Agricultural Producers' Costs of Adoption of Wetland Restoration Beneficial Management Practice: Estimation and Spatial Transferability

by

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Abstract

This thesis estimated agricultural producers' costs of adopting a wetland restoration beneficial management practice (BMP) in the Western Canadian Prairie region using two alternative cost discovery methods. It then explored the spatial transferability of the cost estimates obtained for the two case study sites in Alberta and Saskatchewan. The primary objectives of this thesis were to estimate the costs of adoption of wetland restoration BMP, evaluate if true costs of BMP adoption could be approximated by FC, and assess the accuracy of a spatial cost transfer exercise.

Producer willingness to accept (WTA) for environmental conservation on agricultural land represents the "true" cost of BMPs but, is also unobservable. In this study, producers' WTA for restoring wetlands on their currently active farmland was estimated using stated preference (SP) methods based on the results of an in-person survey of 29 producers with farms located in three rural municipalities in Alberta and one rural municipality in Saskatchewan.

The financial opportunity cost (FC) of wetland restoration was estimated as an alternative measure of the direct cost of BMP adoption for agricultural producers. Farm-level dynamic stochastic cash-flow simulation models were developed for the sampled farms using a combination of farm-specific primary data collected in the survey and secondary data from various sources. Using stochastic crop yields and prices, farm-level FCs of wetland restoration BMP were estimated using Monte Carlo simulation and net present value analysis.

Spatial cost transfer was conducted to address the policy need of obtaining estimates of welfare impact of BMP adoption without conducting a complete direct valuation study. The WTA estimates from the SP auction, FC estimates from the farm-level cash-flow simulation models and salient bids from existing reverse auction studies were used to transfer the estimates of cost of wetland restoration from the designated study site at Alberta to the policy site of Saskatchewan by adapting select benefit transfer methods.

The producers' WTA and the estimated FCs indicated that adoption of wetland restoration BMP imposes net private costs on the producers with significant within- and between-sample heterogeneity in costs. Given the underlying assumptions of the farm-level cash flow models, farm-specific FC estimates were generally lower than the corresponding WTA estimates. Transferring the WTA and FC estimates across sites, using unit cost transfer, simple function transfer and structural function transfer methods, generated errors in the range of 2.74% - 38.01%. Compared to salient reverse auction bids obtained from existing studies in the case study areas, the errors associated with the transferred costs were in the range of 1.43% - 58.39%. Transfer errors were found to be dependent on the transfer method employed, but were lower than the median errors found in the benefit transfer literature. The findings indicated that policy intervention in terms of compensation payments is required to encourage uptake of wetland restoration BMP in Alberta and Saskatchewan. SP auctions and cost transfer could be employed as valid and less expensive cost discovery tools compared to reverse auctions for facilitating wetland policy and design of compensation packages.

Preface

This thesis is an original work by Manikarnika Kanjilal. The research project, of which this thesis is a part, received research ethics approval from the University of Alberta Research Ethics Board, Project Name: "True Cost of Agricultural Beneficial Management Practices - Estimation and Transferability", No. Pro00042694, Date 11/28/2013.

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1 Introduction

1.1 Background

Ecosystem services (ES) are defined by Boyd and Banzhaf (2007) as "... components of nature, directly enjoyed, consumed, or used to yield human well-being" (pp 619, Boyd and Banzhaf, 2007). They noted that final ES are end-products of nature, some of which are marketed (e.g. crops) and thus associated with prices which guide their supply. However, most ES are not marketed. Non-market ES are likely to be under-supplied as their associated benefits (e.g., recreation, flood damage mitigation, species habitat provision, aesthetics) are of a public good nature while the cost of provision may be private. The provision of marketed final ES, such as commercial crop production, often creates a negative externality in terms of under-provision of final ES with non-market values such as wetlands or forests on private land because the public benefits of these non-market ES are not internalized through compensation or some other form of policy intervention.

Beneficial Management Practices (BMPs) are farming practices aimed at reducing the negative impact of agriculture on the surrounding environment and can be thought of as an example of institutional and participatory mechanisms that generate non-market ES. For example, riparian BMPs, in-field BMPs and runoff and discharge BMPs contribute to sustainable agriculture by maintaining/improving soil and water quality. The National Farm Stewardship Program of Canada (2006) defined a BMP as "any agricultural management practice which: mitigates or minimizes negative impacts and risk to the environment, by maintaining or improving soil, water and air quality, and biodiversity; ensures the long-term health and sustainability of land-related resources used for agricultural production; and does not negatively impact the long-term economic viability of producers and others in the agricultural industry"(pp 1, NFSP, 2006). AAFC (2013) indicated that there exist a wide variety of definitions of BMPs as the ecological and agronomic conditions vary from region to region. However, the common theme among the various definitions of BMP is economic sustainability at farm-level and environmental enhancement or protection (Brethour et al., 2007).

Although the definitions of BMPs highlight the importance of simultaneously maintaining long-run economic viability at the farm-level and environmental sustainability, adoption of BMPs often involves direct and indirect costs with uncertain benefits to agricultural producers. Many BMPs impose a net adoption cost on producers (e.g., Jeffrey et al., 2014; Cortus et al., 2011).

Measuring the costs of adoption is a crucial step in the economic evaluation of agricultural BMPs, which will in turn help in evaluation and development of appropriate policy. If producers are guided only by the profit motive based on direct and indirect costs of adopting a particular farming practice then they do not have any incentive to participate unless the BMPs have a direct positive impact on profit, or unless there are specific programs to encourage such participation. These sorts of incentive programs (e.g., Conservation Reserve Program, Environmental Quality Improvement Program, and Conservation Stewardship Program in the United States; Greencover Canada, national and provincial level farm stewardship programs, Environmental Farm Plan Program, Prairie Shelterbelt Program, and Environmental Farm Action Program in Canada; Carbon Farming Initiative in Australia) generally focus on the fact that producers are incurring extra costs to participate in an agricultural production system conducive to environmental conservation and hence need to be compensated for their monetary losses. If intervention in one form or another is needed to induce producers to adopt BMPs, one or more appropriate policy instruments or mechanisms are necessary. Pannell (2008) showed that the relative levels of public and private net benefits should be crucial in the choice of policy mechanism (e.g., positive or negative incentives, or no action) to encourage environmentally beneficial land use change.

A number of approaches are taken in the literature to measure the above-mentioned costs of BMP adoption. One approach is to measure the cost of BMP adoption through estimation of direct costs and benefits for adopting producers, using farm simulation models. An alternative approach involves estimation of producers' willingness to accept[1] (WTA) compensation for BMP adoption using stated preference (SP) methods. Reverse auctions[2] are also used to elicit producers' WTA for BMP adoption.

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[1] Willingness to accept (WTA) is the minimum compensation that an individual must receive to forgo a profit or accept a loss. WTA to forgo an increase in ES is measured by the Hicksian equivalent surplus and that to accept a decrease in the ES is measured by the Hicksian compensating surplus.

[2] A reverse auction is a pricing tool used for environmental conservation. In a reverse auction, multiple private sellers such as agricultural producers or landowners compete to sell an environmental service (such as preservation of habitat and biodiversity through wetland restoration) to a single buyer, typically a governmental or environmental

The literature that deals with estimation of direct costs and benefits of BMPs shows that BMPs often impose net costs on producers (e.g., Cortus, 2011, 2005; Koeckhoven, 2008; Trautman, 2012). This literature typically uses representative farm models that employ dynamic stochastic simulations of farm enterprises. Using Monte Carlo simulation methods to evaluate private costs and benefits for a set of representative cropping farms in Alberta, Canada, Trautman (2012) observed that while positive private net benefits are obtained from a select set of rotational BMPs (i.e., crop rotations that help the natural restoration of soil nutrients), adoption of non-rotational BMPs such as shelter-belts or buffer-strips resulted in a net private cost. In a Spanish study, Fernandez-Santoz et al. (1993) used a simulation and a multi-objective mixed programming model to assess on-farm costs of reducing nitrogen leaching. They noted that BMP adoption may lead to considerable economic losses for the producers. Afari-Sefa et al. (2008) conducted a cost accounting analysis for select structural BMPs (livestock exclusion fencing, off-stream watering and building of stormwater diversion drainage system) in the Thomas Brook Watershed in Nova Scotia, based on farmer records, estimates from technical experts as well as producer estimates of BMP maintenance costs. As a part of the Watershed Evaluation of Best Management Practices (WEBs) Project, the study estimates the annualized cost per meter of fencing and drainage systems based on data for construction and maintenance costs as well as the opportunity costs of farmer time and land taken out of production. Afari-Sefa et al. (2008) however, did not comment on how the BMP adoption affects the economic performance of the farm.

Another body of literature examines the issue of eliciting producers' or landowners' WTA for environmental conservation on agricultural land or BMP adoption using various SP methods. In theory, WTA represents the measure of true costs associated with any proposed change resulting from some environmental policy - in this case land use change through BMP adoption. Amigues et al. (2002) estimated producer WTA for preserving a riparian buffer to be as low as zero. Yu and Belcher (2011) found that while WTA estimates follow a similar distribution to land rental rates, WTA is sometimes less than the net returns to current agricultural production even though it is positive. This suggests that for some producers, benefits from environmental conservation may outweigh costs. Yu and Belcher (2011) noted that a higher perception of

agency. The sellers submit bids for the proposed projects and the winning bids are selected for actual wetland restoration such that the environmental goal of the program could be achieved (Hill et al. 2011).

benefit of conservation program is associated with a higher rate of participation and/or lower WTA. Norton et al. (1994) indicated that whether WTA is less than the loss in profit depends on whether producers benefit from the pollution-reducing management practice. Demand-related factors such as certification and labeling of sustainable agricultural produce, presence of organic niche markets, producers' participation in organizations, and producers' education and awareness may also indicate whether producers perceive a net gain or loss from BMP adoption (Wollni et al., 2010). Measurement approach and treatment of risk are other factors that affect the WTA estimates.

Hill et al. (2011) elicit positive WTAs in a reverse auction for wetland restoration in the Assiniboine River Watershed (ARW) of Saskatchewan, Canada. While the true costs of adopting BMPs may be positive, Ipe and Devuyst (1999) compared the simulated expected payment for a group incentive program with the WTA obtained from subjective expected utility of profit. They concluded that producers' subjective beliefs about the profit response following the potential BMP adoption may be incorrect, causing their WTAs to be higher than the simulated payments.

The study findings regarding producer WTA for BMP adoption raise a few issues, particularly in the context of the quest for an optimal policy as outlined by Pannell (2008). The first involves exploring the "true" welfare impact of BMP adoption. Evaluation of the welfare change that accrues to the producers through BMP adoption would involve exploring their WTA. The existing literature suggests that for adoption of a given BMP there may be a distinction between the associated financial opportunity costs (referred to henceforth as financial costs or FCs), (e.g. as estimated in Trautman ,2012; Cortus, 2005; and Koeckhoven, 2008) and the WTA. WTA would be lower if producers perceive a benefit from the environmental improvements. If producer expectations of future prices and costs is higher than the price and cost assumptions used in the FC estimation approach, their WTA would be higher. Producer uncertainty or unfamiliarity with the BMP and transaction costs associated with BMP adoption may further increase the WTA. The estimates of FCs themselves may be inaccurate or may differ from the WTA as they may not completely capture farm-level heterogeneity (e.g., time preference; land attributes such as soil productivity; management decisions such as fertilizer application rates and farm machinery replacement rates, etc.) and especially the heterogeneity in producer preferences.

FCs provide a baseline estimate of costs net of direct, tangible benefits of BMP adoption such as potential productivity improvements without accounting for producers' preference, and assuming minimal calculation error. The “true” cost reflects adjustments attributable to additional intangible potential benefits (or costs) of the BMP that accrue to the producers as well as other factors such as risk, expectations and heterogeneity. The potential for using FC estimates for designing incentive schemes for BMP adoption can be determined only when the divergence between FC and WTA for adopting BMPs is investigated. The current rate of uptake of agricultural BMPs in Canada is fairly low even with the provision of monetary incentives in the form of flat-rate payments or cost-share schemes. The existing monetary incentives are also determined on an ad hoc basis. The cost discovery would help with the selection of optimal policy instrument (Pannell, 2008). Accurate discovery of true costs would help policy makers decide if an incentive program for BMP adoption is warranted or cost-effective from the policy makers’ point of view. It would also help evaluate if existing incentive schemes are indeed attractive to the producers in terms of providing adequate compensation.

1.2 Economic Problem

Vercammen (2011) noted that there is an extensive literature, based on case studies from North America, Europe and Asia, that focuses on the various aspects of the economic decisions and impacts regarding adoption of conservation agricultural policies in the US and Europe. However, very limited information is available in the Canadian context regarding agricultural producers’ WTA associated with ES produced through agricultural BMPs. This means that little is known about the Canadian agricultural producers’ WTA for adoption of a specific BMP, or whether there is a difference between their financial costs and the WTA. While there are some Canadian studies using representative farm models to estimate FC, representative farm analyses may not be able to completely capture the farm-level heterogeneity in the economics of BMP adoption.

The available Canadian empirical studies (Vercammen, 2011) deal with a limited number of sites. However, having the estimates of benefits and costs of BMPs for a larger number of sites is desirable for policy purposes, as any policy instrument would have a broader scope in terms of its effects. Since valuation studies are costly in terms of resources and time, it may not be possible to evaluate the welfare impact of BMPs across a wide number of sites. Transferability of the welfare impacts of BMPs across sites potentially addresses this issue.

Benefit transfer (BT) is commonly used as a tool to transfer estimated benefit values from original valuation studies to a new application or policy context. Thus, BT methodology addresses the issue of transferability of the benefit estimates such as WTP[3]. A review of the BT literature reveals that there is a considerable amount of research dedicated to exploring methodological issues, challenges and applications of benefit transfer as well as its accuracy (e.g., Johnston et al., 2015; Boyle et al., 2010; Johnston and Rosenberger, 2010; Rosenberger and Stanley, 2006). However, on the cost side, the transferability issue is virtually unexplored even though the estimation and transferability of true costs is a significant issue as it has the potential to create the basis for effective policy formulation and implementation.

In summary, it is important to be able to quantify the true costs of agricultural BMPs available to Canadian producers so that existing policies could be evaluated and new, cost-effective policies could be designed to encourage adoption of these BMPs. However, existing direct valuation studies that explore this issue are limited in number, and also, in terms of scope. They are also resource and time intensive. Obtaining these costs from specific case-studies (study sites), and transferring them spatially across different policy sites for select BMPs would lead to informed and efficient policy-making with a greater applicability.

1.3 Research Problem

The general objective of this thesis was to explore and analyze the costs of BMP adoption by agricultural producers in the Western Canadian Prairie region. The wetland restoration BMP was chosen as the BMP of interest in this study. The thesis investigated whether the true costs of adoption of wetland restoration BMP could be approximated by farm-level financial analysis and whether cost estimates were spatially transferable.

In doing so, this study addressed the following research questions:

- What is the welfare impact of adoption of wetland restoration BMP on agricultural producers in the Western Canadian Prairie region?
- What is the financial opportunity cost of wetland restoration?

[3] Willingness to pay (WTP) is the maximum amount that an individual must pay to secure an increase in environmental goods and services.

- Do FCs of wetland restoration by these producers adequately reflect the associated welfare impact as measured by WTA? What is the deviation between the FCs and the WTA, and what is the nature of the relationship of these two estimates of cost of BMP adoption?
- Can estimated FC or WTA be accurately transferred across space? What are the errors associated with such a spatial transfer?

In the current study, farm-level in-person surveys were conducted to gather information on farm operations and producers' preferences in two different but comparable sites in Alberta and Saskatchewan provinces of Canada. To investigate the potential divergence between the producer FCs and WTAs associated with adoption of BMPs, the study estimated or elicited both of these values for a sample of agricultural producers located in the Black soil region of Central Alberta and Southeastern Saskatchewan.

