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Investigation of Reverse Auctions for Wetland Restoration in Manitoba

by

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Dedication

I would like to dedicate this thesis to my family and friends, and to everyone who made this document possible. Thank you for your continued love and support, and for making this ride so memorable.

Abstract

Reverse auctions for ecological goods and services are an alternative to current agri-environmental government programs to provide incentives for farmers. This thesis reports on a testbed of laboratory auction experiments to assess efficiency and cost effectiveness of different design treatments. These were developed using estimated costs of wetland restoration in southern Manitoba. The testbed included a comparison of payment type (discriminatory versus uniform payments), and ranking rule for both budget based and target based auctions over repeated auction rounds and reserve prices for the target based auctions. It was found that 1) uniform payments outperformed discriminatory payments under a budget constraint, 2) discriminatory payments were superior to uniform payments under a target constraint, 3) where there is no budget constraint a reserve price can greatly increase efficiency and cost effectiveness. These findings highlight the complexity of auction design and may be used as an aid to guide policy decisions and agri-environmental program design.

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Chapter 1 Introduction

1.1 Background

Human impact on the ecosystem is increasing around the globe resulting in the degradation of the local and global environment. This is very apparent when considering Lake Winnipeg in Manitoba, Canada. Human activities have compromised the health and quality of the lake to the point that it has become hazardous to ecological and human health.

According to the Lake Winnipeg Stewardship Board (LWSB), there has been an increase in the level of nutrients and contaminants entering the lake; since the 1970's LWSB (2006) have documented a 10% increase in phosphorus loading and 13% increase in nitrogen loading. Excessive nutrient loading has led to an extreme state of eutrophication[1] in the lake, and massive algal blooms comprised primarily of blue-green algae. Since blue-green algae can fix nitrogen from the atmosphere, phosphorus loading in particular has been the most damaging component because it is the limiting nutrient for blue-green algae. The presence of blue green algae harms the surrounding ecosystem and has a negative impact on the local economy, from releasing toxins to limiting the penetration of sunlight into the water column. Massive algal blooms have also led to the depletion of dissolved oxygen sources; when the algae die, it sinks to the bottom of the lake where is it decomposed by bacteria which use oxygen as a source of fuel.

LWSB (2006) notes that there are a variety of sources contributing to nutrient loads including human sources such as municipal sewage, septic fields, crop fertilizers,

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[1] Eutrophication is an increase in the concentration of nutrients in a body of water which results in an increase in primary productivity (i.e. an increase in the productivity of plant matter).

industrial discharges, livestock manure, and urban runoff (lawn fertilizers, pet waste), as well as natural sources such as soil, the atmosphere, and decaying plant matter. With agriculture comprising 50% of land-use in the watershed, it is a significant source which should be dealt with (LWSB 2006). The LWSB makes several recommendations for handling nutrient loads in Lake Winnipeg from public education, international cooperation initiatives, to specific actions to be taken to tackle nutrient loading and contamination of the lake. One of these actions is to re-introduce or restore wetlands into the landscape by way of engineering and construction.

Environment Canada has defined a wetland as “land where the water table is at, near, or above the surface or which is saturated for a long enough period to promote such features as wet-altered soils and water tolerant vegetation. Wetlands include organic wetlands or “peatlands”, and mineral wetlands or mineral soil areas that are influenced by excess water but produce little or no peat” (Environment Canada 1991). Wetlands are able to provide a multitude of Ecological Goods and Services (EG&S) including habitat for fish and wildlife, carbon sequestration, flood and sediment control, and water quality improvements. Wetlands act as an important nutrient sink. These benefits are well documented and supported by scientific evidence (Mitsch & Gosslink 2007).

Despite the ecological and social benefits derived from wetlands, they ultimately pose an economic problem to landowners or producers. Brown (1976) summarizes by saying that wetlands essentially “[create] a problem of optimal resource allocation” (pp 509) since the principle benefits are accrued by the public, while private landowners are left with the costs of maintaining them. This imbalance leads to market behavior, by farmers, which is not in favour of wetland conservation (Brown 1976). This has resulted in an overall loss in wetland habitat. Since European settlement it is estimated that approximately 20 million hectares of wetland habitat have been drained in Canada primarily due to agricultural development, with about 70% of wetlands drained in Manitoba (LWSB 2006).

This loss of wetlands ultimately means that there is a loss of the EG&S provided by wetlands. Where there are no wetlands on the landscape, nutrients, as well as flood water containing other contaminants and suspended solids, enter aquatic bodies more quickly and in higher concentrations. This is especially true in the spring where drainage networks accelerate the movement of melt water off fields allowing for early seeding and reduction of crop damage (LWSB 2006). Putting wetlands back onto the landscape through restoration can make-up for the lost functions from previous drainage practices. Studies have shown that restored wetlands are still able to provide valuable EG&S comparable to natural wetlands, including nutrient abatement (Kadlec & Knight 1996; van der Valk & Jolly 1992).

The goal of conservation planning is focused on maximizing biological benefits and outcomes, while at the same time minimizing costs. While there may be sound science supporting biological needs, the economic considerations of conservation are usually not included, or if they are not in an appropriate manner (Naidoo et al. 2006). Naidoo et al. (2006) states that including the cost of conservation is important and having a better understanding of the related costs can provide opportunities to increase conservation. Naidoo et al. (2006) also assert that understanding the heterogeneity of costs in the landscape (e.g. differences in land quality, production type, etc) is just as important as understanding the spatial heterogeneity the supply of EG&S.

There have been some issues in the uptake of wetland restoration among landowners. For years wetland drainage has been encouraged by governments through perverse policies (e.g. the Wheat Board quota system, land and tax systems). Van Vuuren & Roy (1993) also state that through income protection for certain commodities, wetland drainage would be directly subsidized (pp 294). While there has been some policy reform there continues to be a benefit to drainage through perverse incentives from pre-existing programs. This sends a conflicting message from governments to producers. In addition, wetland restoration will require a change in practice by producers since wetlands alter the cultivated landscape and force farmers to amend their cropping routines and spend more time and money to maneuver machinery around wetlands. However, time and money is also required to accomplish wetland restoration itself.

An important factor to consider is the disparity between public benefits versus private cost to landowners. There is no incentive for the average landowner to voluntarily restore the desired level of wetlands because they would incur 100% of the cost of wetland restoration and would not receive the full public benefit. This leads to controversial questions of who should pay, and how much for wetland restoration.

1.2 Thesis Purpose and Objectives

The purpose of this thesis is to understand the challenges facing producers with respect to wetland restoration, and to test policy tools to encourage wetland restoration by producers. The specific objectives are to first estimate the cost of wetland restoration and then to assess reverse auctions[2] as a potential policy tool to create incentives to encourage wetland restoration.

Currently, agri-environmental stewardship programs rely on either voluntary behaviour by producers and landowners or shared-cost payment programs. In order to implement effective policies and programs to encourage wetland restoration there needs to be an understanding of the costs producers face so that proper incentives can be granted. There have been some studies investigating the cost of wetlands in Canada (van Kooten 1993; DeLaporte et al. 2010), however their transferability to this region is questionable due to the complex heterogeneous nature of wetlands and producers. While there are some studies in the American context (Gelso et al. 2008; Heimlich 1994; Prato & Hey 2006; Schultz & Taff 2008) it is questionable whether these values could be transferred to the Manitoba context for the same reasons.. This thesis employs the use of multiple data sources in order to estimate the cost of wetland restoration for actual producers in the South Tobacco Creek (STC) watershed in southern Manitoban. A benefit of the data used in this present study is that it is rich enough to allow the investigation of both direct and indirect costs at the field level and gain a better understanding how the rotation and farm type may affect wetland retention and restoration costs. From this data, a actual cost curve was derived for the watershed.

Reverse or conservation auctions are becoming more popular as a method to procure EG&S in many parts of the world. Procurement auctions are a Market Based Instrument (MBI) used to establish prices where there may not be a direct market for the goods in question. The United States Department of Agriculture (USDA) has used

[2] Auctions for EG&S are also known as, or may be referred to as procurement auctions, conservation auctions, or eco-tenders.

conservation auctions since 1993 in their Conservation Reserve Program (CRP), and they have also been utilized in Australia (e.g. eco-tender). In this study we will investigate the design of reverse auctions in the context of wetland restoration. The objective of these auctions is to select producers and distribute compensation for restoring wetlands in a cost effective manner to yield high environmental benefits. Given that we have access to an estimated cost function, we are able to use experiments in order to test the auctions' ability to act as a cost discovery mechanism and what design features contribute – or counteract – efficiency/cost effectiveness, in the auction.

1.3 Study Area

The study area in question for this thesis was the STC Watershed, located in southern Manitoba, Canada. The total size of the STC watershed is 7638 ha (AAFC 2006) and is close to the town of Miami MB, and is south west of Winnipeg (49°9′28″N, 98°21′50″W) (Figure 1). It is located in the Manitoba Escarpment where the drainage area originates in the Pembina Hills and drains into Tobacco Creek, the Morris River, and exits into the Red River and Lake Winnipeg. The overall drop in the watershed is approximately 130 meters over 8 kilometers. The soil type in the area is predominantly clay-loam, overlaying shale bedrock (AAFC undated).

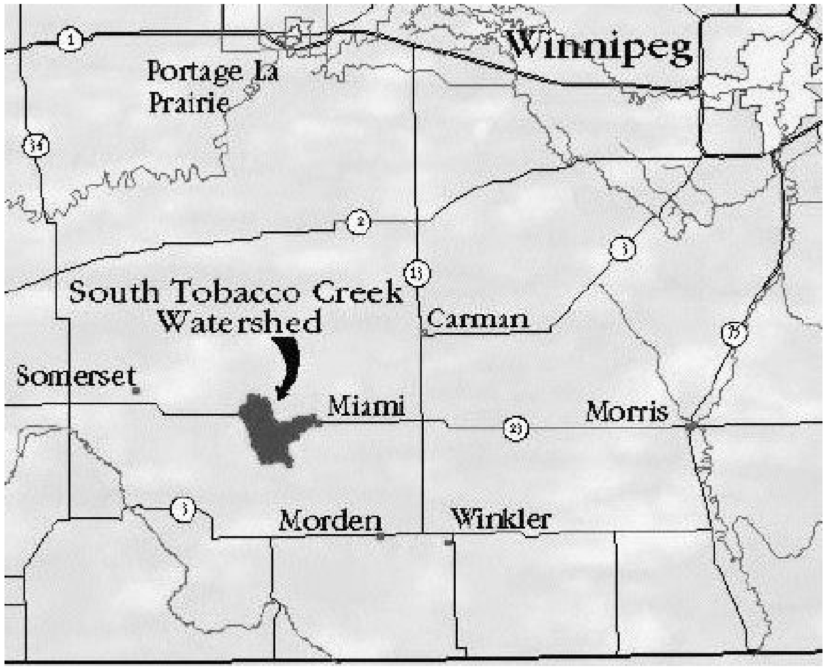

Figure 1 Location of South Tobacco Creek watershed (http://www.cici.mb.ca/deerwood/stc01.html) Deerwood Soil and Water Management Association

The primary land use in the area is agricultural activity (e.g. cropping, forages, and livestock) which has replaced the natural vegetation. As of 2000, 71% of the watershed was cultivated, with the remaining 29% being non-cultivated grasslands, trees, water bodies, road allowances, and yard sites (Yang et al. 2008). The four main crops are wheat, canola, flax, and barley, with other crops including oats, fall rye, triticale, peas, sunflowers, corn, and soybeans in small proportions.

STC has been used by Agriculture and Agri-Food Canada (AAFC) as the source of several scientific research studies for over 20 years pertaining to water sampling (AAFC undated). As a result, there is very rich hydrological data for the STC. It is also part of the AAFC Watershed Evaluation of Beneficial management practices (WEBs) program, which is collecting data on the environmental and economic effects of BMPs in agriculture. In addition to the detailed hydrologic and water quality records, the Deerwood Soil and Water Management Association (DSWMA) have also maintained more than 10 years of economic information on farm production in the area.

1.4 Organization of Study

The following section, Chapter 2, will provide a review of auction theory and conservation auction design. It will begin with information motivating the use of auctions for EG&S in general and also in a Canadian context. This is followed by an overview of auction theory and how conservation auctions are different from conventional auctions. Design issues in conservation auctions are then summarized and explained. The information provided in this chapter is used to motivate the experiments used to test different auction design features in the Manitoba context that would maximize cost efficiency.

Chapter 3 examines the cost of wetland restoration to producers. The methodology and data used to estimate costs are explained in detail. A summary of the costs of wetland restoration in the study area is then provided. The information in this chapter is subsequently used in the auction experiments.

Chapter 4 summarizes the experimental design and results of a testbed of budget constrained auctions. This chapter explains the motivation for different design treatments. An explanation of the experimental auction procedure during the experimental session is also provided. This is followed by an explanation of the regression analysis used to determine the impacts of different design features and auction outcomes. Descriptive results of the auction outcomes and cost effectiveness variables are provided and explained in detail. This is followed by an empirical analysis investigating the effect of auction design on cost effectiveness, and results are compared with the work of Cason & Gangadharan (2004, 2005).

In Chapter 5, the experimental design and methodology as well as results of the testbed of target constrained auctions is provided. Like Chapter 4, this chapter will explain the motivation for design as well as procedures and regression analysis. The descriptive results of auction outcomes and cost effectiveness are provided. Again, regression analysis was used to investigate the effect of auction design treatments on auction efficiency. Results presented in this chapter are compared to those of Schilizzi & Latacz-Lohmann (2007) who also examined target constrained auctions. Comparisons between target and budget based auctions are then drawn.

Chapter 6 provides conclusions and summarizes the contribution of this work to the literature on conservation auctions. Limitations to the study are discussed along with potential areas of research.

Chapter 2 Review of Conservation Auctions

2.1 Introduction

This chapter provides the context and theoretical background for the use of reverse auctions in an environmental context. Section 2.2 provides background information on why auctions should be used along with evidence of their success in other jurisdictions, such as Australia and the United States. Section 2.3 summarizes auction theory and provides a theoretical framework for understanding conservation auctions. This is followed by Section 2.4 which addresses specific auction design factors that contribute to the success of conservation auctions. Since there are few analytical results from auctions to guide conservation auction design this section is primarily based on experimental auctions from the laboratory as well as in the field. The research objectives are summarized in Section 2.5. This chapter concludes with an overall summary.

2.2 Motivation for Procurement Auctions

A challenge in the provision of EG&S is that they are public goods. Landowners provide EG&S through the adoption of Beneficial Management Practices (BMPs), such as wetland restoration, or changing farm practices to improve water quality and the environment (e.g. zero tillage or forage conversion). However, there is little motivation for the private landowner to voluntarily provide EG&S because they would bear the costs through changing their practices or buying new equipment, while the public enjoys the benefits. In response, cost-sharing programs have been developed to offer incentives for landowners to provide EG&S. A national survey of farmers in Canada finds that financial concerns are one of the most important barriers to participation in environmental programming (Environomics 2006). This is coupled with the sentiment that the benefits are reaped by the public (Environomics 2006).

In Canada, EG&S incentive programs have historically been based on fixed payment/cost sharing agreements. In a fixed payment program, all landowners who choose to enter the program are paid the same fixed price for providing EG&S (e.g. $200/acre for affected land). Payments are intended to act as a price signal for landowners to incent a change in behaviour (Windle & Rolfe 2008). Cost sharing agreements imply that a given proportion of costs borne by a producer for providing EG&S will be reimbursed. An example from Canada was the National Farm Stewardship Program (NFSP)[3] available to producers with an Environmental Farm Plan (EFP). These proportional reimbursements of costs were dependent on the type of project allowing for certain projects to receive a larger proportion of compensation. Wetland restoration projects were accepted under the NFSP where producers could apply to receive a reimbursement of 50% of their administrative and construction costs to a maximum of $20,000.

The ultimate intent of these programs is to provide payments to act as incentives to encourage voluntary participation in environmental programs. However, one must ask the question whether sufficient or excessive incentives were being provided? Arguably, appropriate incentives are not being provided for the average producer accounting for the low observed participation rates. As of 2009, only 36% of Manitoban farmers supported the EFP and only 30% were eligible for funding under the cost sharing agreement (data source: MAFRI undated, StatCan 2009).

[3] This program has recently been discontinued; however it was in existence during the course of this study.

The lack of appropriate incentives and low participation rates is ultimately attributed to information asymmetry between the public and producer. This is a significant issue explaining why the existing incentive payments from government programs may not effectively procure E&GS from producers. Information asymmetry exists when multiple parties in a transaction each hold private information that the other party (or parties) is (are) not privy to. Private landowners hold private information related to the costs they would bear if they were to adopt an environmentally friendly practice such as wetland restoration. This is because costs are made up of observable (e.g. cost of capital or consultations) and unobservable components (e.g. opportunity costs, nuisance costs, or environmental preferences) [4]. If governments have access to any cost information, it is most likely the observable cost which is only one component used in the private decision making process.

Information asymmetry contributes to the ineffectiveness of environmental programs. In fixed price schemes information asymmetry creates challenges in the determination of the appropriate level of payment to provide (Groth 2005). Payments set greater than actual costs will not lead to cost minimization and waste money; conversely low payment levels will yield a low rate of participation and high administrative costs per unit of EG&S gained (Groth 2005). Windle & Rolfe (2008) note that where there are heterogeneous costs among farmers a government determined fixed rate cannot provide an appropriate price signal for all farmers to participate. In a cost sharing agreement, the proportion of costs being shared by the government matters as well as what costs are to be shared. Under information asymmetry the inappropriate costs may be shared (e.g. NFSP did not cover opportunity costs which could be a significant component of total

[4] The private costs facing producers will be discussed in further detail in Chapter 3.

costs) and an inappropriate share may be covered by the government for providing benefits to society because of a lack of information.

The government, or public, also holds private information related to their preferences for EG&S and furthermore their value. Landowners are typically unaware or lack understanding of the environmental goals established by the government or have little information about potential EG&S provision on their land. Latacz-Lohmann & Schilizzi (2005) identify that there may also be problems with adverse selection of producers in a fixed price program in the presence of information asymmetry since farmers with a lower EG&S potential would have higher incentives to apply for a fixed price program than producers with higher EG&S potential. For example, a farmer who restores wetlands on low quality land, with low EG&S potential will more likely enter into a contract than a farmer who has good quality land and high EG&S potential. A farmer with low quality land will benefit more because the opportunity cost of wetland restoration is relatively low resulting from land with low productivity. Any payment this farmer would get would directly contribute to income. In contrast, a farmer who has good quality land may have very high opportunity costs related to highly productive land. For this farmer, there are fewer benefits for receiving a payment for restoring wetlands. Relating to the aforementioned comment by Groth (2005: 12) about fixed payments, the level of payment chosen will influence the effect of adverse selection. A low price may be sufficient to induce low potential producers to participate, although excluding those producers who have the capacity to contribute more EG&S. It is very likely that adverse selection would also be a challenge in a cost sharing scheme as well. Similarly, those with low potential for providing EG&S would have higher incentives to participate in the program knowing that some of the costs could be covered for a given activity, and those with high potential may not participate because the payments issued do not cover a sufficient level of their costs out of pocket.

2.2.1 Conservation Auctions

Conservation auctions are an alternative to fixed price or cost sharing programs supported by many governments to buy and encourage the provision of EG&S by landowners. Auctions are a type of Market Based Instrument (MBI) in that they use market forces, prices, or other economic variables to change behavour. MBIs may create a market where no market is currently operating, or improve a market if there is market failure. Given that there is no current market for EG&S from wetland restoration, and there is information asymmetry, conservation auctions may be a useful instrument for the provision of EG&S from wetland restoration.

Auction mechanisms use competitive bidding to reduce information asymmetry and act as a price discovery system for EG&S. In a conservation auction, participants submit bids to the responsible authority representing the amount they would like to be compensated for their actions (e.g. adopting BMPs), and the most cost effective projects are selected until a budget is exhausted or a target is reached. With competition as the driving force, participants are induced to reveal their true compliance costs through the bidding process (Latacz-Lohmann & Schilizzi 2005). This is because participants must face tradeoffs related to the probability of their bid being accepted and their resulting payoff. Thus participants are revealing some of their own cost information to the auctioneer while receiving a payment adequate to cover their costs of a conservation action.

The conservation auction framework has the capacity to increase producer participation in conservation programs and/or activities like BMPs. According to Smith et al. (2007), the main reason why producers do not participate in agri-environmental programs is that they are not comfortable with government control over their land use decisions and the lack of flexibility in the type of activity they can apply. Conservation auctions are typically voluntary, and producers may have the flexibility to choose the type of activity and price they would require. In response to an auction for sediment reduction conducted in the Pomona Lake Watershed, Kansas, US, “bidders indicated that they appreciated the flexibility of choosing their own BMPs and naming their own price in the auction” (p.8) (Smith et al. 2009). The CRP also accepts a variety of activities to achieve different environmental outcomes which are scored in an Environmental Benefits Index (EBI). However, auctions may also target specific activities (e.g. wetland restoration or other specific BMPs) if monitoring is more difficult or there is no comprehensive EBI to differentiate the value of the activities. Auction design can also be tailored to overcome other impediments to conservation programming such as paperwork, complicated mechanisms, or lack of education by simplifying the sign-up process relative to other programs as well as implementing extension programs (Smith et al. 2009).

Conservation auctions for EG&S have been implemented as a program or a pilot project in a number of jurisdictions including the United States, Australia, and the EU. In the United States auctions are used in the CRP to encourage the conservation and rehabilitation of agricultural and natural land since 1993. As of February 2010, 31.2 million acres have been contracted under the CRP program across the US (FSA 2010).

This includes land dedicated to habitat enhancement, water quality improvements, soil erosion control, and other conservation efforts. According to 2008 summary and enrollment statistics, CRP has been successful in improving water quality, enhancing wildlife habitat, reducing greenhouse gas emission, and protecting and improving soil productivity (FSA 2008). The USDA has also announced that the CRP will continue to reflect its dedication to conservation efforts in agriculture in the US (FSA 2009).

Auctions have also been used in the buyout of irrigation rights from farmers in times of severe drought in some American states (Cummings et al. 2004; Hartwell & Aylward 2007). Cummings et al. (2004) tested reverse auctions to buy back water-use permits (irrigation permits) in times of drought, as required by law in the state of Georgia. They conducted both laboratory and field experiments to provide recommendations for the actual auction using public money. They found that the auction was cost effective in purchasing irrigation permits. The auction was also able to acquire information about individuals' willingness to forego irrigation, and thus circumvented problems and inefficiencies of "involuntary usage shutdowns using non-economic criteria" (p. 361) (Cummings et al. 2004).

Hartwell & Alyward (2007) describe the auctions held in Deschutes River Conservation area in Oregon to acquire temporary in-stream transfers of water rights for environmental restoration. There was active participation in the auction, however there were no conclusive results regarding efficiency or cost effectiveness because of a lack of actual data available for comparison.

In Australia auctions have been used for a number of different environmental issues including native vegetation management and conservation, biodiversity, salinity, and groundwater recharge abatement (Latacz-Lohmann & Schilizzi 2005, Stoneham et al. 2003). Stoneham et al. (2003) found that the BushTender trial to address improvement in habitat biodiversity in Victoria was more cost effective than a fixed price scheme by a factor of seven. A factor that contributed to the cost effectiveness of BushTender was the ability to take advantage of the heterogeneity of landowners and their costs providing an opportunity to benefit from landowners who can provide environmental benefits at low costs. Stoneham et al. (2003) also attributes the success of the auction to the ability to extract information required to make decisions about biodiversity conservation benefits.

In Germany field experiments for conservation contracts were used to increase biodiversity and conserve grassland, and to encourage broader participation in agri-environmental programs (Groth 2008). Groth (2008) found improvements in cost effectiveness of up to 36% depending on the fixed-price scheme (assuming the supply function revealed in the auction was equivalent to the actual supply function).

Auction theory in the context of EG&S procurement is a relatively new field of study, and the overall body of literature is somewhat limited and inconclusive. However, traditional auction theory provides a well established point of departure to understand EG&S auctions. The following section provides a summary of traditional auction theory as well as an overview of procurement auction theory and implementation guide.

2.3 Auction Theory

Auctions are usually evaluated according to two properties: efficiency and cost effectiveness. An auction is efficient if the good being auctioned is allocated to the party which values it the most. Cost effectiveness and economic efficiency are not always achievable because of the asymmetric information. Since farmers know more about their costs than regulators and government, some rent may have to be paid to producers with high quality sites in order for them to enter the market.

Auctions may also be evaluated in terms of their distributional consequences. For example, policy makers may want to ensure that contracts are not concentrated in the hands of a few suppliers, or they may want to ensure that goods are awarded fairly across different groups of people. In theory, conservation auctions for conservation contracts can reduce program costs and target specific environmental benefits. However the performance of auctions varies and depends on a number of context specific parameters such as; the type of auction, the payment format, the underlying distribution of private costs of providing conservation, and socio-demographic characteristics.

Auctions are typically associated with the sale of art work or antiques in famous auction houses as well as for cars or livestock. They are characterized as non-cooperative games among the participants who are assumed to bid competitively (Milgrom & Weber 1982). Milgrom (1985) suggests that auctions can be utilized where the price of an item needs to be established. A conventional auction consists of one central seller (or auctioneer) and multiple buyers where buyers place bids and the highest bidder will win the item however, reverse auctions (or procurement auctions) involve multiple sellers and one central buyer (e.g. auction for construction contracts).

There are four main types of auctions: English; Dutch; sealed bid 1st price; and sealed bid 2nd price (also known as a Vickrey auction[5]). English auctions are ascending outcry bids, where bids are increased and accepted until no one will accept a bid increase. A Dutch auction uses descending outcry bids where the bid price is decreased until

[5] Sealed bid 2nd price auctions are given the name Vickrey auction because of Vickrey's seminal work on auction theory and the introduction of this auction method (Vickrey 1961).

someone accepts the bid. Sealed bids imply that everyone participating submits a bid anonymously and the person with the highest valuation will win. In a sealed bid auction, the price paid may be 1st price where the winner pays their own bid; or 2nd price where a winner pays the second highest bid (or the highest losing bid). In a conventional auction the highest bidder (or the one with the highest valuation) for the good is the winner, whereas in a reverse auction, the winner(s) would be the least cost suppliers.

The four auction types can be grouped on the basis of optimal bidding strategy for the auction. The first grouping includes English and sealed bid 2nd price auctions. In both of these auction formats there is a dominant strategy to place a bid equal to one's own valuation. This is because their bidding strategy is not dependent on how the other players bid (unlike the other two auctions where players' bids are based on expectations of other bidders' valuations. As Schilizzi & Latacz-Lohmann (2005) suspect, it is best to place a bid equal to one's valuation because bidding below valuation decreases the chance of winning, and bidding above, while increasing chance of winning, also increases the risk of having a price much higher than one's valuation (this is also known as the *winner's curse*[6]).If players know the probability distribution function of values then on average the auctions yield the same outcomes these auctions yield the efficient outcome as a dominant strategy.

The second grouping includes the Dutch and 1st price sealed bid auction. While on paper the two auction rules could not seem more different, the end result is the same where the highest price will win and that price will be paid (Milgrom 1989). Under these auctions more attention is paid towards bidding strategies or the actual bid amount.

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[6] Winner's curse is usually in reference to a common value auction with incomplete information, however the term has been used loosely in the conservation auction literature

According to Latacz-Lohmann & Schilizzi (2005) bidders will develop expectations about the valuations of other competitors and will bid just high enough to win under the assumption that their own valuation is the highest. Based on this expectation, there is a preferred strategy to estimate the next highest valuation among the other bidders and place that estimate as a bid, understanding the probability distributions from which others draw their valuations is valuable in developing expected utility from a Dutch or 1st price sealed bid strategy (Milgrom 1989).

Despite the four auction types having different bid strategies, they all lead to the same result that the one with the highest valuation will win (on average). This leads to an important outcome known as the Revenue Equivalence Theorem (RET) which states that for each auction, the equilibrium bidding strategy yields the same price, on average, given that the following set of assumptions are held[7](Latacz-Lohmann & Schilizzi 2005, Latacz-Lohmann & Hamsvoort 1997):

- A1. Auction involves sale of a single item
- A2. Bidders are risk neutral
- A3. Bidders have independent private values; i.e. each bidder has a valuation of the traded good that is unknown to the seller and rival bidders and that is not influenced by others' views (no resale value)
- A4. Symmetry among bidders exists where the probability distribution of valuations is the same for all bidders
- A5. Seller does not know each bidder's exact valuation and perceives this valuation to be drawn randomly from some probability distribution. Likewise, bidders have prior knowledge about the probability distribution of rival bidders' valuation, but not about the competitors' exact valuations
- A6. Competitive bidding: all bidders enter the auction with the intent to win and know the number of rival bidders. There is no collusion and bidders do not have the ability to influence price.
- A7. Payment is a function of bids alone
- A8. There are zero costs to bid construction and implementation

[7] This also applies to reverse auctions (Latacz-Lohmann & Schilizzi 2005).

Given that auctions are used as a price discovery mechanism where markets do not exist, it is important to know from the RET that on average, no auction type has any advantage over other types to increase the revenue for the buyer or seller. However this is only in cases where the above assumptions are met. In the case where violations occur one cannot expect RET to hold, and there are no generalized results for auctions. Therefore it is necessary to test results using empirical or experimental methods to provide evidence to predict the results of auction under certain violations.

Conservation auctions are a unique type of independent private value reverse auction where participants submit bids for providing EG&S. There are aspects of these auctions, as they have been practiced, that result in violations of the RET therefore it is not clear which auction design will yield the best result. The relevant violations are listed below.

A1 – Auction involves sale of a single item

Conservation auctions typically deal with the trade of multiple items (e.g. different BMPs), multiple attributes (e.g. types of environmental quality), and/or multiple units (e.g. number of hectares of wetlands), in addition to having multiple winners. The combination of attributes, items, or units depends on the purpose of the auction and the outcomes. These qualities have an impact on how bidders formulate their bids because multiple dimensions must be taken into account. The effects of multi-dimensional auctions are not well known (Latacz-Lohmann & Schilizzi 2005) but there are studies which have explored this issue under different conditions. For example, Klemperer (1999) states that under certain conditions an efficient outcome can be achieved but could lead to acts of collusion and rent seeking. Multi-unit auctions (such as Treasury, spectrum, or electricity markets) cannot be guided by single auction theory and that such auctions have led to auction outcomes that have not maximized revenue and/or are inefficient (Ausubel & Cramton 2002) participants will bid strategically such that their bids do not necessarily represent their true value in order to maximize profit under both first and second price auctions. Binmore & Swierzbinski (2000) assert that multi-unit auctions cannot be guided by single-item auction theory, and that such actions have led to inefficient auction outcomes in Treasury bill auctions in the United States.

A2 – Bidder's are risk neutral

Producers are generally expected to be risk averse rather than risk neutral. This is a widely held assumption for farmers and is used for multiple areas of research in agricultural economics (Unterschultz, J., personal communication, May 2009). Latacz-Lohmann and Van der Hamsvoort (1997) found in a bidding simulation exercise that risk aversion can affect bidding behaviour away from the optimal strategy, thus reducing efficiency. Klemperer (1999) argues that in a second price auction, risk aversion has no effect on bidding strategy and that all participants will bid (or bid up to) their actual value. In a first price auction, a risk averse bidder will bid more aggressively (bid closer to true valuation) since an increase in the bid will slightly increase the probability of winning while slightly reducing the value of winning. This is because they are not willing to risk losing by increasing their potential profit from submitting a lower big. Therefore a risk neutral seller with risk averse buyers prefer the first price auction since revenue potential is higher. However, risk preferences are difficult to quantify in a laboratory setting.

