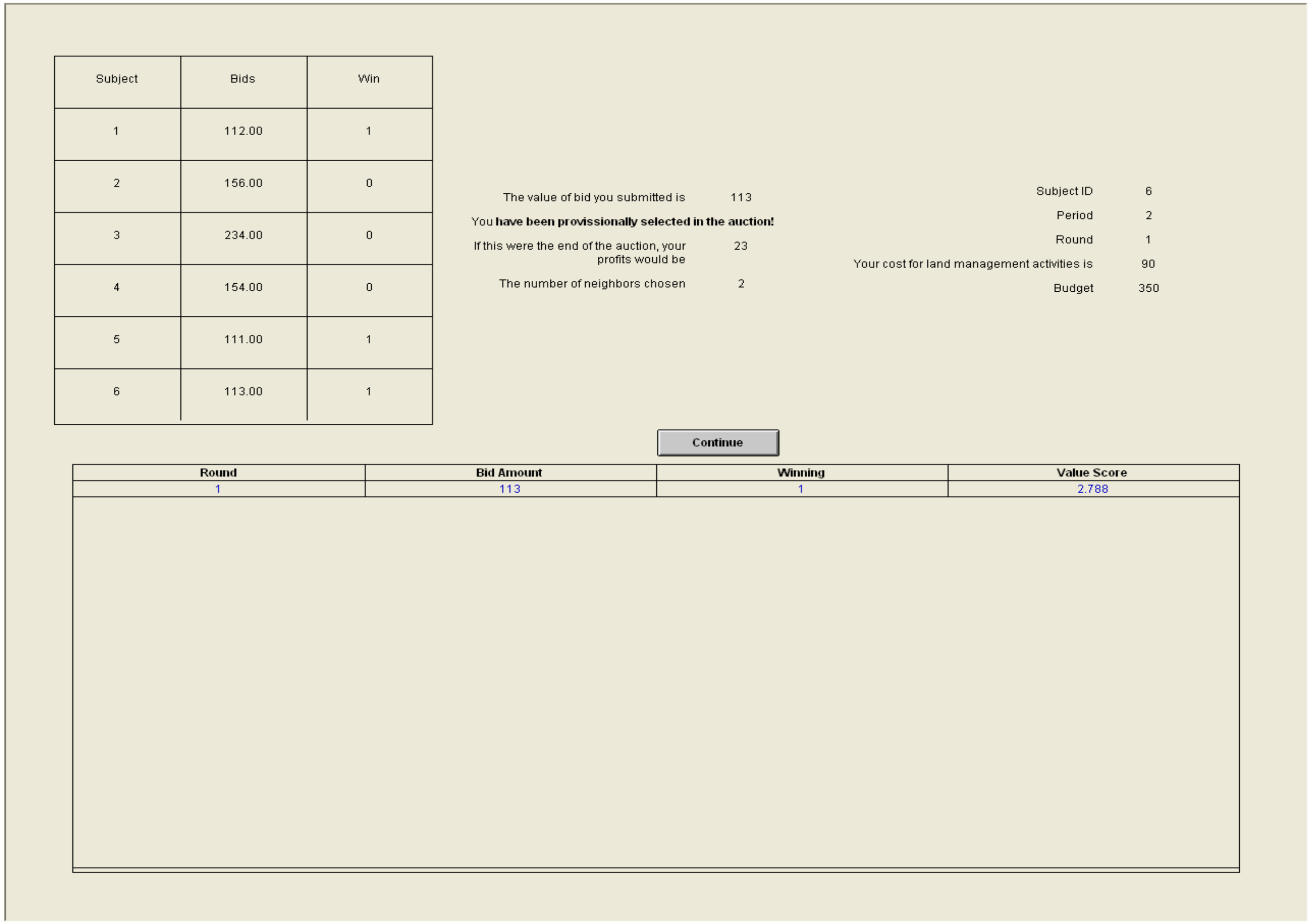


Figure B- 22: Screen 12 (Auction)