Producer WTA for adoption of wetland restoration BMP was elicited using SP methods, using a polychotomous design with uncertain response options. This allowed the study to collect more data than would be available in a traditional dichotomous choice contingent valuation study. The issue was framed in a realistic manner that would be familiar to the producers at the study areas. The valuation questions were framed like an auction with incentive-compatible features. To account for the hypothetical bias issue often inherent in SP studies, a cheap talk script was employed. The analysis also accounted for social desirability bias in responses; that is, controlling for producer's desire to provide a morally acceptable response even if it does not reflect their true WTA. This was done by incorporating an inferred valuation method. The study makes an empirical contribution by estimating agricultural producer WTA for wetland restoration BMP using two case study sites in Western Canada. Additionally, it generates the required data for the proposed cost transfer by estimating the cost of BMP adoption at two spatially different but geographically similar sites such that the relevant pre-conditions for a transfer exercise could be met, at least partially.

In contrast to the WTA elicitation methods that take into account producer's preference heterogeneity driven largely by unobservable factors, estimation of financial cost was undertaken based on farm-level data for observable characteristics. It was noted that as farms in a particular study area vary significantly in terms of the farm characteristics such as farm size, type of enterprise, productivity and management decisions, a representative farm model of financial cost estimation may not fully capture the farm-level heterogeneity in cost. In other words, the estimated financial cost for a representative farm would not be comparable to the farm-level distribution of WTAs. To account for this, farm-specific data collected in the survey was utilized to develop a dynamic stochastic simulation model of farm cash flow using capital budgeting techniques. The estimated distributions and central tendencies of WTA and FCs were used to determine if the estimation of financial cost is sufficient for an analysis of the true welfare impact of BMPs. The current study contributes to the literature dealing with the economics of agricultural BMPs by incorporating the farm-specific data in the stochastic simulation models of cash flow and, thus, accounting for the farm-level heterogeneity in FC directly.

The evaluation of the economic costs of BMP adoption or producers' WTA is location-specific (Mackay and Hewitt, 2006; Koroluk et al., 2005), and the detailed estimation of the true costs of BMPs in multiple sites would be difficult and resource-intensive. A cost transfer analysis involves taking estimated costs from original studies or a "study site" and applying them to a new "policy site" that corresponds to a new policy objective given that these sites satisfy certain conditions of similarity to justify and validate such a transfer. A cost transfer study would evaluate costs of a particular environmental policy based on pre-existing valuation data applied to a different policy context and may be viewed as an alternative to direct valuation studies. The literature review, however, indicates that this has been a relatively unexplored area and the entire transfer literature is about BT (e.g., Johnston et al. 2015; Boyle et al., 2010; Stapler and Johnston, 2009; Johnston, 2007; Johnston and Duke, 2007; Pattanayak et al., 2006; Hanley et al., 2006; Ready and Navrud, 2005; Smith et al., 2002; Morrison et al., 2002; Morey et al., 2002). The final objective of this research was to apply various BT methodologies to spatially transfer costs associated with BMP adoption.

Cost transfer was conducted by adapting suitable transfer methodologies (unit cost transfer, simple function transfer, structural transfer and distribution transfer) to transfer the central tendencies and distributions of estimated WTAs and FCs from the direct valuation components of the study across the two case study sites. The error in transfer was measured by comparing the estimated cost from the direct valuation components of the study with the "calibrated" or "transferred" cost. The case study site in Alberta was designated as the "study site" and the case study site in Saskatchewan was designated as the "policy site" so that errors in transfer could be measured not only with respect to the cost estimates for Saskatchewan obtained in this study, but also the existing reverse auction data from Hill et al. (2011). Transferability of the estimated values that reflect the costs and benefits of an environmental policy has been identified as a major theoretical and empirical challenge. As one of the first studies to deal with this issue, the exploration of cost-transferability helps address the site-specific nature of the direct valuation studies and provides an alternative cost discovery method.

Estimation of distribution of WTA, therefore, makes an empirical contribution by using SP methods as a cost discovery mechanism. Estimation of the distribution of farm-specific FCs sets this study apart from similar representative-farm analyses by explicitly accounting for farm-level heterogeneity. The cost transfer exercise is one of the first in the literature and provides a valid alternative to direct valuation studies.

1.4 Organization of the Thesis

The WTA elicitation is discussed in Chapter 2. The estimation of the distribution of farm-level FC and the comparison with distribution of farm-level WTA is discussed in Chapter 3. The cost transfer analysis is discussed in the Chapter 4. The last and concluding chapter in the thesis summarizes the key findings and discusses the potential for these findings to inform wetland policy in Alberta and Saskatchewan. It also highlights the limitations of the study and the scope for future research in this area.

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2 Estimation of Agricultural Producers' WTA for Adopting Wetland Restoration BMP in Alberta and Saskatchewan

2.1 Introduction

Measuring the costs of adopting agricultural Beneficial Management Practices (BMPs) is a crucial step in the economic evaluation of the BMPs which will in turn help in evaluation and development of appropriate policy. This chapter investigates the cost of adoption of wetland restoration BMPs by agricultural producers in the Black soil regions of Central Alberta and South-eastern Saskatchewan using Stated Preference (SP) methods.

The policy instruments traditionally used in these areas to induce voluntary wetland restoration by producers and landowners can be characterized as flat-rate or cost-share policies. In Alberta, compensation for landowners for wetland restoration is available on a 70% cost-share basis with a maximum funding of $50,000, through On-Farm Stewardship Programs under Growing Forward 2 (AARD, 2015). In Saskatchewan, the Lower Souris Watershed Committee provides producers in the area with an incentive in the form of a one-time payment of $2000 per acre for every acre of re-established slough under the Saskatchewan Wetland Restoration Program and the National Wetland Conservation Fund (LSW, 2015). The Committee also offers to build and install the drainage plugs. An additional one-time incentive program of up to $2000 per acre for wetland restoration is available to producers that live in the Pipestone Creek Watershed, a sub-watershed of Lower Souris Watershed area that contains the study site of this study, under the Pipestone Phosphorous Reduction Program.

Agricultural producers are heterogeneous agents in terms of their preferences, risk perceptions and farm specifications, such as soil productivity, enterprise mix, crop rotation, existing number of wetlands on their land, etc. These factors influence their private cost of supplying environmental services (ES) through adoption of BMPs. In presence of heterogeneity in the cost of providing ES, a flat rate policy would tend to over-compensate some low-cost suppliers and fail to encourage participation among comparatively high-cost suppliers of ES. It would also not be cost-effective from the policy makers' perspective. In order to achieve efficiency and cost-effectiveness of the policy to incentivise producers to adopt wetland restoration programs, the heterogeneity in the cost of service provision needs to be recognized. It is an efficient strategy from the policy makers' perspective to identify the low-cost suppliers of the wetland service. It also helps in identifying the "true cost" of wetland restoration and determining the optimal investment required for wetland conservation.

Conservation auctions attempt to address this issue through a process where multiple sellers submit bids indicating the amount of compensation they are willing to accept for providing an ES. In a typical conservation auction, bids are ranked in terms of the compensation amount and environmental benefit index (e.g., Hill et al., 2011) to identify the low-cost winners, given the budget of the program and/or the environmental target. While the design, empirical application and effectiveness of conservation auctions are widely explored in the literature (e.g., Iho et al., 2014; Kits et al., 2014; Schilizzi and Latacz-Lohmann, 2012), the application of conservation auctions in estimating cost of wetland restoration in Canada is fairly limited. Relevant conservation auctions in Canada have been conducted by Hill et al. (2011) in the Assiniboine river watershed in Saskatchewan, Boxall et al. (2009) in South Tobacco Creek in Manitoba and the conservation incentive program of East Interlake Conservation District in Manitoba (Noga and Adamowicz, 2014; EICD, 2015)

SP methods provide a cost-effective method of agricultural producer preference elicitation and can be used to transfer cost estimates. This study used SP auctions as an alternative approach to identify the central tendencies of and the heterogeneity in the cost of adoption for a wetland restoration BMP. The average welfare impact of BMP adoption was quantified by eliciting agricultural producers' willingness to accept (WTA). The heterogeneity in the cost of ES provision through wetland restoration was quantified by the distributions of WTA obtained for the two samples from the case study sites in the Black soil regions of Central Alberta and Southeastern Saskatchewan. The elicited distributions of WTA from two case study sites in Western Canada address the issue of limited availability of empirical findings in the valuation literature regarding agricultural producers' preference for compensation. Finally, producers' WTAs discovered by this study were used to conduct and validate a cost transfer across the two case study sites.

2.2 Literature Review

The literature on the estimation of WTA for provision of environmental services and land use change using various SP techniques is of interest to this study. The non-market valuation literature reveals that in general there are fewer studies attempting to estimate WTA compared to the number of studies devoted to the estimation of WTP. While a growing number of these SP studies have employed choice experiments (CE) to explore WTA estimation in the context of conservation agriculture and PES, there are a limited number of studies that used the contingent valuation method (CVM). This is also observed by Whittington and Pagiola (2011), in their review of contingent valuation (CV) approach to the design of the payments for ecosystem services (PES).

Even within this limited literature, a number of studies have attempted to understand and explain U.S. landowners' willingness to participate in the Conservation Reserve Program (CRP) or Conservation Reserve Enhancement Program (CREP) using a contingent valuation framework (e.g., Lohr and Park, 1995; Cooper and Osborn, 1998; Kingsbury and Boggess, 1999; and Vanslembrouck et al., 2002). In the context of landowners' adoption of conservation practices under the CREP, Lynch et al. (2002) studied agricultural landowners' WTA for riparian buffer provision in Maryland using a SP phone survey. The study analyzed the likelihood of installing buffer strips by the landowners and the effect of prior knowledge about buffers and previous participation in government programs on their WTA. Amigues et al. (2002) evaluated the benefits and costs of preserving a riparian buffer 10–50 m wide in a natural state by estimating the WTP and the WTA of farm households in a contingent valuation (CV) study based in south-central France. The stated willingness to accept (WTA) of landowners was found to be consistent with revenues generated by crop production on their land. The study observed large percentages of participants reporting a minimum WTA of zero.

Dupraz et al. (2003) investigated the farm-level supply of environmental services provided by the agri-environmental measures (AEM) scheme in the EU using a household production model of farms. The AEMs in the Walloon region in Belgium are winter crop cover, late mown meadows, hedge-row maintenance, low cattle density and grassland field hedges. The farms are paid by local or national authorities that specify the expected environmental services of each AEM and pay the farmers who choose to supply these services as per a contract. Dupraz et al.

(2003) used surveys of both participants and non-participants and conducted a double *ex post* and *ex ante* analysis of the decision to participate. They showed that the WTA for flexible supply of environmental services is higher than the lump sum WTA for fixed levels of consumption.

Dupraz et al. (2003) studied the participation decision by formalizing the adoption probability and used a Probit model to regress participation decision on the level of the fixed factors and the socio-economic characteristics of the farmer including environmental beliefs. The actual and revealed participation were compared using contingent scenarios. It was observed that the significance of the explanatory variables varies depending on whether the model is analyzing actual or revealed participation behaviour. Variables such as tax index (proxy for higher production potential) and livestock density, which imply higher loss of profit from participation, reduced actual participation probability but were not as significant in the contingent scenario because that involves compensation thereby negating the prospect of loss. In their opinion, the comparison of actual and revealed participation behaviour controlled for the hypothetical bias.

Shaikh et al. (2007) found that the WTA compensation required for landowners to plant trees on agricultural land in Western Canada is less than the net returns to current agricultural production because landowners receive non-market benefits from growing trees. These benefits might come from potential reductions in risk from assured annual payments, environmental spillover benefits from forests that may enhance sustainable agricultural production and/or aesthetic benefits.

Using CV methods Bateman et al. (1996) investigated farmers' WTA and households' WTP for establishing woodland. The study investigated whether the compensation demanded by the farmers could be justified by the value of the benefit generated from the program. In 19 farm interviews, farmers were asked how much they would be willing to accept per year per acre for establishing woodland on their land. They were also asked how many acres they would like to allocate to woodland. The study also solicited farmers' profit per acre before asking the WTA question and reported the farmer-reported average profit and WTA per acre as a comparison. Average profit per acre was less than WTA for all but one farmer. They reported that stated compensation levels had a significant positive correlation with average profit per acre.

Yu and Belcher (2011) estimated the compensation required for private landowners to conserve wetland and riparian zones in the Prairie Pothole Region of Saskatchewan. The study evaluated how farm characteristics and landowner attitudes impact on conservation decisions.

The study was based in two different areas with distinct landscapes and used a mail-in survey with questions regarding farm characteristics, perceptions of wetland conservation, WTA questions and demographic questions. The WTA question was a closed-ended format such that the respondent would indicate whether they would accept or reject a specific annual bid payment for adopting a conservation practice such as vegetated riparian zone. Given a large percentage of non-response to the WTA question, the study estimated two models – a binary Probit model treating the non-response as a missing value and considering the yes/no answers only and a multinomial Probit model that takes the non-response into account – so that the two models could be compared to explain the non-response behaviour. It is observed that, in general, the WTA estimates follow similar distributions as the land rental rates implying that the owners consider the opportunity cost of the land while taking conservation decisions. The magnitude of the offered payment and the probability of adoption of the conservation program were found to be positively related. WTA non-response was explained by owners' uncertainty as to farming status in future and unfamiliarity.

Yu and Belcher (2011) showed that the connection of farm as a household reaping the benefits of conservation is strong in the sense that the farmers perceiving that benefits are higher are more willing to adopt conservation programs and/or have lower WTA. The study also highlighted that farmers' past experience with wetland management positively affects conservation decisions among other variables. However, the study did not directly consider risk or time preference heterogeneity of the owners unless it is assumed that age is a sufficient proxy for these aspects of decision making. Even in that case, age was not found to be significant in the analysis.

Southgate et al. (2009) investigated the linkage between WTA of the households for conservation under PES schemes and their livelihood strategies, and highlighted the importance of risk. They conducted a CV analysis of PES in Ecuador and Guatemala. It is noted that PES may reduce the variability in income for subsistence farmers but may not be as attractive to households that have diversified sources of income. This observation may not be relevant to farm households in developed countries that do not use the conservation payments as a livelihood option. However, land tenure and flexibility of operating and transaction costs often seem to be relevant for farmers' decision for adopting land use change.

Lindhjem and Mitani (2012) estimated WTAs for Norwegian non-industrial private forest owners for voluntary conservation, using a CV approach. They elicited WTA as a lump sum of both a non-market welfare measure and foregone timber income. They noted the difficulty faced by forest owners in coming up with a WTA amount and also the low significance of many of the explanatory variables (also noted by Bateman et al., 1996). Using a conceptual supply curve based on the expected cumulative amounts of forest area that would be offered for conservation based on increasingly higher compensation amounts, they noted that a “price discrimination strategy” or sensible targeting on the part of the government might be more cost-effective to achieve the conservation goals depending on whether the biologically valuable features of the forest are homogeneously distributed. They showed that WTA increased with the size of the forest as well as with higher productivity of the forest. They recommended that targeting the smaller forest owners first may be efficient if the forests are homogeneous in terms of the biological properties.

Zhen et al. (2014) used a CV survey to estimate herders’ WTA to control grazing for restoration of grassland ecosystem in Inner Mongolia, China. They analyzed the impact of a top-down PES scheme on the livelihood of herders and evaluated their preference for the aspects of the PES scheme such as payment type and mean amount by eliciting WTA estimates. In a mandatory participation regime that does not satisfy the voluntary participation criteria of a PES scheme, Zhen et al. (2014) explored whether compensation was sufficient and whether the government could improve the compensation package to mitigate potential loss in livelihood. Using both household survey information from a single-bounded dichotomous choice CVM as well as secondary data they estimated the WTA of the herders. Herders’ WTA was almost 132% higher than the amount they currently receive, thus indicating a loss in income even though the program limiting the amount of grazing land seems to have increased or encouraged off-farm income for some herders.

Another branch of SP literature regarding the estimation of WTA for environmental services studies employs choice experiments or conjoint analysis. Porras and Hope (2005) used a conjoint analysis to study the adoption of PES for regulation of water flow by upland farmers in the Arenal watershed in Costa Rica. They reported a strong preference among the respondents for the status quo regarding land usage. High transaction cost has been cited as one major barrier to participation.