A4 – Symmetry among bidder exists where the probability distribution of valuations is the same for all bidders

Under symmetry, all participants are assumed to know their own cost function and have full knowledge about the distribution of costs amongst bidders (i.e. everyone has the same assumptions about costs and they know the distribution with certainty). When the symmetry assumption is violated it is not clear which auction format produces superior results in terms of efficiency or revenue maximization (Myerson 1981; Bulow & Roberts 1989; Klemperer 1999)

Although it is possible that producers are symmetric, there are underlying conditions (e.g. land quality, production type, management strategy) which could contribute to different cost functions. Another contributing factor is that producers may not be aware or have imperfect information about their own cost function. If this is true, there is no clear indication regarding which auction type would be preferable since bidding would not reflect their actual cost distribution but their best estimation. In addition, they may not know the distribution of costs to other bidders or they form their own subjective probabilities about costs (which they update through learning in the auction

As a result of these violations of RET, the results of conservation auctions are indeterminate. There are many aspects of conservation auction design that can influence the outcome in terms of auction efficiency and/or cost minimization. The following section discusses attributes of conservation auction design in further detail.

2.4 Auction Design

Auction design is an important factor in maintaining economic efficiency and cost effectiveness in conservation auctions. Since the predicted results from auction theory are indeterminate, auction experiments in an economic laboratory have been utilized to test different designs to understand their efficiency as well as their ability to act as a cost discovery tool (Latacz-Lohmann & Schilizzi 2005). The best auction design is also context specific, Further supporting the use of experiments to test design prior to actual use with landowners.

Important design measures that are being considered in this thesis are as follows: the method of payment; the type of bid evaluation systems; the use of a target versus a budget constraint; the level of information revealed or hidden; the use of a reservation price or target; and communication. Each of these is reviewed below.

2.4.1 Pricing Method

There are different methods in which payments may be distributed to winners in a reverse auction. The most common methods are discriminatory, uniform 1st price, and uniform 2nd price (or Vickrey auction). Each method has its own pros and cons in relation to their effectiveness in reducing rent seeking and producing an efficient outcome. The pricing rule is a key design feature in conservation auctions because the format dictates how contract payments are determined based on bids (Latacz-Lohmann & Schilizzi 2005), and this directly contributes to the efficiency and cost effectiveness of the auction.

Under discriminatory pricing, a successful bidder in an auction will receive a payment equal to their submitted bid price. This type of pricing resembles that of the Dutch or 1st price sealed bid auction described above and thus invokes similar behaviour patterns. The bidders make expectations about other competitors and bid just high enough to win under the assumption that their valuation is the highest or in this case that their valuation is the most cost effective. This type of pricing decreases the amount of uncertainty a bidder would face as their respective bid would both determine their chance of winning and the price they would receive if successful (Latacz-Lohmann & Schilizzi 2005). Latacz-Lohmann & Schilizzi (2005) also explain that under discriminatory pricing there is a Nash equilibrium strategy and a bid placed depends on someone's own costs and their best guess of the highest acceptable bid. This provides an opportunity for participants to seek rents, or profits in excess of costs, in anticipation of getting the highest possible payment. The optimal strategy for participants is to bid shade in order to receive a large payment and acquire a net gain. This is especially true for those who have low costs because knowing that it is relatively cheap for them to provide a service, they may shade their costs and bid as if they were a high cost landowner in order to achieve net gain from their payment and still remain competitive among other bidders. High cost participants are more likely to bid close to their costs knowing that the highest acceptable bid is probably not much more than their own costs.

Under a uniform pricing framework all successful bidders are paid the same price (full or unit price). In this case, the bid submitted determines the chance of winning, but does not explicitly determine the level of payment (Latacz-Lohmann & Schilizzi 2005). Knowing this, the dominant strategy for participants is to place a bid equal to their own costs because the magnitude of the bid does not affect the payment that will be received - it will only decrease the probability of winning. This is similar to the 2nd price auctions addressed in Section 2.3. While, it should be noted that a weakly dominant strategy is to bid slightly below cost in order to increase the probability of being selected, however, there is risk that the payment received by a bidder will be less than their costs, however (Latacz-Lohmann & Schilizzi 2005). With uniform prices winners will receive a payment greater than or equal to their costs, eliminating the need to shade their bid in order to have a net gain from the auction. Therefore, the dominant strategy is to place a bid equal to or at least closer to actual costs in order to maximize the probability of winning.

The price received under the uniform price format may be determined one of two ways: 1st price, where the price is determined by the last accepted winner; or 2nd price, where price is determined by the first rejected participant. Cason & Gangadharan (2004; 2005) argue that the 2nd price method may be more effective because when first price is being used, the last person to win will not receive a payment greater than their costs while other winners will. It is possible that the participant on the margin will tend to bid shade and thus raise the universal market price making the overall auction more expensive and less efficient. Whereas using the 2nd price method, all winners would receive a payment greater than their costs, thus reducing the incentive to place a bid greater than costs in order to achieve information rents. However, under 2nd price auctions there is also risk that the rejected bid is very high and may greatly increase the amount of rent distributed to the winners.

There is debate as to which pricing rule, discriminatory or uniform, is the most effective in a reverse auction. In the literature there are two approaches to evaluating of pricing rule effectiveness: 1) cost effectiveness and 2) the ability to reveal true cost functions from participants. Cost effectiveness refers to minimizing the total cost of the auction and maximizing benefits procured from a fixed auction budget (i.e. $ spent per unit of EG&S). The ability for the pricing rule to provide incentives for participants to bid their own costs is an important issue in an auction. Without the proper incentive, there may be strategic behaviour in order to maximize information rents by shading bids.

In the event there is an abundance of bid shading, winners in the auction may not be appropriately chosen, ultimately leading to a decrease in efficiency as well as cost effectiveness.

Tenorio (1993) and Umlauf (1993) found that uniform prices yield higher revenues from the sale of financial instruments (e.g. foreign exchange). Similarly, for the sale of US Treasury Bills, the uniform price auction seems to be viewed as more favorable although it is not clear from a theoretical perspective why this would be the case (e.g. Binmore & Swierzbinksi 2000). Unfortunately there is no compelling theoretical reason to expect one payment format will be better than another (Binmore & Swierzbinkski 2000; Hailu & Thoyer 2007).

Latacz-Lohmann & Schilizzi (2005) discuss the cost effectiveness of the two payment types in a budget constrained auction. They stipulate that whether one payment type is better than the other is largely an “empirical question”. They find that the most cost effective method depends on the degree of information rents sought by bidders in the discriminatory auction, and thus make the case for both methods to be cost effective. They base their discussion on two different discriminatory scenarios (Figure 2 and Figure 3); where there is low information rent seeking and when there is high information rent seeking. They also assume that under uniform pricing, participants place bids equal to their own costs.

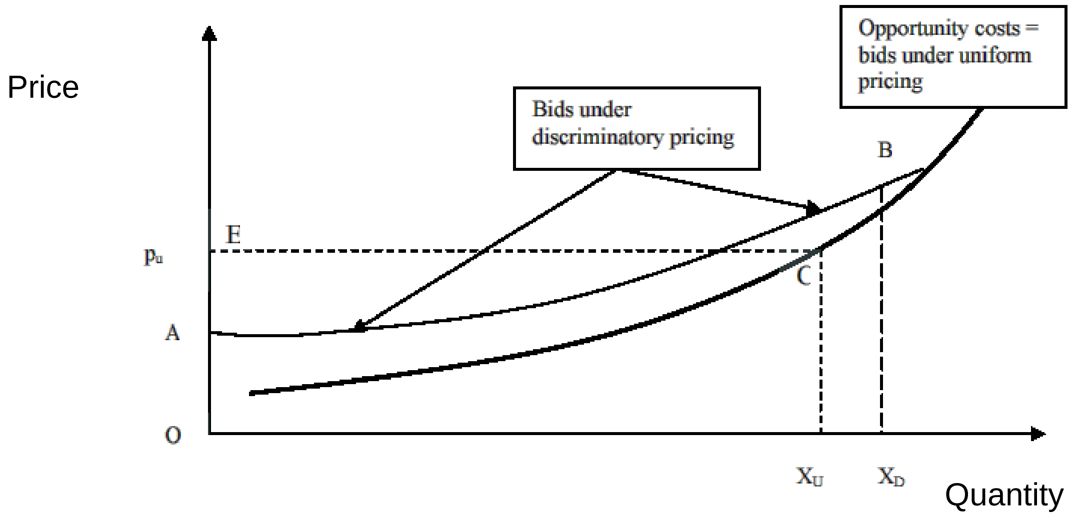

Figure 2 Comparison of uniform and discriminatory pricing when uniform is <u>less</u> cost effective in a budget constrained auction (Latacz-Lohmann & Schilizzi 2005)

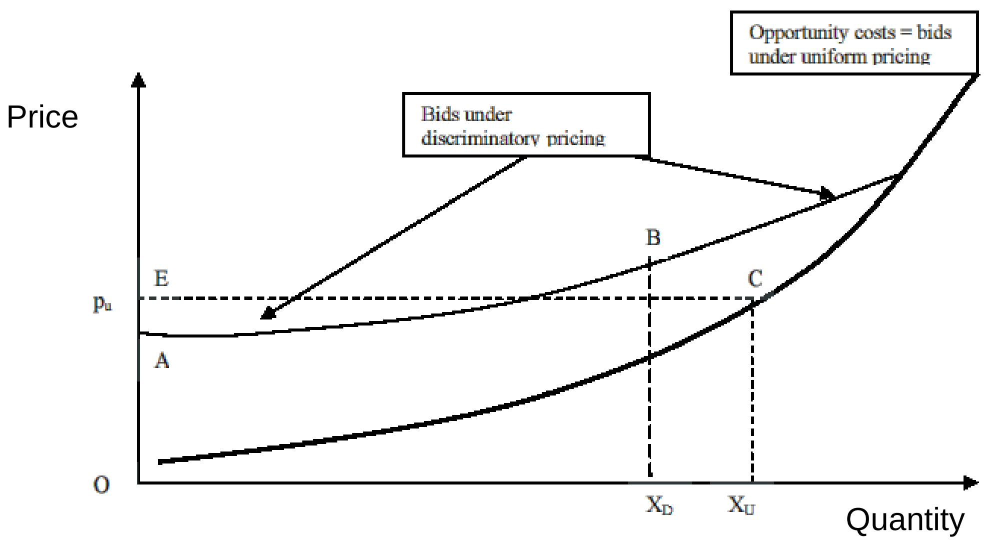

Figure 3 Comparison of uniform and discriminatory pricing when uniform is <u>more</u> cost effective in a budget constrained auction (Latacz-Lohmann & Schilizzi 2005)

In both figures the lower line represents the underlying cost curve and therefore the uniform price bid curve. In the uniform auction X_u units could be bought under a fixed budget with all winners are paid price P_u. The measure of cost effectiveness in $ per unit is estimated using Equation 1. As a result of rent seeking, the discriminatory bid curve lies above the cost curve. In the auction X_d units are bought and each winner is paid a price equal to their bid. Cost effectiveness is given in Equation 2.

$$CE_U = \frac{Budget\ outlays}{Units\ of\ service\ bought} = \frac{p_U \times X_U}{X_U} = \frac{areaOECX_U}{X_U} = p_U$$

Equation 1
[Source: Latacz-Lohmann & Schilizzi 2005]

$$CE_D = \frac{Budget\ outlays}{Units\ of\ service\ bought} = \frac{area\ OABX_D}{X_D}$$

Equation 2
[Source: Latacz-Lohmann & Schilizzi 2005]

Where there are relatively low levels of rent seeking (Figure 2), more units are able to be purchased under discriminatory pricing ($X_d > X_u$) with the same budgetary outlay ($OECX_u = OABX_d$). Therefore the discriminatory auction will be more cost effective because $CE_d > CE_u$. The reason behind this is that under uniform pricing each winner will always receive a payment greater than their costs, and will therefore inflate program costs. Consider the scenario where all participants were to place a bid equal to their costs regardless of payment method implemented. The total cost of a uniform program would be greater because each respective payment would be greater than in the discriminatory format. Where there is relatively high level of rent seeking (Figure 3), uniform pricing outperforms discriminatory pricing as more units are purchased ($X_u > X_d$) for the same budgetary outlay.

A number of experiments have been used to test the performance of uniform versus discriminatory payment rules. In the case of single bid experiments, the evidence seems to favour discriminatory auctions, even though the uniform price seems to lead to bidding behavior that is closer to actual cost (e.g. Stoneham 2002; Cason & Gangadharan

2005). In addition, recent theoretical papers on uniform versus discriminatory auctions in a repeated auction setting suggest that uniform price auctions are better at facilitating collusion, in part uniform payments create greater incentives for low cost producers to not “deviate” from the agreed upon collusive “high cost” bidding strategy (e.g. Fabra 2003; Cincotti et al. 2006). Nonetheless, results are still context specific, and what is true in a single bid setting does not necessarily translate to a multiple-bid setting. Hailu & Thoyer (2007) found that for a multiple bid-multiple unit auction the discriminatory auction had the poorest performance.

Discriminatory pricing has been found to possess characteristics that favour better cost effectiveness than the uniform pricing method. Cason & Gangadharan (2004; 2005) found in their experiments that discriminatory pricing led to lower overall costs of conducting an auction than uniform pricing. Cason & Gangadharan (2004; 2005) also found that under the uniform framework, less environmental benefits would be acquired because the respective price was higher than in the discriminatory case. Similar results have been found in the case of spectrum, or Treasury board auctions (Binmore & Swierzbinski 1999; Ausubel & Cramton 2002). Ausubel & Crampton (2002) also show that bid shading and strategic bidding also occur under uniform pricing in Treasury bill auctions.

An important feature of a procurement auction is the fact that it has the ability to reveal the costs of the individuals participating in order to combat the effect of asymmetric information. It may be desirable for an auction to reveal costs for possible policy including using the auction to establish realistic costs for an activity for future program development. Based on the optimal bid strategy under 2nd price auctions, participants are more likely to place a bid equal to their costs under uniform pricing, and therefore outperform discriminatory pricing on this criterion (Cason & Gangadharan 2004, 2005, Latacz-Lohmann & Schilizzi 2005, Jack et al. 2008). Cason & Gangadharan (2004; 2005) provide empirical evidence showing that uniform pricing yields bids within 2% of costs on average (higher and lower), while discriminatory pricing yielded bids 8% higher than costs. Theoretically speaking, uniform pricing would perform better at revealing the cost curve than discriminatory pricing based on the optimal bidding behaviour in each method in the short run. As was previously illustrated, bidders are more likely to shade their bids above their costs in order to maximize a potential profit; this of course results in a misrepresentative revealed cost function that does not reflect the actual cost function.

Cummings et al. (2004) conducted a study on irrigation permits in Georgia, USA using both laboratory and field experiments to test different auction payment methods. They claim that discriminatory pricing was superior to uniform pricing because of the nature of the auction they were implementing, which included a differing number of multiple units of goods. The authors also stated that uniform pricing would be difficult to explain in reality and could result in large initial losses due to a lack of understanding on behalf of the participants. Another fact brought up by Cummings et al. (2004) is that there may be negative reactions from farmers where low valued land would be paid the same market price as high valued land. Yet if a uniform unit price per benefit was established (as opposed to a single value), the high valued land would be allotted an appropriate payment larger than that of low valued land.

Overall, there are many factors that need to be considered prior to choosing a payment method for reverse auctions. There still remains little clear-cut evidence establishing the best payment method. There remains need for more research into this area taking into consideration factors such as repeated auctions, experience, and levels of information provided to see if there are more differences and characteristics between uniform and discriminatory payments than has been revealed in the literature.

2.4.2 Bid Ranking

Bid ranking is used in conservation auctions to determine how buyers select between heterogeneous producers to determine winners. We distinguish between two different types of bid ranking strategies. The maximum coverage ranking rule treats all bids equally in terms of quantity (e.g. number of wetland acres restored, number of head of cattle included). Therefore from the buyer's perspective the bid selection rule is to minimize cost per unit of environmental benefit under conservation contract for a given budget constraint. However, these auctions are not necessarily the most efficient; in particular they may suffer from the problem of "adverse selection" where cost and environmental benefits are positively correlated. In terms of efficiency, the goal of an auction is to maximize $ per environmental benefits provided, not amount of area in conservation. In order to target higher quality lands, governments can use eligibility rules (for example, only highly erodible lands), and/or an EBI to screen and select contracts.

A number of conservation auctions employ some sort of EBI to rank bids. For example the Victorian BushTender and Bush Broker auctions ranked bids based on hectares of habitat hectares (Parkes et al. 2003; Nemes et al. 2008). The CRP uses an EBI based on a weighted score over a number of factors including wildlife, water quality, erosion, permanence of the practice, and air quality (Claassen et al. 2008).

Babcock et al. (1996) show that the benefits of environmental targeting are dependent on the correlation between costs and environmental benefits. In particular, if environmental benefits are negatively correlated with costs, or if the variation in benefits is small compared to the variation of costs amongst parcels, then the least cost enrollment can approximate an allocation that maximizes benefits. On the other hand, if costs and environmental benefits are positively correlated, then environmental targeting leads to much higher efficiency. In reality, costs can be either negatively or positively correlated with environmental benefits, or there may be no correlation. Babcock et al. (1996) find that the gains from environmental targeting are high for water quality, but low for benefits to wildlife (Babcock et al. 1996; Claassen et al. 2008).

2.4.3 Budget Based versus Target Based Auctions

Conservation auctions can run under one of two constraints: a budget constraint or a target (objective) constraint. Under a budget constraint winning bids are selected until a fixed budget is exhausted. The quantity of EG&S acquired under such an auction is only known *ex post*. A target based auction implies that there is a pre-determined fixed amount of EG&S (or other objective) to be gained from the auction process. In this case, the resulting budget is only known *ex post*. Latacz-Lohmann & Schilizzi (2005) state that there is no *a priori* reason to believe that one is better than the other. Although, they also note that a budget constraint may create an environment which psychologically disciplines bidders to place bids closer to their costs because they are aware that the money available for large payments is limited. This claim, however, has not been tested.

Schilizzi & Latacz-Lohmann (2007) have compared the performance of budget versus target based auctions against a benchmark auction model. The experimental auctions were designed to address nutrient abatement and the authors applied a hypothetical cost function. The budget was set arbitrarily and announced to the participants. The fixed target was determined endogenously from the result of the number of contracts purchased in the first budget based auction. The target was established in this manner in order to observe if a target based auction would out perform a budget based auction in achieving the same number of contracts. The auctions were evaluated using three criteria: budgetary cost effectiveness (value for money); information rents (additional payment above participation cost); and economic efficiency (opportunity cost per unit). They were also compared to an equivalent fixed payment structure that was equal to the one minimum payment needed to achieve the quantity target with the budget used.

Schilizzi & Latacz-Lohmann (2007) found that in a one-shot auction both the budget and target based auction outperformed the fixed price program. However, they also found that the target based auction consistently outperformed the budget constrained auction and was more efficient over the fixed price program than the budget auctions. In contrast, over repeated auctions the target auction’s relative performance over the budget auction eroded in terms of budgetary cost effectiveness and information rents. It is possible that the parcels of information provided to participants between rounds were sufficient enough for bidders to adjust their bids under both auction frameworks. Since under a target constrained auction there is no budget cap, participants had a greater opportunity to rent seek. Therefore, the authors conclude that a budget auction would be more appropriate if an agency was considering multiple signups or planned to hold subsequent auctions in the future.

Although Schilizzi & Latacz-Lohmann (2007) conclude that there is essentially little difference between the constraint types, there are few (if any) studies to support this claim. It is anticipated in this current society where environmental action is important to the public and therefore governments, the target based auction could become popular to ensure that governments do not fall short of their policy objectives or goals, or as EG&S become increasingly more scarce. In fact, the Prairie Habitat Joint Venture has recently reported goals related to wetland restoration targets in the Canadian prairie pothole region for the next 25 years (PHJV 2008). Therefore, the need for information regarding target based auctions may become important in the future.

2.4.4 Reservation Price and Targets

A reserve price in the context of a non-reverse auction is the minimum value for the good in question. In the context of conservation auctions the reserve price is the maximum amount willing to be paid for a unit of the good being traded (Latacz-Lohmann & Schilizzi 2005). The reserve price essentially acts as an alternative budget constraint if the auction environment is susceptible to factors leading to rent seeking and the submission of large bids.

Latacz-Lohmann & Schilizzi (2005) identify two reasons to consider the use of a reserve price in an auction:

- The implementation of a reserve price contributes to the risk that a bidder may lose from bidding too high. This will increase bidder competition enabling the agency to gain from information rent that would have otherwise been transferred to the winning participants. It also eliminates the possibility of submitting extremely high bids, or “blue sky” bids.

- The reserve price may also act as a price signal of the agency's (or society's) maximum willingness to pay for conservation services, thus somewhat representing the demand side of the conservation market

While reserve prices are not required in all conservation auctions, in some cases including a reserve price would be appropriate. There are a number of different factors that arise that may affect cost effectiveness by providing potential opportunities to rent seek such as low competition, collusive behaviour, or bidder learning (Latacz-Lohmann & Schillizzi 2005). Lower competition implies when a bid is increased the probability of winning decreases at a relatively lower rate when compared to an auction with high competition. There may be opportunities for the participants to increase their bids significantly and still win in the auction. By including a reserve price, a cap is placed on the maximum bid allowed to be entered into the auction which can ensure that rent seeking is maintained to a certain degree.

Collusive behaviour implies that there is an agreement among the participants to bid in a particular way that would yield a high gain to the entire group. Similar to the effect under low competition, a reserve price creates a price ceiling that limits possible rent seeking and benefits of collusion.

If there are repeated auction rounds there is an opportunity for participants to learn (see section 2.4.5) aspects of the auction such as the available budget, or the average price paid to winners. With this learned knowledge, there again is an opportunity for participants to rent seek through the bidding process. The implementation of the reserve price would limit the extent of the potential for rent seeking.

Determining the optimal reserve price can be difficult for goods whose market values are unknown. An optimal reserve price requires that the buyer already knows the distribution of costs. This may not be realistic for agri-environmental programs. Even if the distribution is known, other factors such as the EBI can result in a complex problem. In the absence of sufficient information to set the reserve price optimally, the buyer might just use a rule of thumb about the politically acceptable value of the conservation contract, or simply just announce the existence of the reserve price without the amount. The CRP uses bid caps and stratifies bidders in different categories by levels of EBI in order to encourage competition amongst low opportunity cost bidders (Kirwin et al. 2005).

A reserve price may be less important where auctions have a strict budget constraint which acts like an implicit reservation price (Latacz-Lohmann & Schilizzi 2005). In the event there is a fixed budget to be used for a number of auctions, a reserve price would be beneficial in that it limits the extent of rent seeking so that the budget may be more evenly distributed between auctions.

Latacz-Lohmann & Schilizzi (2005) define a reserve quantity as the maximum allowable bid accepted in reference to the amount of EG&S submitted. A reserve quantity may be used to achieve equity objectives in situations where one (or very few) bid represents a large fraction of the objective being considered in the auction (Latacz-Lohmann & Schilizzi 2005). For example, in the auction for Landscape Recovery in Western Australia a bid which constituted a large fraction of the total area under the auction was rejected despite having a competitive $/ha cost in order to spread the budget among more participants (Latacz-Lohmann & Schilizzi 2005).

2.4.5 Information and Learning

The level of information provided to participants in the reverse auction can have implications on the outcome. The amount of information influences the level of information asymmetry between buyers and sellers. More information levels the playing field and the incidence of adverse selection decreases and efficiency increases. However, this comes at a cost since participants may be able to use it to their advantage to extract information rents and decrease cost effectiveness. Therefore, careful consideration should be taken when determining what information to provide to participants. Information has been broken down into two categories: budget and reserve prices, and goods and services attributes. The effect of learning and how it is influenced by information provision will also be discussed in this subsection.

Budgets and Reserve Prices

Revealing information related to budgets and/or reserve prices can send signals to bidders as to the price the program authority is willing to pay for EG&S. The tradeoffs of announcing a reserve price are similar to those of announcing a budget constraint: disclosure can either increase the competitiveness of bids, or it may signal the value of the contract and anchor bids at a higher level than would have otherwise been the case.

If both the budget constraint and the quantity target are known, participants may drive up procurement costs if they don't perceive the auction as being very competitive, or they may anchor their bids on a perceived "average cost". In an auction with few participants bidders might inflate their bids if they know that there is a fixed quantity target (Cummings et al., 2004). On the other hand, announcing that a unit cap is in effect without specifying the level may reduce spurious bidding (Hartwell and Aylward, 2007).

In the event a reserve price or quantity is used in an auction, it may be announced or unannounced prior to the outset of the auction – much like a budget or environmental target may be announced or left concealed prior to the auction. With evidence from the CRP, announcing a reserve price may create anchoring bias (Reichelderfer & Boggess 1998) in that bidders will submit a bid equal to the reserve price knowing that it is the maximum accepted offer. Given that there are different bidding strategies depending on the payment type (i.e. discriminatory versus uniform) announcing the reserve price may have different effects on bidder behaviour as well.

Goods and Services Attributes

Administrators may choose to reveal to participants the amount of environmental benefits they could provide, if this information is known. There are advantages and disadvantages to revealing this type of information. The disclosure of such information to landowners reveals opportunities to increase auction efficiency by reducing barriers created by information asymmetry. Landowners are informed which can encourage long-term investment into conservation programs to increase environmental benefits and there is an increase in the perceived fairness and transparency in the auction. However, revealing environmental information can encourage rent seeking and thus reduce cost effectiveness (see Cason & Gangadharan 2004).

Chan et al. (2003) argue that the optimal information policy depends on who holds the information about the EG&S on private land: landowners or the program authority (e.g. government). Landowners are more likely to have private information pertaining to the environmental impact of their management practices (e.g. potential effects on particular tracts of land and or species (Latacz-Lohmann & Schilizzi 2005)).

However, the program authority may have access to more detailed information of the ecological/environmental significance of their land and characteristics and how they match with policy goals and objectives (Latacz-Lohmann & Schilizzi 2005).

If landowners hold detailed private information about the level of EG&S that could be provided by their actions, Chan et al. (2003) recommends that the scoring rules and relative weights should be announced if quality can be accurately verified after the auction. In this case, landowners are able to bundle their attributes to best suit the program and increase their probability of being selected thus overcoming the adverse selection problem. However, this also leads to over-paying for EG&S as landowners may exploit their information advantage and shade their bid above their costs (Chan et al. 2003; Latacz-Lohmann & Schilizzi 2005). When EG&S submitted in a bid cannot be verified, announcing the scoring rules and weights could lead to adverse selection and price competition, and subsequently the purchase of lower quality because participants can misrepresent their quality from knowing what would be required to get a high score in the auction (Chan et al. 2003).

If the program authority has more information pertaining to the level of EG&S on bidders' land, they have one of two choices: to reveal or not to reveal. If full information is revealed to landowners, there is incentive for bidders to extract information rents, especially for those who have desirable levels of EG&S (Chan et al. 2003). If they only reveal the information related to the scoring rule it must be symmetrical among bidders. Bidders would then make predictions about the preferred EG&S qualities relative to their predictions of their own EG&S potential. Chan et al. (2003) stipulates that in this situation bidders will avoid price competition in order to maximize their profit potential.

Price competition will drive down prices and minimize expected profits and not necessarily improve their chances of winning.

When the program authority does not reveal its private information about the EG&S bidders will have to make their own assessment of their environmental quality and how it will meet the preferences of the authority. As a result, bidding becomes more like guesswork because of the uncertainty of their EG&S provision in addition to their cost considerations (Chan et al. 2003). This increased uncertainty will encourage participants to bid closer to their costs (lower than their bids in the previous scenarios) for all levels of EG&S in order to increase the chance of winning in the auction (Chan et al. 2003). However, while there may be an improvement in cost effectiveness, there still remains the possibility of adverse selection remaining due to information asymmetry.

Cason & Gangadharan (2004) and Cason et al. (2003) test the effect of information on bidding behaviour using laboratory auction experiments by manipulating the amount of information provided to participants. In one treatment the environmental benefits information was revealed, and in the other treatment it was not. They found that when environmental benefit information was withheld from bidders, the bids were closer to their costs. However, with the provision of environmental benefits information bidders were more likely to misrepresent their costs, especially those with high levels of benefits. The result was a reduction in cost effectiveness. This is because the high benefits participants know that they would be prioritized in the auction, and therefore behave strategically to get the highest profit possible (Cason & Gangadharan 2004, Cason et al. 2003). There was no explicit exploration into the effect on efficiency/adverse selection in their information treatment.

Despite this finding, there may also be long run advantages to revealing information. According to Stoneham et al. (2003), full disclosure of environmental asset information to participants sends signals to participants as to the priorities of the program authority. This provides participants with an opportunity and incentive to invest in conservation activities, and/or bundle specific assets or activities in order to increase their probability of being selected in the auction.

Since the level of information to provide to the prospective bidders is an *ex ante* decision, the program authority must first weigh its different policy objectives and goals. There should also be some consideration as to who would hold the most significant information regarding EG&S.

Learning

Another aspect of information provision is that which is learned over time by participants. After each auction round, bidders acquire some information based on the auction outcomes. Depending on their auction outcome, the bidder may choose to exploit this information by adjusting their bid accordingly to further their success in the auction and/or to increase the level of rent extraction.

The level of learning is contingent on the amount of information announced after each auction round. Any information provided could be used to send signals to bidders and aid in bid adjustment to improve their gains from trade or accelerate the rate of learning. Essentially the same behaviour as described above concerning *a priori* information would result; i.e. promotion of rent seeking.

Hailu & Schilizzi (2005) used agent based modeling techniques to assess the effect of 30 repeated auctions on learning and auction efficiency. They found that while learning may be evident in an auction, the level of competition may be able to combat the effect and thus maintain auction efficiency. In the model, a learning algorithm which enforces a direction on bid adjustment based on previous auction outcomes was imposed[8]. They found that auction efficiency does in fact erode over repeated auction rounds when learning is accounted for. By the 15th period (out of 30) almost all winning bids were equal to the marginal bid (the first unsuccessful bid).

Hailu & Schilizzi (2005) explain that when learning occurs, participants with previously successful bids or feedback exploit this information by experimenting with bid mark-ups. Through the process of learning and adjustment of bids, the infra-marginal[9] bidders (bidders who are preferred by the auctioneer) mark their bids up to where it equates the marginal bid. This leads to decreasing environmental benefits procured per budgetary outlay over each auction round. Hailu & Schilizzi (2005) also identify two trends which contribute to the loss of efficiency. First, there is a crowding out effect since fewer participants are accepted in the auction resulting in lower participation; and second, the proportion of rent seeking above opportunity costs increases over time. They also find that auctions become less efficient than fixed price payment methods over time because of learning. Because of this phenomenon, short term efficiency does not necessarily equal long term efficiency (Hailu & Schilizzi 2005).

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[8] The learning algorithm used was developed by Roth & Erev (1995) and Erev & Roth (1998); it is widely accepted in psychology literature (Hailu & Schilizzi 2005). The learning rule is as follows (as written in Hailu & Schilizzi 2005):

1) If an agent wins a contract in the previous auction, it will maintain the same bid or increment it by 10%.
2) If an agent loses in the previous auction, it will maintain the same bid or lower it by 10%.
3) Bids do not go below own opportunity costs.

[9] An infra-marginal bidder that is ranked higher than the marginal or lowest ranked winner (Hailu & Schilizzi 2005).

Schilizzi & Latacz-Lohmann (2007) also encountered learning in an auction experiment using human subjects. The result of learning over three auction periods was also a decrease in auction efficiency due to increasing rates of rent extraction. Learning was also documented in the CRP program which resulted in infra-marginal bidders increasing their bids to equate the implicit bid price (Reichelderfer and Boggess, 1988).