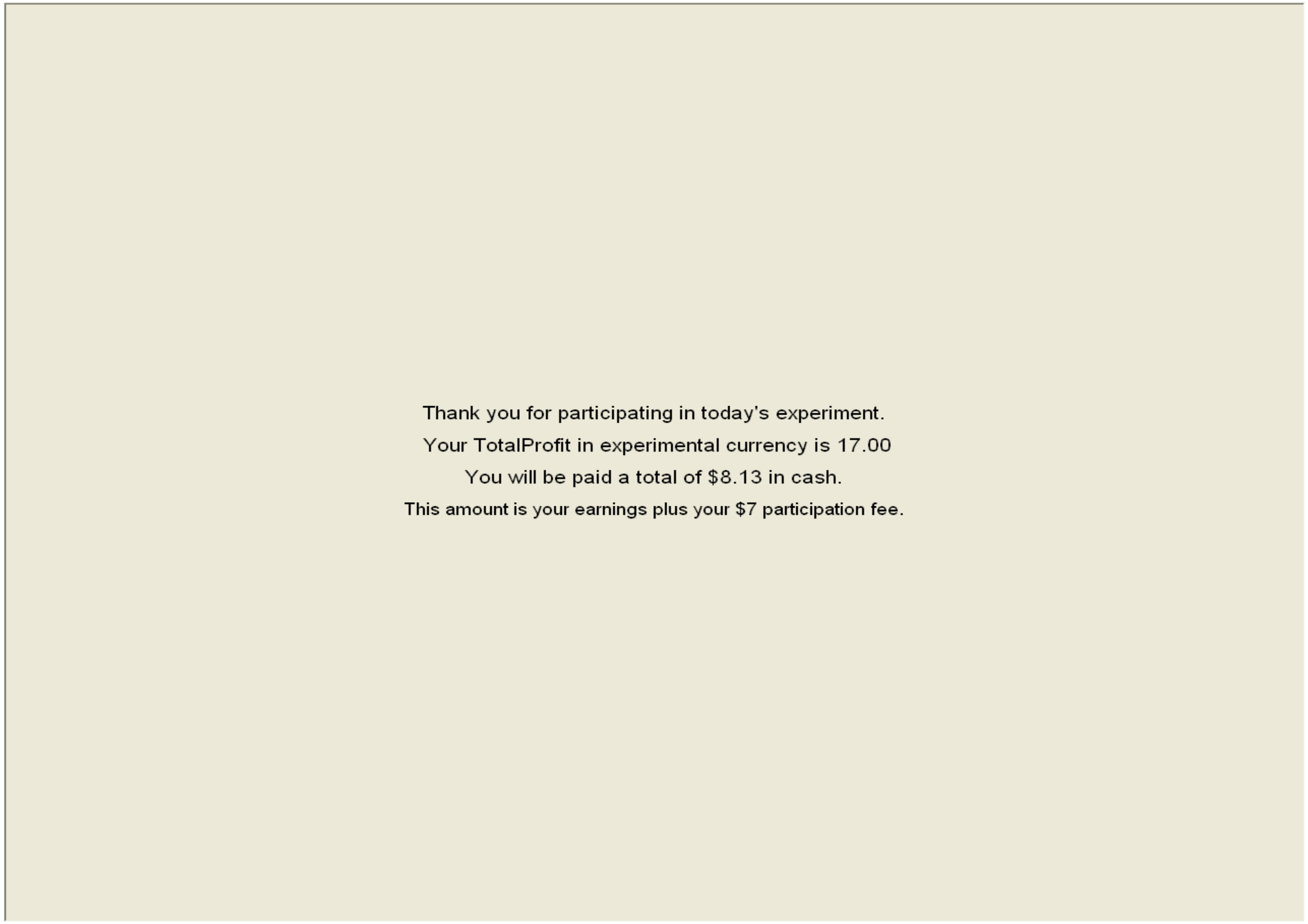


Figure B- 23: Screen 13 (Auction)

VITA

Simanti Banerjee: Simanti@psu.edu

Education

- Doctoral Candidate, Department of AERS, Penn State University **2005 – present**
- Master in Economics, Department of Economics, Jadavpur University, India **2004**
- Bachelor in Economics, Department of Economics, Jadavpur University, India **2002**

Research Experience **2005 – 2010**

- Incentive schemes for ecosystem conservation (Dissertation research)
- Ecosystem services and environmental markets outreach
- Pricing credits for a habitat bank
- Analysis of demand for Organic Food Products
- Markets for stacked ecosystem services

Presentations

- **Banerjee, Simanti,** James S. Shortle and Anthony M. Kwasnica. An experimental analysis of coordination games in open neighborhoods: A case study of Agglomeration Bonus mechanisms. Selected paper, NAREA meetings, Burlington, Vermont, 2009
- **Banerjee, Simanti,** James S. Shortle and Anthony M. Kwasnica. Auctions for spatially contiguous habitat management. Selected paper**.** AAEA meetings, Milwaukee, Wisconsin, 2009
- **Banerjee, Simanti,** James S. Shortle and Anthony M. Kwasnica, Incentive mechanisms for landscape management: the Agglomeration Bonus with technological externalities in different neighborhoods. Selected paper, 10th Bioecon Conference, Cambridge, UK, 2008
- Ready, Richard C, **Simanti Banerjee** and Nga P. Nguyen, Spatial Models of Open Space loss in the Mid-Atlantic region of the US. Selected paper, NAREA meetings, Rehoboth Beach, Delaware, 2007

Distinctions

- **Wilson A. and Mae C. Cease Memorial Scholarship,** College of Agricultural Sciences, Penn State University **2009**
- **Competitive Grant Award,** College of Agricultural Sciences, Penn State University **2009**
- **Student Spotlight**, Penn State Institutes of Energy and the Environment**,** Penn State University **2008**
- **AAEA Foundation Travel Grant,** AAEA **2009**
- **Student Travel Award,** NAREA **2009**
- **Gamma Sigma Delta** **2008**
- **National Scholarship:** Ministry of Human Resource Development, Government of India **1997-98, 2002-03-04**

Professional Memberships

- The Association Of Environmental Resource Economists **2010 – 2011**
- Agricultural and Applied Economics Association **2009 – 2010**
- Northeastern Agricultural and Resource Economics Association **2006 – 2010**