Horne (2006) investigated Finnish forest owners' WTA and preference for contract terms for forest conservation using a choice experiment approach. Horne (2006) noted that forest owners are heterogeneous in terms of their preference for compensation for conservation contracts and this is supported by the study findings. They may value conservation and internalize this in their own objective function or the compensation may act as an alternative to potential harvesting revenue. It was observed that forest owners preferred a bottom-up approach to conservation, less restrictive management plans, shorter contract length, and flexibility in the decision to opt out of the program. About one third of the respondents chose the status quo. Horne (2006) estimated two mixed logit models including and excluding (respectively) the Nay-sayers and observed that the welfare impact changed from -224€ /hectare/year for the base case (including Nay-sayers) to +62€/hectare/year for the sample excluding Nay-sayers. The welfare impact was observed to be greatly dependent on contract terms and to decline dramatically as the contract got more restrictive.

On a similar note, Ruto and Garrod (2009) investigated how the design of agri-environmental schemes (AES) could influence farmers' participation in these programs across the EU. Using choice experiment survey data obtained from farmers spread over ten case study sites, they showed that longer contracts, complex paperwork and less flexibility entail higher levels of financial incentives for participation in AES. Using a latent class model they also showed that farmers can be classified into segments indicating their different degrees of resistance for adoption of the AES.

Espinosa-Goded et al. (2010) also took a choice experiment approach to explore Spanish farmers' ex-ante preference and estimated their WTA for AES designs. The chosen AES scheme is the cultivation of alfalfa which is a nitrogen-fixing crop. The study was conducted using data from two different case study sites and preference heterogeneity between regions and within region was analyzed. The study reported evidence of significant variation in preference between regions as well as farmers and also the evidence of status quo bias. The preference heterogeneity was reflected in significant difference in WTA estimates as well as attribute ranking. Within a region, the main source of heterogeneity was pointed out to be the previous experience of AES schemes and compensation amounts.

Kaczan (2011) used a choice experiment to quantify farmers' preference for a PES program designed to reduce on-farm deforestation in Usambara, Tanzania. Kaczan (2011) observed that co-investment in a farm input, such as manure fertilizer, elicited high interest for participation. Preference for individual payments as opposed to group payments, high level of accountability and static payment rate was observed. There was evidence of significant preference heterogeneity. Kaczan (2011) also tested for social desirability bias by comparing the CVM results with a set of inferred valuation results obtained following Lusk and Norwood (2009).

Trenholm et al. (2013) used a choice experiment to understand both farm and non-farmer landowners' preference for wetland restoration in the Credit River watershed, Canada. They found that farmers would require an average compensation of $655.57/acre/year to restore wetlands on their productive land and $171.86/acre/year for their marginal land. They also noted that non-farmer landowners could be divided into two distinct groups regarding their attitude towards the wetland conservation program. Approximately one-third of the non-farmer landowners indicated that they would accept $199-$434 per year to convert their land into wetlands. The second group of non-farmer landowners that were more likely to be better-educated than the first group and identified to have less financial motivation indicated that they would not need any compensation for the wetland conservation programs in their land.

The literature review leads to the following observations. A myriad of preference elicitation survey frameworks are used. Most of the studies focused on estimation of WTA along with exploring the effects of various covariates deemed relevant for the ecosystem service provision problem at hand. The commonly used covariates in these studies are prior knowledge and participation in conservation programs (e.g., Lynch et al., 2002; Yu and Belcher, 2011); stewardship behaviour among the farmers (e.g., Amigues et al., 2002); flexible vs. fixed payment (e.g., Dupraz et al., 2003); farm production potential and size of holdings (e.g., Dupraz et al., 2003; Lindhjem and Mitani, 2012), income risk reduction (e.g., Shaikh et al., 2007; Southgate et al., 2009), preference for status quo, transaction cost and flexibility (e.g., Horne, 2006; Ruto and Garrod, 2009; Porras and Hope, 2005). Only a handful of studies compared estimated WTA with revenue from current production activities (e.g., Amigues et al., 2002; Shaikh et al., 2007) and with land rental rates (e.g., Yu and Belcher, 2011). Kaczan (2011) and Dupraz et al. (2003) discussed the issue of incentive compatibility and inherent biases in the SP models. While Dupraz et al. (2003) claimed that similarity of the contingent conservation scenario with the existing conservation programs kept hypothetical bias in responses to a minimum, Kaczan

(2011) used a cheap talk script and inferred valuation method to control for the hypothetical and social desirability biases. Also a very small number of studies discussed or explored the issue of heterogeneity of WTA across farmers and the implications for policy (e.g., Ruto and Garrod, 2009; Horne, 2006; Lindhjem and Mitani, 2012; Espinosa-Goded et al., 2010; and Kaczan, 2011).

2.3 Conceptual Framework

The random utility model(RUM) forms the basis for the conceptual framework of most studies focusing on producer or landowner WTA for environmental conservation. Assuming the producer is maximizing utility, the indirect utility for producer *i* is given by $V(\Pi_i, X_i, \varepsilon_i)$ where Π_i is the profit of the farm-household, X_i is the vector of individual characteristics and ε_i is the error term. A producer would participate in a wetland restoration BMP if the utility from participation and the compensation is greater than the utility from the status quo.

$V_1(\Pi_{i1} + Bid, X_i, \varepsilon_{i1}) > V_0(\Pi_{i0}, X_i, \varepsilon_{i0})$ where 1 = participation in BMP, 0 = status quo and *Bid* refers to the compensation amount. The probability of producer *i* accepting a bid amount as compensation for participation in a restoration program is given by:

$$Prob\ (Yes_i) = Prob[V_{1i}(\Pi_{i1} + Bid, X_i, \varepsilon_{i1}) > V_{0i}(\Pi_{i0}, X_i, \varepsilon_{i0})] \qquad \text{2-1}$$

It is assumed that utility is additively separable in deterministic and stochastic preference components. Then,

$$\begin{aligned} Prob\ (Yes_i) &= Prob[v_{1i}(\Pi_{i1} + Bid, X_i) + \varepsilon_{i1} > v_{0i}(\Pi_{i0}, X_i) + \varepsilon_{i0}] \\ &= Prob[v_{1i}(\Pi_{i1} + Bid, X_i) - v_{0i}(\Pi_{i0}, X_i) > \varepsilon_{i0} - \varepsilon_{i1}] \end{aligned} \qquad \text{2-2}$$

If the random term is specified as $\varepsilon_{i1} - \varepsilon_{i0} = \varepsilon_i$, then

$$Prob\ (Yes_i) = Prob[v_{1i}(\Pi_{i1} + Bid, X_i) - v_{0i}(\Pi_{i0}, X_i) + \varepsilon_i > 0] \qquad \text{2-3}$$

Assuming the deterministic component of utility to be linear in profit and covariates,

$$v_{ji} = \beta_j X_i + \gamma_j (\Pi_i) \qquad \text{2-4}$$

Therefore, assuming that the marginal utility of income stays constant across states and farm income does not change across states (Haab and McConnell, 2002)

$$v_{1i} - v_{0i} = (\beta_1 - \beta_0)X_i + \gamma_1 \cdot Bid \qquad 2\text{-}5$$

This implies,

$$\begin{aligned}\text{Prob}(Yes_i) &= \text{Prob}[(\beta_1 - \beta_0) \cdot X_i + \gamma \cdot Bid + \varepsilon_i > 0] \\ &= \text{Prob}[\beta \cdot X_i + \gamma \cdot Bid + \varepsilon_i > 0]\end{aligned} \qquad 2\text{-}6$$

where $\beta = (\beta_1 - \beta_0)$. Given data on producers' acceptance of compensation, farm characteristics and producer attributes, the above model could be solved to determine the welfare impact of BMP adoption.

2.4 Empirical Methods

The conceptual estimation of the cost of change in land use from active agricultural use to restoring previously drained wetlands has been examined in this chapter using SP methods. The proposed program is similar to a Payment for Environmental Services (PES) program since the objective is to determine the minimum compensation that sellers of the environmental service, in this case agricultural producers, would be willing to accept for providing the service; that is, for restoring wetlands in their active farmland. A producer survey framed as a SP auction is used to obtain the primary data for the analyses.

2.4.1 Elicitation Technique and Survey Design

The valuation literature shows that a spectrum of elicitation formats are used ranging from discrete binary choice, sequence of binary choice, one-shot multinomial choice to sequence of multinomial choice or choice experiment format. Carson and Groves (2007) discussed the various elicitation formats in terms of their incentive and informational properties and noted that these properties depend on various factors such as the particular type of the good being valued and valuation context. In particular, it is often up to the analyst to decide the suitability of a particular format given the trade-off between various methods and the contextual nature of the valuation problems.

The advantages and challenges of the available SP survey formats are generally discussed in relation to WTP studies in the literature or in the context of a WTA-WTP gap. Boyle and Bishop (1988) compared CVM techniques such as dichotomous choice, iterative bidding and payment cards method to show that each method has its strengths and weaknesses. A single dichotomous choice format presents a "take it or leave it" choice at the offered price to the respondent (e.g. Bishop and Heberlein, 1979). While it is incentive-compatible in many contexts, the preference information contained in the responses to a single dichotomous choice (DC) survey is the most relevant for public goods. It is worth noting, however, that while DC is the best approach in case of public goods it may not be so in a private good context. The amount of preference information collected in a DC survey is rather limited. Also, the issues associated with the use of DC are relatively less explored in a WTA context. Generalization and extensions of the single DC format focus on gathering more information about preferences and improving the statistical efficiency of value estimates (e.g. Hanemann et al., 1991; Welsh and Poe, 1998). Shrestha and Alavalapati (2005) used a DC CVM to estimate cattle ranchers' WTA for silvopasture practices.

The commonly used extensions of the dichotomous choice format include multiple price lists (MPL), iterative bidding (IB) and payment cards (PC). In the MPL format, the respondent is presented with an array of ordered prices in a table with one price per row. Each respondent is asked to indicate "yes" or "no" for each price (Holt and Laury, 2002; Anderson et al., 2006). Iterative bidding in a WTA framework starts with the respondent being offered an initial bid. If the respondent is willing to accept the initial bid, the bid is revised downward incrementally until a negative WTA response is obtained. Iterative bidding is based on continuous responses and allows a convergence towards the elicited value through iterations. The payment card method is a technique introduced by Mitchell and Carson (1981, 1984) to address the starting point bias of iterative bidding. This method is data-intensive to design and often suitable for in-person surveys.

The WTA studies using these formats are extremely limited although they are very often used in WTP elicitation. The MPL method can be disadvantageous in that it is complex, elicits interval responses and not 'point' valuations, there may be framing effects and the respondent can switch back and forth from row to row, thus demonstrating inconsistent preferences. While the auction-like nature of IB makes it an attractive tool for value elicitation in a WTA framework, it suffers from starting point bias (Boyle, Bishop and Welsh, 1985). The payment card method can suffer from interviewer effects and the effect of the anchor values is uncertain.

The above discussion shows that all SP value elicitation methods have advantages and disadvantages as evidenced in the literature. The choice of appropriate methodology depends on the objectives of the study as well as practicability of survey design and administration. In the context of the present study the main objective is to achieve the best approximation of the true cost of BMP adoption by inducing producers to reveal their WTA. As the current study is interested in the elicitation of compensation and not in evaluating particular attributes of the wetland restoration program, a choice experiment format was deemed unnecessary. A CVM study with a simple dichotomous choice format would gather minimal information about farmer preference for BMPs. Since auctions (e.g., uniform pricing format using first or second price as determinant of price) can be incentive-compatible, it was deemed useful to consider combining features of different SP techniques to design a survey instrument framed like an auction that would be efficient in eliciting preference in an acceptably incentive-compatible manner.

2.4.2 Mitigating Biases

A major concern with SP studies is that there is potential for responses that are not incentive-compatible since the respondents face no real consequence of their stated actions or choices. This may lead to them answer the SP questions strategically to skew the results or without paying much attention to the trade-off or problem posed by a SP question. This issue may manifest as hypothetical bias or social desirability bias. Hypothetical bias can take the form of real WTP being less than what the respondents said they would be willing to pay for a good, or a discrepancy between their real WTA and stated WTA. Social desirability bias is observed when a respondent receives utility from saying that they are willing to pay more or willing to accept less for a good than they would in an actual transaction (Lusk and Norwood, 2009).

There is a significant literature on the distinction between real versus hypothetical WTA and methods to reconcile these two estimates. A review of the literature reveals that although some studies indicate that the distinction between real versus hypothetical scenarios may not influence choice models quite significantly, there is an abundance of evidence to the contrary.

The issue of hypothetical bias in SP studies has been widely discussed in both WTP and WTA frameworks although there are relatively fewer WTA studies. Bishop and Heberlein (1979), in a CV study, showed that real and hypothetical WTA estimates differ significantly. Li et al. (1996) showed that the difference between these estimates may be accounted for by decision uncertainty. They also commented that the observed WTA may not be the true WTA at all. Respondent uncertainty could be a factor in the difference between estimates of welfare measure obtained using different methods (Welsh and Poe, 1998). SP studies that employ a certainty threshold approach generally involve follow-up questions about the certainty of a response in a traditional dichotomous choice CV survey. By using a confidence level based on a follow-up question about the certainty of a response, these studies adjust the estimated welfare measure. Using a choice experiment Ready et al. (2010) showed that hypothetical bias in an SP study might be due to respondent uncertainty and follow-up questions might be used to calibrate hypothetical data.

Smith and Mansfield (1998) used a dichotomous choice elicitation format to compare real and hypothetical WTA for respondents' time. It was observed that while income and the size of the offer significantly influenced decision making, whether the offer type was real or hypothetical was not significant. However, many SP studies note that the choice of an appropriate technique to ask the valuation question is crucial. List and Gallet (2001) conducted a meta-analysis using data from 29 studies and showed that hypothetical and real responses differ by a factor of three and the elicitation methods do influence this gap. Nape et al. (2003) used a dichotomous choice setting for WTA elicitation and showed that hypothetical bias exists and identifiable demographic characteristics can be responsible for the bias.

Harrison (2007) discussed at length the issue of incentive compatibility and the merits of various techniques that can be used to address this issue. Harrison (2007) noted that hypothetical bias can be mitigated through proper choice of the elicitation format, design of the instrument, instrument calibration and statistical calibration. Carson and Groves (2007) investigated how rational agents answer survey questions designed to elicit preferences. They noted that survey formats differ in terms of revealing information to the respondent, respondent's incentive in answering the questions and preference information revealed in the answers. Carson and Groves (2007) went on to comment on the importance of correct interpretation of survey data in the light of these differences. They argued for the terms "consequential"[4] and "inconsequential" rather than "hypothetical" to be better descriptions of the contingent nature of the preference studies.

[4]Carson and Groves (2007) defined survey questions as consequential if a respondent perceived that the results of the survey would potentially influence an agency's actions which might in turn impact the respondent's utility and thus the respondent would treat the survey questions as an opportunity to influence those actions.

Carson and Groves (2011) note that when the costs of a public program presented to respondents are characterized as uncertain by means of a payment card design with multiple bids, the preference elicitation design is generally consistent with incentive compatibility, if compared to a simple DC design.

To deal with hypothetical bias and strategic response, in this study an auction-like design similar to a payment card is used with a cheap talk script followed by multiple bids with uncertain response options. The design is discussed in detail in Appendix A.

Social desirability bias (Lusk and Norwood, 2009) or warm glow (Becker, 1974; Andreoni, 1990) or other-regarding behaviour (Charness and Rabin, 2002) may be attributed to people's utility from conforming with social norms[5] or from an interviewer effect in an in-person SP study whereby the respondents tend to answer in a way that they feel would please the interviewer. Note that identifying hypothetical bias or social desirability bias or an interviewer bias from warm glow in the context of CV survey can be problematic (Carson, Flores and Meade, 2001).