In order to prevent this characteristic of repeated auctions, Hailu & Schilizzi (2005) suggest altering the rules (e.g. imposing reserve price, adjusting reserve price) of the auctions slightly between rounds or after a certain number of rounds in order to maintain a sense of information asymmetry between the bidders and the auctioneer. This will limit the amount for time infra-marginal bids to converge to the margin or reserve price. However, by changing the rules of the auction behind closed doors may also decrease the level of trust between participants and the auctioneer which could lead to a reduction in participation.

The only documentation for learning in the literature has been in reference to discriminatory price auctions. This payment method encourages rent seeking in the first place, and repeated auctions create an environment where the rate of rent seeking can increase over time with few ramifications. Although not yet supported by literature, it is possible that uniform pricing would be more robust under repeated auction rounds. There is no incentive for the infra-marginal bidders to increase their bid to equate the margin, since any increase in a bid could compromise the chance of winning a contract.

2.4.6 Communication

Social aspects may also influence auction outcomes and influence issues such as collusion. Conservation auctions typically use sealed bids and only the auctioneer is able to see all of the submitted bids. However, if producers have an opportunity to communicate during an auction (for example, if auction rounds are held over a period of days or weeks; or if several auctions for conservation contracts are sequenced over a longer time frame), then they can learn about each other's bidding strategies and have an opportunity to coordinate their strategies in order to game the auction. In the most extreme case, producers might develop side contracts which allow them to split the rewards of using a coordinated strategy. "Cheap talk" refers to pre-play communication which allows landowners to coordinate their behavior. One concern with cheap talk is that it will facilitate tacit collusion between players in the auction. On the other hand, it may be valuable to encourage this type of communication between farmers, particularly if benefits are increased when producers coordinate their conservation actions (e.g. Parkhurst et al., 2002), or if conservation actions are irreversible and regulators only have one chance to get it right (Warziniack et al. 2007).

2.5 Research Objectives

Despite the wide body of literature investigating auction theory, gaps still remain in the realm of conservation auction theory. While economic experiments have tested design theory which has been used to guide the practical use of auctions, there are limitations to the current body of work. For instance, uniform pricing is often omitted when testing design features other than payment method. Theory clearly suggests that the nature of uniform pricing diminishes the incentive for bidders to rent seek. However, Cason & Gangadharan (2005) demonstrate empirically that discriminatory pricing yields higher efficiency, but benefits from employing uniform pricing are not acknowledged.

Therefore, this thesis will test the claims by Cason & Gangadharan (2005) with regards to payment method.

While budget based auctions are the norm for conservation auctions, there may be more pressure on governments from the public to pursue more specific goals related to EG&S. This may lead to a higher demand in the use of target based auctions where governments cannot fall short of their policy goals. The theory surrounding this design feature is limited to Schilizzi & Latacz-Lohmann (2007), and it is limited in providing practical guidance if they are to be implemented in reality. This thesis will delve further into the investigation of target based auctions and how factors such as payment method, repeated auctions and reserve prices influence their efficiency.

2.6 Summary

Many environmental programs today rely on voluntary participation by private landowners or producers in fixed payment or cost sharing programs to encourage environmentally friendly behaviour to procure EG&S. However, there exists a degree of information asymmetry between the program authority and landowners; the authority is completely unaware of the costs facing producers to provide EG&S, and landowners do not possess knowledge of the value of their services or the preferences of the authority. This has resulted in relatively low participation in current programs, in addition to economically inefficient programs.

An alternative option to the widely used fixed payment or cost sharing agreements, are conservation auctions. These resemble procurement auctions (or reverse auctions) in that there is one central buyer and multiple sellers compete for contracts on a fixed budget. Auctions are typically used where there are no existing prices or markets for goods or services. They are essentially price discovery mechanism which makes use of competition between bidders to reveal the true price because the optimal and efficient solution is to bid one's own value. In the context of EG&S, bidders form bids based on the level of compensation they would like to receive in return for their services. They must face tradeoffs between increasing their bid to make a profit or being included in the auction at all. Likewise to the conventional auction, the optimal or efficient outcome boils down to revealing the true cost, or value of the good.

Conventional auction theory is evaluated based on RET, which states that given a set of assumptions, all auction institutions will yield the same level of revenue from trade. However, given the unique nature of conservation auctions, several assumptions are violated; thus conventional auction theory should not be used to guide design. Much of conservation auction theory has been developed using economic experiments where designs are tested and evaluated to see what yields the most efficient outcomes. Significant design features to be considered are payment method; budget based versus target based auctions; reserve prices; and information and learning. Each feature contributes to the end efficiency of an auction as well as the auctions ability to act as a cost discovery mechanism.

Based on the literature available for review, conservation auctions pose a vibrant method to be used in the case of wetland restoration. They are becoming increasingly more popular globally. For example, Australia has implemented them for a number of environmental projects ranging from habitat rehabilitation to soil conservation; the US has used auctions for soil conservation in the CRP and are also used under state jurisdiction for water/irrigation rights; there is also upcoming use in Scotland and Germany for habitat rehabilitation programs.

Chapter 3 Determination of Wetland Restoration Costs

3.1 Introduction

The literature describing and empirically evaluating the economic cost of wetlands on producers/landowners almost exclusively deals with the United States. The general consensus of the studies was that wetlands do indeed impose a cost to producers. The costs however, were not consistent across studies due to the highly variable and heterogeneous nature of wetlands and their surrounding environments. A summary of the estimated costs are provided in Table 1.

Table 1 Summary of wetland restoration cost studies

Study	Location	Method	Price
Schultz & Taff (2008)	USA	Hedonic price model	$161/acre (non-eased) $321/acre (eased)
Gelso et al. (2008)	Kansas, USA	Production model/ Contingent Valuation Method	$1.72/acre (low dispersal) - $15.31/acre (high dispersal)
Prato & Hey (2006)	Illinois, USA	Gross production value loss	$874.78/ha (corn) $626.99/ha (soybeans)
Heimlich (1994)	USA	Empirical analysis	$48/acre (prairie pothole region) - $1193/acre (Appalachia region)

Schultz and Taff (2004) employed a hedonic model in order to evaluate the implicit price of wetland easements in the United States. The intent of their study was to show that the framework to determine easement payments used at the time was not correct based on inaccurate methods. In their hedonic model, sale prices of agricultural land was the dependent variable which varied in certain land sale characteristics, productivity measure (revenue/acre), wetland characteristics (temporary versus permanent wetlands) and easement characteristics (eased versus non-eased). Their goal was focused on finding the implicit price specific to the easement which was modeled as the implicit price of an eased wetland acre minus the implicit price of a non-eased wetland acre. Schultz and Taff (2004) found that the implicit price of permanent wetlands was $161/acre if not eased, and $321/acre if eased. These implicit prices indicate that the presence of non-eased permanent wetlands would decrease the sale price of agricultural land by $161/acre, and $321/acre for land with wetlands which are eased. The authors conclude that the implicit cost of an easement was $160/acre (difference between eased and non-eased wetlands). In order to put this in the context of this study, $160/acre would be the unit cost of a wetland. However this essentially only takes into consideration the opportunity cost of selling land. It does not take directly into consideration nuisance costs associated with having wetlands present on land however they are indirectly accounted for in the opportunity cost.

Gelso et al. (2008) developed a conceptual framework with a production model under uncertainty to derive the implicit cost of wetlands, and tested it with data collected via a Contingent Valuation (CV) survey. In the author's conceptual model, the certainty equivalent of the gain from converting all wetlands to upland habitat was used to derive the implicit cost; where uncertainty was held in the returns from wetland and upland acreage dependent on random amounts of precipitation. Gelso et al. (2008) felt that wetland costs were a product of the number of wetlands in a given area, their size, and their dispersion in a given area. These factors were assumed to fluctuate in response to the amount of hydration. They also included additional tillage costs resulting from wetlands as a measure of nuisance costs.

In the conceptual model, Gelso et al. (2008) show that there is a positive relationship between wetland dispersion (i.e. the number of wetland areas) and costs However, there was an ambiguous affect to costs with regards to the frequency of wetlands and their size. The authors claim that this is due to the fact that there is a negative correlation between lowland (i.e. wetland) and upland productivity. In the event of a wet season, the upland area will be highly productive, but the lowland area will have excessive moisture, more wetland acreage, and will be less productive. Conversely, when there is a dry season, the lowland area will be productive, because it will have manageable levels of moisture and smaller wetland acreage, while the upland area will suffer and be less productive (Gelso et al. 2008). These conclusions were subsequently validated with their survey data and tobit regression models.

In the survey, respondents were required to answer anchored-open ended questions regarding their Willingness To Pay (WTP) to rent land with a certain number (given as % of landbase) of either seasonal/temporary or permanent wetlands (given by number of years they would be hydrated out of 5) with the knowledge that land without wetlands would cost $35/acre. The authors established the perceived cost of wetlands to be the difference between the response in $/acre and $35/acre. The average WTP responses ranged from $16/acre to $31/acre depending on the wetland scenario given. The predicted costs from the tobit model yielded the cost to range from $1.72/acre (temporary, low dispersal wetlands) to $15.31/acre (permanent, high dispersal wetlands).

Heimlich (1994) investigated the cost of a wetland reserve program costs based on permanent easement payments. The easement payments were composed of opportunity costs and cost of wetland restoration. Opportunity costs were estimated as the discounted (r = 7.5% (Economic Research Service)) net returns that would be lost if a given area was eased. The cost of wetland restoration was based on previous location specific projects in the United States. Restoration costs ranged from $48/acre (prairie pothole region) to $1193/acre (Appalachia region). Heimlich (1994) designated areas suitable for wetland restoration based on soil type. He stated that areas with hydric soils (soils which are saturated or flooded in their un-drained condition) are a key identifying feature for wetlands, and would most likely be areas where wetlands previously existed. By combining the suitable areas with easement cost estimates, Heimlich (1994) was able to estimate the cost of easing land for the intention of wetland restoration with simulation methods.

Heimlich (1994) carried out different empirical analyses to emulate different easement program enrolment conditions (e.g. least cost; national pool, regional pool; proportional enrolment) for 3 different easement acreage goals (1, 2.5, and 5 million acres eased). Heimlich (1994) found that the least cost [10]total cost to establish a reserve size of 1 million acres would be $194 to $286 million, giving an average cost of $194 to $286/acre, and a marginal cost of $310 to $457/acre. Increasing the total reserve size subsequently increased the cost of the program by up to 82% (Heimlich 1994). Heimlich (1994) also established that a national pool for enrollment would be more cost effective than having several regional pools. This is most likely because some areas in the country

[10] Least cost assumes that easements would be paid from lowest enrollment to highest enrollment cost until the reserve target was reached (Heimlich 1994).

would be more expensive than others, therefore in a regional pool they would be selected, while in a national pool they would be overlooked. This would reduce costs while still maintaining the overall reserve area.

Prato & Hey (2006) estimated the economic impact of wetland restoration in Illinois using the Impact Modeling for PLANing (IMPLAN) model to estimate changes in the output of corn and soybeans in the project area using average crop yields (by soil type), and crop acreage and corn and soybean prices in Illinois for 1999 and 2000. The decrease in gross value of crop production from wetland restoration was $874.78/ha for corn and $626.99/ha for soybeans. The economic impacts were first estimated on an annual basis for a 20 year period (2000 – 2019) and then converted to a net present value using a discount rate of 3%. They found that wetland restoration would have a negative economic impact on corn and soybean producers in terms of total output ($826,412 and $640,552 respectively), farm income ($191,067 and $208,728 respectively), and employment for both corn and soybean producers.

The opportunity costs of wetlands and the costs of wetland restoration are multi-faceted; they will reflect current and future commodity markets, individual characteristics, and the particular landscape being considered and are subject to change given the environmental conditions. Therefore costs from one region may not be applicable to another. Given this fact, this chapter will investigate the cost of wetlands and wetland restoration for a specific region in Canada, the South Tobacco Creek Watershed (STC) in Manitoba, Canada, by combining actual economic data with hydrological data.

This chapter will summarize work completed to estimate the cost of wetland restoration in the South Tobacco Creek Watershed in Manitoba, Canada. The combination of existing hydrologic modeling and on farm economic data in the watershed allowed for accurate estimates of the costs facing producers with respect to wetland restoration. The research presented in this chapter partly includes work completed by other researchers.

3.2 Wetland Restoration Scenarios

In order to accurately evaluate producer costs and environmental benefits associated with wetland restoration, it was necessary to first identify suitable areas for wetland restoration in STC. This information was provided by Yang et al. (2008)[11] who used GIS functions and Lidar Digital Elevation Models (DEM) to estimate potential wetland surface areas that had been lost in the watershed. The DEM was used to identify depression cells, or locations of low elevation on the fields, which would be likely locations for wetlands to occur. This information was then used to generate depression polygons with areas from 0.1 to 7.0 acres. These areas are consistent with the size range for Ducks Unlimited Canada (DUC) wetland restoration projects in the watershed (personal communication, Yang, W., 2009). These potential wetland restoration sites were linked by GIS with producers' field boundaries and ownership data provided by the DWSMA[12]..

Four different wetland restoration scenarios were created to represent different levels of restoration of the potential wetlands in the study area. The scenarios were based on 100%, 50%, 25%, and 12.5% restoration of the lost wetland area (scenarios 1, 2, 3,

[11] Details regarding the wetland restoration scenarios may be found in Yang et al. (2008).
[12] Wetlands were only classified based on size and no other characteristic.

and 4 respectively). Each of the scenarios below the 100% level involved spatial random selection of wetlands from the higher restoration level. This was done in order to maintain an equal distribution of wetlands among the producers in the watershed; in some cases this involved the exclusion of a fraction of wetlands on each producer's property (Yang et al. 2008). As well, this was done to ensure that a maximum number of producers would be engaged in the analysis of costs and program options. The random sampling was done such that the resulting samples of drained wetlands less than 100% involved as many of the original producers as possible. This method of sampling the 100% drained wetlands to develop the other three scenarios does not necessarily predict the actual pattern of restoration that would occur in the STC watershed.

In each scenario, it was assumed that each producer would restore all potential wetlands selected under each scenario and would pay the associated total costs for this action. The differences between each wetland scenario are depicted in Figure 4. Scenario 1 yielded the maximum number of restored wetlands with 963 water bodies distributed between all 36 producers in the watershed. In the remaining scenarios a given producer would restore either the same number of wetlands or less. Wetlands which were excluded in one scenario would continue to be excluded for the remaining scenarios. If a producer was excluded (i.e. could restore no wetlands) in a previous scenario, they would continue to be excluded for all proceeding scenarios. Subsequent scenarios had smaller wetland counts and total restored wetland acreages which corresponded to the percent of wetland restoration described for each scenario.

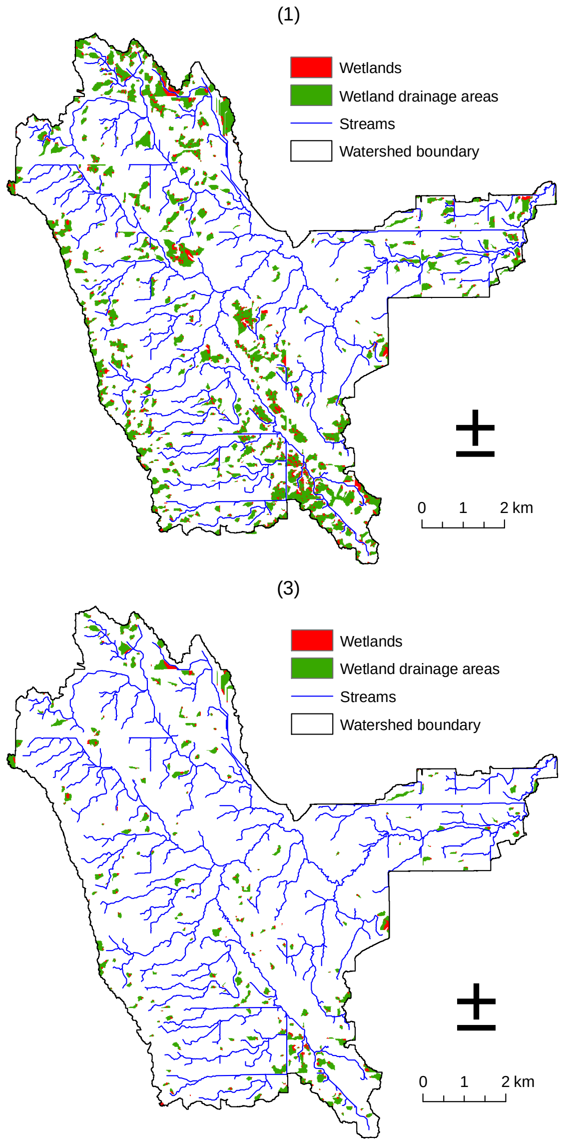

Figure 4 Wetland restoration scenarios in the South Tobacco Creek watershed with restored wetland areas of (1) 2.71% (100%); (2) 1.32% (50%); (3) 0.69% (25%); and (4) 0.35% (12.5% of the total watershed area [source: Yang et al. 2008]

Estimates of environmental benefits arising from wetland restoration were also developed by Yang et al. (2008) using a SWAT model. The SWAT model is a process based watershed model that assesses the impact of land management practices on water, sediment, nutrients and other agricultural chemical yields in a watershed with varying soils, land use, and management conditions or periods of time . The main inputs into the model are weather, soil properties, topography, vegetation, and land management practices for simulating hydrologic and water quality processes (including flow, sediment, crop growth, and nutrient cycling) in a watershed at a daily time step (Arnold et al., 1998; Neitsch et al., 2005).

The model can be used to evaluate predictive scenarios using alternative input data such as climate, land cover change and land use practices, runoff, sediment and nutrient yields measured at the producer level. In this study, wetland restoration scenarios were included into the SWAT model to predict its effect on hydrologic and water quality processes in STC.

Environmental benefits considered in this study were runoff reduction and abatement of sediment, nitrogen and phosphorous under each wetland scenario. The benefits of wetland restoration are a function of the quality of land and hydrology in the localized drainage area. Land characteristics affecting the performance of wetland restoration include slope, soil type, and surface area of the wetland and drainage areas respectively (Yang & Weersink 2004). As nutrient loading into Lake Winnipeg is of major concern in the Manitoba, nutrient abatement – specifically phosphorus abatement – was considered for detailed analysis in this study.

3.4 Wetland Restoration Descriptive Statistics

Across the scenarios, the majority of wetlands were situated on private land (approximately 85%), while the rest were located on crown land. In this study we are strictly concerned with the cost of wetland restoration to private landowners, thus those wetlands located on crown land were excluded from the analysis.

Table 2 provides information regarding the four simulated wetland restoration scenarios. Wetlands less than 0.1 acres were excluded from analysis in order to remain consistent with the wetland size distribution for DUC wetland restoration projects in Manitoba (Yang, personal communication, 2009). The mean size of restored wetlands in the STC watershed was roughly the same size for each scenario, ranging between 0.463 acres and 0.494 acres. However, the total restored wetland acreage decreases for each scenario according to the percent restoration.

Table 2 Wetland restoration simulation scenario descriptive statistics in South Tobacco Creek

Scenario	No. of Producers required to restore	No. of wetlands to be restored	Mean wetland size (acres)	Standard Deviation	Total wetland acreage to be restored
1	36	963	0.494	0.022	475.92
2	34	481	0.486	0.028	233.92
3	31	249	0.486	0.042	120.99
4	30	130	0.463	0.053	60.16

Table 3 describes the environmental outcomes (runoff, sediment abatement, and nitrogen and phosphorus abatement) resulting from wetland restoration as determined from the SWAT model. In Scenario 1 (100% restoration), a total of 1374 kg of phosphorus per year would be abated with restoration, or an average of 38.17 kg/year per producer. The actual amount of phosphorus abated per wetland could not be explicitly determined because these measurements were taken at the outlet of each farm and the total decrease could not be linked back to individual wetlands. Scenarios involving restoration less than 100% resulted in the provision of fewer environmental benefits since fewer wetlands were created.

Table 3 Environmental reductions as a result of wetland restoration simulation scenarios in South Tobacco Creek

Scenario		Runoff $10^4 m^3/y$	Sediment kg/y	TN kg/y	TP kg/y
1	Sum	72.364	1047748	5504	1374
	Mean*	2.01	29104.11	152.89	38.17
	(S.D.)	(2.41)	(33035.60)	(196.41)	(44.79)
2	Sum	37.997	582115	2991	759
	Mean	1.12	17121.03	87.97	22.32
	(S.D.)	(1.29)	(18849.28)	(108.68)	(24.85)
3	Sum	19.478	295593	1808	451
	Mean	0.61	9237.28	56.50	14.09
	(S.D.)	(0.67)	(9662.65)	(64.97)	(14.58)
4	Sum	14.91	228257	1415	348
	Mean	0.53	8152.04	50.54	12.43
	(S.D.)	(0.59)	(8704.08)	(57.87)	(13.40)

* Mean per producer assuming complete restoration of all potential wetlands respectful of scenario

Depending on the physical environment, some wetlands have greater potential to provide different EG&S, therefore some wetlands are able to abate phosphorus more effectively than others. Aggregated up to the producer, some producers will be more influential than others in terms of the amount of nutrient abatement they could provide. This will also influence how cost effective producers are in providing EG&S in the watershed. Therefore, any program designed to procure EG&S from producers should acknowledge this heterogeneous nature of abatement so that those producers who provide EG&S cost effectively are favoured over others.

3.5 Costs

The following section describes the framework used to determine the costs to producers for wetland restoration[13]. The cost functions are estimated and derived in Boxall et al. (2008). The total cost of restoring a given wetland for a specific producer is comprised of both direct and indirect elements. Direct costs were the actual restoration

[13] Restoration costs were deflated to 2004Cdn$ (CPI=103.8) in order to remain consistent with the other cost estimations; restoration cost was then $146.93, and administrative costs were distributed between wetlands for a producer and then CPI adjusted.

costs associated with the construction and restoration of wetlands; while indirect costs are the opportunity costs of the land to be converted to a wetland from reduced output, and the nuisance cost associated with maneuvering machinery around the restored wetland. Figure 5 provides an overview of these costs with more detailed descriptions provided below.

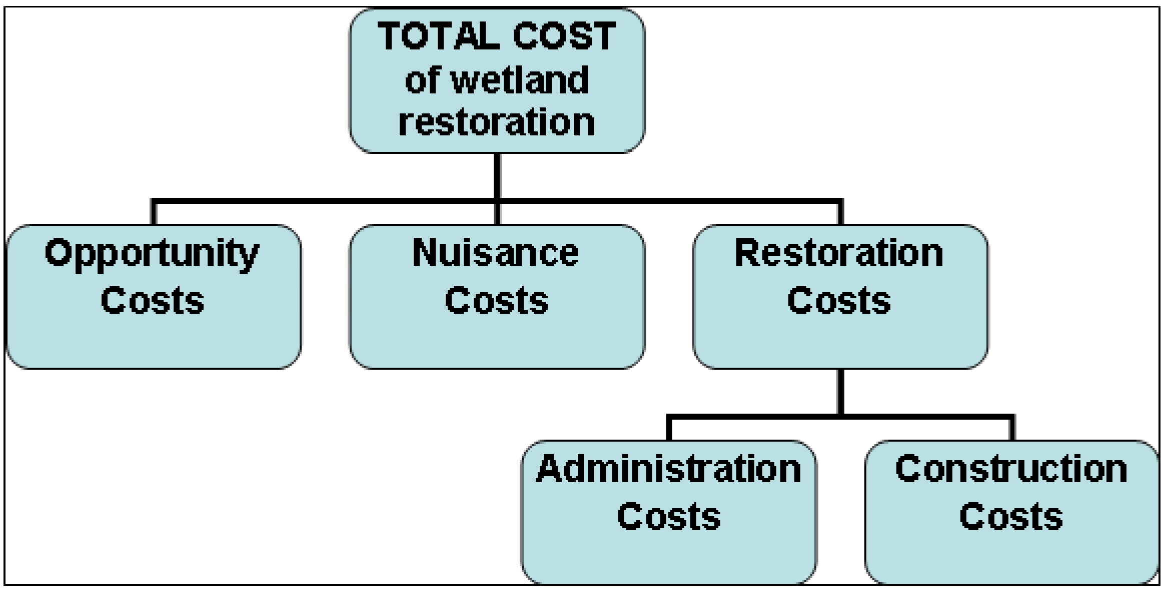

Figure 5 Breakdown of the total cost of wetland restoration into opportunity, nuisance, and restoration costs

3.5.1 Restoration Cost

The direct restoration cost is the one time cost of restoring a wetland, including administrative and physical construction costs. Direct costs were based upon estimates provided by DUC (Andrews, R., personal communication. 2008) where a wetland restoration project typically costs about $500/project – $343.02 per producer for administration and $156.98 per wetland for restoration. These costs are based on wetland restoration being carried out by plugging existing drainage ditches. Administrative costs consider consultation and logistics, and construction costs involve machinery rental and labour. The restoration cost was considered to be a fixed cost per acre per producer, while the administration cost was a fixed cost for each producer regardless of the number of wetlands they could restore.

3.5.2 Opportunity Cost

The opportunity cost of wetland restoration was defined as the foregone income due to lost productive area from a baseline practice. Broadly speaking Opportunity Cost (*OC*) is the difference in net income resulting from wetland restoration, which is defined as the following equation:

$$OC = net\_income_{base} - net\_income_{wetland} ,$$

where net_income_{base} is the baseline level of income in the original case with no restoration imposed; and $net\_income_{wetland}$ is the net income produced after the wetland restoration scenario has been applied.

The baseline level of net income was established using yield functions which were developed by Boxall et al. (2008). Yield functions were based upon historic land use, soil and climate data provided by DSWCA for the period 1991-2006. The yield models, based on crop yields over this period, were subsequently used to forecast foregone yields over a 12 year future rotation (2007-2018).Yield functions were applied to each producer and each field specific to crop type to generate producer specific and field specific costs. The linear yield model used is provided in Equation 3

$$Y_i = \phi_1 + \phi_2 \frac{GS}{GDD} + \phi_3 \left(\frac{GS}{GDD} \right)^2 + \phi_4 N + \phi_5 N^2 + \phi_6 P + \phi_7 P^2 + \phi_8 Pest + \phi_9 SC_1$$
$$+ \phi_{10} SC_2 + \phi_{11} NoTill + \phi_{12} Continuous + \phi_{13} legume + \sum_{j=1}^{41} \varphi_j D_j + \varepsilon,$$

Equation 3 Source: Boxall et al. 2008

where Y_i = yield of crop *i* (bushels per acre), ø= constant, *GS/GDD* = weather variable, *SCi*= soil class dummy variables for Regosols and Brunisols respectively, *N* and *P* = nitrogen and phosphorous applications (kg/ha/year), *Pest* = pesticide application index, *NoTill* = 1 if zero till was employed and 0 otherwise, *Continuous* = 1 if crop type was the same in two consecutive years, *Legume* = 1 if legumes were planted the previous year, and D_j = dummy variables for each producer in the data. Dummy variables are given for each producer in order to account for heterogeneity between farms.

Table 4 Example of projected rotations for 12 years for producer 33 on fields 128, 129, 130, and 131

Field (Rotation)	1	2	3	4	5	6	7	8	9	10	11	12
128 (Forage)	forage	barley	canola	wheat	barley	forage	forage	forage	forage	forage	forage	forage
129 (continuous crop)	oats	canola	wheat	wheat	flax	wheat	wheat	canola	oats	wheat	flax	barley
130 (continuous crop)	wheat	wheat	canola	oats	oats	wheat	wheat	wheat	canola	wheat	oats	wheat
131 (continuous crop)	canola	barley	wheat	canola	wheat	oats	canola	wheat	wheat	canola	wheat	wheat

A 12 year projection period was selected in order to account for three cereal rotations, or a full forage cycle of seven consecutive years followed by a cereal/oilseed rotation. An example of a projected rotation is provided in Table 4. Additional considerations were made for the yield function for forage rotations as forage improves soil characteristics like aeration and water holding capacity. The forage model also includes the indirect benefits of boosting the yields of subsequent crops cultivated after forage (Entz et al, 1995). When this is coupled with the yield functions and other information, the producer income derived for each field was calculated for the projected time period. This land use data was combined with soils data from the ‘Manitoba Soil Database (AAFC, 2002) including soil class, soil texture, and slope, and climate data including temperature and precipitation obtained from, Environment Canada (2005, 2007), for the meteorological station at Miami Thiesen, Manitoba.. Information on crop prices for crops and forage were obtained as a 10 –year average from 1994-2003, to reduce the effect of year-to-year price variation. Prices for crops were obtained from SAF (2003) and for forage from personal communication with Sumach (2007). Boxall et al. (2008) provides more details.

Fields that historically were in pasture were assumed to remain in pasture during the forecast period. The net revenue from pasture was estimated by multiplying the number of animals the pasture could carry by the maximum number of days the pasture could be grazed. Potential wetlands on pasture land may incur economic benefits (i.e. negative opportunity costs due to reducing input requirements). However, wetlands restored on pasture may incur an added cost of installing watering devices and fences to keep livestock away from restored wetlands.

Imposing the potential wetland boundaries as determined by Yang et al. (2008) reduces the productive area for future years. An estimate of the net income loss from this reduction in acreage could be generated by combining Figure 4 with regression equations in for each year until 2018. The difference in net income was then disaggregated to an opportunity cost per wetland. It was also assumed that producers would not alter their rotations after the establishment of wetlands. The total of this income forgone, discounted at 10% over the 12 year period (Section 3.5.4) provides an estimate of the opportunity costs of the wetland restored by wetland for each producer.

Fencing and Watering Costs

The restoration of wetlands in pasture areas required additional considerations. Wetland restoration on pasture results in net benefits rather than costs because the land requires fewer inputs, such as fertilizers. However, there may be additional costs for certain producers grazing cattle on pasture who may install fences or watering devices after restoring wetlands to better manage their cattle and land (personal communication, Hutton, 2008). Therefore, the costs of purchasing of fencing and/or offsite waterers for livestock were included as part of wetland restoration costs on pasture fields.

The decision for installing fencing was based upon the permanency of wetlands in pasture fields. Wetlands less than 1-2 acres are assumed to be transitional wetlands that dry up in the summer season (Hutton, D., personal communication, 2008). If wetlands are not permanent, producers may still allow cattle to graze in that area without being fenced. We therefore assume that only wetlands greater than one acre in surface area will be fenced. Wetlands were also assumed to be circular in shape. The total cost of fencing was therefore calculated by multiplying the unit price of fencing by the circumference of the wetland. The total cost of fencing was assumed to be 2004 CDN$ 1.97 per meter (SAF, 2007). To find an annual cost for fencing, costs were depreciated over 20 years at a rate of 3.5%. We also assumed an annual repair rate of 2% (MAFRI, 2008a).

In addition to fencing, producers may install off-site waterers for livestock in order to provide a location other than the wetland for livestock to obtain water. A producer will install a watering device on a field if his cattle have to walk more than a mile to the next field on his property (Hutton, D., personal communication, 2008). In some cases producers will be able to share waterers among fields. When a producer does not have a shared pasture field less than a mile away close enough to share a waterer, but the wetlands on the field are located close to the center of the field, a waterer would not be installed as cattle are as likely to spread around the field and evenly graze, which is not the case when the wetland is at the edge of the field[14]. Table 5 shows the assumptions used in estimating waterer costs and which producers fit what criteria.

Table 5 Producer assumptions for installing watering devices

Assumption	Number of Producers Affected
Producer shares watering device with other pasture fields less than a mile away	2
Producer installs a watering device because he does not own a pasture less than a mile away and the wetland is at the edge of the field	2
Producer does not install a watering device because he has a wetland close to the center of the field	4

The annual cost for the waterer on a pasture field includes the amortized fixed cost as well as repair. The cost was divided between the numbers of relevant wetlands, depending on how fields share the watering device. The total cost of a watering device was assumed to be $ 6,552 amortized over 20 years at a rate of 3.5% and a repair rate of 2% (MAFRI, 2008a).

3.5.2 Nuisance Costs

Nuisance costs arise from the increased costs from maneuvering machinery around restored wetlands (Cortus 2005; Desjardins 1983; Accutrak Systems Ltd. 1991; and Aldabagh & Beer 1975). Cortus (2005) conducted a simulation analysis investigating the effect nuisance costs have on the decision to drain wetlands and found that nuisance costs increased the amount of land which would be drained by 4 ha for a farm consisting of 8 quarter sections. Likewise, an additional 8 ha would be drained for a farm consisting

[14] We identified four producers who would not install watering devices on isolated fields: 4, 24, 26 and 103.

of 16 quarter sections. Therefore, it is important to consider nuisance costs as an indirect private cost to landowners.

Estimates of nuisance costs for this study were adapted from Cortus (2005) who estimated nuisance cost based on farm size, number of wetlands present, and machinery operating costs. We used his formula and parameters for estimating nuisance costs:

*Nuisance Cost = Nuisance Factor * Machinery Operating Costs*.

The nuisance factor represents the percent increase in machinery operating costs from the presence of wetlands than the case where there are no wetlands (Cortus 2005). It is determined by the number of wetlands present and farm size (number of quarter sections) where farm size is a proxy to estimate machinery implement size[15]. A larger farm size implies larger machinery implement size which results in higher nuisance costs. It was assumed that nuisance factors would increase at a constant rate with respect to increasing farm size and increasing numbers of wetlands as shown in Table 6.

Table 6 Wetland nuisance factors increasing at constant rate with respect to increasing farm size and increasing number of wetlands (Source: Cortus 2005)

Number of Wetlands	Farm Size (number of quarter sections)				
	4	8	12	16	20
1-3	8.0%	9.5%	11.0%	12.5%	14.0%
4-6	9.5%	11.0%	12.5%	14.0%	15.5%
7-9	11.0%	12.5%	14.0%	15.5%	17.0%
>9	12.5%	14.0%	15.5%	17.0%	18.5%

Machinery operating costs (e.g. fuel) were derived for each crop type in a given rotation year based on MAFRI (2004) crop budgets. Machine operating costs were not

[15] The nuisance factor was estimated at the farm level. In other words, the nuisance factor was determined by the number of wetlands present on the entire farm as opposed to wetlands present on individual fields. While it would be more accurate to disaggregate wetlands to the field level in order to account for spatial concentration of wetlands, this model does not take into account spatial considerations. Nuisance costs were assumed to be $0 on pasture fields, as there is no associated machinery operating costs. It is suspected that if spatial recognition was included in the nuisance cost model nuisance costs would escalate significantly.

specific to each producer, but were specific to crop type. Therefore, nuisance costs depend on where a producer is in his rotation.

An example of this calculation for two fields belonging to Producer 4 is presented in Table 7. The nuisance factor for producer 4 was 14% as their farm is made of 8 quarter sections and 11 potential wetlands were present in the 100% restoration scenario. Nuisance costs in Table 7 are given in \$/acre. To acquire the individual nuisance cost for a wetland one would multiply the wetland acreage by the nuisance cost per acre.

Table 7 An example of nuisance cost calculations for 2 fields for a producer in STC

Producer 4								
Field ID	2007				2008			
	Rotation	Operating Cost/acre	Nuisance Factor	Nuisance Cost/acre	Rotation	Operating Cost	Nuisance Factor	Nuisance Cost/acre
276	Canola	17.6	12.5%	2.46	Wheat	17.15	12.5%	2.40
349	Forage	12.82	12.5%	1.79	Forage	12.82	12.5%	1.79

3.5.3 Discounting

The opportunity and nuisance costs were discounted at a 10% interest rate. This rate is commonly used in agricultural finance literature (Unterschultz, personal communication, 2008). Discounting is a common practice in economics in order to account for differences in time preference of money across time periods. An annualized cost was estimated to capture per year costs. An annualized cost differs from an annual cost in that it takes into account discounting across the time period. Restoration costs were not discounted because they are a one-time upfront cost.

The total costs of restoration were calculated as follows:

$$TC_i = RC + \sum_{t=1}^{12} \frac{OC_i^t}{(1+r)^t} + \sum_{t=1}^{12} \frac{NC_i^t}{(1+r)^t};$$

where T*C* is the total cost, *RC* is restoration cost, *OC* is opportunity cost, *NC* is nuisance cost, *r* is the interest rate (10%), *t* is time, and *i* is a given wetland. This represents the cost to restore an individual wetland *i*.

3.6 Wetland Restoration Cost Results

This section presents descriptive results of the cost of wetland restoration in the STC. Only Scenario 1 is considered for the remainder of the analysis, as the subsequent scenarios are linear transformations of the first. The evaluation of the costs associated with wetland restoration is provided at two different levels of aggregation: at the wetland level, and at the producer level. These two different levels of aggregation allow for the expression of different perspectives with respect to wetland restoration costs.

Total Costs

Table 8 provides mean values of wetland restoration costs on a wetland basis. The average restoration cost was approximately $160/wetland, which is less than the DUC estimated cost of restoration (including administrative and construction costs) which was $500/wetland. This is because our estimate combines the restoration of multiple wetlands at one time; therefore the restoration cost would be spread between wetlands located on a single producer's property. The average opportunity cost was $295/wetland, although the range of opportunity costs is very large. In some cases producers would actually accrue negative opportunity costs, or benefits. This occurs where wetlands were located on pasture or forage fields because taking land out of production would actually decrease input use, and fences and waterers would not be required. The average nuisance cost arising from wetland restoration was $7.50/wetland. The summation of all cost components gives an average total cost of $461.77/wetland or $1147.07/acre. The average annualized cost was $67.77/year or $168.35/year/acre. The large range of variation in all costs presented in Table 8 is a reflection of the high variation in wetland sizes with a range of almost 9.0 acres as well as heterogeneity among producers and their operations.

Table 8 Breakdown of the average costs of wetland restoration by wetland in South Tobacco Creek

	Restoration Cost	Opportunity Cost	Nuisance Cost	Total Cost	Total Cost/ Acre	Annualized Cost	Annualized Cost/Acre
Mean	158.81	295.44	7.52	461.77	1147.07	67.77	168.35
Median	152.33	178.36	4.65	337.64	1141.55	49.55	167.54
S.D.	25.86	436.61	11.11	458.14	337.14	67.24	49.48
Minimum	147.28	-60.08	0.00	99.09	104.13	14.54	15.28
Maximum	467.96	5065.22	142.85	5507.54	2420.70	808.30	355.27

Table 9 Average cost of wetland restoration per producer in the South Tobacco Creek

	Restoration Cost	Opportunity Cost	Nuisance Cost	Total Cost	Annualized Cost
Mean	4248.11	7902.99	201.21	12,352.31	1812.87
Median	4063.97	6030.20	156.50	9282.69	1362.36
S.D.	4475.78	9778.16	278.64	14373.52	2109.51
Minimum	467.96	169.26	2.84	641.79	94.19
Maximum	24,561.97	53,065.08	1587.95	79,215.00	11,625.86

Table 10 Descriptive statistics for environmental improvements (restored wetland acres and phosphorous abatement) at the producer level (100% Restoration Scenario)

	Total Cost	Annualized Cost	Wetland Acres	Total Cost /Acre	Annualized Cost/ Acre	kg P abated /yr	Total kg P abated (12 yrs)	Total Cost /Total kgP	Annualized Cost/kgP
Mean	12,352.31	1812.87	13.22	1066.70	156.55	38.17	458	32.49	57.22
Median	9282.69	1362.36	10.58	1007.93	147.93	29.5	354	26.50	46.67
S.D.	14373.52	2109.51	17.12	302.15	44.34	44.79	537.53	18.51	32.59
Min	641.79	94.19	0.27	662.45	97.22	1	12	9.44	16.63
Max	79,215.00	11,625.86	98.39	2420.70	355.27	261	3132	105.17	185.22

The average cost by producers in the STC is $12,352.31 or $1812.87 annualized per year. Restoration costs represent the largest proportion of the total costs at 66% followed by opportunity costs at 33%, and nuisance costs at 1% (Figure 6). The small contribution of nuisance costs is contrary to the opinion held by producers who perceive nuisance costs to be very high. Cortus (2005) also had a similar result where nuisance costs were between 2.5% and 3.5% of the total variable costs depending on the size of the farm and the assumption used for calculating the nuisance factor. The small contribution of nuisance costs could be due to the fact that machinery operating costs are a small portion of total operating costs. It is suspected that if spatial concentration were included in the nuisance cost model, these costs would probably make up a larger portion of the costs.

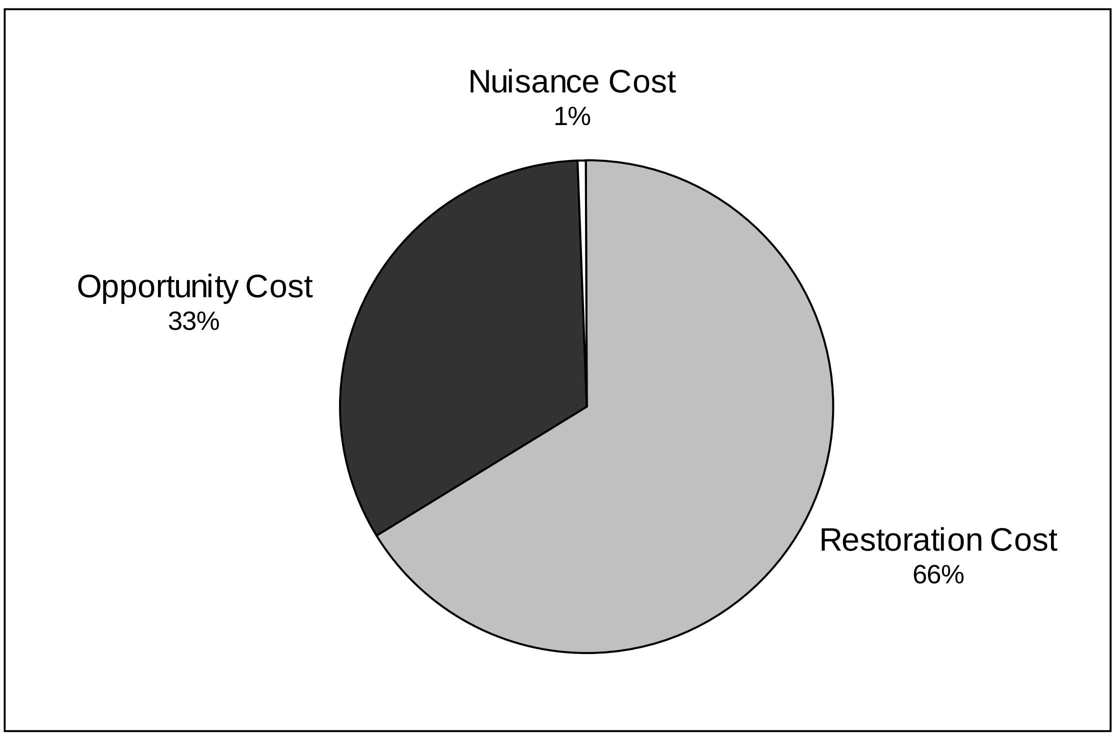

Figure 6 Breakdown of total cost of wetland restoration in South Tobacco Creek based on mean estimated costs

Indirect costs contributed 34% of the total costs facing producers. This fact has important implications for policy makers, as it is often only the direct costs of wetland restoration that could be compensated (e.g. NFSP program). These costs are more likely to be compensated because they are directly known to the producer and exact numbers can be attributed to the restoration cost. The indirect costs may not be obviously known by the producer and are certainly less known to the policy maker. However, actions should be taken to understand these costs seeing as they contribute more than a third of the costs for wetland restoration.

The derived cost information was integrated with the environmental benefit information in order to understand the cost of phosphorus abatement delivered through wetland restoration. In order to be comparable with the total cost estimate which was summed over 12 years, phosphorus abatement was also summed over 12 years since the measurement was given in kg/year. Table 10 shows costs with respect to EG&S, specifically wetland acreage and nutrient abatement, that were derived from wetland restoration in the STC. The average cost per acre was $1066.70/acre, or $156.55/acre/year. Average annualized abatement cost of phosphorous was $57.22/kg/yr, with a range of $16.63/kg/yr to $185.22/kg/yr. This table illustrates significant heterogeneity between producers in terms of cost effective provision of nutrient abatement, suggesting spatial targeting of wetland restoration would be valuable from a benefit cost perspective.

The subsequent scenarios with less than 100% restoration effectually decreased the total cost of restoration for producers. This is because the number of wetlands producers would be restoring was declining. However, the abatement benefit cost ratio (where benefit is either wetland acres or kg P) was increasing over the scenarios, indicating that abatement is actually becoming more expensive for the producer because less benefits are being provided at the aggregated level. In other words, the cost of each wetland remains the same but the overall benefit being provided by the producer is declining.

Wetland Restoration Total Cost Curves

Total cost and marginal cost curves for wetland restoration acres and phosphorous abatement are shown in Figure 7 and Figure 8 below, based on ranking the cost data by producer for all 36 producers in the watershed. Using the total cost function, one can determine the wetland area or total phosphorus abatement that could be achieved from a particular budget. For example, with a budget of approximately $100,000 roughly 110 wetland acres could be restored on the farms of 21 producers. Considering the abatement total cost function, $100,000 translates into approximately 4000 kg of P abated.

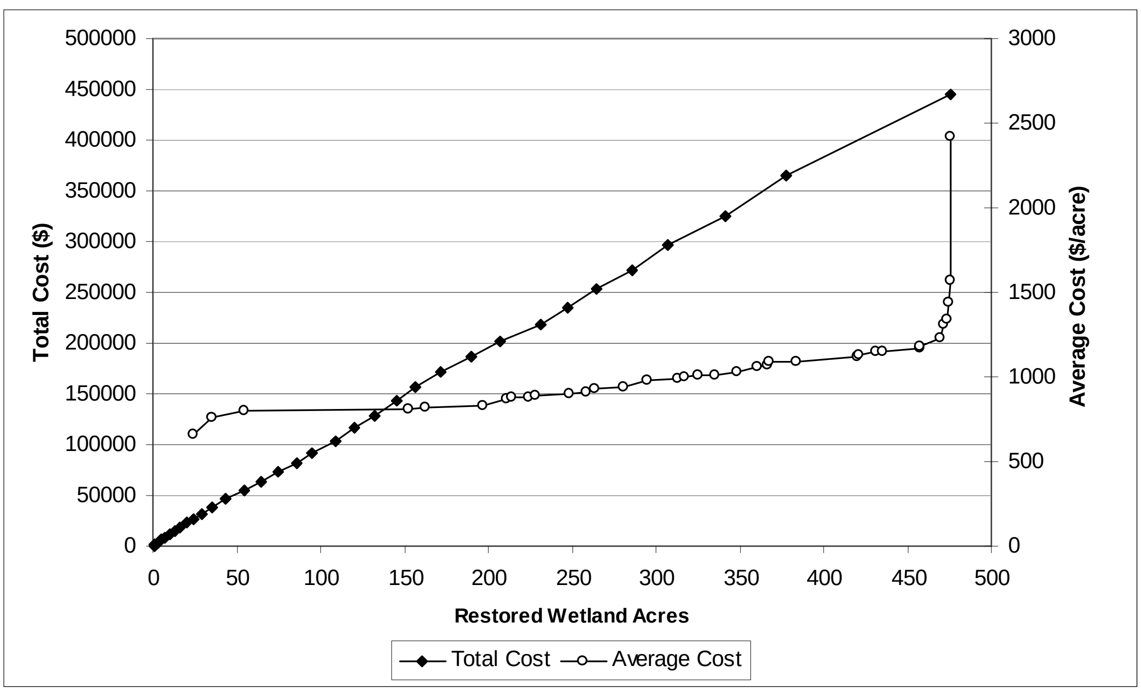

Figure 7 Total cost and average cost curve for restored wetland acres by producer in the STC

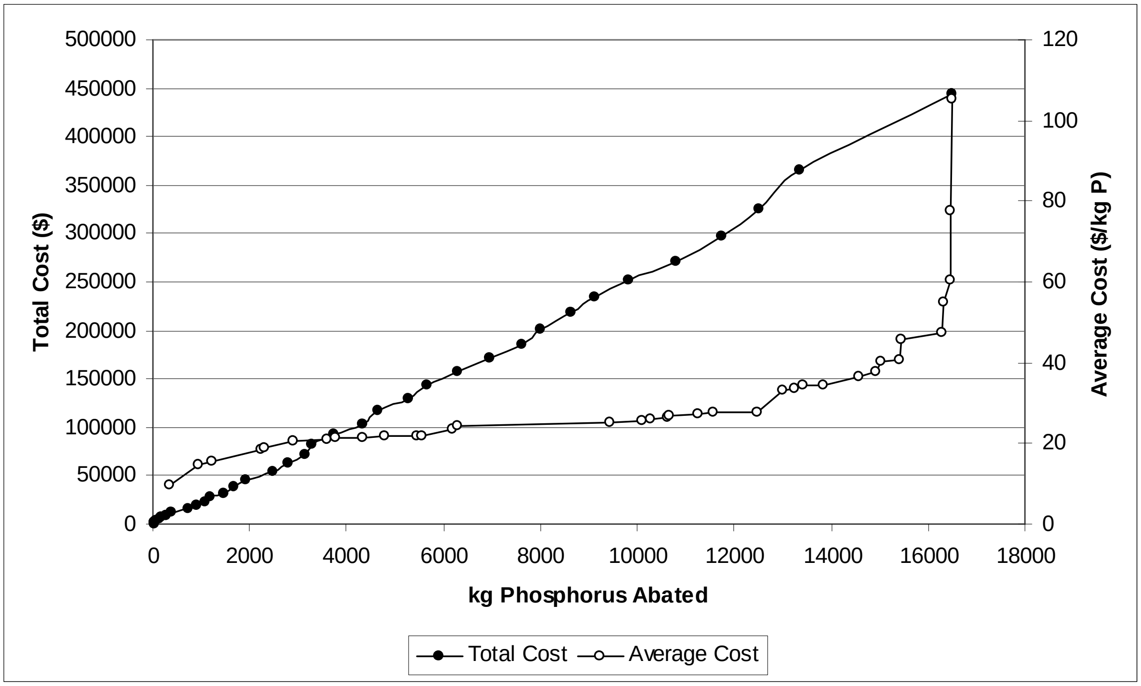

Figure 8 Total cost and average cost curve for kg phosphorus abated from wetland restoration by producer in the STC

Wetland Restoration Policy Relevant Cost Curves

An important economic concept is the marginal costs of supplying goods and services. The marginal cost is the incremental cost of increasing the supply of wetlands by one unit. From a policy perspective, it is important to supply goods if the marginal cost is less than the marginal benefit, i.e. if the benefits of the next unit produced exceed the costs. Thus in determining the optimal number of wetlands to restore, the marginal costs are important information. In agri-environmental policy development, knowledge of the economic supply function for EG&S is commonly unknown since opportunity costs are private information held by producers.

Given the cost estimates we were able to develop policy relevant cost functions for wetland restoration in either “acre-space” (quantity of acres supplied at a given cost or price) or “abatement-space” (quantity of phosphorous abatement supplied for a given cost or price). Since we estimated these using constant returns to scale, these average costs can be considered marginal costs as well. Figure 7 shows the costs associated with supplying restored acres and Figure 8 shows the costs associated with phosphorus abated (kg). Each point in these functions represents the costs borne by an individual producer in STC. This cost curve suggests that the majority of the wetland acres could be restored for under $1500 per acre. Implementing the full 100% restoration scenario is expensive primarily because of the high cost group. Note that extra cost required to achieve complete wetland restoration, versus 400 acres. Moving from 200 acres to 400 acres increases the cost by less than $1000/acre whereas moving from 400 to 500 acres the cost increases by more than $2000/acre. Omitting these high cost individuals and working only with the lower cost producers would likely achieve cost effective restoration. A similar pattern and story emerges in the supply curve shown in abatement space in Figure 8.

Value of Spatial Targeting

Figure 9 and Figure 10 below suggest the benefits of auctions and of spatial targeting of wetlands to improve the environmental benefits of restoration relative to costs. We can illustrate this by examining Producer 17. Consider Figure 9, Producer 17 is a relatively high cost producer in terms of restoring wetlands. In procuring wetland services, then, we may not want all producers to restore 100% of their wetlands, but only a few of the ‘cheap’ wetlands (remember that each producer’s location on the supply curve shows their wetland cost per acre, i.e., the cost of adding an additional wetland). Based on Figure 9, Producer 17 could be assumed to be relatively cost ineffective at supplying wetland restoration as most of their wetlands are high cost. On the other hand, examining Figure 10, one can see that Producer 17 is actually very efficient considering environmental benefits per acre, rather than just acreage. This is a result of heterogeneity between producers. There is an opportunity to take advantage of this heterogeneity in order to pay least cost for the desired environmental outcome through targeting. If this trait is not addressed there is potential that payments are distributed to relatively "undesirable" producers, in that they appear to have low costs but in relation to EG&S, they are actually more expensive.

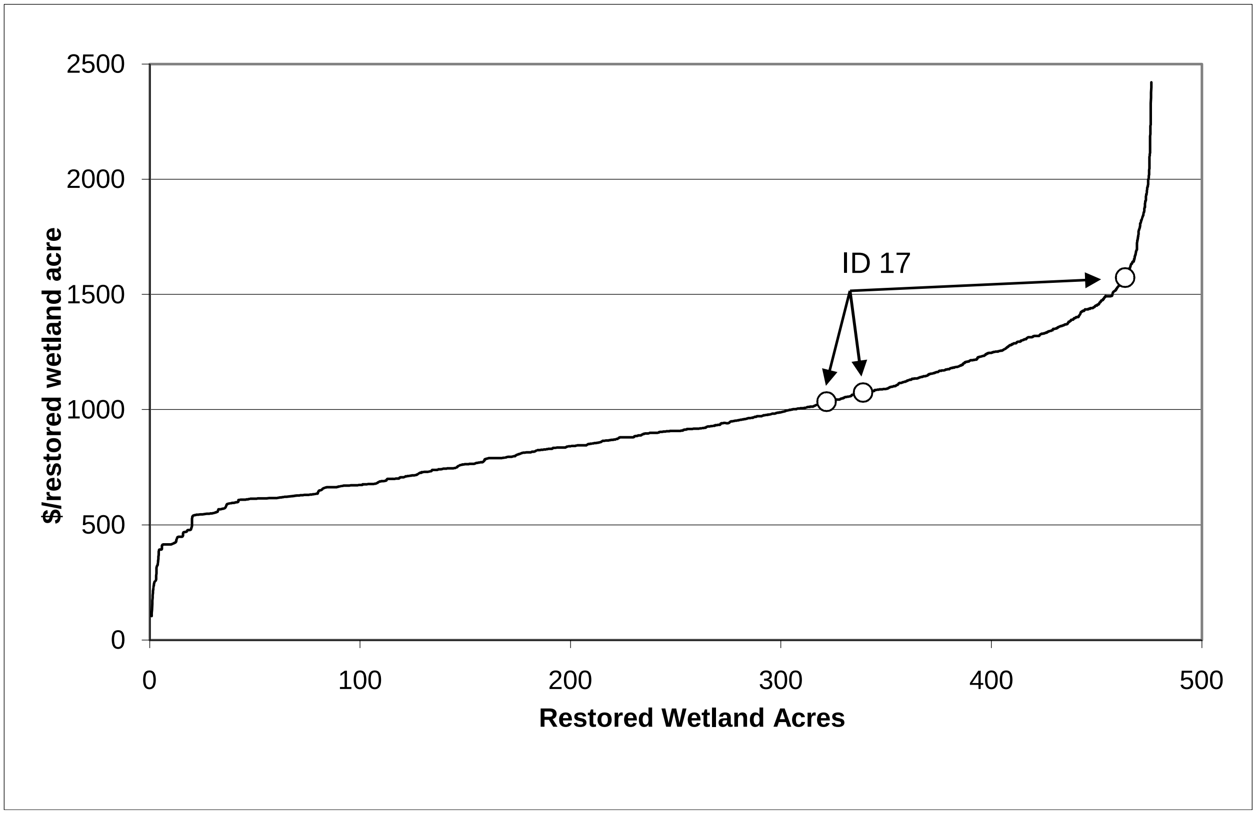

Figure 9 Average Costs of Wetland Restoration in South Tobacco Creek showing costs for for Producer 17

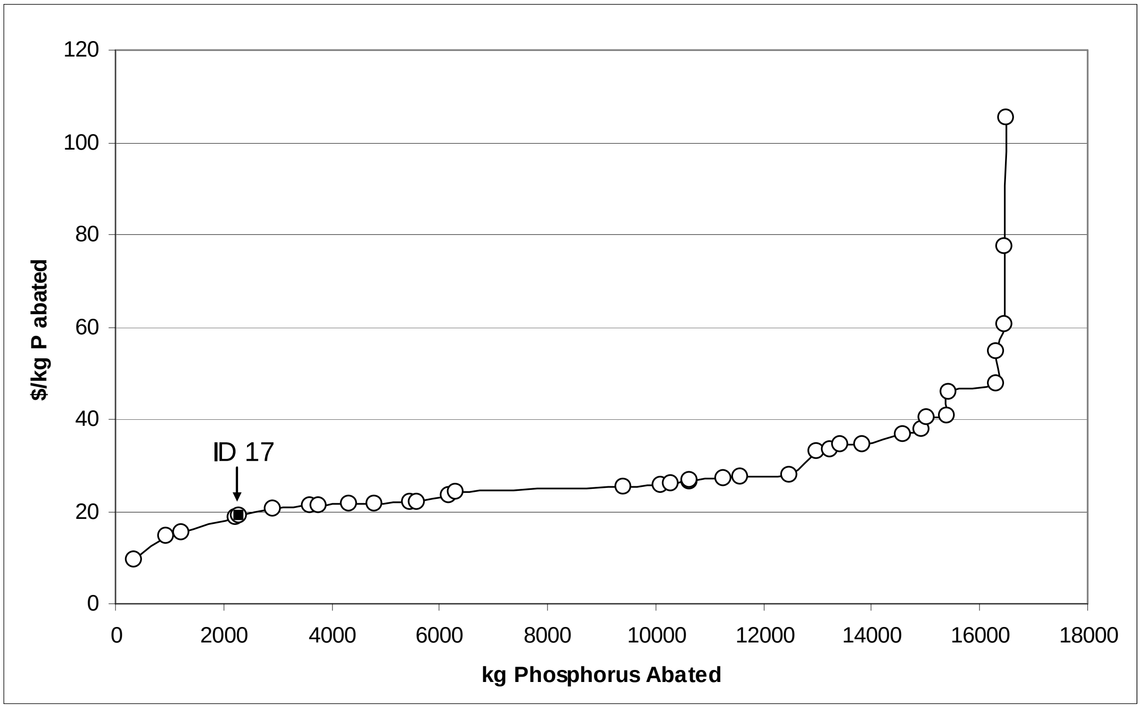

Figure 10 Average Costs of Phosphorous Abatement for South Tobacco Creek Producers showing costs for Producer 17

With the knowledge of costs and benefits of wetland restoration, one can estimate the potential budget that could have been spent under the NFSP framework addressed in Chapter 2. Under the NFSP, applications for wetland restoration fell under Category 21 (Enhancing Wildlife Habitat and Biodiversity) and 28 (Biodiversity Enhancement Planning). Under these categories, applicants may receive 50% of their restoration cost (administration and construction costs) in compensation up to a total of $20,000. The estimated budget and associated environmental improvements are presented in Table 11. This table presents the estimated budget for wetland restoration, as well as for other BMPs (estimated in Boxall et al. 2008) as a point of comparison. Since the NFSP only covered restoration costs, and opportunity costs could not be accounted for, the resulting budget is only capable of paying 18 of the cheapest producers their full costs to restore wetlands. In comparison with the other BMPs, wetland restoration is a viable option in terms of cost per environmental benefit. However, $161/acre is still less than the marginal cost curve presented in Figure 7. This leads one to believe that this program did not provide sufficient compensation for producers, at least with respect to wetland restoration. This scarcity in funds could be a reason why the adoption rate of BMPs in Manitoba was only 36%. In addition, there would be no guarantee that EG&S was being provided since the program was not targeted and cost and abatement heterogeneity was not taken into account. These observations confirm that cost-sharing agreements for EG&S from producers are not likely adequate policy instruments.

Table 11 NFSP estimated for BMPs in STC [source for other BMPs: Boxall et al. 2008]

BMP	Number of affected producers in STC	Estimated total costs of 100% adoption over 10 years	Available Budget (NFS Payments)	Estimated reduction of pollutants with 100% adoption
Riparian area management[1]	6	$294,884	$100,434	P – 69.9 kg N – 275 kg Sediment – 55.1 t
Holding ponds[2]	12	$112,462	$56,231 (~$57/head)	P –73.85 kg N – 416.26 kg Sediment – 28.47 t
Zero-till	36	$1,444,175	$433,253 (~$94/acre)	Not yet available
Forage conversion	36	$2,860,727	$858,218 (~$62/acre)	Not yet available
Wetland Restoration	36	$444,683.10 (adoption over 12)	$76,466.03 (~$161/acre)	P – 1374 kg N – 5504 kg Sediment – 1048 t

[1] Riparian areas only fall within the farms of 6 producers in the watershed
[2] Only 12 of the 36 producers had livestock in 2006 and would be eligible for constructing a holding pond.

3.7 Summary

Four different wetland restoration scenarios were estimated in the STC Watershed using hydrologic GIS modeling techniques to identify potential wetland restoration locations as well as their size. Environmental improvements based on runoff potential and nutrient abatement, were also estimated but only phosphorus abatement was considered here. There is potential to restore 476 acres of wetlands in the watershed would affect all 36 producers in the watershed. This level of restoration would generate 1374 kg of phosphorus abatement per year.

The wetland restoration data was then merged with on farm economic data from the STC watershed to estimate the costs associated with wetland restoration. The costs were comprised of three components: the direct cost of restoration, and the indirect opportunity and nuisance costs from restoration. The integration of this data allowed for an accurate estimate of the costs that producers in the STC watershed would face if they were to restore wetlands on their land.

Cost curves for wetland restoration were constructed to understand the cost relationships. It was found that a large portion of the potential wetlands could be restored at relatively low cost, roughly $1000/acre for 12 years of restoration. Complete 100% restoration is also not an advisable policy goal because a majority of wetlands can be restored with a relatively low budget. In order to include the last few acres of restoration, these costs increase significantly.

Producers were heterogeneous in costs and supply of some EG&S which makes some producers more influential if they were to restore wetlands than others. Programs should be designed to take advantage of the fact that some producers can provide a large quantity of EG&S at relatively low cost. The heterogeneity in producer costs does not support the use of fixed payment of cost sharing schemes proposed in most environmental programs in agriculture, as no one payment would be sufficient to restore the entire STC watershed. Auctions provide an opportunity for all producers to name their own individual price they would require to recover the costs associated with restoration. Having access to the detailed cost and environmental data for the STC watershed provides a unique opportunity to test and design conservation auctions specific to the area as well as practice.

Chapter 4 Budget Based Auctions

4.1 Research Questions

There are relatively few studies investigating/comparing auction design and their effects on performance in the context of conservation auctions. While there have been numerous studies investigating auction design in contexts such as Treasury, electricity, or spectrum auctions, their findings may not be directly applicable to conservation auctions because of differences in the market framework. This portion of the study will investigate the effect of two different payment rules (discriminatory and uniform 2nd price) and two different ranking rules (maximize coverage (acres) and maximize phosphorus (kg phosphorus abated)) on budget based auctions with repeated periods. The respective hypotheses for these issues are presented in Table 12.