Lusk and Norwood (2009) noted that a possible cause of the social desirability bias is that people receive utility out of their responses to the SP question and one way to mitigate this bias would be to ask the respondents how they think another person would value the good in question. If respondents are asked to value a good on behalf of another person, they use their own values as a reference point but do not receive any utility out of providing a "pleasing" answer or a picking a normative answer. The indirect questioning reduces the incentive to provide socially desirable answers and, thus, reduces social desirability bias and hence hypothetical bias. Lusk and Norwood (2009) noted that the advantage of this inferred valuation method (IVM) is that it helps mitigate social desirability bias but does not depend on a particular elicitation format. Kaczan (2011) used IVM in estimating the preference for PES design for reducing deforestation in Usambara, Tanzania. In an experimental study, Stachtiaris et al. (2013) found that IVM helps mitigate social desirability bias in valuation problems with low commitment cost and high normative motivations. The IVM is used in this study along with multiple-bid auctions for estimating preference for wetland restoration in both cropland and pasture. It may be noted that while the cheap talk script, uncertain response options and the SP

[5] The experimental literature that deals with modelling or testing observed altruism under laboratory conditions includes studies by Andreoni and Miller (2002), Rutström and Williams (2000), and McKelvey and Palfrey (1992).

auction design are used in this study, it may still be preferable to use a second-price conservation auction design to ensure incentive compatibility and minimize information rent. The detailed discussion on the question format and data collection is given in Appendix A. The questionnaire is provided in Appendix B.

2.4.3 SP Survey Questions

The hypothetical wetland restoration program involved restoring seven acres of wetland for a period of 12 years. A seven acre restoration plan was chosen to match the average number of wetland acres offered for restoration per bid in the Hill et al. (2011) study. The respondents were presented with a list of 11 bids ranging from \$0 to \$1280 per acre per year for restoration on their best cropland (referred to as Crop-Own scenario henceforth). If a producer had pastureland suitable for wetland restoration, they were asked to indicate their preference for compensation for restoring wetland on the owned pasture (referred to as Pasture-Own scenario). For WTA compensation for wetland restoration on pastureland they were presented with bids with a range of \$0-\$240 per acre per year. The respondents were also asked to complete the same preference elicitation tasks for a typical farmer in their area (referred to as Crop-Inferred and Pasture-Inferred scenarios henceforth).

For each bid amount four response categories were provided. The respondents had the option of indicating whether they would “definitely not accept”, “probably not accept”, “probably accept” and “definitely accept” the presented bid amount as a compensation. The response categories were re-defined during the analysis as “definitely no”, “probably no”, “probably yes” and “definitely yes”, respectively. The own and inferred valuation questions for restoration in cropland are presented in Figure 2-1 and those for restoration in pasture are presented in Figure 2-2. A detailed discussion concerning question format and data collection is provided in Appendix A. The questionnaire is provided in Appendix B.

Suppose you were asked to submit a sealed bid that represents the amount that you will be willing to accept in compensation for participating in the program. The agency would select the winning bids by choosing the lowest bids according to their budget.

1.1. Please indicate whether you would be interested in restoring wetlands on 7 acres of your best cropland for each of the following compensation amounts in Table 1.1. Please note that the land given up for wetland restoration would not be available for agricultural purposes for the next **<u>12 years</u>**.

Table 1.1. For **7 <u>acres</u>** of wetland in your **<u>annual cropland</u>**

Amount	Definitely not accept	Probably not accept	Probably accept	Definitely accept
$0 /acre/year				
$160 /acre/year				
$320 /acre/year				
$480 /acre/year				
$576 /acre/year				
$640 /acre/year				
$704 /acre/year				
$800 /acre/year				
$960 /acre/year				
$1120 /acre/year				
$1280 /acre/year				

1.4. Do you think a typical farmer in your area would be willing to participate in such a program?
Yes/No

1.5. How much compensation do you think they would be willing to accept if you think they would participate in restoring 7 acres of wetland in their best cropland? For each amount please indicate if you think **a typical farmer in your area** would definitely accept, probably accept, probably not accept or definitely not accept, in exchange for the restoration of the wetland.

Table 1.5. For **7 <u>acres</u>** of wetland in the **<u>annual cropland of a typical farmer</u>**

Amount	Definitely not accept	Probably not accept	Probably accept	Definitely accept
$0 /acre/year				
$160 /acre/year				
$320 /acre/year				
$480 /acre/year				
$576 /acre/year				
$640 /acre/year				
$704 /acre/year				
$800 /acre/year				
$960 /acre/year				
$1120 /acre/year				
$1280 /acre/year				

Figure 2-1: Stated Preference Questions for Restoration in Cropland – (Crop-Own Scenario in the Top Panel and Crop-Inferred Scenario in the Bottom Panel)

2.1. **If you have pastureland**, please indicate whether you would be interested in restoring wetlands on 7 acres of your pastureland for each of the following compensation amounts in Table 2.1. Please note that the land given up for wetland restoration would not be available for agricultural purposes for the next **12 years**.

Table 2.1. For **7 acres** of wetland in your **pastureland (if applicable)**

Amount	Definitely not accept	Probably not accept	Probably accept	Definitely accept
$0 /acre/year				
$30 /acre/year				
$60 /acre/year				
$90 /acre/year				
$108 /acre/year				
$120 /acre/year				
$132 /acre/year				
$150 /acre/year				
$180 /acre/year				
$210 /acre/year				
$240 /acre/year				

2.4. Do you think a typical farmer in your area would be willing to participate in such a program?
Yes/No

2.5. How much compensation do you think they might be willing to accept if you think they would participate in restoring 7 acres of wetland in their pastureland? For each amount please indicate if you think **a typical farmer in your area** would definitely accept, probably accept, probably not accept or definitely not accept, in exchange for the restoration of the wetland.

Table 2.5. For **7 acres** of wetland in pastureland **of a typical farmer**

Amount	Definitely not accept	Probably not accept	Probably accept	Definitely accept
$0 /acre/year				
$30 /acre/year				
$60 /acre/year				
$90 /acre/year				
$108 /acre/year				
$120 /acre/year				
$132 /acre/year				
$150 /acre/year				
$180 /acre/year				
$210 /acre/year				
$240 /acre/year				

Figure 2-2: Stated Preference Questions for Restoration in Pastureland – (Pasture-Own Scenario in the Top Panel and Pasture-Inferred Scenario in the Bottom Panel)

2.4.4 Data Description

2.4.4.1 Producer Characteristics

There were 29 respondents, 15 in Alberta and 14 in Saskatchewan. All respondents in this study were male. All 15 respondents in Alberta used computers for farm business and used or had access to high speed internet. Minimum age of a respondent in Alberta was 35 years and maximum was 70 years. In terms of highest education level, 50% of the Alberta respondents were high school graduates and 50% had a Bachelor's degree or diploma. Of the 15 Alberta respondents 11 (73%) respondents worked full time in the farm and four (27%) worked only part time. For the full time producers in Alberta, farm income constituted 50%-100% of their total income and for the part time producers, 45%-60% of their income came from farm income.

Out of 14 respondents in Saskatchewan, 13 respondents used computers for farm business and used or had access to high speed internet. Half of the Saskatchewan respondents were high school graduates while the other half had obtained a Bachelor's degree or diploma. The minimum age of the respondents in Saskatchewan was 28 years and the maximum was 66 years. Nine respondents in Saskatchewan (64%) were employed full time in the farm and five (36%) worked in the farm on a part time basis. For the part time producers farm income constituted 20-50% of their total income and for the full time producers 70-100% of their income came from the farm.

Eight producers (53.3%) in Alberta were members of one or more farm organizations. Five producers (33.3%) were members of conservation and stewardship groups and five producers belonged to recreational hunting or fishing organizations. Among the respondents in Saskatchewan, seven producers (50%) were members of farm organizations. Three producers (21.4%) were members of recreational hunting or fishing organizations and only one (7%) belonged to a conservation stewardship organization.

2.4.4.2 Past Land Use Changes

Respondents were asked if they had made any land use changes on owned land over the past 12 years (2001-2013). Seven respondents in Alberta (46.7%) indicated that they had made land use changes during that period (Table 2-1). An average of 8.3 acres (range 5-10 acres) was converted by these producers from annual cropland to wetlands or buffer strips and shelterbelts in the last 12 years. An average of 15.4 acres (range 2-40 acres) was converted by producers from wetlands and/or woodlands to annual cropland, tame forage or pasture.

Table 2-1: Past Land Use Changes

	Agricultural to environmental use		Environmental to agricultural use		
	Number of producers	Mean area (Range) (acres)	Number of producers	Mean area (Range) (acres)	Total no. of producers
Alberta	3	8.3 (5-10)	5	15.4 (2-40)	7
Saskatchewan	2	3.5 (2-5)	8	243.5(18-820)	10

In Saskatchewan, 71.4% of respondents indicated that they had made land use changes in the last 12 years in their farm (Table 2-1). Only two producers indicated that they had undertaken land use change from agricultural use to environmental use. In addition, the mean area affected per producer is less than half the magnitude compared to Alberta respondents. Conversely, wetland drainage projects or clearing of woodland for expanding cropland area were undertaken by the respondents in Saskatchewan to a significantly greater extent when compared to their Alberta counterparts. On an average, 243.5 acres were converted by each producer with a minimum of 18 acres and maximum of 820 acres. Figure 2-3 illustrates the difference in magnitude of various types of land use change across study areas as conducted by the respondents on owned land.

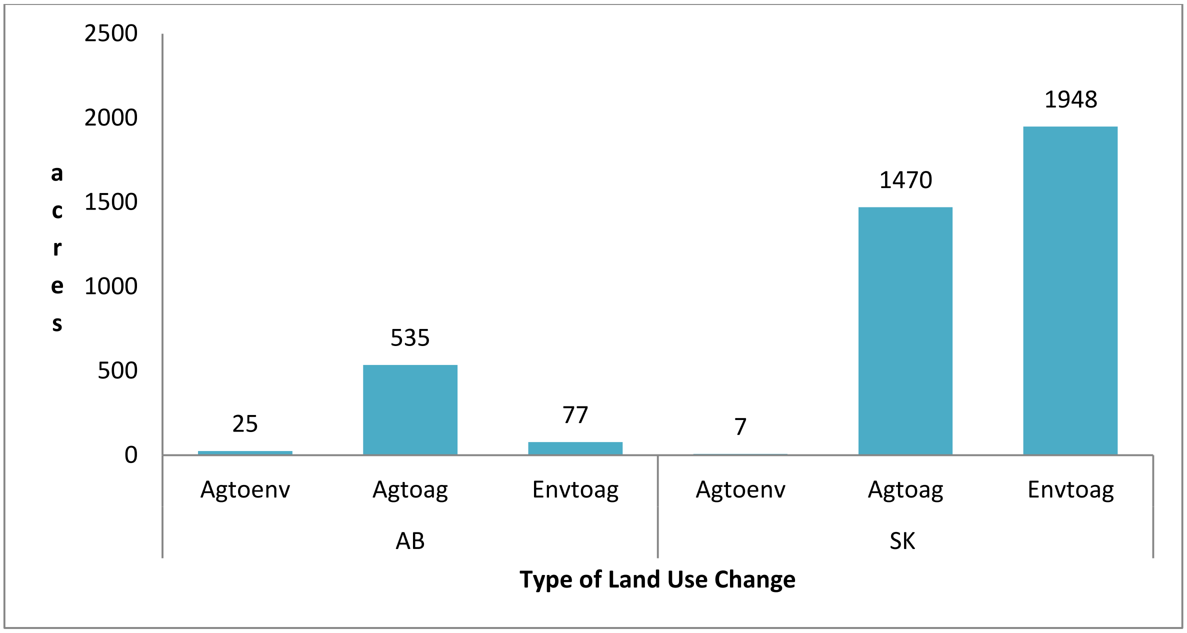

Figure 2-3: Land Use Change Comparison

(Agtoenv represents change in land use from agricultural usage to environmental usage; Agtoag represents change in land use from one agricultural usage to another; Envtoag represents change in land use from environmental usage to agricultural usage.)

(AB represents Alberta. SK represents Saskatchewan.)

2.4.4.3 Farm Characteristics

Significant variability was observed among the producers at both sites in terms of farm characteristics. Total farm size in Alberta varied from a minimum of 500 acres to a maximum of 11040 acres. While some farms had no cattle and were primarily grain operations, the average number of livestock owned by mixed enterprise farms and cow-calf operations was 149, with a maximum of 1120. An average of 309 acres was in tame or seeded pasture and 176 acres were in natural pasture for the Alberta farms. The average area of woodland and wetland on the farms surveyed in Alberta was 100 acres (range 0-600 acres) and 144 acres (range 0-940 acres), respectively. On average, farms in Alberta reported 34 permanent waterbodies (range 1-285) that never dry out except in severe drought. These are the wetlands least likely to be drained, as informally indicated by some of the survey respondents. The average number of seasonal wetlands for the surveyed farms in Alberta was 26 (range 2-108). Seasonal wetlands have water present in them until mid-summer and therefore are most likely to be drained in order to facilitate machinery operations. The average number of temporary wetlands that are flooded for a very short period in spring or after precipitation was reported to be 24 (range 0-100) (Table 2-2).

Table 2-2: Farm Characteristics - Alberta[a]

Description	Mean	Std. dev.	Minimum	Maximum
Total farm size (acres)	3524	2600.95	500	11040
Area in annual crop (acres)	2030	2131.15	70	8000
Area in tame or seeded pasture (acres)	309	425.03	0	1165
Area in natural pasture (acres)	176	220.94	0	820
Woodland area (acres)	100	159.35	0	600
Wetland area (acres)	144	225.14	0	940
Difference in yield between best and worst field (%)	26	0.26	0	90
Number of livestock	149	273.66	0	1120
Number of permanent waterbodies	34	70.46	1	285
Number of seasonal wetlands	23	32.35	2	108
Number of temporary/ephemeral wetlands	29	27.67	0	100

[a]: Number of Observations =15

The average farm size in Saskatchewan was 3713 acres (range 160-8800 acres). The average number of livestock was 105 (range 0-550). The average area in tame or seeded pasture on Saskatchewan farms was 80 acres (range 0-500 acres) which is less than that in Alberta. The average area in natural pasture (392 acres) was, however, greater than that for Alberta farms. The average woodland (70 acres) and wetland (63 acres) areas on Saskatchewan farms were significantly less than those reported by the Alberta farms. This is corroborated by the land use changes reported by the Saskatchewan farms as they made significantly larger changes from environmental use to agricultural use when compared to their Alberta counterparts. The average number of permanent and seasonal wetlands was also less than that reported by Alberta farms (Table 2-3). The average difference in yield between the best and the worst fields owned by Alberta and Saskatchewan farms was 26%. However, Alberta farms seem to have more variability in yield (range 0%-90%) than do the Saskatchewan farms (0%-50%).

Table 2-3: Farm Characteristics - Saskatchewan[a]

Description	Mean	Std. dev.	Minimum	Maximum
Total farm size (acres)	3713	2674.16	160	8800
Area in annual crop (acres)	2184	2463.01	135	8000
Area in tame or seeded pasture (acres)	80	143.81	0	500
Area in natural pasture (acres)	392	478.81	0	1790
Woodland area (acres)	70	81.19	0	200
Wetland area (acres)	63	55.86	0	200
Difference in yield between best and worst field (%)	26	0.14	0	50
Number of livestock	105	149.24	0	550
Number of permanent waterbodies	28	52.94	0	210
Number of seasonal wetlands	18	31.51	0	126
Number of temporary/ephemeral wetlands	55	104.52	0	420

[a]: Number of Observations = 14

Among the surveyed farms in Alberta and Saskatchewan, nine in each site reported crop production to be their main enterprise. This constitutes 60% of Alberta respondents and 64% of Saskatchewan respondents. There were four farms (27%) in Alberta that reported cow-calf as their main enterprise. Two farms in Alberta (13%) and five in Saskatchewan (36%) reported a mix of crop and cow-calf as their main enterprise (Table 2-4).

Table 2-4: Type of Main Enterprise

	Alberta	Saskatchewan
Crop	9	9
Cow-Calf	4	-
Mixed	2	5

2.4.4.4 Distribution of Valuation Responses

As the respondents completed two sets of valuation questions for restoration on cropland and two sets of valuation questions for restoration on pastureland (if applicable), there are four different restoration scenarios for each study area. These are summarized in the Table 2-5. The actual response distributions for the valuation questions are presented in Appendix C.