Table 12 Budget based auction hypotheses

Treatment	Hypothesis
Payment Rule	a) Uniform payments will out-perform discriminatory payments in terms of efficiency and cost effectiveness b) Uniform payments will be more reliable as a price discovery mechanism
Repeated Auction Rules	Learning will occur under repeated auction rounds and it will lead to reduced auction efficiency and cost effectiveness.

There is some debate in the conservation auction literature as to which payment type is superior between discriminatory and uniform payments. Theory cited in the conservation auction literature indicates that the structure of uniform payments has the ability to induce participants to bid their costs (Latacz-Lohmann & Schilizzi 2005; Cason & Gangadharan 2004, 2005). Cason & Gangadharan (2004, 2005) explored the effect of pricing method on auction outcome efficiency and cost effectiveness on fixed budget auctions with 30 repeated auction periods. They found that discriminatory pricing was the superior pricing rule in terms of cost effectiveness, but not superior in terms of the ability to reveal the cost curve. This conclusion has lead to many studies using discriminatory payments without considering the effectiveness of the uniform payment approach (e.g. Cummings et al. 2004, Schilizzi & Latacz-Lohmann 2007). We propose the following hypotheses related to the pricing rule:

A) Uniform payments will out-perform discriminatory payments in terms of efficiency and cost effectiveness. This is because the rent seeking under discriminatory payments will be greater than the uniform payments determined in the auction.

B) Uniform payments will also be more reliable as a price discovery mechanism.

Cason & Gangadharan (2004, 2005), Schilizzi & Latacz-Lohmann (2007) and Cummings et al. (2004) have all investigated the effects of repeated auction periods and its effect on auction performance over time using experimental auctions. These authors all found that with time auction performance deteriorates. Hailu & Schilizzi (2005) also found that learning over time has a negative effect on auction performance in their agent based model. Since some auction programs have implemented multiple auction sign-ups (e.g. CRP) it is important to understand how it affects participant learning and subsequently auction efficiency and cost effectiveness. The hypothesis is that learning will occur under repeated auction rounds and that learning will be expressed differently between the two payment rules.

An important challenge of implementing auctions is to discriminate offers so that the cheapest environmental benefits are selected first. The selection rule allows the discrimination of bids based on the amount of environmental benefits an individual is providing. Under each selection rule, maximize coverage and maximize phosphorus abatement, bids are ordered by $ per environmental benefit from low to high and offers are selected until a budget is exhausted. One of the important environmental benefit goals associated with wetland restoration is to increase nutrient abatement capabilities. However, in the absence of detailed hydrologic information, this is difficult to quantify changes in abatement and therefore not ideal as a bid ranking metric. Acquiring this information may also be expensive and difficult to collect in a short period of time. Restored wetland acres are easier to measure and may potentially act as a proxy for phosphorus abatement. This study will also investigate if ranking bids by restored wetland acres (maximize coverage) will act as a sufficient proxy for phosphorus abatement.

4.2 Auction Design

Table 13 Experimental Design for Testing Wetland Restoration Auctions in South Tobacco Creek

Treatment	Discriminatory	Uniform
Maximize Coverage	2	3
Maximize kg Phosphorus Abated	2	3

In total, 10 experiments with 15 periods each were completed (Table 13)[16]. The treatments were the maximize coverage bid ranking rule with discriminatory or uniform payment rule (now referred to as MCD and MCU respectively) or the maximize phosphorus abatement bid ranking rule with discriminatory or uniform payment rule (now referred to as MPD and MPU).

These are induced value experiments where each participant was provided with farm parameter information for one farm from the STC. Farm parameters displayed were the total cost, environmental benefit, and the cost/environmental benefit. The environmental benefit was dependent on the bid ranking rule treatment: acres under maximize coverage, or kg P under maximize phosphorus abatement. The specific units of the environmental benefit were not disclosed. Participants were not provided with information regarding other farms in the

[16] Additional repetitions were run for the discriminatory treatment but were not included due to data complications

experiment. The amount of information presented follows the approaches used by Boxall et al. (2008). Each experimental session also contained the same level of information. Those individuals who were accepted in the auctions were assumed to restore 100% of their wetlands and pay all of the associated costs dictated in the respective farm parameters.

4.2.1 Auction Costs and Budget Determination

The estimated costs presented in Chapter 2 were used to test the ability of different auctions to act as a cost discovery mechanism. It is difficult to determine the actual efficiency of auctions without comparison to a benchmark. For example, the efficiency gains of 700% from auctions over fixed price programs described by Stoneham et al. (2003) are difficult to prove in the absence knowledge of the underlying cost curve. Many experimental studies utilize a hypothetical cost function (Cason & Gangadharan 2004, 2005; Cason et al. 2003; Cummings et al. 2004). This present study allowed us to test hypotheses generated from experimental and empirical literature in the STC context where the underlying cost function was generated from actual producer costs.

Twelve farms were selected from the sample of 31 farms in the experiments[17]. They were selected so that the distribution of costs given by the shape of the cost curve was represented in the auction experiments[18]. This was done by taking the proportional distribution in quartiles of the entire distribution. The costs were not discounted, also to remain consistent with Boxall et al. (2008), so that future comparisons may be drawn between the studies. It was not necessary to include the discounted cost estimates since it was more important to represent the shape of the cost curve. The cost parameters used are presented in Table 14.

[17] Twelve producer costs were used in order to remain consistent with the experiments presented in Boxall et al. (2008).
[18] It was important to keep the shape of the underlying supply curve in order to reflect the inherent heterogeneity as well as to capture bidding behavioural effects along the curve.

Table 14 Farm parameters used in budget based experimental auctions

Participant I.D.	Total Cost	Wetland Acres	kg P Abated
1	1,210.17	0.73	6
2	15,233.79	10.68	64
3	7,429.50	5.38	47
4	8,004.15	5.49	38
5	3,015.41	1.61	14
6	8,900.46	4.90	51
7	735.36	0.21	3
8	15,192.80	11.23	83
9	4,433.93	2.78	16
10	9,747.98	6.15	57
11	38,956.29	22.43	71
12	11,577.47	10.38	50
Total	124,437.31	81.97	500

The budget used for the experiments reflects what would have actually been paid by the NFSP (e.g. Boxall et al., 2008). We used the NFSP budget that would have been allocated to producers for them to restore all wetlands on their property (i.e. Scenario 1)as the total amount of money that would be willing to be spent by the government for a wetland restoration program. A budget based on this calculation (see Section 3.6) was estimated based on all costs borne by the 12 producer costs (e.g. opportunity, nuisance, and restoration costs). This provided a budget cap of $62,218.65.

In the experiments, the costs and budget were scaled down by a factor of 100. This was done so that the numbers would be more comprehendible by the participants.

4.2.2 Auction Procedure

The experiments were computer based using Z-Tree software (Fischbacher 2007) and were conducted in university computer labs. Each auction consisted of 12 participants and one system operator acting as the auctioneer/buyer of conservation services. Each experiment was scheduled to last for an hour maximum, but usually lasted an average 45 minutes.

Participants in the auction experiments were undergraduate and graduate students, as well as employees of the University of Alberta. They were selected from an online database created using ORSEE software (Greiner 2004). Participants were able to sign up for experiments multiple times; however, only once per treatment. Student participants have also been used in studies conducted by Cason et al. (2003), Cason & Gangadharan (2004, 2005), Latacz-Lohmann & Schilizzi (2007) and Boxall et al. (2008). It is assumed that students would behave and make similar decisions as a rational profit maximizing entity.

Participants were provided instructions for the task in a PowerPoint presentation. Students were shown the ranking strategies and pricing rules, so they would have an understanding of the auction mechanism. They were also shown how the outcomes of the experiment would translate into their cash payment. Participants were required to read the instructions on their own and were permitted to ask questions throughout the duration of the experiment.

The experimental auction involved 15 independent auction periods and one practice round. The practice round was used to give participants a chance to become familiar with their farm parameters as well as give them a risk-free chance to become familiar with the auction mechanism. Each round was 60 seconds (or less if all bids were submitted prior to) and 15 seconds were permitted to see the results of the auction. On the results screen participants were informed if they had been selected in the auction or not, as well as their payment, net income, and cash profit if they were selected. Participants were not aware of who else was accepted in the auction or the cutoff price at the end of each round.

At the completion of the 15 periods, participants were given their cash payment earned from the experiment. In order for the experiments to be incentive compatible for participants, the cash payment was reflective of the decisions and behaviour in the auction. Profit is accrued in each round based on Equation 4.

Equation 4

$$Profit = \$1 + \left(\frac{payment - cost)}{x}\right),$$

where *payment* is the payment received in the auction, *cost* is the total cost for that producer, *x* is a conversion factor used to relate net income to realistic cash terms, and *$1* represents base income. The conversion factor is also used as a tool to make payments fair for participants by limiting the cash payment for participants who were drawn farm parameters with a high chance of winning in the auction. This conversion factor was not revealed to participants; however, they were aware that it was being used in their payment calculation. The profit from each round was summed to give the end payment to participants in cash. Participants also received a $5.00 show-up fee. The maximum cash allowance given to participants was $35 including their show-up fee. The cap on the cash allowance was put in place for budgetary purposes.

4.2.3 Econometric Analysis

Three market performance metrics, based on those developed and used by Cason et al. (2003) and Cason & Gagadharan (2004, 2005), were estimated in order to evaluate the effectiveness of the auction designs. These were the Proportion of Maximum Outcome Realized (PMOR), Proportion of Optimal Cost Effectiveness Realized (POCER), and Percent rent generated (PRENT)[19]. The PMOR and POCER measure are specific to the ranking treatment where the maximum acres were used in the Max Coverage case, and the maximum kg P abated was used in the Max P case. PMOR was defined as:

[19] PMOR was based on the P-MAR measure (Percent of Maximum Abatement Realized) established by Cason & Gangadharan (2004, 2005), which was the amount of pollution abatement realized from the auction as a percentage of the maximum that would have been achieved by the auction budget. The term has been altered for this study from *abatement* to *outcome*, in order to accommodate maximizing both abatement of phosphorus and accumulation of wetland acres with the auction mechanism.

$$PMOR = \frac{outcome\ achieved_i}{maximum\ expected\ outcome},$$

where *i* is period. Using the fixed auction budget as a constraint, the maximum for both acres and kg P abated was calculated with the Solver add-in package in Excel 2003 assuming that the successive producers of the set of 12 would be paid their costs. With a fixed budget of $62,219 a maximum of 332 kg P could be abated and 45.94 acres of wetlands would be restored.

Cason & Gangadharan (2004, 2005) defined the POCER metric as "the actual quantity of abatement per dollar spent in the auction, as a percentage of the quantity of abatement per dollar spent (unit/$) in the 'maximal abatement' solution" (Cason & Gangadharan 2005) described above. The measurement was defined as such:

$$POCER = \frac{\left(^{outcome\ achieved}/_{budget\ spent}\right)_i}{^{maximum\ outcome}/_{funds\ required}},$$

for every auction period *i*. *Funds required* refers to the amount of money required to reach the maximum outcome assuming cost minimization, while *budget spent* refers to the amount of money spent in the auction to achieve the outcome. This measure directly takes into account the level of resources used in the auction (Cason & Gangadharan 2005). This is useful to assess the effectiveness of auction mechanisms presuming that an objective would be to maximize outcomes per dollar spent (Cason & Gangadharan 2005). Again, this measure was estimated specific to each ranking treatment taking into account both kg P abated and wetland acres accumulated (similar to the estimation of PMOR).

Lastly, the rent or profit accumulated for producers for each auction was also used to assess the auction mechanism. This was defined as the additional payments made to producers above what it should have cost if the producers were paid their costs rather than the auction derived payment. This measure is used to assess whether the budget is being inefficiently used as profit for producers instead of being used to buy more environmental benefits. This was calculated as:

$$Rent_i = \sum_i payments_i - \sum_i actual\ costs_i$$

$$\%Rent = \left[\frac{Rent_i}{\sum_i payments_i}\right] * 100\%$$

Econometric Model

Cason & Gangadharan (2005) employed a panel regression model with a random effects error structure, with the experimental session representing the random effect for both auction efficiency measures. The random effects error structure was applied on the session in order to account for the correlation of market outcomes within a session (Cason & Gangadharan 2005, pp 61). Cason & Gangadharan (2005) separated their bid ranking rules and conducted two independent sets of regressions. In this present study all treatments were considered in one regression for each measure with dummy variables identifying the treatment.

The econometric models used in this study to determine the effect of auction design on auction efficiency are as follows:

$$\begin{matrix} PMOR \\ POCER \\ PRENT \end{matrix} = \alpha + \beta_1 Coverage_{it} + \beta_2 Uniform_{it} + \beta_3 CovUni_{it} + \beta_4 \ln(period_{it})$$

$$+ \beta_5 \ln(period_{it}) * Uniform_{it} + \varepsilon_{it} + \mu_i$$

Similar to Cason & Gangadharan (2005), it was assumed that auction outcomes were a function of the experimental treatments imposed and the period of the experimental session (recall that there were 15 periods in each experimental auction).

Table 15 provides a description and rationale for each variable. Additional demographic data was collected from participants but was not used in the analysis. While individual participant traits, such as risk attitudes or experience, may have some influence on the over auction outcome, individual effects are difficult to index to the aggregated session level of evaluation.

Table 15 Description of variables used in the empirical analysis of budget constraint auctions

Variable	Description
$Coverage_{it}$	Dummy variable for bid ranking rule; where 1=max coverage, and 0=max phosphorus abatement
$Uniform_{it}$	Dummy variable for payment rule; where 1=uniform payment, and 0=discriminatory payment
$CovUni_{it}$	Interaction term of bid ranking and payment rule
$\ln(period_{it})$	Represents time trend for each session
$\ln(period_{it}) * Uniform_{it}$	Interaction term of time trend and payment rule

The dataset used for the analysis was in panel format, with i representing the experiment session (of which there were 10) and t indexing the 15 auction periods. An OLS panel regression was employed with a random effects error structure, with individual specific effects with respect to the auction session. The random effects model assumes that variations, μ_i, between sessions are random and uncorrelated with the independent variables. The error term is composed of two elements: a time invariant part, μ_i, and the remainder which is uncorrelated over time, ε_{it} (Verbeek 2004). The unobserved characteristics (e.g. risk attitudes, experience, group combination) in each session are then controlled for assuming that they do not change over time. The alternative fixed effects model assumes that time invariant characteristics are unique to one entity (e.g. session). Since the independent treatment variables do not vary across the session, fixed effects may be ruled out[20].

4.3 Results and Discussion

The following section provides a summary of results of the data collected from the budget based experiment conservation auctions described above. Two main themes are investigated in this section: the auctions' ability to reproduce the supply curve and cost effectiveness/efficiency. General results and panel regression analysis will be summarized, in addition to providing a comparison with the studies conducted by Cason & Gangadharan (2004; 2005).

4.3.1 Descriptive Statistics

In total, 10 experiments with 15 periods each were completed. In order to evaluate the experimental results, the expected (or baseline) auction results were estimated using the greedy algorithm. This is an algorithm which finds the global optimum solution by making locally optimal choices[21]. In this case, the approach selects winners based on pricing and ranking rules until the budget is exhausted, assuming that individuals place bids equal to their costs (Boxall et al. 2008). Assuming that participants bid their costs, we have an idea of what the most efficient outcome from the auction could be, and this information provides a basis for comparison with the experimental auctions. These results are summarized in Table 16 for each auction treatment (e.g. MCD, MCU, MPD, and MPU).

[20] Note, a Hausman test to determine the appropriateness of random or fixed effects could not be completed because the independent treatment variables were time invariant across session.
[21] An example of a greedy algorithm is the "make change" problem, where one attempts to make change with the fewest number of coins.

Table 16 Expected auction results for each treatment estimated using the greedy algorithm

	Maximize Coverage		Maximize kg P Abated	
	Discriminatory	Uniform	Discriminatory	Uniform
Total Acres	43.16	37.66	35.49	33.88
Total kg P Abated	282	244	296	282
Auction Total Cost ($)	57437.71	54880.80	53500.46	60738.90
Real Cost ($)	57437.71	49433.56	53500.46	50485.05
Seller Profit ($)	0	5447.23	0	10253.84
$/Acre	1346.85	1457.15	1588.54	1541.92
$/kg P	198.73	202.67	187.77	215.39

Based on these predictions, auctions under discriminatory payments are expected to perform better than uniform payment auctions because of greater cost effectiveness since a proportion of the budget goes towards seller profits in the uniform case. However, this result relies on the assumption that individuals would bid their costs in a one shot auction under both payment rules. In practice, auction performance may vary because of the tendency of participants to seek rents and learn over repeated auctions, especially under discriminatory payments.

Table 17 shows the relative performance of the experimental auctions given as the percentage of the expected results[22]. The experimental outcomes were averaged over all 15 periods for each treatment. Since multiple periods also provide opportunities for participants to learn, this may influence outcome results. Therefore averages were also calculated over groups of 5 periods (e.g. 1-5, 6-10, and 11-15) in order to assess how the outcomes changed in each treatment and if they were influenced by repeated trials. Table 26 and 27 show the relative performance as well as the actual auction outcome averages in the Appendix.

[22] Tables summarizing the actual average results are provided in Appendix

Table 17 Means of percentage differences in various performance measures between the auction and expected results generated using the greedy algorithm.

Mean of the Differences								
Maximize Coverage Bid Selection Rule								
	Discriminatory (N=30)				Uniform (N=45)			
Periods	1-5	6-10	11-15	1-15	1-5	6-10	11-15	1-15
Total Acres	3.82	-14.23	-12.37	-7.60	-0.80	-2.15	-3.66	-2.20
Total P Abated	-3.09	-10.07	-11.38	-8.18	1.89	-1.75	-1.89	-0.58
Budget Spent	-8.86	-2.94	-2.62	-4.80	-5.32	0.80	-2.92	-2.48
Actual Cost	9.71	-9.05	-10.66	-3.33	2.42	-1.67	-2.84	-0.69
Seller Profit*	n/a	n/a	n/a	n/a	-75.61	23.21	-3.67	-39.03
$/acre	-13.26	11.82	9.80	1.79	-4.55	3.02	0.80	-0.27
$/kg P	-3.61	10.62	12.63	6.26	3.13	13.86	9.81	8.86
Maximize Phosphorus Abated Bid Selection Rule								
	Discriminatory (N=30)				Uniform (N=45)			
Periods	1-5	6-10	11-15	1-15	1-5	6-10	11-15	1-15
Total Acres	-3.97	-9.10	-9.41	-7.50	12.43	0.44	-3.98	2.95
Total P Abated	-14.16	-19.09	-16.86	-16.70	-0.83	-5.18	-4.40	-3.47
Budget Spent	1.07	3.16	6.78	3.67	-6.67	-5.13	-5.61	-5.80
Actual Cost	-5.66	-14.22	-13.59	-11.16	12.69	-0.56	-4.46	2.56
Seller Profit*	n/a	n/a	n/a	n/a	-102.00	-27.60	-11.31	-46.97
$/acre	-0.13	7.70	11.85	6.34	-3.47	9.83	14.31	6.38
$/kg P	13.33	22.72	23.62	19.80	-5.89	0.05	-1.28	-2.42

*relative seller profit for discriminatory payments could not be determined since it was expected to be 0 if bids were equal to costs (See Table 16).

The quantities of P abated were closer to the expected levels in the uniform treatments. MPD performed the worst as it recovered the smallest percentage of the expected amount of kg P. Here MPD is clearly out-performed by its uniform counterpart, as well as by MCD. MCU realizes the fewest kg P abated. However this falls in line with the fact that this treatment was not expected to perform well in terms of actual units of abatement because the objective was to maximize acres. MPU was able to acquire the highest amount of abatement across the entire 15 rounds, thus outperforming MPD, which was expected to attain the highest level of abatement. Using the Tamhane's T2 test for unequal variances, MPU was found to be significantly higher than MCU (p-value = 0.002) and MPD (p-value = 0.024) in rounds 6-10, and also significantly higher than MCU (p-value = 0.027) in rounds 11-15.

Generally speaking, the costs per unit measures were above the predicted price (Table 17); in other words the auctions were less cost effective than expected assuming bids equaled actual costs, where cost effectiveness refers to the mean price per unit of outcome (e.g. wetland acre or kg of P abated) in the auction. The discriminatory treatments yielded relatively higher dollar per unit measures than predicted compared to the uniform treatments. While the MC treatments were relatively cost effective in acquiring acres, this was not translated into cost effectiveness in terms of kg P abated. This has implications if acres are to be used as a proxy for P abatement because there is less certainty of the level of abatement that could be acquired from the auction. This was also true for the MP treatments, in that they were less cost effective in terms of acres. However, this is less important since coverage is meant to act as a proxy for abatement.

MP treatments had significantly higher $/acre (p-value = 0.00) than the MC treatments. This was expected since the MP treatments are maximizing phosphorus abatement not acres. There was no significant difference found between MCD and MCU or between MPD and MPU suggesting that the two payment types were equal in cost effectiveness in terms of $/acre. There was also no significant change in the mean $/acre over the 15 periods for any treatment.

In general, the $/kg P cost was lower in the first five periods. An interesting trend is that in the discriminatory treatments $/kg P would increase over the 15 periods, while in the uniform treatments $/kg P would decrease over the last five periods; although only periods 1-5 in MPD were significantly lower than the other groupings. Over all 15 periods, $/kg P was significantly higher in MPD than MPU (p-value=0.00). Specifically, this was found over periods 11-15.

Since the experimental results did not exactly equal the predicted auction results, it is speculated that this may be attributed to individuals not bidding their costs, and more specifically raising their bids to seek rents. Generally, seller profit is increasing over time, with the exception of MCU. The increases were not statistically significant. There was also higher variance in the first 5 periods. This may be an indication that participants are still learning the auction mechanisms and testing different bidding strategies. For instance, in MCD it is obvious that the within the first 5 periods people were more likely to bid below their costs or were testing extreme bid values. There was an individual in one MCD session that was drastically under-bidding their costs out of a lack of understanding of the auction mechanism. After those periods their bidding patterns changed and negative rent seeking was no longer apparent. As the treatment continued, the variance of bids tightened suggesting that individuals were learning their optimal bid strategy and were less likely to test extreme bids[23]. The MPD treatment had higher mean levels of seller profit than the other treatments over each group of periods. Over all 15 periods only MPD was significantly higher than MCD (p-value = 0.00). This is most likely due to the fact that negative rent seeking was more prevalent in MCD. Considering the groupings of periods, MPD was significantly higher in periods 6-10 with MCD (p-value = 0.1) and in periods 11-15 with MCU (p-value = 0.00) using the Tamhane's T2 test for unequal variances. The mean value of seller profit for period 11-15 in MCU was significantly lower than both MPD and MPU (p-value = 0.00)

4.3.2 Revealing the Cost Curve

An important function of the auction is its ability to be used as a cost discovery mechanism where the costs of conservation are unknown. The conditions under uniform payments have more potential to reveal costs than discriminatory payments, as established in Chapter 2. However, the ability of both payment structures to act as a cost discovery mechanism

[23] This is not to say that extreme bids were not tested by participants. The raw data indicates that there were individuals who were still playing with bid values; however on average they were more stable.

is influenced by the prevalence of rent seeking. Examining the degree of rent seeking provides an indication of how well an auction can reproduce the supply curve. In the previous sub-section, rent referred to the additional payment above the cost of adoption. While this measure provides some insight into the overall cost effectiveness of the auction, it does not provide substantial information about cost discovery because it only considers those individuals who receive a payment; therefore it does not capture the bidding behaviour of all participants. Another aspect of rent is veiled in the actual bids submitted, not just payments.

Figure 11 and Figure 12 present the relationship between bids offered and actual costs for each farm represented under discriminatory and uniform payments respectively. In the discriminatory treatments (both MCD and MPD) 85.5% of the bids submitted were above costs, while only 57.3% of bids were above costs in the uniform case. We would expect fewer individuals to exhibit rent seeking behaviour in the uniform treatments. However, according to Figure 12 there were specific farms, namely the two most expensive farms (the last two farms on the line), who exhibited high rent seeking behaviour. It is possible that these farms had little chance of being selected in the auction and therefore were submitting bogus bids to pass the time in the experiment. This is also evident in Figure 11 for the last point on the line. There was also a high incidence of individuals (30) submitting bids below their costs in the uniform case. Bidders were also slightly more likely to place bids equal to costs in the uniform case, 12.6%, than in the discriminatory case, 7.76%. Cason & Gangadharan (2005) considered a similar figure to compare payment types in their study**Error! Reference source not found.**. They found that 99% of bids were above costs in the discriminatory case; while in the uniform case 64% were above costs. There were also an abundance of bids below costs in uniform, however the frequency was not provided.

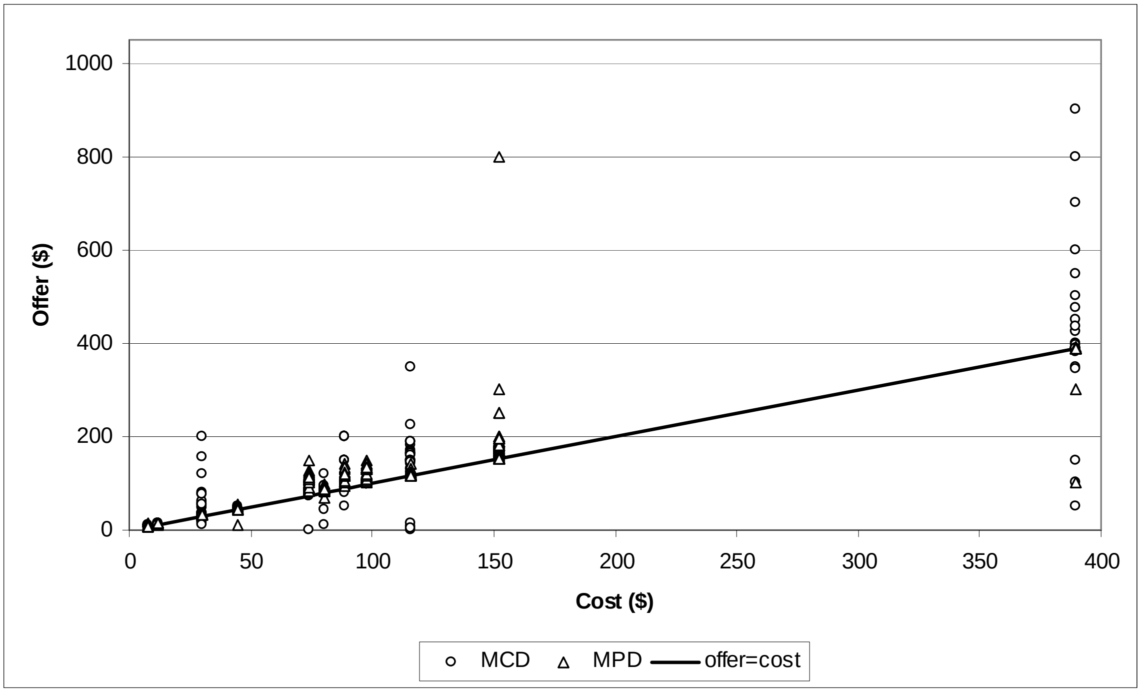

Figure 11 Relationship between bids offered in max coverage and max P abatement auctions and actual farm costs under discriminatory payments

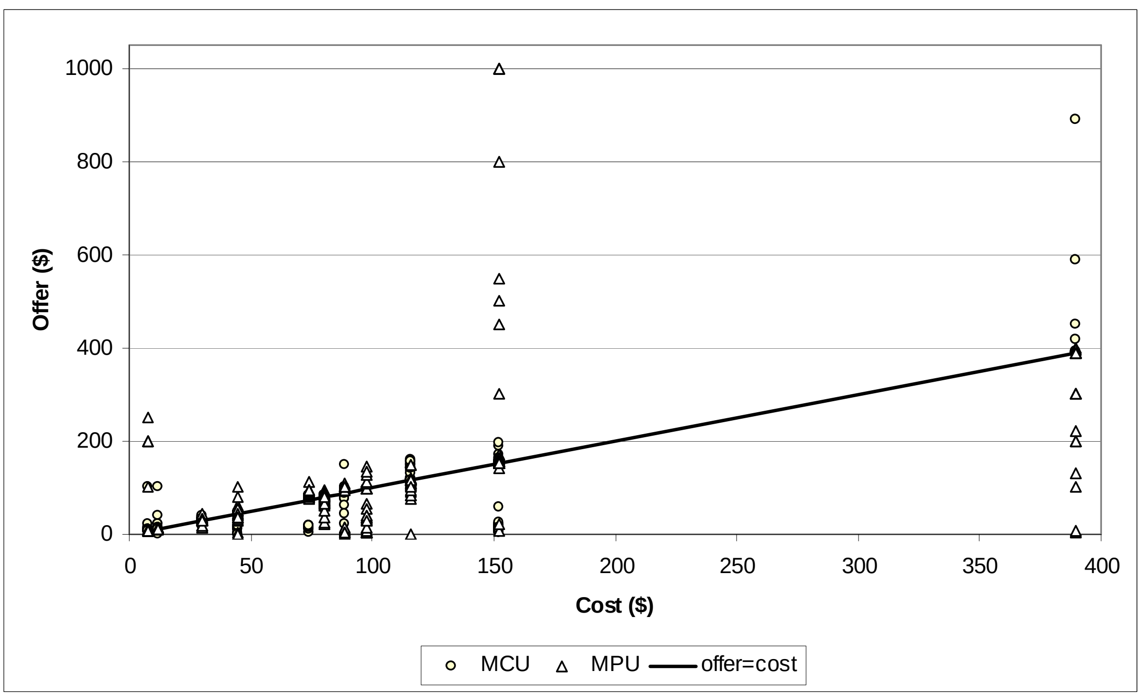

Figure 12 Relationship between bids offered in max coverage and max P abatement auctions and actual farm costs under uniform payments

Figure 13 and Figure 14 present the average revealed supply curve generated for each treatment (i.e. MCD, MCU, MPD, and MPU) over all 15 periods. This was done by taking the average bid level for every farm represented over all 15 periods. The average discriminatory revealed curve fell above the actual cost curve indicating rent seeking. This is consistent with the theory presented in Section 2.4.1 which predicts more rent seeking under discriminatory payments. The uniform curve tended to fall below the actual cost curve. This follows from the observation that 30% of individuals bid below their costs (Figure 12).