Table 2-5: Summary of the Wetland Restoration Scenarios

Study Area	Type of land[a]	Valuation method	Legend
Alberta	Crop	Own valuation	ABCO
Alberta	Crop	Inferred valuation	ABCI
Alberta	Pasture	Own valuation	ABPO
Alberta	Pasture	Inferred valuation	ABPI
Saskatchewan	Crop	Own valuation	SKCO
Saskatchewan	Crop	Inferred valuation	SKCI
Saskatchewan	Pasture	Own valuation	SKPO
Saskatchewan	Pasture	Inferred valuation	SKPI

[a]: Type of Land where the proposed wetland would be restored

The response distribution in the ABCO scenario is presented in Table C1 in Appendix C and in Figure 2-4. A consistent response of "definitely no" was selected by 13% of respondents. These included the non-responses and protest bids. The protest bids were identified using debriefing comments and questions that followed the valuation questions in the questionnaire. If a respondent picked "definitely no" for all the bid amounts and indicated explicitly in the debriefing section that they are against the proposed project and/or deem it unnecessary even with compensation, their response was considered as a protest bid and not just an indicator of WTA being higher than the highest bid amount presented to them. Conversely, 80% of respondents answered "definitely yes" to bids of $960 and higher. Approximately 46% of respondents answered in uncertain terms ("probably no" and "probably yes") for the lowest positive bid of $160/acre/year. Approximately 7% of people were uncertain about the highest bid presented and picked "probably yes". With the exception of the protest bids, all respondents picked "probably yes" or "definitely yes" for bids of $800 or higher.

For the ABCI scenario, 20% of respondents in Alberta did not pick any bid as they indicated that in their opinion a typical farmer would not participate in such a wetland restoration project (Table C2). For the lowest positive bid, 53% picked "definitely no" and 27% picked the uncertain response categories. For the highest three bids, all respondents picked either "definitely yes" or "definitely no" indicating that beyond some bid threshold there was no uncertainty when they were making these inferred choices. The corresponding response distribution is presented in Figure 2-5.

For the wetland restoration scenarios in pastureland, responses were obtained only from individuals who have pastureland that is suitable for restoration activity. Hence, these responses are from a sub-sample of respondents with a corresponding lower actual response rate (approximately 60% of all respondents in Alberta). For the ABPO scenario, approximately 54% selected "definitely no" or "probably no" for the lowest bid of $0/acre/year. A response of "probably yes" for $0/acre/year for pastureland in Alberta was provided by 7% of respondents, while 7% picked "definitely no" and another 7% picked "probably no" for the highest bid of $240/acre/year. Approximately 47% picked "definitely yes" for the highest bid for pasture. From observing the response distribution alone, there is no clear threshold for switching from no-responses to yes-responses in pasture scenarios, when compared to the crop scenario (Figure 2-6 and Table C3). This may be attributable to the bid range presented in the pasture scenario not being high enough.

For the ABPI scenario (Figure 2-7 and Table C4), responses for the $0/acre/year bid were either "definitely no" or "probably no". This may be because respondents that indicated probable interest to participate in a restoration project in own pastureland for zero monetary compensation, did so given the specific details of their farm and the topography of the field. The responses to the debriefing questions and general comments made by the respondents strengthen this hypothesis. This may also indicate that respondents considered the valuation questions in the own scenarios as potentially real or at least at least gave serious consideration to the questions. Approximately 7%-20% respondents picked uncertain responses for various bid amounts.

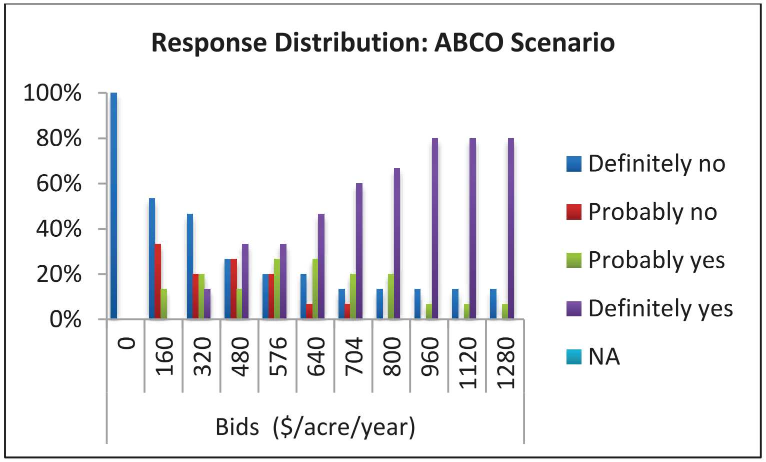

Figure 2-4: Response Distribution: ABCO Scenario

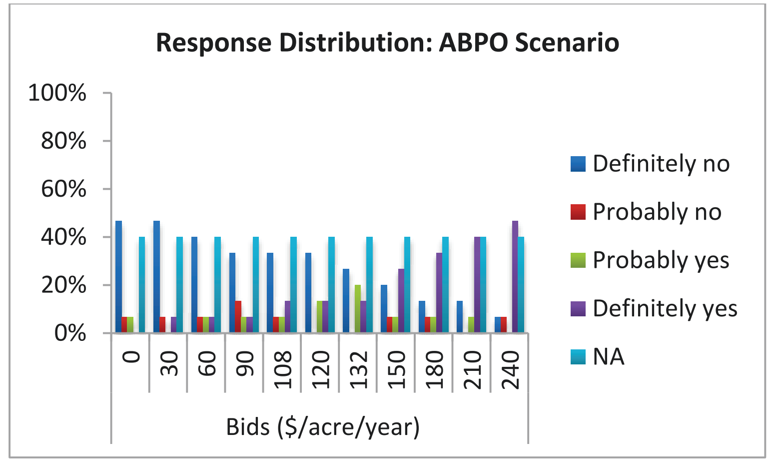

Figure 2-6: Response Distribution: ABPO Scenario

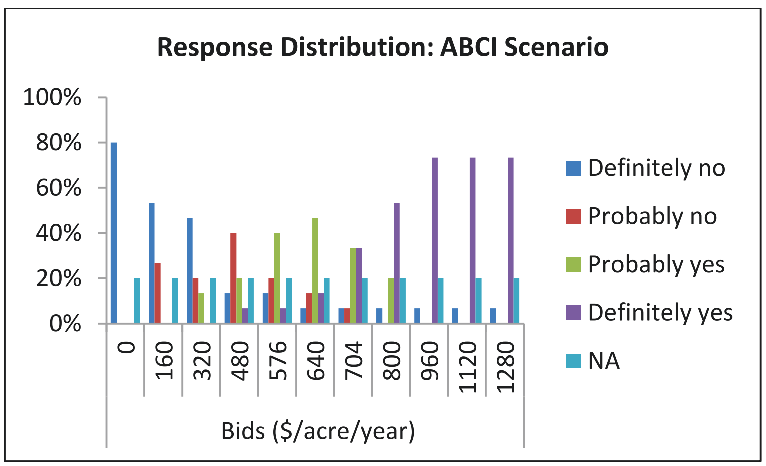

Figure 2-5: Response Distribution: ABCI Scenario

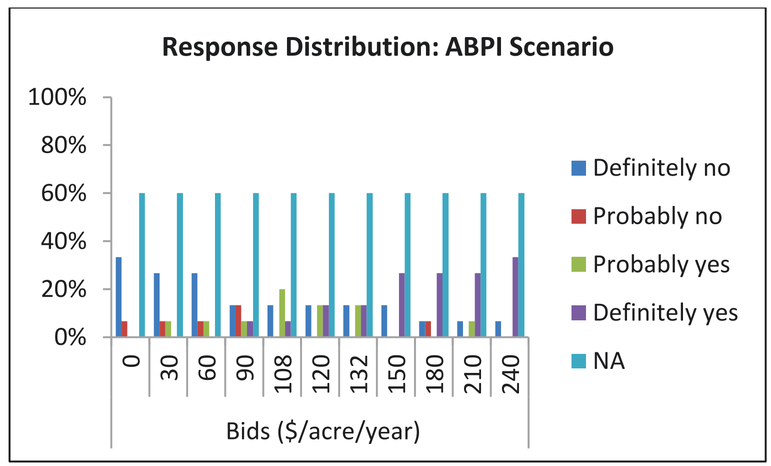

Figure 2-7: Response Distribution: ABPI Scenario

The response distribution for the SKCO scenario is presented in Figure 2-8 and Table C5. At the lowest positive bid ($160/acre/year), approximately 92% answered “probably no” or “definitely no” and 7% answered “definitely yes”. Uncertain response categories were used by 7%-50% of respondents, for various bid amounts. At the highest bid amount 7% respondents picked “definitely no” and all other pickeds either “definitely yes” or “probably yes”.

For the SKCI scenario (Figure 2-9 and Table C6), the lowest bid for a “definite yes” response was $480/acre/year. The uncertain response categories for this scenario were used by 7%-57% of respondents. At the highest bid amount 21% responded “definitely no” and 78% responded either “definitely yes” or “probably yes”.

For the SKPO scenario (Figure 2-10 and Table C7), approximately 92% respondents picked “definitely no” or “probably no” for the lowest positive bid. The minimum bid for which a “definitely yes” response was obtained is $90/acre/year. Uncertain response options were used by 7%-35% of respondents. At the highest bid, 21% respondents picked “definitely no”, 7% picked “probably no” and 64% picked “definitely yes” or “probably yes”.

For the SKPI scenario, 14% respondents answered “definitely yes” at a minimum bid of $90/acre/year. At the highest bid, 93% responded “probably yes” or “definitely yes” with only 7% responding “definitely no”. Uncertain response options were used by 14%-57% of respondents (Figure 2-11 and Table C8).

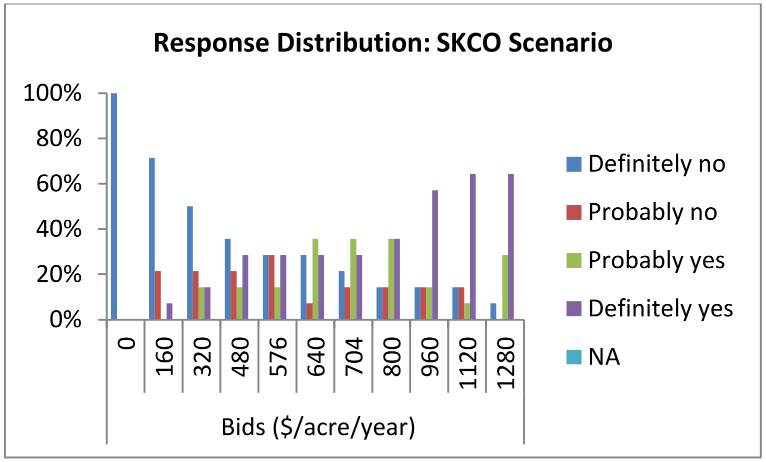

Figure 2-8: Response Distribution: SKCO Scenario

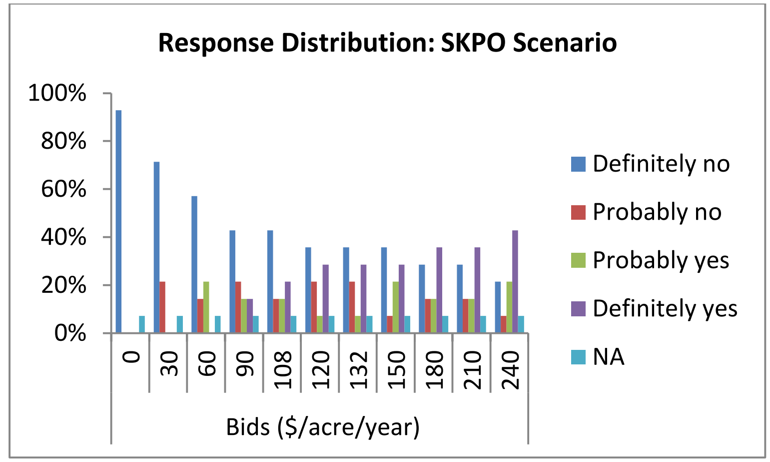

Figure 2-10: Response Distribution: SKPO Scenario

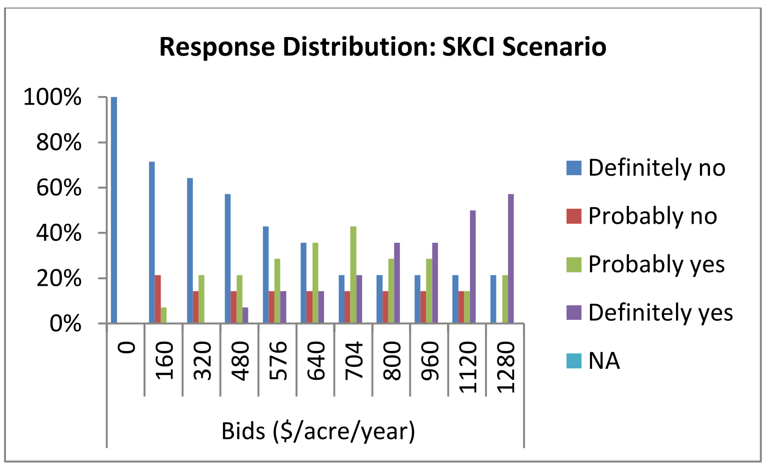

Figure 2-9: Response Distribution: SKCI Scenario

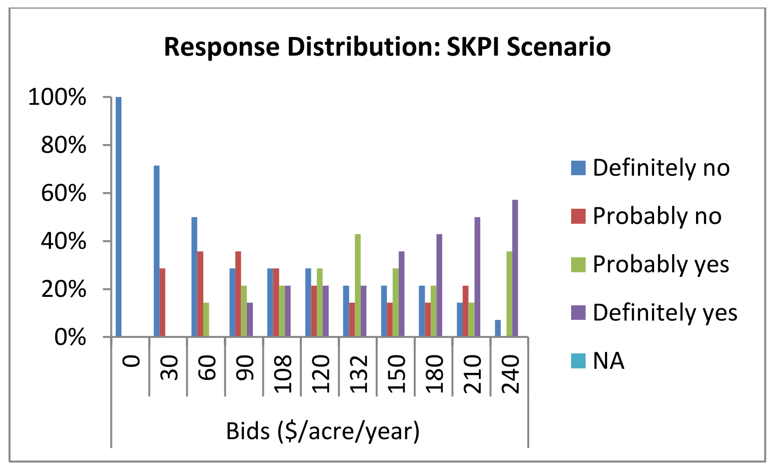

Figure 2-11: Response Distribution: SKPI Scenario

2.5 Econometric Methods and Results

The small sample size in this study limited the scope of fitting complex econometric models for the estimation of WTA. Hence, the focus was on obtaining the estimates and distributions of WTA from relatively simpler econometric models that best fit the data and then comparing the estimates to see if the results are consistent across various econometric models. An ordinary least squares (OLS) estimation of the midpoint of the switching intervals was conducted to identify the univariate distribution of WTA and obtain farm-specific predicted WTAs in section 2.5.1. Kernel density estimators (KDEs) were obtained to graphically present the distributions of WTAs based on the midpoint analyses. Finally, random effects (RE) Probit models were estimated in section 2.5.2 to obtain central tendencies of WTA by evoking the conceptual model presented in section 2.3.

The choice to participate in the restoration program is conceptualized as being guided by a RUM framework implying that a respondent only chooses a bid when the indirect utility from the adoption of restoration program and acceptance of the bid amount is at least equal to the indirect utility of the status quo (section 2.3).

The SP auction design for eliciting the WTA takes the form of a multiple-bounded choice question. For k number of bids presented to a respondent, the latent WTA is conceptualized to reside in any one of the k+1 intervals. As each respondent was presented with 11 bids for each valuation scenario, the number of possible bid intervals that could contain the latent WTA for each resident is 12. The bid interval where the respondent switched from a “definitely no” to “definitely yes” response identifies the relevant bounds of the latent WTA. The statistical information underlying each respondent’s choice when presented with multiple bids helps improve the efficiency of the discovery of the latent WTA.

The econometric models described below differ in the treatment of the available statistical information embedded in the bid intervals – especially where the respondents made the switch from no to yes responses. The midpoint analyses explicitly treat only the switching interval as relevant and assume that a single WTA represented by the exact midpoint of the switching interval is the relevant latent WTA measure. The RE Probit models do not assume that a single WTA value is underlying the choices being made by respondents for each sequence of presented bids, and instead let WTAs at each bid level be correlated with each other.

2.5.1 Midpoint Analyses

The analyses of the producers' preference for wetland restoration started with a simple OLS analysis of the midpoints of the switching intervals. If the actual WTA of the respondent lies in the bid interval where a respondent switched from "probably yes" to "definitely yes", the midpoint of that interval (hereby referred to as "interval midpoint") is assumed to be the expected WTA of that respondent. As the raw data indicated that there is considerable heterogeneity in the WTA of the respondents, the midpoint analysis was conducted as a simple exercise to quantify the variability by using a proxy of the true unobserved WTA.

This was a preliminary exercise before delving into the estimation of the central tendencies of WTA using the RUM framework. Obtaining the midpoints of the intervals assists in fitting a univariate distribution of WTA, the values are useful for comparison to the farm-specific estimates of FC of BMP adoption as discussed in the following chapters and finally the simplistic OLS regression analyses allow the identification of the correlation of various socio-economic variables with WTA. Of course, the assumption that the midpoint of the interval is a proxy for the unobserved WTA is likely to induce inefficiency in predicting the unobserved WTA.

An interval midpoint analysis was done in this study by fitting the following linear equation:

$$Y_i = \alpha + \beta . X_i \qquad 2\text{-}7$$

where Y_i was the interval midpoint scaled by dividing the value by 1000. The regressors included in X_i are age (AGE), acres under production of annual crops in 2013 (ANNCROP), acres of past land use change from environmental use to agricultural use (ENVTOAG), the number of seasonal wetlands in their land (SEASWET), and total number of livestock (TOTALCOW).

The reason for choosing these variables as explanatory variables of interest was that they capture observable heterogeneity in demographics, farm size, presence of existing wetlands in the field, and producers' past experience in changing land use away from ES. It may be noted that the variables SEASWET and ENVTOAG are potentially endogenous. Producers' past land use changes would partially determine the extent of the currently existing wetlands on the farms.

Also, their underlying preference would determine the scope of past land use changes and current area under crop production. Inclusion of these variables with potential endogeneity is done in order to examine their correlations with WTA.

The estimation was done in Limdep 10.0. The midpoint regressions were conducted separately for own and inferred valuation scenarios in the two study sites. The OLS estimation results are presented in Appendix D. The R-squared of the fitted crop models were in the range of 0.3866-0.6171 and that of the pasture models were in the range 0.2894-0.5799. However, significance of the explanatory variables of interest was very low. It may be noted here that the dependent variable in these models is the amount of compensation and not the probability of participation by the respondents. Therefore, the coefficients indicate the change in compensation demanded due to a change in the value of explanatory variables.

A possible reason for the low significance of the explanatory variables might be low level of variability. AGE has a negative and small coefficient for all four cropland models, indicating that older producers are likely to demand marginally less compensation for wetland restoration. As the number of seasonal wetlands increases, producers demand higher compensation to restore wetlands in cropland in Alberta under both own and inferred valuation scenarios. However, in Saskatchewan the coefficient of SEASWET is positive in the SKCI scenario while it is negative in the SKCO scenario. Comparing the ABCO and SKCO scenarios, it is observed that the coefficients switch sign for the other three covariates as well. It is difficult to say whether this is because of sample size issues, or if starkly different preferences across sites are underlying the results.

For the pasture scenarios, since the data were even more limited as only a subset of respondents answered the pasture questions, the “full” model could not be fitted. Number of seasonal wetlands and total number of livestock were used as explanatory variables. SEASWET has a negative coefficient across the pasture models except in the ABPO scenario. This indicates that given a large number of existing wetlands, producers might demand less compensation if they restore wetland in their less productive land that is accessed by livestock. WTA for restoration in pastureland falls as the number of livestock increases in Alberta. In Saskatchewan, the opposite effect is observed.

Given the estimates of $\hat{\beta}$, the farm-specific fitted values of $\hat{Y}_i$ were also obtained from the equation $\hat{Y}_i = \hat{\alpha} + \hat{\beta}.X_i$. The predicted WTA was obtained by multiplying $\hat{Y}_i$ by 1000 (Table 2-6). Note that once the estimates of $\hat{\beta}$ were obtained, it was possible to impute for the missing observations of $\hat{Y}_i$ if data for the regressors were available for those particular observations. This is a crude but simplistic method of imputing the values of the predicted WTA for producers that did not switch from "probably yes" to "definitely yes" for any bid. These are producers that did not pick any bid either as a protest response or because their true WTA is higher than the highest bid amount used in the study. The advantage of imputing their WTA is that it allows the comparison of their predicted WTA with the estimates of their FC instead of dropping the observations in the comparison analyses.

Figure 2-12 and Figure 2-13 compare the KDEs[6] of the farm-specific predicted WTAs from the midpoint analyses to the actual midpoint of the switching intervals for ABCO and SKCO scenarios, using logistic kernel and a common bandwidth parameter of 0.337865. It appears that the predicted WTAs are closer to the actual midpoints of the switching intervals for ABCO scenario compared to the SKCO scenario. This indicates that the assumption that the midpoint of the interval is a proxy for the unobserved WTA is likely to induce less inefficiency in the estimation of predicted WTA for the Alberta subsample than it would for the Saskatchewan subsample.

[6] A KDE is a non-parametric estimator for the probability density function of a random sample.

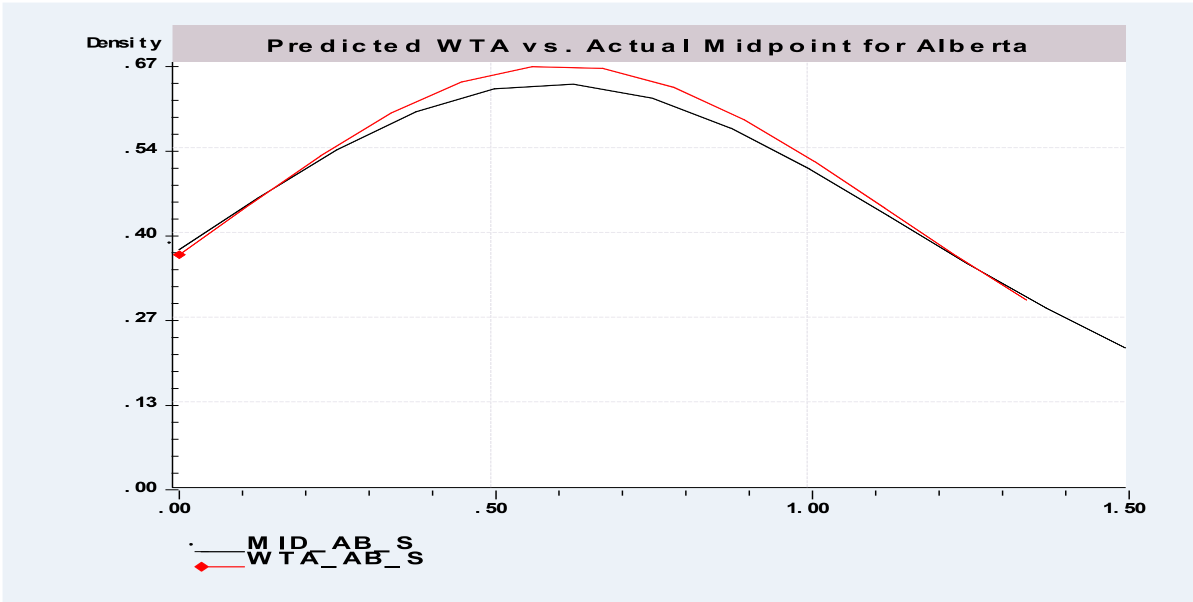

Figure 2-12: Kernel Density Estimators of Actual Midpoint of Switching Intervals vs. Predicted WTA from Midpoint Analyses (ABCO Scenario)

(MID_AB_S: Scaled Actual Midpoint; WTA_AB_S: Scaled Predicted WTA; Logistic Kernel; Bandwidth = 0.337865)

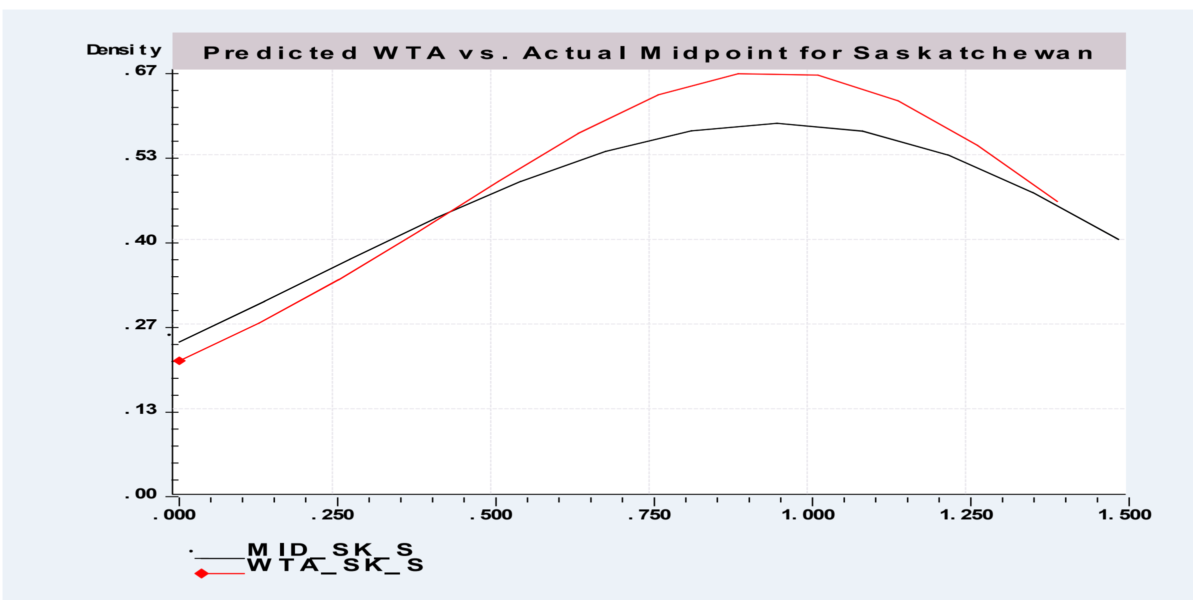

Figure 2-13: Kernel Density Estimators of Actual Midpoint of Switching Intervals vs. Predicted WTA from Midpoint Analyses (SKCO Scenario)

(MID_SK_S: Scaled Actual Midpoint; WTA_SK_S: Scaled Predicted WTA; Logistic Kernel; Bandwidth = 0.337865)

It was observed that both for Alberta and Saskatchewan, the average predicted WTA for cropland is higher in the inferred case than in the own valuation case. However, the average predicted WTA for pasture is marginally lower in the inferred valuation case than in the own valuation case. This may indicate that producers perceive their own pasture as marginally better quality land compared to that of their peers.

Average predicted WTA is higher in Saskatchewan than in Alberta for both cropland and pasture. Excluding the imputed values, average predicted own WTA for restoration in Alberta cropland was $617.85/acre/year while that in Saskatchewan was $882.67/acre/year. Average predicted inferred WTA for restoration in Alberta cropland was $720.00/acre/year and that in Saskatchewan was $894.40/acre/year. The average inferred WTA is 16.53% higher than own WTA in Alberta and 1.33% higher than own cropland WTA in Saskatchewan for restoration in cropland. The average own WTA for restoration in Alberta pasture is extremely close to the average inferred WTA value for pasture with the inferred value being slightly lower (0.67%). For Saskatchewan, inferred WTA for restoration in pasture is 4.89% less than the own WTA.

The imputed values of predicted WTA were obtained for Farms 3, 4 and 20 in the ABCO and SKCO scenarios. The imputed WTA values for these farms were $2520.47, $2155.11 and $869.93 per acre per year, respectively. The imputed values for Farms 3 and 4 are considerably higher than the highest bid amount ($1280/acre/year) presented in the study.

Table 2-6: Midpoint Analyses - Predicted WTA Excluding Imputed Values ($/acre/year)[a]

		Crop		Pasture	
	Farm ID	Own	Inferred	Own	Inferred
Alberta	1	702.21	724.43		
	2	382.25	616.35	153.30	177.55
	5	320.72	765.31	23.81	80.72
	6	859.39	830.84		
	7	427.13	644.15	152.75	169.44
	8	454.18	605.20	173.25	147.03
	9	562.43		154.44	
	10	744.56		172.79	
	11	417.60	639.37		
	12	1111.01	878.27		
	13	551.10	725.63	150.67	121.26
	14	850.26	768.79		
	15	649.15	721.66		
	Average	617.85	720.00	140.14	139.20
Saskatchewan	16	1024.33	862.25		
	18	558.39	483.69	146.63	134.13
	19	1013.61	994.28	184.67	180.47
	21	1054.53	999.52	172.82	164.87
	22	178.22	597.18	88.75	72.92
	23	957.08	801.76	159.82	148.07
	24	953.55			
	25	996.60		160.96	149.28
	26	798.06	803.35	143.77	131.10
	27	949.00	967.99	177.10	172.08
	28	933.97	1099.41		
	29	1174.67	1334.58	238.48	248.08
	Average	882.67	894.40	163.67	155.67

[a]: The missing values for the inferred scenarios indicate that the respondent did not answer the inferred valuation questions and stated that they are unable to predict a typical producer’s choices. The missing values for the Pasture-Own scenario refer to respondents that did not have any pasture suitable for wetland restoration and hence did not answer these valuation questions.

KDEs for the predicted WTAs for the ABCO and SKCO scenarios were compared including and excluding the imputed values. These are presented in Figure 2-14 and Figure 2-15 respectively. The peak of the density function for the Alberta subsample overlaps with the left tail of the density function for the Saskatchewan subsample indicating that for Alberta there are fewer number of producers with very high values of WTA compared to the Saskatchewan subsample. Inclusion of the imputed WTAs affects the shape of the density function for Alberta and generates a long and narrow right tail.