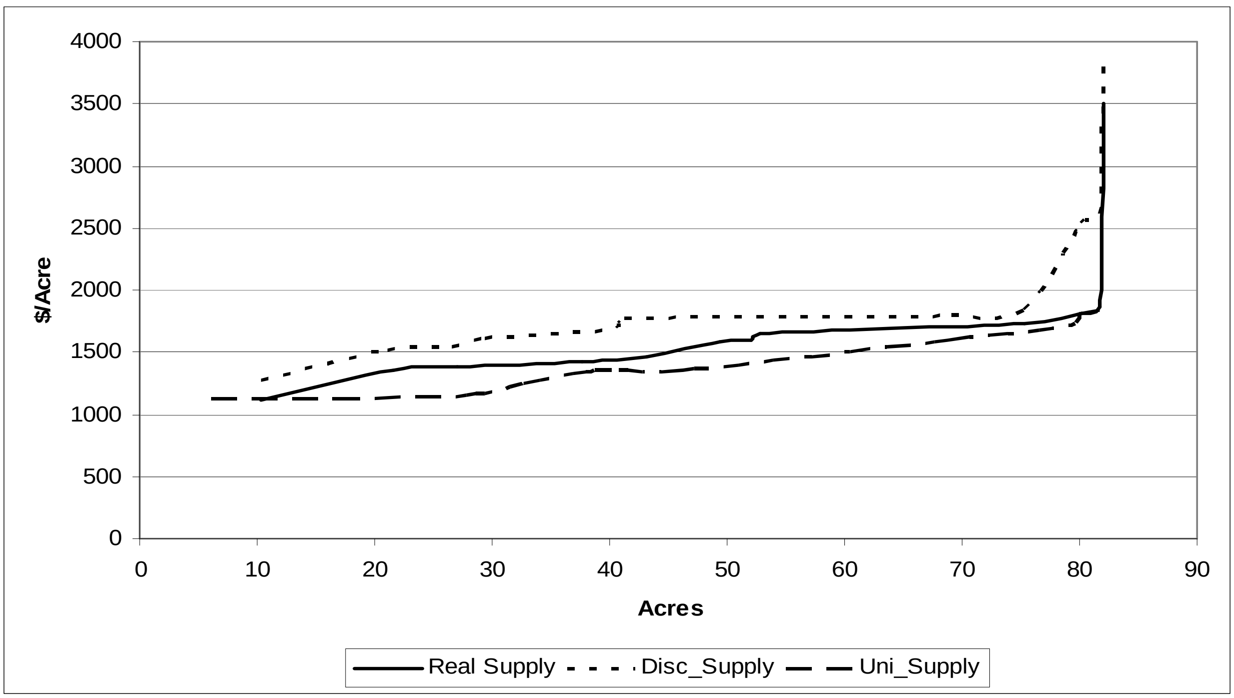

Figure 13 Comparison of average revealed cost curves derived from discriminatory and uniform payments with the actual cost curve for the max coverage bid ranking rule over all 15 periods

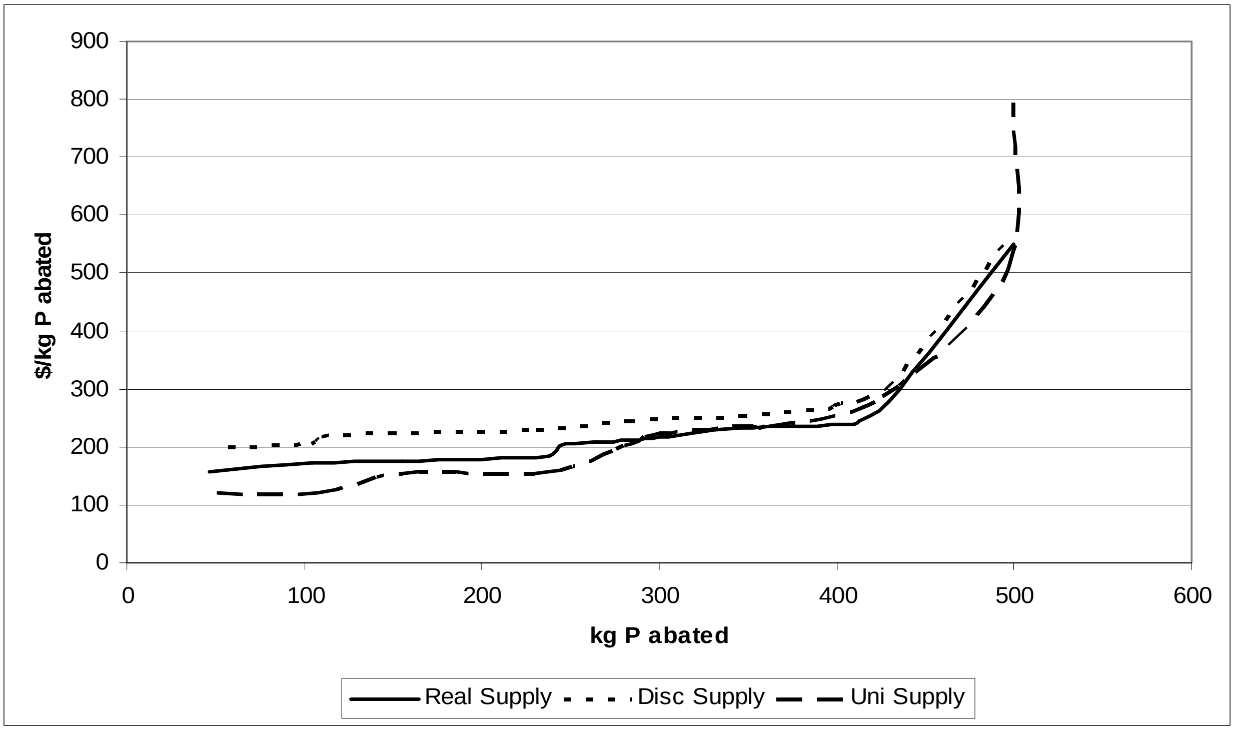

Figure 14 Comparison of average revealed cost curves derived from discriminatory and uniform payments with the actual cost curve for the max P abated bid ranking rule over all 15 periods

Again, because of the potential for bidders to learn over the 15 periods, it is beneficial to consider the evolution of the auction cost curve throughout the duration of the experiment. Therefore bids were averaged over periods 1-5, 6-10, and 11-15. Figure 15 and Figure 16 present the evolution of the revealed cost curve for MCD and MPD; the two discriminatory payment treatments. The MCD revealed cost curve is relatively close to the actual cost curve over periods 1-5 and progressively moves upward over the remaining periods indicating a higher frequency of rent seeking. This shows that participants were using the information gained at the end of each period to adjust their bid in order to maximize profit. This behaviour resembles that which was described by Hailu & Schilizzi (2005) in their agent based model to investigate learning. In the MPD treatment the distinct upward movement of the revealed cost curve is not as apparent, but it is clear that participants were able to learn in a similar fashion exhibited in MCD. An interesting observation is that in periods 11-15 the curve is almost an exact parallel shift above the actual cost curve.

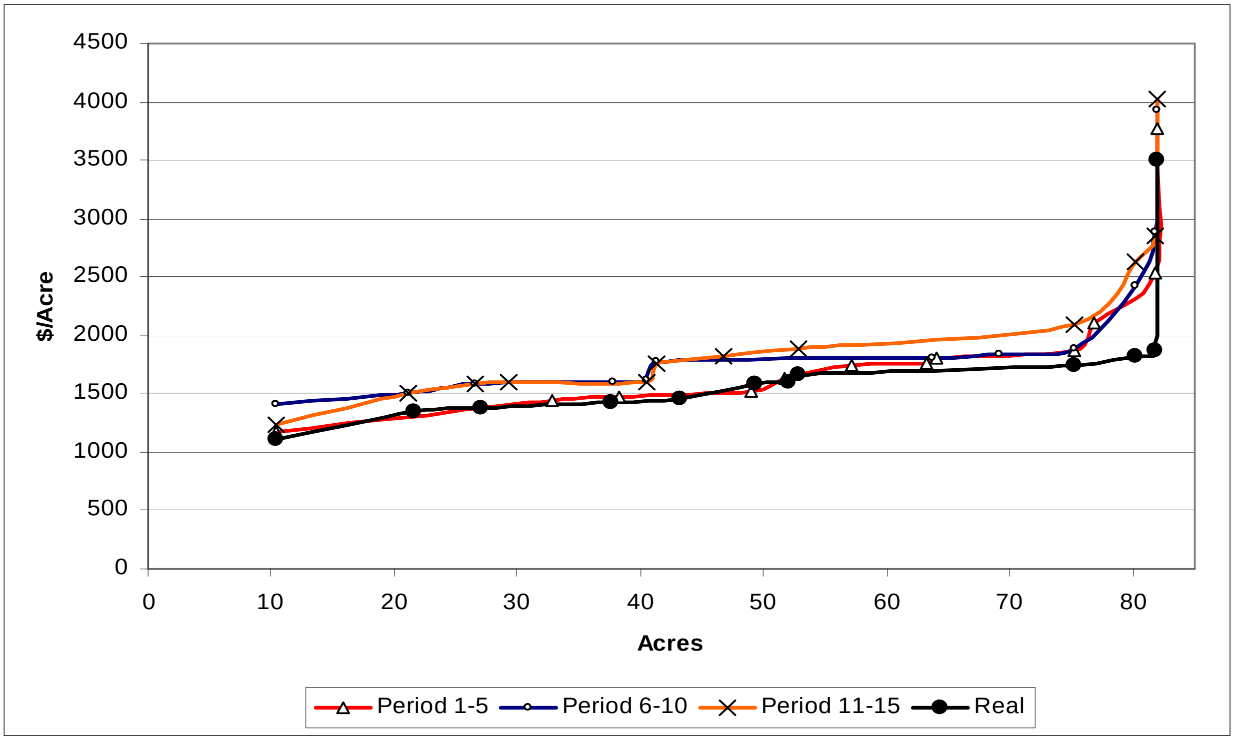

Figure 15 Comparison of mean revealed cost curve for periods 1-5, 6-10, and 11-15 under discriminatory payments compared with the actual max coverage cost curve

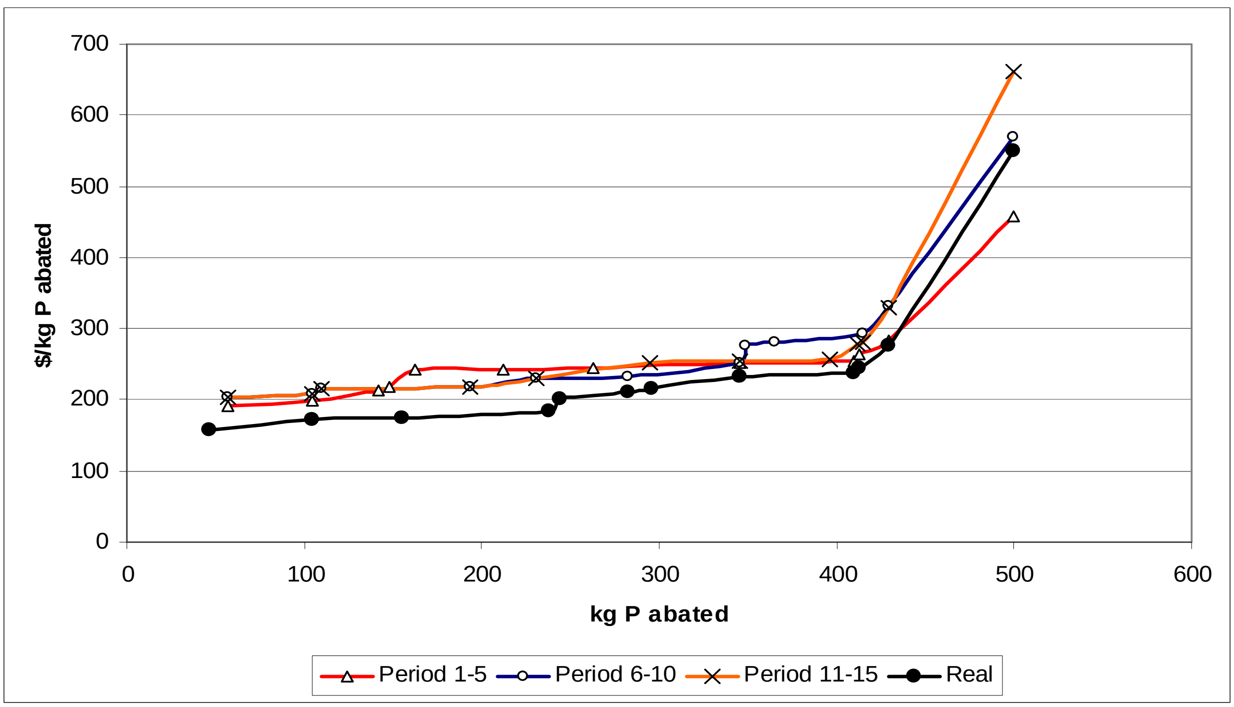

Figure 16 Comparison of mean revealed cost curve for periods 1-5, 6-10, and 11-15 under discriminatory payments compared with the actual max P abatement cost curve

Figure 17 and Figure 18 show the average revealed cost curves for MCU and MPU respectively. In the MCU treatment, the revealed cost curves are almost entirely below the actual cost curve. This suggests that individuals chose to increase their probability of being selected in the auction by lowering their bid in anticipation that the uniform payment would be sufficient to cover their costs. Similarly, In MPU individuals were also willing to bid below their costs. It is suspected that the position of a farm along the actual cost curve will also influence bidding strategies (Figure 11 and Figure 12). There is some evidence that leads us to believe that individuals who lie on the lower portion of the cost curve below the marginal bidder, are likely to behave in a way to maximize profit. This occurs because they are able to learn that they can provide EG&S at relatively low cost and therefore have room to shade their costs.

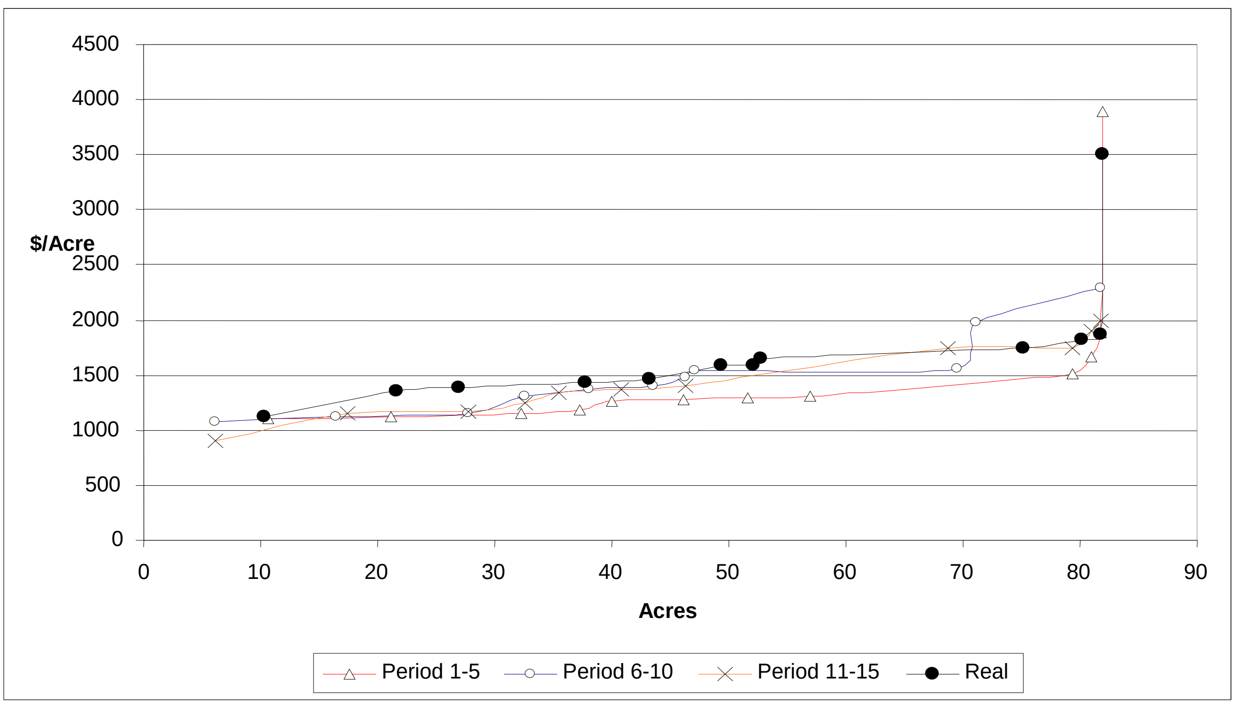

Figure 17 Comparison of mean revealed cost curve for periods 1-5, 6-10, and 11-15 under uniform payments compared with the actual max coverage cost curve

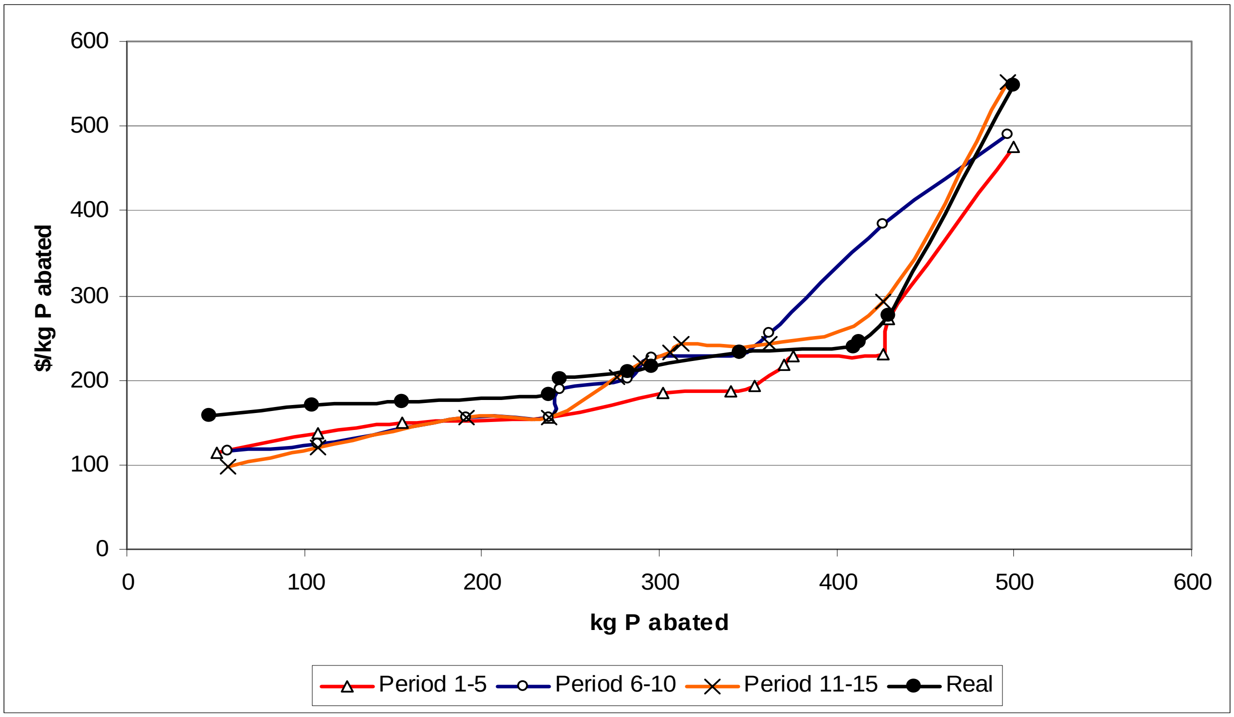

Figure 18 Comparison of mean revealed cost curve for periods 1-5, 6-10, and 11-15 under uniform payments compared with the actual max P abatement cost curve

In the discriminatory treatment, bids were above costs; while in the uniform treatment bids were below costs to ensure a payment. Despite bidding below costs, participants were still profitable (on average) given that there was positive rent seen in Table 17. The same trend of cost misrepresentation was found by Cason et al. (2003) when participants had information of their own quality.

Finally, those farms that lie above the marginal bidder tended to submit very large bids, suggesting bogus bids, knowing that they have no chance to win in the auction. The alternative choice was to not participate which was also more prevalent for those subjects who had high costs of providing environmental benefits.

4.3.3 Cost Efficiency

This section will provide the results of the market efficiency measures described in Section 4.1.1: PMOR, POCER, and PRENT. Figure 19 shows the average PMOR measure over 15 periods for both payment types in each bid ranking scenario. The discriminatory payments yield higher PMOR estimates 8 out of 15 periods in maximize coverage. However, uniform was more stable sitting around 80% of the optimal. Discriminatory is notably higher in the first 3 periods because of poor performance from one individual, which was addressed above. Since this participant was undercutting their costs, more money was left on the table to acquire more acres in these periods. Disregarding these periods, the highest level of PMOR achieved under discriminatory payments was 96% in period 11, versus 89% of the optimal under uniform in period 4. The lowest achieved PMOR for discriminatory payments was 68% in period 4, versus 76.6% in periods 5, 10, 11, and 12% in uniform.

Figure 20 shows the mean level of POCER over the 15 periods for discriminatory and uniform payments in both max coverage and max phosphorus abatement bid ranking systems. Disregarding the first three periods in the max coverage case, the measurements of POCER for discriminatory and uniform payments are relatively close in range as well as in stability of the measurement. Employing a *t*-test for unequal variances, no significant difference was found between the two payment types (p-value = 0.26) (excluding the first 3 periods). Therefore, on average discriminatory and uniform payments are of equal cost effectiveness at least in terms of maximizing coverage.

The POCER estimate is consistently higher under uniform payments than discriminatory for all periods under the maximizing phosphorus abatement treatments. Both curves are also somewhat stable with discriminatory lying close to 0.8 and uniform holding around 0.9. These estimates were found to be significantly different (p-value = 0.00) using a t-test assuming unequal variances.

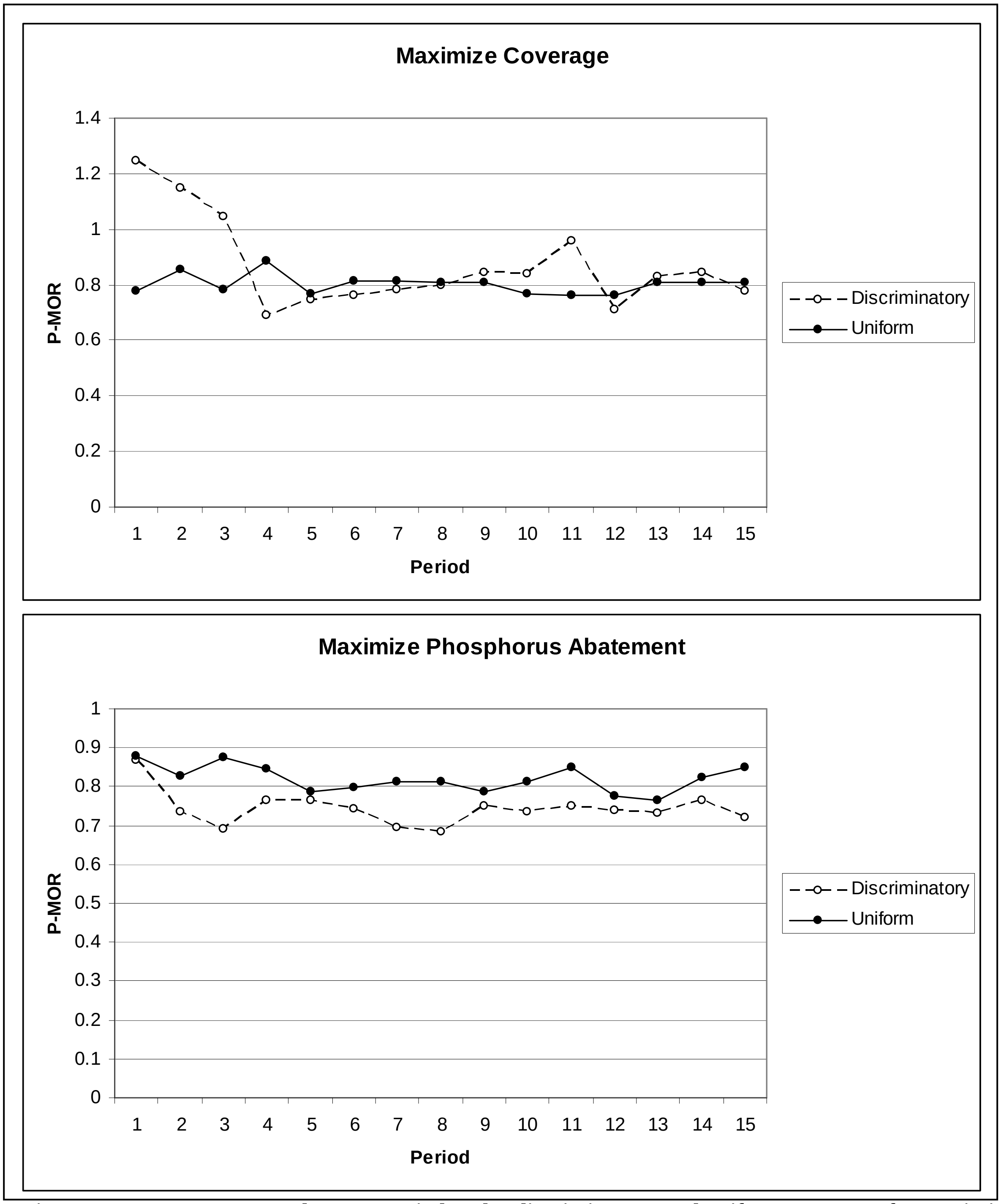

Figure 19 Average PMOR values per period under discriminatory and uniform payments for maximize coverage and maximize phosphorus abatement bid ranking rules

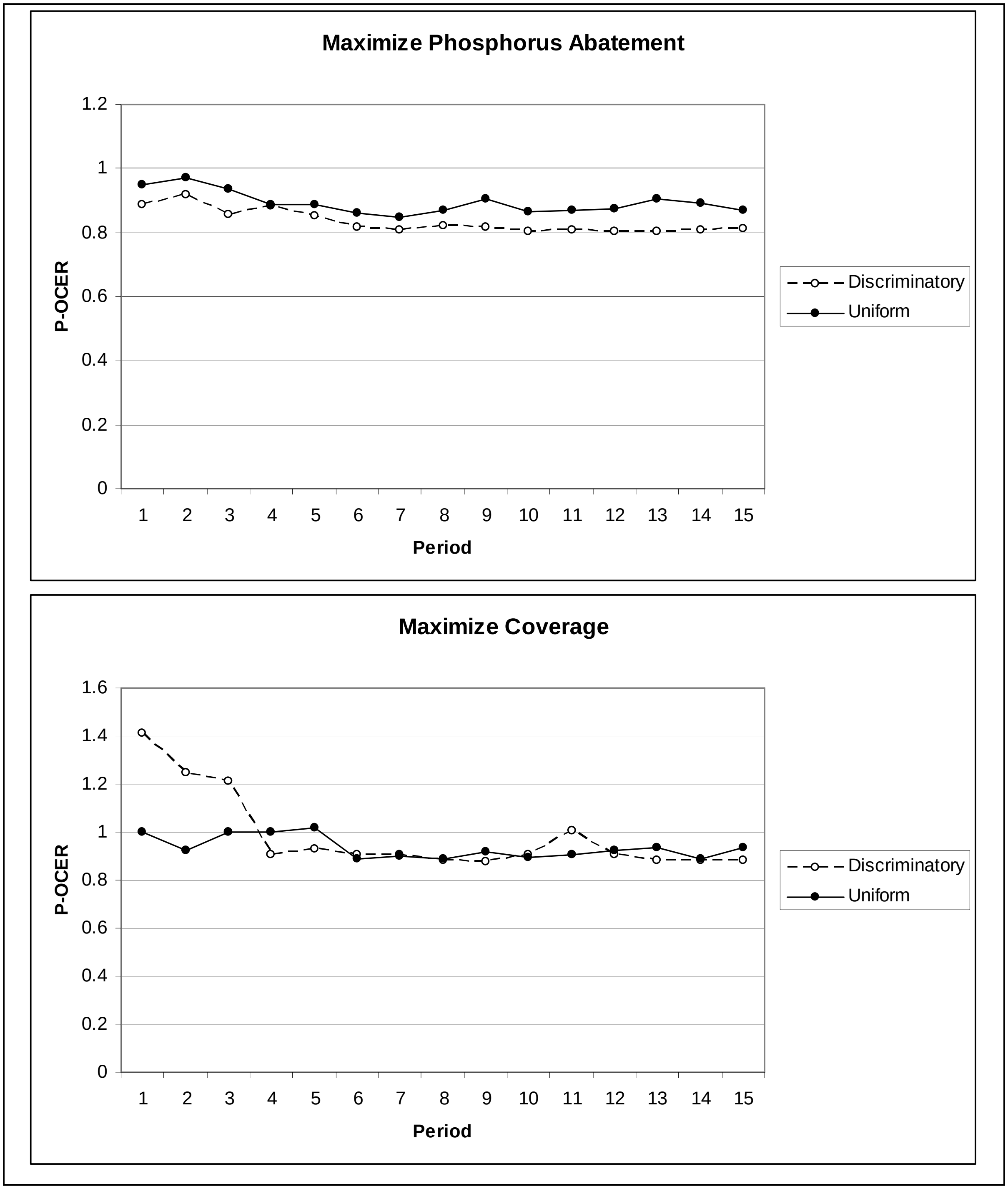

Figure 20 Average POCER values per period under discriminatory and uniform payments for maximize coverage and maximize phosphorus abatement bid ranking rules

4.3.4 Econometric Analysis

Regression analysis of the data was conducted using STATA 11.0. The estimation results for the models described are presented in Table 18. In total five variations the models presented in Section 4.1.4 were estimated. Descriptive statistics suggested that the auction outcomes of one of the MCD treatments were influenced by a single participant submitting very low bids. Therefore, additional models excluding the “bad” periods from that session, or excluding the entire session (columns 2 and 3 of Table 18) were estimated to investigate if that session skewed the regression results. Given our previous hypotheses of learning occurring in the first few periods of the auction, we tested this effect by estimating the models excluding periods 1-3 and 1-5 from all of the sessions (columns 4 and 5 of Table 18).

Autocorrelation was found in the estimation for POCER and PRENT using the Wooldridge test for serial correlation (p-values<0.1). Therefore, to address this issue these models were re-estimated with robust standard errors, which according to Stata, are robust to autocorrelation and heteroskedasticity (Stata Longitudinal-Data/Panel-Data Reference Manual, Release 11, p.464). Autocorrelation was not found in the estimation of PMOR.

Table 18 Results of panel regression, with random effects error structure, for PMOR, POCER, and PRENT

	All Data	Exclude Period 1-3 from Session 1	Exclude Session 1	Exclude Periods 1-3	Exclude Periods 1-5
PMOR					
$Coverage_{it}$	0.125*** (0.034)	0.092*** (0.032)	0.094** (0.039)	0.061* (0.035)	0.083** (0.038)
$Uniform_{it}$	-0.004 (0.039)	0.041 (0.036)	0.034 (0.036)	0.133** (0.041)	0.106** (0.042)
$CovUni_{it}$	-0.144*** (0.044)	-0.110*** (0.041)	-0.112** (0.047)	-0.070 (0.045)	-0.096* (0.049)
$\ln(period_{it})$	-0.077*** (0.013)	-0.043*** (0.012)	-0.049*** (0.012)	0.022* (0.012)	0.016 (0.012)
$\ln(period_{it}) * Uniform_{it}$	0.010*** (0.003)	0.005* (0.003)	0.005** (0.003)	-0.036** (0.015)	-0.019 (0.015)
$Constant$	0.887*** (0.034)	0.823*** (0.032)	0.833*** (0.032)	0.700*** (0.031)	0.707*** (0.032)
N	150	147	135	120	100
$\mathcal{R}^2$	.3196	.2146	.2444	.1904	.2319
POCER					
$Coverage_{it}$	0.151*** (0.01)	0.120*** (0.01)	0.133*** (0.01)	0.087*** (0.01)	0.095*** (0.01)
$Uniform_{it}$	-0.037 (0.06)	0.002 (0.05)	-0.003 (0.06)	0.057 (0.04)	0.042*** (0.03)
$CovUni_{it}$	-0.108*** (0.03)	-0.077** (0.03)	-0.091*** (0.03)	-0.040** (0.02)	-0.062*** (0.02)
$\ln(period_{it})$	-0.106*** (0.03)	-0.076** (0.03)	-0.080** (0.03)	-0.018*** (0.01)	-0.003** (0.00)
$\ln(period_{it}) * Uniform_{it}$	0.012* (0.01)	0.007 (0.01)	0.008 (0.01)	0.001 (0.02)	0.016 (0.01)
$Constant$	1.028*** (0.06)	0.973*** (0.06)	0.980*** (0.06)	0.848*** (0.01)	0.813*** (0.00)
N	150	147	135	120	100
$\mathcal{R}^2$	.4890	.4090	.4412	.3567	.4482
PRENT					
$Coverage_{it}$	-15.52*** (2.83)	-11.86*** (1.08)	-12.11*** (1.18)	-9.68*** (1.14)	-10.74*** (0.83)
$Uniform_{it}$	3.01 (8.06)	-1.54 (7.43)	-0.59 (7.53)	-6.48 (4.97)	-4.27 (6.22)
$CovUni_{it}$	14.06*** (4.98)	10.40** (4.31)	10.66** (4.30)	4.65* (2.50)	7.72*** (2.18)
$\ln(period_{it})$	15.04*** (3.73)	11.57*** (3.10)	12.30*** (3.28)	1.75** (0.89)	1.54 (1.10)

$\ln(period_{it}) * Uniform_{it}$	-1.04 (0.76)	-0.47 (0.66)	-0.59 (0.67)	1.89 (2.72)	0.21 (3.27)
$Constant$	-13.91* (7.44)	-7.46 (6.44)	-8.82 (6.78)	14.18*** (1.79)	15.61*** (1.59)
N	150	147	135	120	100
$\mathcal{R}^2$	.3927	.3035	.3176	.2145	.2232
***=significant at 1 level, **=significant at 5 level, *=significant at 10 level					

The constant may be interpreted as the level of PMOR, POCER, or PRENT that is achieved in the auction holding all treatments constant. The coefficients show improvement or deterioration of the measure based on treatments (e.g. uniform versus discriminatory, or max coverage versus max P abatement), or time (e.g. period).