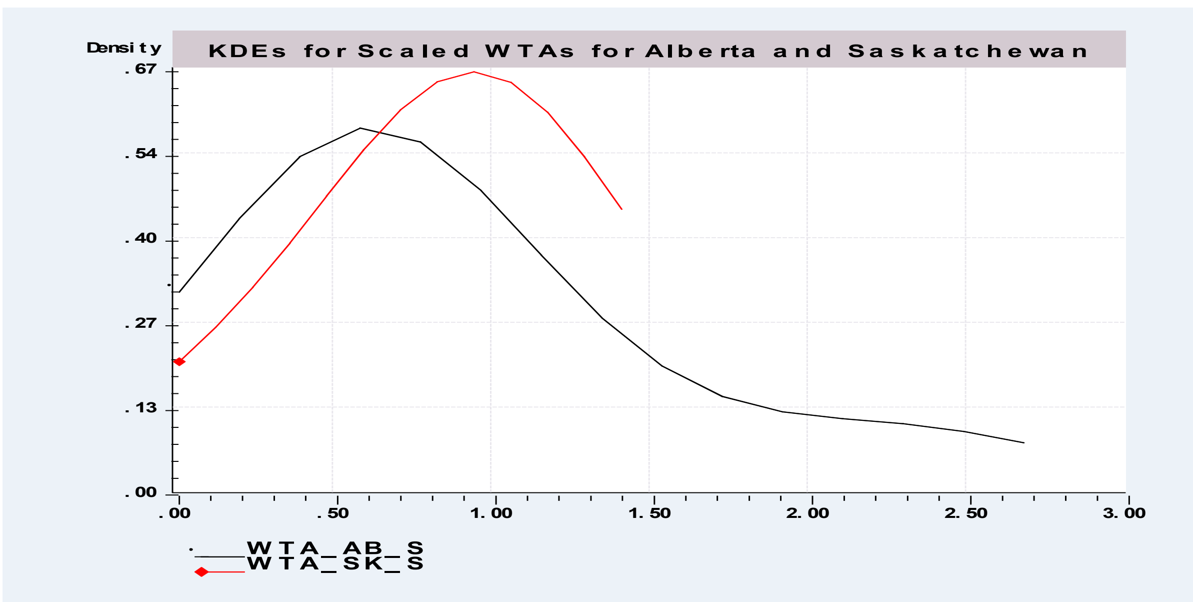

Figure 2-14: Kernel Density Estimators for Scaled Predicted WTA (Including Imputed Values) (WTA_AB_S: Scaled Predicted Own WTA for Alberta, WTA_SK_S: Scaled Predicted Own WTA for Saskatchewan; Logistic Kernel; Bandwidth = 0.337865)

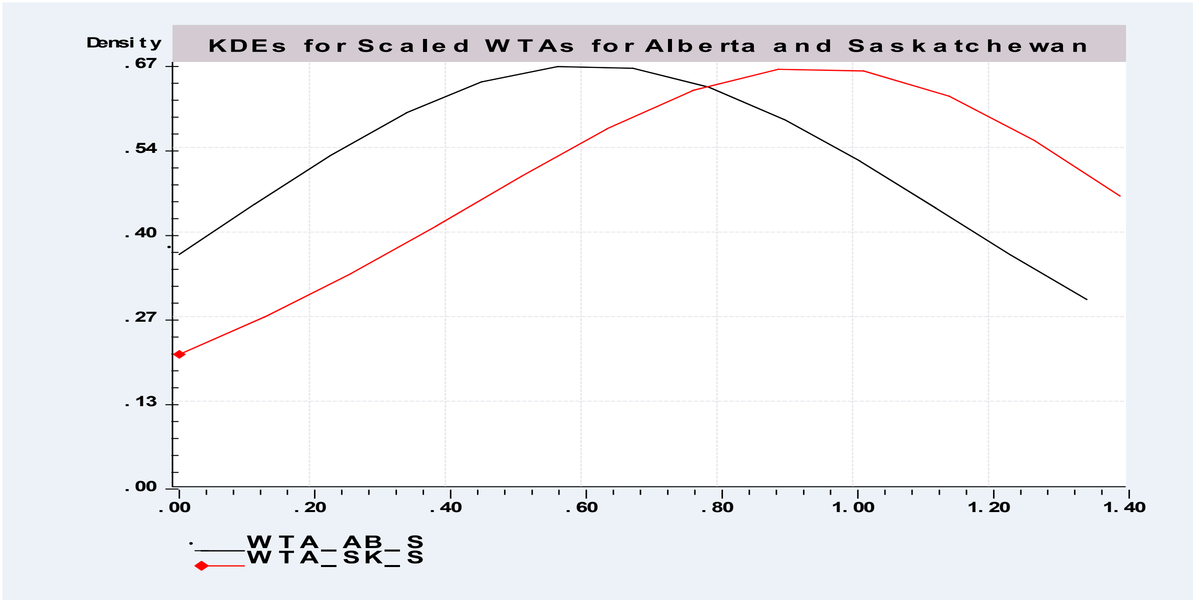

Figure 2-15: Kernel Density Estimators for Scaled Predicted WTA (Excluding Imputed Values) (WTA_AB_S: Scaled Predicted Own WTA for Alberta, WTA_SK_S: Scaled Predicted Own WTA for Saskatchewan; Logistic Kernel; Bandwidth = 0.337865)

2.5.2 Random Effects Probit

The RE Probit model was the main econometric model of interest for estimating the median WTA for wetland restoration in cropland and pastureland in the two study sites, assuming certainty in response. Following Welsh and Poe (1998) and Alberini et al. (2003), the uncertainty in responses was "assumed away"; that is, the "probably yes" and "probably no" answers were treated as "definitely no". This involved re-coding the response data as binary choices where "definitely yes" is coded 1 and all other responses are coded as 0. The choice data thus captured a repeated DC for 11 own bids and 11 inferred bids in crop and pasture scenarios. A RE model assumes that for each respondent the answers to each bid question are correlated.

Given that respondents expressed their choice for 11 bid amounts in each of the relevant valuation scenarios with some "NA"s, the own, inferred and combined choice data resulted in an unbalanced panel dataset. The model specified in section 2.3 could be estimated using a RE Probit model with a maximum likelihood estimator (MLE).

The structural RE model is given by:

$$Z_{it} = \beta X_{it} + \gamma \cdot Bid_{it} + u_i + \eta_{it}$$
$$Y_{it} = 1 \quad \text{if} \quad Z_{it} > 0 \qquad \text{2-8}$$
$$Y_{it} = 0 \quad \text{otherwise}$$

where Z_{it} = vector of latent variable, Y_{it} = vector of observed indicator variable, X_{it} = vector of explanatory variables, β = vector of coefficients, i = individuals and t = no. of responses per person.

The RE model assumes that the error term in Equation 2-6 can be formulated as a sum of two error components; u_i, an unobserved heterogeneity uncorrelated with X_{it} and, η_{it}, in Equation 2-8 (Greene, 2008). The RE Probit model allows estimation of the correlation coefficients between responses. It may be noted that the estimation of the RE binary choice model presents considerable estimation challenges due to the restriction imposed on the heterogeneity (Greene, 2008). As prescribed in the literature, Butler and Moffitt's (1982) method of reformulating the likelihood function using quadrature approximation method has been adopted for estimation of the RE models in this section using NLogit 5.0.

2.5.2.1 Estimation of Median WTA with Partial Linear RE Probit Models - Test of Social Desirability Bias

To test if the own choices are significantly different than the inferred choices for adoption of the restoration program, partial RE Probit models (using only bid and the intercept as explanatory variables) were estimated separately for both the study sites using own valuation data and inferred valuation data. The same models were also estimated using a combination of own and inferred valuation data. The producer's decision to accept the bids was regressed only on the bid amounts which were re-scaled by dividing the bids by 1000. In the partial models with combined own and inferred data, the models were restricted to have the same intercept to explain both own and inferred choices. The socio-demographic variables were not included in the partial RE Probit models. The observations with non-response were removed before estimating the models. The effective sample sizes are reported with each estimated model.

2.5.2.1.1 Crop Scenarios

Table 2-7: Partial RE Probit Models - Alberta Crop

	Own and Inferred			ABCO[d]			ABCI[e]		
	Coefficients		St. error	Coefficients		St. error	Coefficients		St. error
Constant	-4.25646	***	0.43747	-7.90126	**	3.99845	-15.55960		11.62255
CROPBID[a]	7.37567	***	0.52421	17.38230	**	8.33656	24.03240		17.98130
Rho[b]	0.87743	***	0.03705	0.97347	***	0.02481	0.97554	***	0.03286
LL[c]	-71.90735			-34.22317			-28.91851		
Restricted LL	-119.27081			-65.36877			-52.70168		
No. of obs.	286			154			132		
No. of indiv.	14			14			12		
AIC	149.8			74.4			63.8		
WTA	577.10		38.84	454.56		26.01	647.44		18.12

[a]: Presented bid for restoration in cropland (in $/acre/year)/1000. [b]: coefficient of correlation between responses from each individual. [c]: Log-likelihood estimate. [d]: Alberta-Crop-Own scenario. [e]: Alberta Crop-Inferred scenario. ***: Significant at 1% level. **: Significant at 5% level. *: Significant at 10% level.

The likelihood ratio (LR) test for statistically significant differences between two sets of valuation data/models indicates that for the Alberta_Crop scenario, LR=-2{-71.9074-(-34.2232-28.9185)}=17.5314 with degrees of freedom (d.f.) = 3. This is higher than the LR critical value at a 1% level and hence the hypothesis of the own and inferred preferences being the same can be rejected. Respondents indicate that their own preferences are significantly different than that of a typical farmer in their area. This implies that while it may be desirable to pool own and inferred data in order to have more explanatory power of the model, it may not be justified. However, pooling the own and the inferred valuation data improved significance of the explanatory variables as for each respondent the responses include the own and the inferred choices. In the pooled model, the intercept and the bid variable are significant at a 1% level as well as the rho. In the ABCO model, the intercept and the bid variable are significant at a 5% level. In the ABCI model, only the correlation coefficient (rho) is significant while the intercept and bid variable are not significant (Table 2-7).

Table 2-8: Partial RE Probit Models - Saskatchewan Crop

	Own and Inferred			SKCO[d]			SKCI[e]		
	Coefficients		St. error	Coefficients		St. error	Coefficients		St. error
Constant	-2.72057	***	0.55099	-14.57870		13.04959	-14.18320		11.13718
CROPBID[a]	4.38085	***	0.24848	19.88050		19.04767	18.50720		14.41018
Rho[b]	0.72292	***	0.11540	0.98512	***	0.02440	0.98615	***	0.02140
LL[c]	-89.86274			-28.81980			-29.96900		
Restricted LL	-133.75293			-63.47837			-68.77105		
No. of obs.	264			132			132		
No. of indiv.	12			12			12		
AIC	185.7			63.6			65.9		
WTA	621.01		108.38	733.32		50.42	766.36		20.49

[a]: Presented bid for restoration in cropland (in $/acre/year)/1000. [b]: coefficient of correlation between responses. [c]: Log-likelihood estimate. [d]: Saskatchewan-Crop-Own scenario. [e]: Saskatchewan-Crop-Inferred scenario. ***: Significant at 1% level. **: Significant at 5% level. *: Significant at 10% level.

Similar results as obtained in the Alberta_Crop scenarios were also obtained in the Saskatchewan_Crop scenarios (Table 2-8). While the LR test[7] rejected the null hypothesis that the two sets of valuation data could be combined, the individual models based on only own valuation or inferred valuation data lack significance of explanatory variables, in this case the bid variable, and have large standard errors. This is attributable to the limited sample size and the latent nature of the dependent variable.

2.5.2.1.2 Pasture Scenarios

Since only a subset of respondents completed the pasture valuation question, and the sample size is therefore even smaller, the data from the two sites were combined to test if own and inferred valuation data could be pooled. The partial RE Probit results are presented in Table 2-9. The LR[8] test indicated a failure to reject the null hypothesis that own and inferred valuation

[7] LR=-2{-89.8627-(-28.8198-29.969)}=62.1478 which is greater than the critical value with 3 degrees of freedom at a 1% level of significance.

[8] LR=-2{-103.8185-(-57.22062-46.53261)}=0.13054 which is less than the critical value with 3 degrees of freedom at a 10% level of significance.

data on preference for wetland restoration in pastureland could be pooled. Note that this is the only RE Probit model estimated for investigating preference for wetland restoration in pasture given the significant data limitation.

Table 2-9: Partial RE Probit Models - Alberta and Saskatchewan Pasture with Combined Data

	Own and Inferred			Own			Inferred		
	Coefficients		St. error	Coefficients		St. error	Coefficients		St. error
Constant	-4.71638	***	0.38785	-4.90571	***	1.75295	-10.39750	**	4.58602
PASTBID[a]	38.22900	***	3.03178	47.60620	***	16.3942	95.28820	**	42.44697
Rho[b]	0.86281	***	0.02017	0.96704	***	0.01852	0.97402	***	0.02091
LL[c]	-103.8185			-57.22062			-46.53261		
Restricted LL	-233.5395			-129.8217			-101.38053		
No. of obs.	429			231			198		
No. of indiv.	21			21			18		
AIC	213.6			120.4			99.1		
WTA	123.37	***	5.75	103.05	***	3.95	109.12	***	3.94

[a]: Presented bid for restoration in pasture (in $/acre/year)/1000. [b]: coefficient of correlation between responses. [c]: Log-likelihood estimate. ***: Significant at 1% level. **: Significant at 5% level. *: Significant at 10% level.

2.5.2.2 Estimation of Median WTA with Linear RE Probit Models and Pooled Own and Inferred Data

Although the LR tests with partial RE Probit models suggested that data from two valuation methods ideally should not be pooled, another set of models were estimated using dummy variables for the type of valuation method as a separate assessment. RE Probit models were estimated for combined own and inferred valuation data using an interaction between bid and the type of valuation method for the two sites.

Median WTA was obtained as a ratio of the attribute coefficients to the bid coefficients fitted at the mean of the explanatory variables. From Equation 2-6, the median WTA in a model with covariates is given by $\text{WTA} = \overline{X}'(-\frac{\hat{\beta}}{\hat{\gamma}})$ and the standard deviation of WTA is given by $-\frac{1}{\hat{\gamma}}$.

For a partial model with only bid and no covariates, the median WTA is given by $\text{WTA} = (-\frac{\hat{\beta}}{\hat{\gamma}})$.

Using the Probit estimates, WTA estimates in the partial model with bid and no covariates were calculated as follows:

$$WTA_{own} = -1000*[\frac{\beta_{one} + \beta_{own} * own}{\beta_{cropbid} + \beta_{cropbid*own}}] \quad \text{2-9}$$

and $WTA_{inferred} = -1000*[\frac{\beta_{one}}{\beta_{cropbid}}]$ 2-10

Similarly, WTA estimates in the full model with covariates are calculated as:

$$WTA_{own} = -1000*[\frac{\beta_{one} + \beta_{own} * own + \beta_{age} * age + \beta_{anncrop} * anncrop + \beta_{envtoag} * envtoag}{\beta_{cropbid} + \beta_{cropbid*own}}] \quad \text{2-11}$$

$$WTA_{inferred} = -1000*[\frac{\beta_{one} + \beta_{age} * age + \beta_{anncrop} * anncrop + \beta_{envtoag} * envtoag}{\beta_{cropbid}}] \quad \text{2-12}$$

A complete list of the explanatory variables is given in the Table 2-10. The Probit models with interaction terms were fitted for the crop scenarios only. The results for Alberta are reported in Table 2-11 and those for Saskatchewan are reported in Table 2-12.

Table 2-10: Definitions of Explanatory Variables for the RE Probit Models with Combined Own and Inferred Data

Variable	Description
CROPBID	Presented bid for restoration in cropland (in $/acre/year)/1000
OWN	Dummy for type of valuation; 1 if own, 0 if inferred
CROPBID*OWN	Interaction of CROPBID and OWN
AGE	Respondent's age in years
ANNCROP	Number of acres under annual crop production in 2013
ENVTOAG	Number of acres of wetland or woodland brought into crop production in the last 12 years
SEASWET	Number of seasonal wetlands

Table 2-11: Random Effects Binary Probit Model of Preference for Wetland Restoration in Cropland - Alberta (with Combined Own and Inferred Data)

	Partial model			Full model		
	Coefficients		St. error	Coefficients		St. error
Constant	-5.13861	***	0.92099	-0.11535		2.28139
CROPBID	8.02450	***	1.30470	8.68197	***	1.62152
OWN	-0.16285		0.82957	-0.68991		0.91837
CROPBID*OWN	2.34456		1.46297	3.61354	**	1.69934
AGE				0.00846		0.04187
ANNCROP				-0.00239	**	0.00110
ENVTOAG				0.15075	**	0.07353
Rho[a]	0.91412	***	0.03674	0.91011	***	0.07040
LL[b]	-65.08064			-63.63701		
Restricted LL	-118.07045			-104.05011		
AIC	140.20			143.30		
No. of obs.	286			286		
No of indiv.	14			14		
WTA_Own	511.28		24.75	286.71		77.36
WTA_Inferred	640.36		35.00	326.57		111.03

[a]: coefficient of correlation between responses. [b]: Log-likelihood estimate. ***: Significant at 1% level. **: Significant at 5% level. *: Significant at 10% level.