Comparing the coefficients in the first 3 columns, there was little difference found between the original models using all observations with the additional models where the bad periods or entire session were excluded. The constant for PRENT became insignificant when the data was adjusted for the bad session; meaning that everything held constant, there was zero percent rent. The additional treatment coefficients indicate a change in PRENT depending on the treatment. Since there were no large differences between the models, the original model with all 150 observations will be used for interpretation.

The max coverage treatment tended to produce more favourable auction outcomes than max kg P abated for all measures; PMOR was higher by 12.5%, POCER by 15%, and PRENT was lower by 16.5%. This is encouraging given that this bid ranking system is more readily applicable to real world auctions due to the lack of hydrologic models in many Canadian watersheds. It is possible that the differences between the max coverage and max abatement cost curves may have contributed to this finding.

Based on the original estimation with all observations, the uniform treatment was not significant for any measure. Therefore, there was no significant difference in efficiency between the uniform and discriminatory treatments. However, the MCU treatment did not perform as highly as MCD; PMOR was 14% less, POCER 11% less, and PRENT 14% more. However, this essentially counteracts the effects produced by the max coverage treatment. In this case, it is possible that the amount of rent seeking under discriminatory payments was not as high as the additional payments distributed under the uniform treatment.

The negative and significant coefficient on *ln(period)*, for PMOR and POCER suggests that the auctions were acquiring fewer units of the specific objective (e.g. acres and kg P). They were also becoming less cost effective compared to the maximum optimal scenario over the progression of the auction periods; decreasing at rates of 8% and 11% respectively. These rates of degradation were not as high in the uniform treatment (7% and 9% respectively). The decrease in efficiency could be as a result of participants changing their bids to increase their profit based on their learned experiences. This is supported by the positive and significant sign on ln(*period*) for PRENT, demonstrating that the percentage of the budget spent contributing to participant profit was increasing by 15% in both uniform and discriminatory treatments. The fact that the rate of degradation was higher under discriminatory payments is an indication that participants were learning from the results of the repeated auction rounds and changing their bids to increase their profit potential. This type of learning would not necessarily occur under uniform payments since individual bids do not determine the level of profit.

To examine the effect of potential learning occurring in the first few periods of the auction experiment session, periods 1-3 and periods 1-5 were excluded from the analysis, to see if this would have any effect on the regression results. After the first 3 periods the constants for the PMOR and POCER models were positive and significant and decreased by almost 20%. The constant for PRENT increased by 14% compared to the case where all 15 periods were included.

This difference may be because the first segment of the auction was used to learn the auction mechanism and what to bid or test rent seeking strategies. This is different than learning the distribution of costs based on information gathered between auction rounds. Beyond this horizon, however, individuals' bidding appeared to stabilize. Therefore the amount of rent being paid to participants stabilized as well as the amount of acres or kg P gained in the auction. This was not the case for POCER, where there remains a decreasing trend over time. This may be attributed to an increasing budgetary outlay, but not the percent that is contributing to rent, thus decreasing cost effectiveness. However, this effect is very small (>1.0). This observation may have implications to administering an auction in the real world and the number of bidding or auction rounds included in the program. Based on this, some practice rounds may be required for potential bidders so that they fully understand the auction mechanism as well as learn their own bid strategy/bid function. While the practice rounds may result in increased rent seeking, there will be a reduction in bidding errors made by participants.

The uniform treatment dummy is also positive and significant for PMOR and POCER, meaning that the uniform payment treatment is more efficient by 11% and 4% respectively in acquiring the objective in a cost effective way. This is contrary to the result found by Cason, who found that the uniform treatment decreased efficiency. Cason & Gagadharan (2004, 2005) concluded that this was because winners in a uniform auction will always be paid more than their costs, thus more money is being spent on participant profit rather than purchasing environmental units. However, relating back to the comment made by Latacz-Lohmann & Schilizzi (2005), the relative cost effectiveness of uniform and discriminatory auctions depends on the degree of rent seeking occurring under discriminatory payments. In Cason & Gagadharan's (2004, 2005) case, there were probably relatively low degrees of rent seeking. Therefore the uniform auction in their study had relatively poor performance; even though they document that uniform performed relatively better as a cost discovery mechanism. In the results presented in this study, there was a high degree of rent seeking behaviour under discriminatory payments, especially in the MPD treatment. Based on the results for PRENT, when these periods are excluded, the same proportion of profit was being paid to participants under both pricing schemes.

These results suggest that the auction results in the first five periods were different than those from the rest of the auction. If these periods were not distinct, one would not expect to see changes that were significant. A Chow test for structural breaks was also conducted which indicated that those periods were significantly different. Although the $\mathcal{R}^2$ values are reduced between every model, these are still valid observations that require consideration. Based on this finding, there appears to be an initial learning stage where participants are able to develop their optimal bidding strategy. The more efficient payment method also seems to be contingent on the presence of this stage. Discriminatory payments may be more cost effective during this learning stage as participants have learned the maximum extent to which they can rent seek, and therefore bidding closer to their costs. Beyond this stage, participants can begin to make assumptions about their expected payoff. Under discriminatory payments this leads to raising bids above costs, while under uniform payments the optimal strategy would be to place a bid equal to costs, or just below costs. This has important implications on the use of conservation auctions to achieve real policy goals. If multiple auction sign-ups are anticipated (e.g. CRP), uniform payments may be more efficient in the long run.

The contrary conclusions between this study and Cason & Gangadharan (2004, 2005) also emphasizes that the overall auction framework can influence the comparison of pricing rules. In Cason & Gangadharan's (2004, 2005) study, the experimental auctions had repeated auction periods, each with different cost parameters for every period and concealed quality. Discriminatory pricing would be more cost effective in this case because participants would not be able to make assumptions about their expected payoff because their parameters change every period. The degree of rent seeking would also be lower because they are unaware of their quality measures. In the present study repeated auctions were employed using the same individual farm parameters and also the inclusion of quality in addition to costs. By having the farm parameters remain the same for every period, a more realistic scenario was provided if repeated sign-ups were to occur, since farm parameters are likely to stay relatively the same. Also, it is anticipated that participants would have some information on quality otherwise participation would be low. In addition, many auctions presented in case studies provide some quality information [e.g. BushTender (Stoneham et al. 2003), CRP (Reichelderfer & Boggess 1998)].

4.3.5 Summary

A total of 10 budget based auction experiments were completed applying four different auction design treatments: MCD, MCU, MPD and MPU. The experimental auction outcomes were compared to expected outcomes predicted using the greedy algorithm. Each bid ranking rule was proficient in acquiring the specified environmental unit. Max coverage could be used as a tool to proxy nutrient abatement, however adverse selection would need to be addressed. The MPD treatment was the most cost-ineffective compared to the other treatments; rent seeking was prevalent which led to a higher cost of acquiring environmental units thus reducing the amount of units acquired under the auction.

The discriminatory payment treatments revealed cost curves that lie above the actual cost curve, which is consistent with theory. The uniform payment treatments, however, revealed cost curves that were below the actual cost curve, indicating that individuals were submitting bids below their costs. While this is not the dominant strategy predicted by theory, it is still a potential strategy. It is interesting however, that it was very prevalent in these experiments.

On average, uniform payments had higher levels of PMOR and POCER than discriminatory payments. These measures were also more stable over the course of the experiment. Regression analysis demonstrated that when considering all 15 auction periods, there was no significant difference between uniform and discriminatory payments in terms of PMOR and POCER. There was also no significant difference in PRENT between uniform and discriminatory payments, therefore the higher payments in uniform equated rent seeking in discriminatory. However, when leaving out the first 5 periods from the analysis, uniform payments yielded higher PMOR and POCER results. These findings are contrary to those published by Cason & Gangadharan (2004, 2005), who found that the discriminatory payment structure was more efficient. It is believed that the conflicting conclusions are due to different auction design parameters.

Based on the results provided above, the max coverage ranking rule could be a sufficient proxy for maximizing phosphorus abatement where hydrological data is difficult to obtain. According to the descriptive statistics, by maximizing coverage, kg of phosphorus abatement were able to be acquired cost effectively. However, this is also dependent on the relationship between restored wetland acres and phosphorus abatement. Max coverage also had more efficient and cost effective auction outcomes compared to max phosphorus abatement based on the regression results. This is an interesting result and suggests that the differences between the cost curves can influence how efficient or cost effective an auction is.

Chapter 5 Target Based Auctions

5.1 Research Questions

There is limited research on the subject of target constrained conservation auctions to date. However as resources become more scarce this type of auction could gain popularity to serve as a tool to achieve EG&S where governments cannot fall short of certain measureable EG&S goals. Therefore understanding the characteristics of budget constrained versus target constrained auctions is important, particularly if target constrained auctions are subject to the same influences as budget constrained auctions and if the budget constrained design is applicable for target constrained auctions. This chapter will investigate the effect of the payment rule (discriminatory versus uniform), learning under repeated auction periods, and how a reserve price will affect auction efficiency and cost effectiveness. The hypotheses of these issues are provided in Table 19.

Table 19 Hypotheses for target based auctions

Treatment	Hypothesis
Payment Rule	Uniform payments will outperform discriminatory payments in terms of cost effectiveness and efficiency
Repeated auction rounds	Repeated rounds will decrease cost effectiveness
a. Inclusion of reserve price b. Announcing reserve price to participants	a. The inclusion of a reserve price will improve auction outcomes b. Announcing the reserve price will decrease efficiency

Latacz-Lohmann & Schilizzi (2007) only considered discriminatory pricing in their investigation of target auctions and found that target and budget based auctions had relatively similar outcomes. Since little research has focused on target based auctions, especially investigating the pricing mechanism, it is felt that comparing discriminatory and uniform payments is required to make sound decisions about this important design feature. This study continues the comparison of the discriminatory and uniform pricing mechanisms to determine if one payment mechanism leads to more desirable outcomes in a target auction (e.g. cost effectiveness, auction efficiency), and whether similar conclusions can be made about the pricing rule between budget and target constrained auctions. Similar to the budget constrained auctions, it is suspected that the more efficient pricing mechanism is largely an empirical question based on the degree of rent seeking occurring under the discriminatory rule. It is hypothesized that the uniform pricing mechanism will provide more desirable auction outcomes much like the budget constrained auctions.

Learning is a potential side effect of having repeated auction sign-ups. Latacz-Lohmann & Schilizzi (2007) found in their study comparing budget and target constrained auctions that repeated auctions did have a negative effect on performance and concluded that budget based auctions were more robust. Therefore, it is hypothesized that auction performance will deteriorate over repeated rounds.

Initially the auctions were run with only a target constraint. Since there was no constraint on the budget spent, submitted bids escalated to extremely high levels and participants would receive the maximum allowable cash payment within the first few periods. This is reflective of the type of learning described by Hailu & Schilizzi (2008) where participants would increase their bid until they were excluded from the auction and subsequently decrease their bid. In this case however, the signal to decrease high bids was not strong or consistent. Cummings et al. (2004) also found that in the Georgian auction for water permits the lack of a fixed budget constraint lead to inflated monetary outlay. A reserve price was subsequently introduced as a potential tool to regain lost cost effectiveness. Some agencies have chosen to announce the reserve price; however this could lead to detrimental effects on efficiency and cost effectiveness. We also compared the effect of announcing the reserve price to bidders versus not announcing to see how this affected learning and overall auction outcomes.

5.2 Auction Design

Table 20 Repetitions of target constraint treatments

Treatment	Discriminatory	Uniform
No Reserve	3	3
Unannounced Reserve	2	2
Announced Reserve	2	2

In total, 14 target based auctions were completed (Table 20). The same 12 producers as the budget constrained auctions were used to establish farm level parameters for the auction. However, in these experiments different levels of "participation" were offered in order to provide an opportunity for participants to make multi-unit offers with respect to price and environmental quantity. This also creates a more realistic scenario where producers would not be required to restore 100% of their wetlands. Levels of participation were the estimated acres of wetland restoration under the different scenarios presented in Chapter 3: 12.5%, 25%, 50%, and 100% restoration. Some of the producers would have 4 levels of participation, while others had 3, 2, or 1 level as determined by the scenarios given by Yang et al. (2009) (see Table 28 in Appendix).

A wetland restoration target for the watershed was chosen based on an assumed policy goal of 55% wetland restoration in the STC based on acreage. The target is assumed to reflect an EG&S goal that may be a science based goal or to satisfy the public[24]. The target for this study was 45 acres, which is 55% of all the wetlands that could be restored by the selected farm

[24] In their comparison of budget and target auctions, Schilizzi & Latacz-Lohmann (2007) chose a target that was determined endogenously in a budget constraint auction. While this may be useful for comparing efficiency, it does not necessarily reflect realistic goals made by governments.

parameters used in the experiment. This equated 55% of the total wetland acreage that could be achieved under the 100 wetland restoration scenario by the farms included in the auction.

The reserve price was set roughly equal to the uniform price estimated from the optimal combination of farm parameters (assuming that bids were equal to costs) at $1750/acre. Any bid that was submitted above the reserve price was automatically rejected from selection. The reserve price was established in this manner since there was access to an estimated cost curve. In the absence of this knowledge other methods should be explored in the determination of a reserve price.

5.2.1 Auction Procedure

The auction procedure for this set of auctions was the same as that described in Section 4.2.2. With respect to the instructions, participants were informed that it was a target based auction, so that bids would be accepted until an acreage target was reached, as well as the pricing mechanism being used. The only difference was with respect to the reserve price. When there was a reserve price used the participants were told that there was a maximum allowable bid, and that any submitted bid greater would automatically be excluded from the selection process. In the announced treatment, participants were told the amount of the reserve price during the introduction prior to the first practice auction. The price was also written on a white board in the experimental lab as a reminder. This information was not given in treatments when the reserve price was not announced.

5.2.2 Econometric Analysis

Two efficiency/cost effectiveness metrics were used to evaluate the target auction treatments: POCER (Proportion of Optimal Cost Effectiveness Realized) and PRENT (Percent

RENT). POCER was defined in the same way described in Section 4.1.4 where the optimal combination of farm parameters was solved to reach the acreage target and minimize the budget spent. The definition for rent can also be found in Section 4.1.4. The metric PMOR (Proportion of Maximum Objective Realized) was not considered for this analysis since the auctions were a target based auction.

Econometric Model

The empirical models used to estimate the effect auction treatments on cost effectiveness are provided below and described in Table 21:

$$\begin{matrix} POCER \\ PRENT \end{matrix} = \alpha + \beta_1 Uniform_{it} + \beta_2 Announced_{it} + \beta_3 Unannounced_{it} + \beta_4 \ln(period_{it})$$

$$+ \beta_5 \ln(period_{it}) * Uniform_{it} + \varepsilon_{it} + \mu_i$$

Table 21 Description of variables included in econometric models investigating the cost effectiveness of target based auctions

Variable	Description
$Uniform_{it}$	Dummy variable for payment rule; where 1 = uniform, and 0 = discriminatory payment
$Announced_{it}$	Dummy variable for announced reserve price; where 1 = announced reserve price, and 0 = no reserve price (base case)
$Unannounced_{it}$	Dummy variable for announced reserve price; where 1 = unannounced reserve price, and 0 = no reserve price (base case)
$\ln(period_{it})$	Represents the time trend for each session
$\ln(period_{it}) * Uniform_{it}$	Interaction term of time trend and payment rule

The data set used was also in panel format with the cross-section based on auction session and time series based on 15 auction periods. Therefore, panel regression was used with random effects error structure, with the individual specific effect on session. This was done for the same reason explained in Section 4.1.4. Since Schilizzi & Latacz-Lohmann (2007) only considered 3 repetitions in their analysis of target based auctions versus budget based auction, we also estimated the above models with only 3 periods in order to draw some comparisons between studies. Autocorrelation was present in the model for both POCER and PRENT; therefore both models were estimated using Robust Standard Errors which corrects for autocorrelation and heteroskedasticity.

5.3 Descriptive Results

The uniform treatments were generally more effective in achieving the wetland restoration acreage target (Table 22). Under uniform payments, the frequency of reaching the target decreased when a reserve price was included in the auction; conversely it increased under discriminatory payments.

Table 22 Average proportion of target achievement for each target auction treatment

	Discriminatory	Uniform
No Reserve Price	0.49 (N=45)	0.91 (N=45)
Unannounced Reserve Price	0.50 (N=30)	0.83 (N=30)
Announced Reserve Price	0.83 (N=30)	0.87 (N=30)
Total N=210		

The descriptive statistics of the auction outcomes are presented in Table 23. The highest budgets required to achieve the target were found when there was no reserve price, as expected. When there was no reserve price the average discriminatory budget spent was about $200,000, while the average uniform budget spent was about $400,000; roughly 100% greater. However, on average, more wetland acres were recovered when uniform payments were used: 48.66 acres under uniform and 44.6 acres under discriminatory. Despite this, the uniform $/acre was significantly higher than the discriminatory $/acre ($8893.67/acre versus $4728.73/acre respectively).

In cases where the target was not met, payments were still distributed thus limiting the scarcity in the selection of winners, and ultimately payments were given to every participant who submitted a bid. In the uniform auctions the market price would be equal to the highest $/unit, grossly increasing the monetary outlay. Consider Figure 21 which illustrates the effect of rent seeking when the target was not achieved. Assuming the same level of bid inflation under both uniform and discriminatory pricing, one can see that all participants would receive a payment. The points P_uOQ_AA represent the budget spent under uniform pricing, and POQ_AA represents the budget spent under discriminatory pricing. It is clear that the budget spent under uniform pricing is much larger than the budget under discriminatory pricing; $P_uOQ_AA > POQ_AA$. This illustration supports the use of a reserve price, or restricting the distribution of payments when the target is not met.

The inclusion of a reserve price reduced the budgetary outlay by between 30% and 40% with discriminatory payments, and about 20% with uniform payments (Table 23). This was expected as the reserve price essentially acts as a price ceiling, although not as strict as a fixed budget. Announcing the reserve price resulted in higher budgets, on average, but it was not statistically significant. Using discriminatory payments the announced reserve price budget was roughly 30% higher than the unannounced discriminatory budget. Under uniform payments the difference between announcing and not announcing was smaller at 7%. It is suspected that when the reserve price was announced participants could make expectations about their maximum payoff and subsequently increase their bid to the reserve price in the first auction periods, whereas this would need to be learned over the initial periods when the reserve price was unannounced.

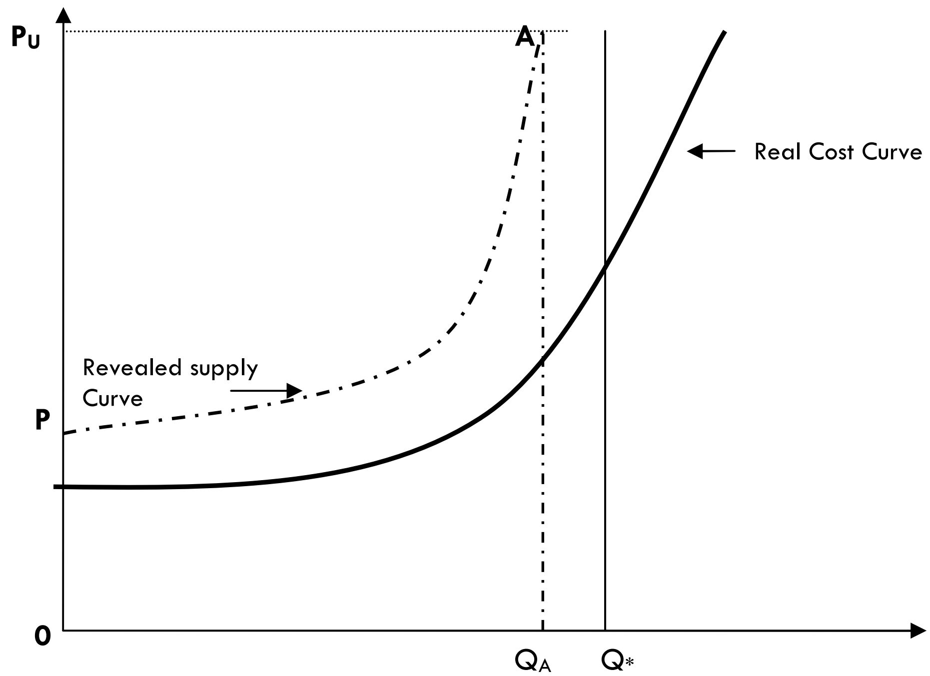

Figure 21 Effect of rent seeking on the budgetary expenditure when the target is not achieved using hypothetical cost and revealed cost curves

The budgetary outlay was consistently higher under uniform payments for all reserve price treatments. The difference in budget between discriminatory and uniform payment types was much smaller when there was a reserve price, about $16,000 when the reserve price was not announced, and $4000 when the reserve price was announced (compared to 100% difference).

Table 23 Descriptive statistics for target based auction treatments

	Discriminatory					Uniform				
	Budget spent($)	No. of Acres restored	$/acre	PRENT	POCER	Budget spent($)	No. of Acres restored	$/acre	PRENT	POCER
No Reserve Price										
Mean	197,585.60	44.60	4728.73	0.47	0.48	414,704.30	48.66	8,893.67	0.45	0.51
Median	123,571.00	44.83	2918.47	0.49	0.46	102,771.40	48.48	2,159.83	0.31	0.62
S.D.	166,340.50	5.33	4489.67	0.27	0.25	771,112.60	4.83	16,808.09	0.3	0.28
Minimum	61,473.00	32.33	1550.08	0	0.08	72,172.12	35.64	1,594.96	0.02	0.02
Maximum	637,800.00	54.92	17570.3	0.92	0.87	3,819,200.00	66.57	80,000.00	0.98	0.84
N=45						N=45				
Announced Reserve										
Mean	80,117.17	48.34	1652.52	0.14	0.82	84,113.00	49.34	1,704.59	0.16	0.79
Median	79,123.50	48.49	1696.9	0.16	0.79	81,708.42	49.19	1,705.48	0.17	0.79
S.D.	11,371.06	5.25	94.27	0.05	0.05	10,698.88	5.93	53.89	0.04	0.03
Minimum	48,998.00	34.14	1337.69	-0.02	0.78	55,615.00	31.78	1,499.82	-0.02	0.77
Maximum	99,324.00	57.63	1723.48	0.2	1	101,685.60	58.22	1,750.00	0.22	0.9
N=30						N=30				
Unannounced Reserve Price										
Mean	62,540.73	39.51	1561.13	0.05	0.9	78,480.37	47.41	1,658.71	0.15	0.81
Median	66,946.50	44.65	1663.73	0.13	0.81	78,538.45	49	1,657.53	0.17	0.81
S.D.	23,740.85	12.50	235.29	0.32	0.26	9,431.32	5.58	97.34	0.07	0.05
Minimum	19,100.00	16.90	617.84	-1.53	0.78	47,617.50	27.21	1,426.40	-0.04	0.77
Maximum	96,346.00	56.06	1731.24	0.25	2.17	101,587.50	58.05	1,750.00	0.23	0.94
N=30						N=30				

The difference in budgetary outlay between payment types resembles the scenario described by Latacz-Lohmann & Schilizzi (2005) where the payment above costs paid under uniform payments is greater than the extent of rent seeking occurring under discriminatory payments. While rent seeking was apparent in both pricing mechanisms, the effect was magnified under uniform because of the nature of the payment in conjunction with no real budget constraint. In the uniform payment auctions, participants chose to increase their bid to seek rent; this would ultimately increase the uniform payment distributed to winners. Under discriminatory payments, while everyone would be rent seeking, only a few participants would receive a very large payment.

Table 24 presents the average statistics taken over groups of 5 periods (e.g. 1-5, 6-10, and 11-15). Similar to the budgetary auctions, it was suspected that repeated auctions would contribute to participant learning, and potentially result in the deterioration of auction efficiency. Indeed there is evidence of learned behaviour over the 15 periods which resulted in increasing budgets, especially under discriminatory payments. The increase in budgets is coupled with the increase in the percent of the budget going towards rent. This trend was less pronounced in the uniform treatment.

The same overall trends were observed for \$/acre as budgetary outlay, because any fluctuations in \$/acre depend on the variation occurring in terms of the budget since the number of acres is relatively constant because of the target (Table 23). When the reserve price was imposed on the auctions, \$/acre would drop to about the same level as the reserve price, \$1750/acre. The mean \$/acre was lower in the unannounced reserve price treatment than the announced treatment under both payment types. This is because it would take participants longer to learn the reserve price when it was unannounced.

Table 24 Average auction outcomes for groups of 5 periods (1-5, 6-10, and 11-15)

		Discriminatory					Uniform				
Treatment	Periods	Budget spent	No. of Acres restored	$/acre	PRENT	POCER	Budget spent	No. of Acres restored	$/acre	PRENT	POCER
No Reserve Price	1-5	112,092.33	43.88	2,612.30	0.34	0.59	674,699.76	49.20	14,268.07	0.52	0.45
	6-10	199,209.27	46.27	4,455.79	0.51	0.45	163,540.13	47.27	3,679.77	0.35	0.6
	11-15	281,455.33	43.66	7,118.09	0.58	0.39	405,873.00	49.53	8,733.15	0.47	0.49
Announced Reserve Price	1-5	71,287.00	44.08	1,612.47	0.11	0.84	83,360.29	49.00	1,701.40	0.14	0.79
	6-10	80,056.50	48.93	1,634.54	0.13	0.83	81,330.53	47.41	1,715.77	0.17	0.78
	11-15	89,008.00	52.03	1,710.55	0.17	0.78	87,648.18	51.61	1,696.60	0.18	0.79
Unannounced Reserve Price	1-5	39,967.60	30.03	1,358.21	-0.14	1.07	72,996.62	44.88	1,637.54	0.12	0.83
	6-10	65,075.70	40.05	1,621.02	0.13	0.83	81,802.83	48.33	1,692.68	0.18	0.79
	1-5	82,578.90	48.44	1,704.16	0.14	0.79	80,641.65	49.04	1,645.93	0.15	0.82

Table 24 presents averages over groups of 5 periods (1-5, 6-10, and 11-15) to observe any effects learning may have on results. When comparing $/acre, there was a steady increase in $/acre under discriminatory payments for all reserve price treatments. This trend is not apparent under uniform pricing because learning patterns are likely different under this pricing regime. This provides evidence that individuals were using information from previous rounds to make expectations of their maximum payoff so they could rent seek to that point. This is also evident from the increase in the percent of the budget contributing to rent. It is speculated that learning also occurred under uniform payments; however a distinct trend is less evident.

A concern with having the same reserve price over repeated auction rounds is that participants will be able to learn the reserve price and subsequently bid that price to extract the maximum possible rent. This was observed in the CRP according to Reichfelder & Boggess (1988). In the present study, under the discriminatory price treatment, bids converged to the reserve price at different periods depending on whether the reserve price was observed or not. When it was not announced, the $bid/acre for all participants started to equal the reserve price at about period 6. However, when the reserve price was announced, this bidding behaviour was observed at period 3. After the respective periods, participants would chose the level of participation with the lowest $/acre (or highest value for money) in order to extract the maximum amount of rent possible (Figure 22).

Under uniform pricing, bids did not converge to the reserve price. Participants would often either bid their costs or below their costs in order to increase their probability of being selected in the auction, with the exception of some participants bidding the reserve price to set the market price. The uniform market price, however, was fairly close to the reserve price from period 1 in both information treatments, although in one repetition when the reserve price was unannounced the uniform price remained below the reserve price for the duration of the session. The uniform market price was often dependent on whether the target was achieved or not. Figure 23 illustrates the typical bidding behaviour under uniform pricing.

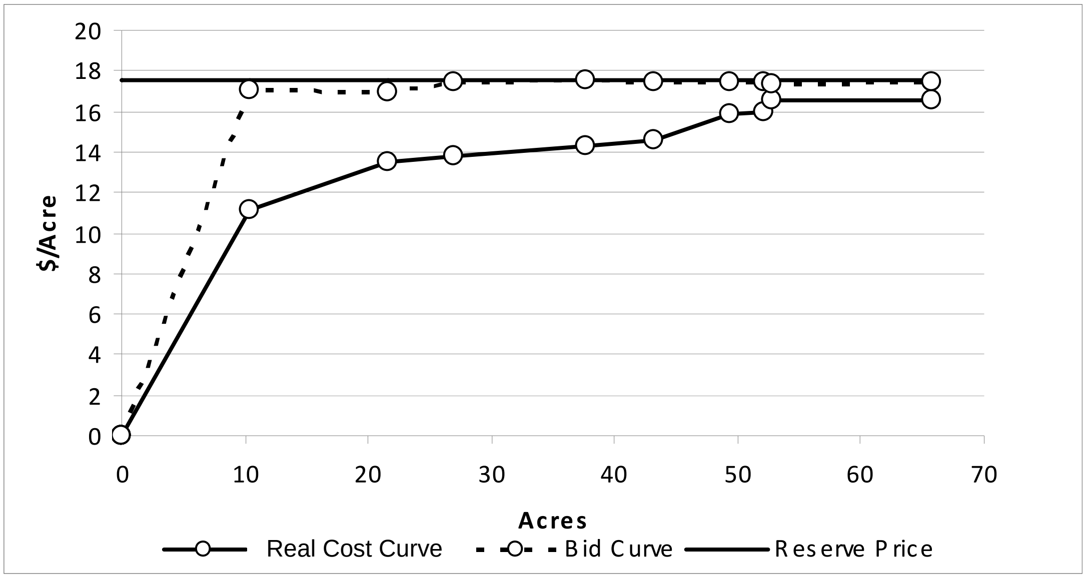

Figure 22 Bid curve compared to the actual cost curve and reserve price under discriminatory pricing
Note: This curve represents the discriminatory bid curve for the 15th period when the reserve price was announced. This figure was chosen because it gave the best representation of the trend that was evident in the periods after bid convergence in both the announced and unannounced reserve price treatments.

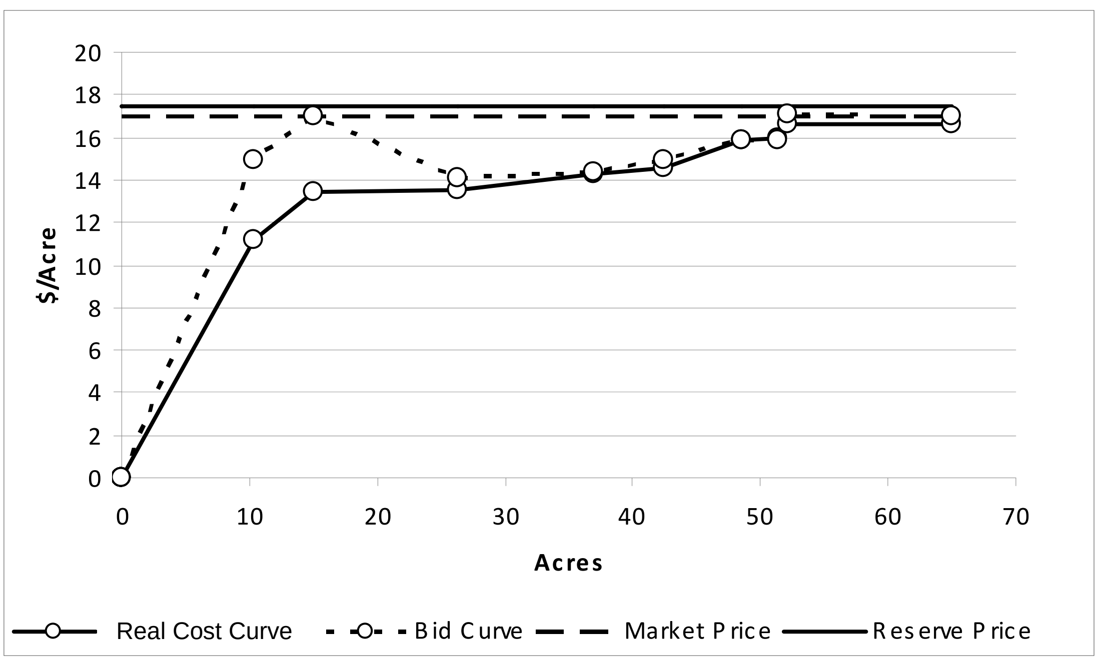

Figure 23 Bid curve compared to the actual cost curve and reserve price under uniform pricing
Note: This curve represents the uniform bid curve for the 12th period when the reserve price was announced. This curve gave the best depiction of the behaviour that was observed for a majority of the auction periods.

5.4 Cost Effectiveness and Empirical Model

POCER is a measure of cost effectiveness introduced by Cason & Gangadharan (2004, 2005) and discussed in 4.2.4. POCER was relatively low when there was no reserve price for both pricing treatments, around 50% (Table 23). This indicates that auction cost effectiveness was about half of what the optimal would be. This is mostly due to the high prevalence of rent seeking which results in higher required budgets than the optimal. POCER increases when a reserve price is incorporated into the auction from 50% to 80% or 90%. This was expected since the reserve price reduces the budgetary outlay. Generally POCER is higher under discriminatory pricing. Likewise it was higher when the reserve price was not announced, but it was not statistically significant (Tamhane's T2 p-value = 0.12).

Similar trends were observed in PRENT. The highest PRENT was recovered when there was no reserve price, 34% under discriminatory payments and almost 50% with uniform payments. The incidence of rent decreased when the reserve price was included. With respect to discriminatory payments, the average PRENT when the reserve price was not announced was 5% and 14% when it was announced; and under uniform payments the average PRENT was 15% when the reserve price was not announced and 16% when it was announced. The amount of the budget going towards rent also explains the results found for budgetary outlay and $/acre measure.

Under discriminatory payments, cost effectiveness deteriorated, in terms of both POCER and PRENT, over the 15 periods (Table 24). There was a less pronounced trend under uniform payments. This suggests that learning is different depending on the payment type chosen. In discriminatory auctions, participants are more likely to follow through with the learning described by Hailu & Schilizzi (2005), while under uniform pricing the market price is set by the marginal bidder. Also, there is no benefit from anchoring a bid on the reserve price under a uniform payment since there that is what the market price may end up being.

To further investigate the cost effectiveness of target based auctions, panel regression analysis using a random effects error structure, with the individual specific effect on the auction session was conducted using Stata 11.0. Panel regression analysis allows for further understanding of how auction treatments influence auction outcomes. Autocorrelation was present in the data; therefore robust standard errors were used. The results are presented in Table 25.

Table 25 Target constraint panel regression results for cost effectiveness and rent

POCER	Periods 1-15	Periods 1-3
$Uniform_{it}$	-0.267**	-0.338**
	(0.111)	(0.155)
$Announced_{it}$	0.307***	0.274**
	(0.094)	(0.082)
$Unannounced_{it}$	0.359***	0.451**
	(0.100)	(0.150)
$\ln(period_{it})$	-0.128***	-0.262**
	(0.049)	(0.131)
β $\ln(period_{it}) * Uniform_{it}$	0.135**	0.255*
	(0.054)	(0.154)
$Constant$	0.741***	0.803***
	(0.117)	(0.128)
$\mathcal{R}^2$	0.4761	0.531
N	210	42
PRENT		
$Uniform_{it}$	29.60**	40.42**
	(12.975)	(19.099)
$Announced_{it}$	-31.07***	-28.19***
	(9.669)	(8.923)
$Unannounced_{it}$	-36.29***	-47.45***
	(10.530)	(17.425)
$\ln(period_{it})$	14.63**	32.24*
	(5.868)	(16.619)
$\ln(period_{it}) * Uniform_{it}$	-14.67**	-33.68*
	(6.315)	(18.740)
$Constant$	17.71	10.01
	(13.134)	(15.241)
$\mathcal{R}^2$	0.444	0.485
N	210	42

First the results including all 15 periods are discussed. In terms of POCER, the uniform treatment was less cost effective than the discriminatory treatment by almost 30%. This suggests that the uniform payments were greater than the individual rent seeking occurring under discriminatory pricing. This is supported in the PRENT regression, showing that the there was 30% more of the budget went towards rent. Not announcing the reserve price improves cost effectiveness (both POCER and PRENT) more than announcing the reserve price over not having a reserve price; about 5%.

Including a reserve price into the auction stood to improve auction performance, as suggested in the descriptive statistics (Table 23). With an unannounced reserve price, POCER improves by about 35%, and reduces PRENT by about 36%. The announced reserve price also improved auction performance, although not as well as not announcing the reserve, where POCER improved by 30% and PRENT was reduced by 31%.

The results in Table 25 also show that auction performance decreases over time under discriminatory pricing, however the effects are essentially nil in uniform pricing, as the coefficients on $\ln(period_{it}) * Uniform_{it}$ are roughly equal to $\ln(period_{it})$. Essentially auction performance was relatively stable across the auction session under uniform payments. In conjunction with the descriptive tables above, it is possible that the poor auctions were balanced out with better auctions.

One can see that auction performance is better when considering only the first 3 periods of each auction session,, where the constant for POCER increased by 10%, but the constant for PRENT was still not significantly different than zero. This is similar to the results observed by Schilizzi & Latacz-Lohmann (2007). Discriminatory pricing still outperformed uniform pricing. These results suggest that in a shorter period of time, there is less opportunity to learn from previous outcomes. However considering the variable $\ln(period_{it})$ for periods 1-3, its coefficient is much higher than its coefficient for the model using periods 1-15. This suggests that learning in the first few periods is very steep. Schilizzi & Latacz-Lohmann (2007) also found that auction performance deteriorated over time; however it was not explicitly quantified. One can still observe that there is no distinct time trend associated with uniform payments, similar to the result with all 15 periods.

The results presented in this chapter lead one to believe that discriminatory pricing is more desirable when considering a target based auction. However, like Latacz-Lohmann & Schilizzi (2005) identified, the preferred pricing mechanism is largely based on the degree of rent-seeking occurring under discriminatory pricing. In this case, assuming equal quantity (because of quantity constraint), the uniform price was more expensive than individual rent seeking under discriminatory pricing; this led to large payments, where 50% of the budget went towards individual profit. Figure 24 compares the two pricing mechanisms with no reserve price using hypothetical ordered bid curves based, the uniform budget is represented by P_uOQ^*A and the discriminatory budget by P_dOQ^*A where Q* is the target, P_u is the uniform price and P_d is the vertical intercept of the discriminatory bid curve. In this case, $P_uOQ^*A > P_dOQ^*A$, illustrating that the uniform budget is greater than the discriminatory budget.

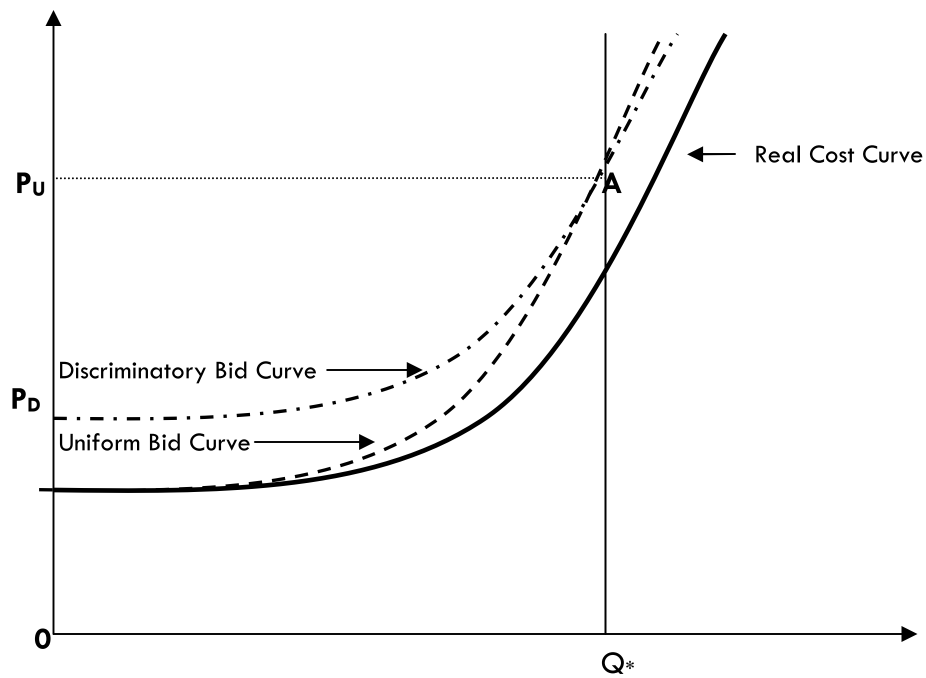

Figure 24 Comparison of discriminatory and uniform payments under a target based auction assuming the target was achieved

It is possible that the target chosen was not high enough to provide an adequate level of competition among bidders. Therefore a reserve price was necessary to act as a price ceiling in order to maintain any cost effectiveness. Since the target was chosen endogenously in the study by Schilizzi & Latacz-Lohmann (2007), the target suited the level of competition accurately; hence they did not require a reserve price. Choosing an appropriate target is a concern if a target constrained auction is to be used in the real world. Relying on a science based target may not be appropriate if participation is not there, otherwise there will be consequences similar to the results where there was no reserve price. Therefore, there needs to be communication between scientists and economists in order to establish both ecologically and economically efficient EG&S targets.

Concealing the reserve price to bidders proved to have advantages over announcing it. By announcing the reserve price, a direct price signal is sent to the participants and they are induced to submit a bid equal to the reserve price as opposed to a bid reflecting costs. While participants were still able to learn the reserve price over repeated auction periods, it was not until the 6th period where bids would begin to converge under discriminatory payments. Announcing the reserve price under uniform payments also diminished auction efficiency, however not in the same way as under discriminatory payments. Participants were more likely to submit a bid equal to their costs under announced or unannounced reserve pricing; however the uniform market price was equal to the reserve price more often when it was announced because of the direct price signal.

Incorporating a reserve price was necessary to maintain economic efficiency in the target based auctions presented in this study. By comparing the announcement treatments of the reserve price allows one to understand the effect of learning with respect to the reserve price. Provided that the participants were able to learn the reserve price and in relatively few periods (less than half of the session length), this is a concern for the authority of a real conservation auction. In order to prevent the negative effects of learning, the auction parameters could be changed prior to participants making accurate expectations. This concept was also recommended by Reichefelder & Boggess (1988) for the CRP when they found evidence of learning their minimum allowable EBI.

5.5 Comparison of Target and Budget Auctions

Based on the results discussed for budget and target constrained auctions, it appears that the two auction formats may be fundamentally different and are subject to different influences. Since the two auction designs had many different elements, a direct comparison cannot be made; however the overall results give an idea of underlying issues as well as identify future areas of study.

The desirable payment treatment was different for each constraint. In this empirical application, uniform payments yielded better auction outcomes in the budget based auction, whereas discriminatory payments outperformed uniform payments under a target constraint. This potentially can be influenced by the difference in the level of competition under each constraint or the inclusion of the levels of participation in the target based application described here. This leads one to believe that the better payment mechanism is dependent on the level of competition present in the auction. When there is low competition, there is still variation in bids (i.e. some bids close to costs, some much higher than costs). However, uniform payments are more volatile since a large bid could result in very large payments to all winners, while under discriminatory pricing only that individual will receive that large payment. While this was what was found under the target constrained auction, this would also hold true under the budget constrained auction.

Based on the results, and observing individual behaviour, a target constraint may not be as robust as a budget constraint in terms of auction performance in repeated auction sign ups. When there is no reserve price included in the target based auction, this auction type is more susceptible to adverse learning effects over repeated auction sign-ups. Once bidders learn that they can win in the auction, they apply the learning technique described in Section 2.4.5 of increasing their bid until it is rejected. Bidders are less likely to be rejected because there is no budget cap, therefore bids can increase infinitely. Therefore, target based auctions are more likely to have higher budgets with a higher proportion of the budget contributing to participant profit. According to the results presented, there may be up to 50% of the budget going towards rent in a target based auction compared with up to 20% in a budget based auction.

When it comes to governments' balance sheet, a budget based auction may be more reliable since the budget is known *a priori*. However, the level of competition is a significant contributing factor if the auction mechanism is to be cost effective. If competition is a concern, a reserve price should be established.

Having knowledge of the underlying cost curve is a key element that will contribute to the effectiveness of a reverse auction under both budget and target constraints. This empirical study was unique in that there was access to the actual underlying cost curve for wetland restoration in the STC watershed. With that, there is more concrete observation on the effectiveness of the auction mechanism in that watershed. Where the underlying cost curve is not known, it is difficult to conclude that an auction is cost effective or not since there is no actual level of comparison: one would be unsure if some producers could have been paid less for the same service. While the target constraint was arbitrarily determined, knowledge of the cost curve was required to set a reserve price in order to maintain cost effectiveness. Understanding the costs that face producers is also essential even in determining a budget constraint so that there remains an appropriate level of competition to encourage revelation of the underlying cost curve. It is possible that the shape (e.g. slope or curvature) of the underlying cost curve can also influence the outcome of a reverse auction.

Chapter 6 Conclusion

The current method used in the procurement of EG&S from producers' leaves room for improvement. Fixed price or cost sharing agreements are not an effective tool because they do not appropriately reflect actual producer costs incurred. These programs may be excluding those influential producers who can provide a large amount of EG&S. However, their costs may also be high, while at the same time encouraging those who have low costs and low EG&S potential to participate for income support. An alternative method is to utilize market forces by applying an MBI such as a conservation auction. Conservation auctions have the capacity to buy EG&S in a cost effective and equitable manner than other types of compensation programs.

Auction design is multi-faceted and also context specific. While there is a large body of literature and theory related to conventional auctions, conservation auctions in practice violate a number of assumptions that guide these conventional auctions. Therefore conventional auction theory is not necessarily an appropriate guide. A majority of the theory for conservation auctions has been based on experimental auctions in laboratories or in the field.

Auction design is a very important factor that influences the success in conservation auctions. The intent of auction design is to guide bidding behaviour to the theoretical optimal outcome and to reveal the actual cost of adopting an EG&S friendly practice. Important design features are the pricing mechanism, bid ranking rule, target versus budget constraint, and level of information. In the literature there is some contention as to what is the best auction design. This study attempted to further investigate auction design theory to establish what factors should be considered in choosing a design framework.

The purpose of this study was to investigate conservation auction design as it relates to wetland restoration in the STC watershed in southern Manitoba. Wetlands have the capacity of providing a large amount of EG&S, and are highly desirable to have in the landscape. However, there has been a progressive loss of wetlands and therefore a loss of EG&S. Programs have been in place to encourage wetland restoration projects in the area, however there has not been any documented success. Some studies have identified that financial concerns pose as a significant barrier for producers wanting to participate in environmental programs. Therefore, conservation auctions are proposed as a potential method to encourage more wetland restoration.

In this study, on farm costs and EG&S associated with wetland restoration were estimated in the STC watershed. This allows for the more accurate representation of those producers in the auction. Therefore there is a better understanding of the bidding behaviour that could occur in that area.

There were two main testbeds of experiments presented in this study: budget constrained auctions and target constrained auctions. Within the budget constrained auctions, design factors that were investigated were the pricing rule (discriminatory versus uniform payments), bid ranking rule (maximize coverage versus maximize phosphorus abatement), and repeated auction periods. Under the target constraint the pricing rule (discriminatory versus uniform), reserve prices (announced and unannounced), and repeated auction periods were tested. An additional feature that was added to the target constraint auction was that participants were permitted different levels of participation determined by different level of wetland restoration. This was included to both better reflect actual producer decision making as well as to give a quantity choice for the target constraint auction.

Under the budget constrained auctions, using uniform payments outperformed discriminatory payments. The revealed bids were closer to the actual underlying costs, re-affirming theory which states that the optimal bid would be equal to costs. It was also found that higher levels of PMOR and POCER occurred under uniform payments. In addition, panel regression analysis identified that there was no significant difference in PRENT between the two pricing mechanisms. Essentially this leads to the conclusion that the higher payments distributed under uniform payments were equal to the rent seeking apparent under discriminatory payments. This is contrary to the seminal work on pricing rules by Cason & Gangadharan (2004, 2005). They found that discriminatory payments were more cost effective based on their measures for cost efficiency. This result influenced the auctions being conducted in Australia.

In comparing the bid ranking rules, each rule (e.g. maximize coverage and maximize phosphorus abatement) was efficient in acquiring the desired outcome (e.g. acres or kg phosphorus). The intent of testing this rule was to establish if procuring wetland acres could act as a reasonable proxy for nutrient abatement. This is important since nutrient abatement is a pressing issue in Manitoba and the actual measure of nutrient abatement is difficult to measure practically speaking. It was found that procuring restored wetland acres was sufficient as a proxy for phosphorus abatement. However, there is still risk of adverse selection, where producers who are cost effective in providing acres do not actually contribute a large portion of phosphorus abatement. In order to remedy this, more research is required in the area of hydrologic modeling related to measure the EG&S potential of wetlands.

Under the target constrained auctions, discriminatory payments outperformed uniform payments overall. While the restored wetland acreage target was achieved more often under uniform pricing, it came at a very large cost. The auctions using uniform payments yielded relatively low cost effectiveness compared to the auctions using discriminatory payments, although when there was no reserve price both payment types did not perform well; 50% below optimal efficiency. When the reserve price was included into the auction, performance improved under both payment types; however the budgetary outlay, and therefore PRENT, was still greater under uniform payments. Unlike in the budget constrained case, we observed that the uniform payment was greater than the rent seeking occurring under discriminatory payments.

This result leaves one to believe that there may be different bidding strategies at play under each of the two constraint types. Further research into this area is required in order to make sound observations in support of this conclusion. However, there may be an issue related to the level of competition that is influencing the performance of each payment type as well.

Both auction types were influenced by participant learning over the course of the 15 periods of the auction session. Based on the regression analysis for the budget constrained auction, there was a threshold at period 5 where afterwards the learning effect was not significantly different from zero. In other words, the first 5 periods were used to understand the auction mechanism and to make assumptions about their expected payoff from a bidding strategy. In the target constrained auction, auction outcomes differed between periods 1 to 3 than periods 1-15, in particular there was a stronger effect associated with time that lessened when considering all 15 periods. Degradation of auction performance was also stronger under discriminatory payments in both constraint types. This leads one to believe that rent seeking may be more prevalent under discriminatory payments, and that participants are satisfied with their payments in uniform pricing. These learning effects associated with repeated auctions have implications in the practical use of auctions. If repeated sign-ups are anticipated for an environmental program, practitioners must be aware that after the first few sign-ups degradation in efficiency is to be expected. Therefore measure should be taken to avoid the negative effects of learning in the auction.

A sound conclusion cannot be made with respect to the best constraint type because of the multiple differences between the two methods. The two constraint types are both subject to the same influences that affect cost efficiency, such as rent seeking and learning. However, rent seeking behaviour is a greater concern in a target based auction simply because there is no budget constraint. While the desired amount of EG&S may be acquired, the cost of doing this could be large. Conversely under a budget based auction the desired amount of EG&S may not be acquired, however what is bought will more likely be cost effective.

Competition is an important factor that influences both auction constraints as well. If there is in adequate competition in either type, cost efficiency will decrease because participants will not have to face tradeoffs in the same way one would if there was high competition. If competition is a concern, a reserve price should be included as a way to induce competition without changing the constraint.

6.1 Limitations and Future Research

While this study has provided interesting results and conclusions related to conservation auction design, there are some limitations to the study. There were limited repetitions – a maximum of 3 for some treatments. More repetitions would be desired in order to be more confident with the results. Also, there was no direct link between the budget and target based auctions. This was not anticipated in the design phase of the target constrained auctions and was only realized after the completion of the sessions.

The established cost of wetland restoration for producers sheds light on an area that has not been investigated in Canada. However, the STC watershed is a very unique area in that there have been almost 100% of the wetlands drained, and the physical characteristics are not representative of the prairie pothole region. Therefore the estimated costs may not accurately reflect the costs for a majority of the region. There were additional issues related to the hydrologic model which may compromise the validity of the EG&S estimates, however, that was not a major concern in this study.

Another concern is that the estimated costs presented in Chapter 3 may not be entirely representative of the actual costs producers would face in restoring wetlands. Based on anecdotal accounts, the method used to estimate nuisance costs may underestimate the actual nuisance cost and therefore indirect costs may actually contribute a larger portion of the cost. Further research would be required to develop a sound method to estimate these costs.

There still remains a great opportunity for research in the area of conservation auctions. Given that these auctions are becoming more popular around the world, this research is required so that the auction mechanism may be used and designed appropriately. In order to have a better understanding of the differences between target and budget constrained auctions, a budget based auction should be conducted incorporating multiple levels of participation. This will also give a more accurate representation of a real world situation.

Research should also be dedicated to establishing a bid function in order to have a better understanding of individual behaviour and how it influences auction outcomes. Latacz-Lohmann & Van der Hamsvoort (1997) have authored one of the only papers estimating a bid function with risk aversion. Having a better understanding of individual bidding behaviour can better the use of auctions as well as improve auction design.

Investigating the incorporation of group payments/bonuses with a target based auction would also be beneficial. In this study, payments were distributed regardless of whether the target was reached or not: it may be argued that this provides a negative incentive to not submit higher volumes of EG&S into the auction. Therefore, a potential amendment would be to only pay winners if the target was reached and correcting for this negative incentive. This would also allow for further investigation into the differences between target and budget based auctions.

6.2 Policy Recommendations

In the event that a decision maker or government chooses to use conservation auctions as a tool to distribute compensation to farmers there are some issues and recommendations that can be drawn as a result of the findings in this present study.

The auctions should be developed and executed in a manner that garners trust between government and farmers in order to encourage participation and subsequently results. This may require more transparency on behalf of the government (i.e. reducing information asymmetry) than may be favoured. This could include divulging more information related to environmental benefits, budget allocation, or communicating consistent rules governing the auction. Therefore, the government may have to be willing to sacrifice cost effectiveness by providing more information in order to increase efficiency.

In this study, students were used to represent farmers in order to test auction design. While their motivation may be the same – to maximize profit – other characteristics may differ based on experience and attachment with the task. If an auction were to be conducted with farmers additional steps should be taken. Extension may be required in order to educate farmers on the auction mechanism and how it will affect them and their operation. Based on the results it was found that participants used the first few periods in the auction were used to learn the auction mechanism as opposed to learning their relative placement in the cost curve. Therefore additional practice may be required in order to prevent mistakes when real money is on the table. Extension may also be required providing tools for farmers to estimate their costs effectively in order to prevent costly mistakes.

The selection of the appropriate pricing rule (e.g. discriminatory and uniform payments) is an integral part of auction design and directly contributes to cost effectiveness. In this present study, conclusions could be made on the optimal pricing method since there was access to the actual underlying cost curve to draw comparisons from. In addition, knowledge of the shape of the underlying cost curve may also influence the effectiveness of the payment rule and one cannot assume that all cost curves for EG&S will have the same shape (e.g. wetland restoration has a large flat (elastic) portion). Therefore, in order to make a sound decision between discriminatory and uniform pricing, some knowledge about costs is required.

A potential alternative for estimating costs of EG&S provision is to use current land values as a proxy for opportunity cost. This may yield a more conservative measure, however it can provide a basis from which to build on.

Based on the results, using a max coverage ranking rule (i.e. wetland acreage) could be an effective proxy rule in achieving other environmental goals such as nutrient abatement. This is beneficial because acreage is much easier to measure, and therefore easier to monitor. However, if other environmental goals are to be addressed in the auction, the relationships and synergies between acres and the objectives should be understood. Ideally the development of an EBI would produce the best results that are specific to the needs of the affected community.

Enforcement and monitoring is a vital part of agri-environmental programming, and therefore should be included while estimating the costs of a program. In the event that participants are aware that enforcement and monitoring is lenient, there would be an incentive to not fulfill their obligations and not complete their task identified under the agreement of being successful in the auction. This will result in a misallocation of funds as well as missed opportunities to provide EG&S.

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Appendix

Table 26 Relative performance of experimental auction outcomes to the expected outcomes for each treatment

Maximize Coverage								
	Discriminatory (N=30)				Uniform (N=45)			
Period	1-5	6-10	11-15	1-15	1-5	6-10	11-15	1-15
Total Acres	103.82	85.77	87.63	92.40	99.20	97.85	96.34	97.80
Total P Abated	96.91	89.93	88.62	91.82	101.89	98.25	98.11	99.42
Budget Spent	91.14	97.06	97.38	95.20	94.68	100.80	97.08	97.52
Actual Cost	109.71	90.95	89.34	96.67	102.42	98.33	97.16	99.31
Seller Profit*	n/a	n/a	n/a	n/a	24.39	123.21	96.33	60.97
$/acre	86.74	111.82	109.80	101.79	95.45	103.02	100.80	99.73
$/kg P	96.39	110.62	112.63	106.26	103.13	113.86	109.81	108.86

Maximize Phosphorus Abated								
	Discriminatory (N=30)				Uniform (N=45)			
Period	1-5	6-10	11-15	1-15	1-5	6-10	11-15	1-15
Total Acres	96.03	90.90	90.59	92.50	112.43	100.44	96.02	102.95
Total P Abated	85.84	80.91	83.14	83.30	99.17	94.82	95.60	96.53
Budget Spent	101.07	103.16	106.78	103.67	93.33	94.87	94.39	94.20
Actual Cost	94.34	85.78	86.41	88.84	112.69	99.44	95.54	102.56
Seller Profit*	n/a	n/a	n/a	n/a	-2.00	72.40	88.69	53.03
$/acre	99.87	107.70	111.85	106.34	96.53	109.83	114.31	106.38
$/kg P	113.33	122.72	123.62	119.80	94.11	100.05	98.72	97.58

*relative seller profit for discriminatory payments could not be determined since it was expected to be 0 if bids were equal to costs (See Table 16)

Table 27 Average auction outcomes for groups of 5 periods (1-5, 6-10, 11-15) and all 15 periods for all treatments and expected outcomes based on "greedy algorithm"

Treatment	Period	Total Acres	Total Phosphorus Abated	Budget Spent	Actual Cost	Seller Profit ($)	$/acre	$/kg Phosphorus abated
MCD	1-5	44.81	273.30	$52,351.60	$63,017.76	-10,666.16	1168.32	191.55
		11.33	*57.23*	*5468.61*	*18525.36*	*14591.88*		

	6-10	37.02 *2.79*	253.60 *44.08*	$55,751.40 *4566.96*	$52,239.17 *4551.81*	3512.23 *3008.21*	1506.06	219.84
	11-15	37.82 *4.41*	249.90 *32.79*	$55,932.40 *4781.92*	$51,314.03 *6328.61*	4618.37 *5079.99*	1478.86	223.82
	Overall	39.88 *7.81*	258.93 *45.41*	$54,678.47 *5065.25*	$55,523.65 *12432.35*	-845.19 *11269.27*	1370.98	211.17
	Expected	43.16	282.00	57437.71	57437.71	0	1346.85	198.73
MCU	1-5	37.36 *3.85*	248.60 *21.35*	$51,958.65 *9144.28*	$50,630.12 *4526.85*	1328.54 *7631.07*	1390.85	209.01
	6-10	36.85 *2.15*	239.73 *11.75*	$55,320.72 *3473.69*	$48,609.41 *2909.35*	6711.31 *1958.65*	1501.21	230.76
	11-15	36.28 *2.87*	239.40 *21.08*	$53,279.01 *4200.54*	$48,031.61 *4309.56*	5247.40 *2234.37*	1468.74	222.55
	Overall	36.83 *3.00*	242.58 *18.68*	$53,519.46 *6165.67*	$49,090.38 *4048.72*	3321.43 *5881.14*	1453.23	220.63
	Expected	37.66	244.00	54880.80	49433.56	5447.23	1457.15	202.67
MPD	1-5	34.08 *6.25*	254.10 *25.61*	$54,072.00 *4924.66*	$50,471.81 *10473.79*	3600.19 *10615.54*	1586.49	212.80
	6-10	32.26 *2.99*	239.50 *15.27*	$55,189.40 *3781.12*	$45,891.53 *3101.32*	9297.87 *2390.29*	1710.82	230.44
	11-15	32.15 *3.24*	246.10 *12.55*	$57,127.80 *3066.34*	$46,229.08 *3046.82*	10,898.72 *1155.98*	1776.75	232.13
	Overall	32.83 *4.35*	246.57 *19.01*	$55,463.07 *4065.74*	$47,530.81 *6663.66*	7932.26 *6878.18*	1689.32	224.94
	Expected	35.49	296.00	53500.46	53500.46	0	1588.54	187.77
MPU	1-5	38.09 *6.78*	279.67 *26.02*	$56,687.16 *5661.85*	$56,892.44 *11628.34*	-205.28 *13599.40*	1488.44	202.70
	6-10	34.03 *4.02*	267.40 *17.28*	$57,623.67 *4687.77*	$50,199.98 *6710.34*	7423.69 *8334.61*	1693.43	215.50

	11-15	32.53	269.60	$57,328.53	$48,234.81	9093.72	1762.52	212.64
		3.01	*20.26*	*5385.08*	*3953.71*	*1937.00*		
	Overall	34.88	272.22	$57,213.12	$51,775.74	5437.38	1640.29	210.17
		5.32	*21.69*	*5155.12*	*8739.06*	*9944.81*		
	Expected	33.88	282.00	60738.90	50485.05	10253.84	1541.92	215.39

Table 28 Farm parameters used in target based auctions

Producer	Level	Acre	Cost
1	1	0.73	1210.171
1	2	0.368	768.052
2	1	10.68	15233.79
2	2	4.04	6173.72
2	3	2.973	4265.506
2	4	1.868	2381.516
3	1	5.375	7429.496
3	2	4.63	6235.911
3	3	2.432	3326.562
3	4	0.398	765.2739
4	1	5.493	8004.148
4	2	2.287	3680.028
4	3	1.633	2646.259
4	4	1.124	1757.943
5	1	1.614	3015.406
5	2	0.58	1317.89
5	3	0.247	767.3473
6	1	4.902	8900.461
6	2	1.522	3237.727
6	3	0.758	1821.814
6	4	0.572	1447.911
7	1	0.21	735.3576
8	1	11.23	15192.8
8	2	4.96	7399.468
8	3	2.754	4465.62
8	4	0.662	1584.652
9	1	2.78	4433.934
9	2	0.573	1321.383
10	1	6.147	9747.978
10	2	1.626	3020.374
10	3	0.987	1923.037
11	1	22.427	38956.29
11	2	12.965	21518.27
11	3	3.799	7161.864
11	4	1.766	3661.104
12	1	10.378	11577.47
12	2	6.504	6463.337
12	3	2.335	2823.779
12	4	1.121	1494.701