Table 2-12: Random Effects Binary Probit Model of Preference for Wetland Restoration in Cropland - Saskatchewan (with Combined Own and Inferred Data)

	Partial model			Full model		
	Coefficients		St. error	Coefficients		St. error
Constant	-2.82775	***	0.95851	-0.53857		12.89810
CROPBID	4.23329	***	0.75920	4.20495	***	1.24266
OWN	-0.05402		0.85280	-0.01813		1.48503
CROPBID*OWN	0.93186		0.99887	0.86797		1.69987
AGE				-0.06531		0.26676
ANNCROP				0.00038		0.00183
ENVTOAG				-0.00028		0.01758
Rho[a]	0.73734	***	0.12161	0.56601	***	0.17478
LL[b]	-86.57676			-83.10043		
Restricted LL	-132.24942			-103.99974		
AIC	183.20			182.20		
No. of obs.	264			264		
No of individuals	12			12		
WTA_Own	557.93		92.44	626.09		264.03
WTA_Inferred	667.98		132.26	751.01		272.28

[a]: coefficient of correlation between responses. [b]: Log-likelihood estimate. ***: Significant at 1% level. **: Significant at 5% level. *: Significant at 10% level.

Estimating the RE Probit models with interaction was informative as the coefficient of correlation between responses was of high magnitude and was statistically significant across almost all specifications. The high and significant ρ observed in all RE Probit models indicates that multiple responses should be treated as dependent on each other or correlated. This implies that the WTA amounts underlying the response at each bid level are correlated. In all specifications the bid variable had a positive and significant coefficient at 1% level which implies that the probability of participation in the BMP would increase with the amount of compensation. The dummy variable OWN had a negative coefficient which indicates that the probability of participation is lower in the Own scenario than in the Inferred scenario. This means that respondents infer that a typical farmer in the study area in Alberta is more likely to participate in this type of wetland restoration programs. The positive coefficient of

CROPBID*OWN interaction implies that higher compensation would lead to higher probability of respondents' own participation compared to the participation of a typical farmer. This implies that the respondents perceive that higher compensations are needed to persuade them to participate than they think it would impact others' decisions. ANNCROP had a negative and significant coefficient in Alberta and a positive but not significant coefficient in Saskatchewan. This implies bigger farms in Alberta are less likely to participate. Own WTA is found to be less than inferred WTA thus indicating the presence of social desirability bias in both the partial and full RE Probit models for Alberta_Crop and Saskatchewan_Crop scenarios.

The median WTAs for Alberta_Crop and Saskatchewan_Crop obtained in the partial models are quite close in terms of magnitude. The partial RE models with interaction terms indicated that the own median WTA in Alberta is $511/acre/year and inferred median WTA is $640.36/acre/year for restoration in cropland. Own median WTA for Saskatchewan is $557.93/acre/year and inferred median WTA is $667.98/acre/year based on the partial RE model with interaction. Compared to the median WTA values in Alberta, the own median WTA in Saskatchewan is higher by 9.1% and the inferred median WTA for Saskatchewan is higher by 4.3% based on the partial model with interactions.

However, the estimated median WTA for wetland restoration in cropland from the full models are significantly different in magnitude. The WTA values for Saskatchewan based on the full RE models with interaction are more than double of the estimated median WTA values for Alberta. This observation coupled with the low significance of the covariates in the full model specification indicates that the full RE Probit model may not be suitable with such small datasets.

2.6 Discussion

The objectives of the current chapter were three-fold. First, to the best of the author's knowledge, no previous studies exist that use SP methods to examine the welfare impact of wetland restoration in the Western Canadian Prairie region. Thus, the study used SP methods and elicited agricultural producers' WTA compensation for restoring naturally occurring wetlands in their cropland and pasture in two case study sites in Alberta and Saskatchewan. Secondly, the study accounted for the heterogeneity in cost of BMP adoption and the corresponding preferred compensation by eliciting distributions of WTAs as it was hypothesized that the failure to do so would have implications for the popularity and success of a wetland restoration compensation program. Finally and most importantly, the study generated welfare impact estimates that would make it possible to investigate the relationship of these estimates with farm-level wealth impact and also use in a cost transfer exercise.

A number of observations can be made based on the various models fitted for elicitation of median WTA, despite the limitations on econometric analyses due to data challenges. Own WTA is found to be less than inferred WTA indicating the likely presence of social desirability bias. This result is robust across model specifications. Median WTA is higher in Saskatchewan than in Alberta indicating between-sample variability as well as within-sample variability observed in the farm-specific estimates. This may reflect a bias in the sample since a bigger percentage of the Alberta sample were members of conservation groups or were involved with some wetland conservation programs already. This may also be due to the fact that the sampled producers in Alberta have reportedly invested a lot less resources in past drainage activities.

Results suggest that the cost of adoption of BMP is heterogeneous across samples from the two sites as well as within sample. The study explored the midpoint analyses as a simple method to identify heterogeneity in bids. A more formal estimation was done using the RUM framework. The models based on RUM framework help identify this heterogeneity in a post-estimation fashion. This study used SP auctions as an alternative approach to identify the heterogeneity in the cost. It estimated the cost by eliciting central tendencies and distributions of the agricultural producers' WTA for the samples from the study sites.

The observed heterogeneity of WTA estimates indicates that a one-size-fits-all compensation package for wetland restoration BMP may be inefficient. Cost heterogeneity and the corresponding need for targeted policy was also noted by Boxall et al. (2013) although they employed a conservation auction experiment. The findings indicate that the heterogeneity is captured in a SP auction in a similar manner to the conservation auctions with real payments. This implies that a SP auction could be a cheaper alternative to conservation auctions as a means of cost discovery. The findings lend themselves for comparison with similar estimates of cost obtained from financial models of farm net cash flow analyses and also provide the basis of the transfer analyses explored in the following two chapters.

Various Probit specifications were used to be able to compare the central tendencies of the WTA and cross check if they provide consistent estimates. Table 2-13 provides a summary of mean WTA values obtained using the OLS midpoint analyses and estimated median WTA values from various RUM specifications described above for wetland restoration in cropland.[9] [10]

Table 2-13: Comparison of WTA Values - Cropland ($/acre/year)

Models	Mean / Median (Std. error)	Std. dev.	Mean/ Median (Std. error)	Std. dev.
	ABCO[c]		ABCI[d]	
Midpoint Analyses[a]	617.85	292.67	720.00	142.03
Partial RE Probit[b]	454.56 (26.01)	57.53	647.44 (18.12)	41.61
Partial RE Probit with Interaction[b]	511.28 (24.75)	96.44	640.36 (35.00)	124.62
Full RE Probit with Interaction[b]	286.71 (77.36)	81.33	326.57 (111.03)	115.18
	SKCO[e]		SKCI[f]	
Midpoint Analyses[a]	882.67	375.66	894.40	316.55
Partial RE Probit[b]	733.32 (50.42)	50.30	766.36 (20.49)	54.03
Partial RE Probit with Interaction[b]	557.93 (92.44)	193.61	667.98 (132.26)	236.22
Full RE Probit with Interaction[b]	626.09 (264.03)	197.13	751.01 (272.28)	237.82

[a]: Mean. [b]: Median with std. error in parentheses. [c]: Alberta-Crop-Own scenario. [d]: Alberta-Crop-Inferred scenario. [e]: Saskatchewan-Crop-Own scenario. [f]: Saskatchewan-Crop-Inferred scenario.

The large standard deviations indicate that a nontrivial portion of the sample switched from "probably yes" to "definitely yes" responses at very high levels of offered bids or indicated that they will probably accept the highest amount offered. This is especially true for the Saskatchewan sample.

The RUM models present a range of median WTAs indicating that elicited WTA is dependent on model specification. This leads to the issue of identifying the specification that best fits the data. A quick comparison indicates that the full RE Probit model with interactions for Alberta generated a significantly smaller estimated median WTA and the highest standard errors

[9] The distribution of actual responses revealed that even at the higher bid amounts the proportion of definitely yes responses were less than 100%. This indicated a potentially skewed distribution of preferences. To check if a non-linear specification would improve significance of the explanatory variables compared to the partial RE linear models, a lognormal RE Probit model was also estimated. However, it led to very high standard errors for crop scenarios and non-stable models for pasture scenarios.

[10] It may be noted that comparisons between WTA estimates are made using the values in Table 2-13 in terms of their numerical values. However, no tests of statistical equality of means were conducted due to the small sample size.

of WTA, when compared to the other RE models. For Saskatchewan, these models have very high standard errors of WTA. As mentioned earlier, as some of the covariates of the full RE Probit models with interaction potentially suffer from endogeneity, the estimated coefficients of these variables are likely to be biased. One such variable is ENVTOAG which had a positive and significant coefficient in Alberta but a very small and negative coefficient in Saskatchewan. This would affect the elicited WTA. Therefore, while the full model helped to loosely identify the effect of observable heterogeneity on median WTA, it is not an ideal model. The estimated WTA values of interest are obtained from the corresponding partial models that exclude the potentially endogenous variables.

For the partial models the absolute value of coefficients of the constant term and the bid variables varied significantly across the own and the inferred models. The ratio of the constant and the coefficient of the bid variable are of more interest. The level of significance of the variables in the partial models with interaction is higher than in the partial models fitted with separate own and inferred data although the standard errors are higher as well. It is difficult to say whether the higher significance is due to the pooled nature of the data used. However, a higher standard error of the median WTA indicates lower precision of the measured central tendencies in terms of ability to predict the population mean. By this criterion, the partial RE Probit model fitted with separate own and inferred valuation data seems to be the best fit. Figure 2-16 plots the distributions of the corresponding median WTAs.

If inferred valuation WTA estimates are to be highlighted as the true underlying estimates, given that they are corrected for social desirability bias, then the median WTA obtained for ABCI and SKCI scenarios represent the required average compensation in Alberta and Saskatchewan, respectively. A producer in Alberta would require an average compensation of $647.44/acre/year and a producer in Saskatchewan would require $766.36/acre/year for restoring wetlands in cropland.

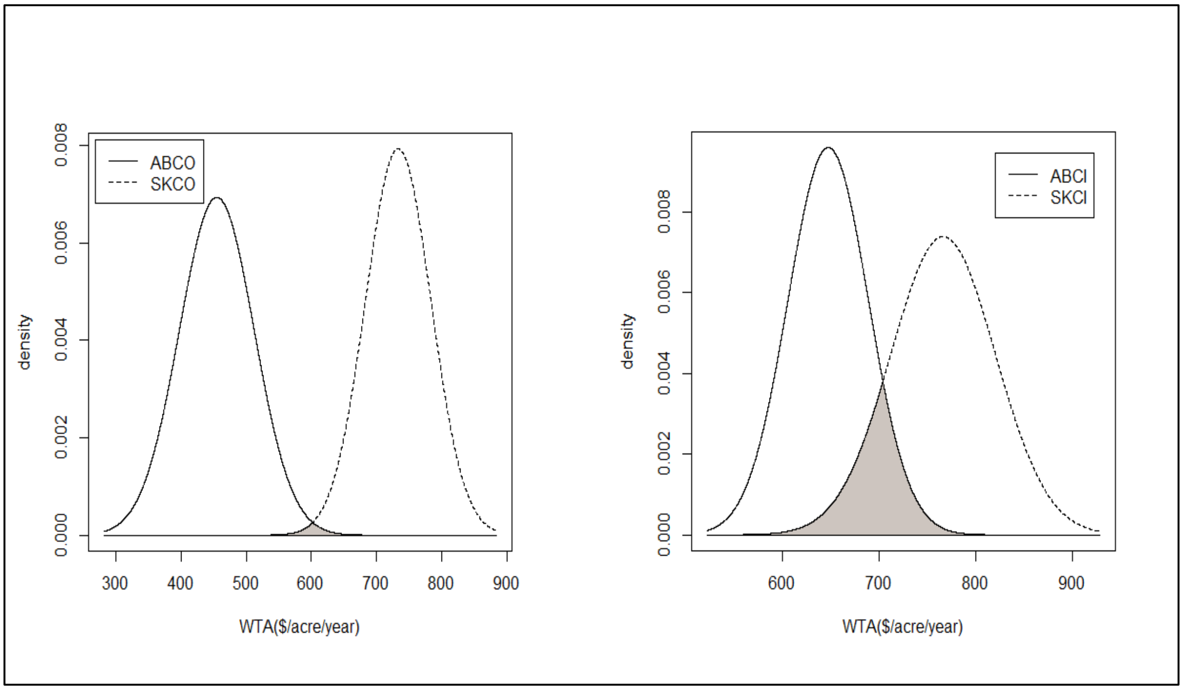

Figure 2-16: Comparisons of the Distributions of Own and Inferred WTA across Sites (ABCO: Alberta-Crop-Own scenario. SKCO: Saskatchewan-Crop-Own scenario. ABCI: Alberta-Crop-Inferred scenario. SKCI: Saskatchewan-Crop-Inferred)

In general, estimated WTA values are considerably less than the average farmland values in the study areas. It may be noted that farmland values are expressed in $/acre and elicited WTA values are in $/acre/year and, thus, they may not be directly comparable. However, estimated fair market values were used by Hill et al. (2011) to screen bids that were too high and would be more suitable for a "revolving purchase"[11] scheme. For a similar comparison, farmland values are obtained from FCC (2015) for the study site RMs for comparison with the WTA estimates. The mean farmland values in all three RMs in Alberta are higher than the mean farmland value in Moosomin (Table 2-14). However, it may be noted that for Moosomin, the land value summary is based on only four records available during the relevant period. FCC (2014) reported that Saskatchewan experienced the highest growth in average farmland values at 28.5% in 2013 and Alberta experienced an increase of 12.9%. It may be that growth of farmland values rather than the magnitude played a bigger role in a higher median WTA for the Saskatchewan sample.

[11] A revolving purchase conservation scheme refers to an alternative method of restoring wetland which involves outright purchase of land by the restoration agency. The land is resold in the market after wetland restoration is undertaken and a conservation easement is put in place (Hill et al., 2011; DUC, 2015).

Table 2-14: Farmland Values ($/acre)[a]

Study site	Rural municipality	Minimum	Mean	Maximum	Period
Alberta	Beaver	150.04	1694.65	3316.91	January-December 2013
Alberta	Vermilion River	1062.50	1799.55	3340.25	January-December 2013
Alberta	Wainwright	1792.45	1932.83	2107.32	April-November 2013
Saskatchewan	Moosomin	901.00	1263.00	1469.00	April 2013-April 2015

[a] : Source: FCC (2015).

It is possible that producers view the participation in the wetland restoration program as a rental arrangement. In the open-ended comments sought in the questionnaire about the program and producers' choices in the SP auction, one respondent indicated that he considered his chosen bids to be sufficient as they are at par with the rental values in the area. Another respondent indicated that he chose the higher bids as they are comparable with oil lease and wind turbine agreements. Therefore, the observed heterogeneity in bids may also be driven by the available substitute PES schemes in the area apart from the opportunity cost from agricultural production. A future study could further explore these aspects of anchoring of WTAs.

It is relevant to juxtapose the elicited WTA values with the findings of similar cost discovery studies, particularly those close to the study areas or in Canada. Hill et al. (2011) reported that in their reverse auction in the Assiniboine river watershed in Saskatchewan with two rounds, the range of submitted cropland bid value per acre per year in the second round was $619.2-$666.7 in 2009 dollars although none of the cropland bids were finally approved[12]. The range of all submitted cropland bids as received by Hill et al. (2011) was $83.33-$1000.00/acre/year in 2009 dollars ($91.58-$1099.06/acre/year in 2014 dollars).[13] Out of 17 cropland bids received by Hill et al., only three bids were at the maximum of $1099.06/acre/year (2014 dollars), with the rest being no greater than $734.74/acre/year (2014 dollars). Trenholm et al. (2013) found that farmers in the Credit River watershed in Ontario required an average compensation of $655.57/acre/year (2012 dollars, $677.64/acre/year in 2014 dollars) to restore wetlands on productive land. This is similar to the median WTA estimated in this study for

[12] Approved bids refer to successful bids that were selected after the second round in the reverse auction and that led to actual restoration.
[13] The authors permitted the use of first-round bids received by Hill et al. (2011) for comparison and validation of the findings of this study.

Alberta ($647.44/acre/year). The median WTA for Saskatchewan is approximately 4.39% higher than the highest revised bid received by Hill et al. (2011) after converting to 2014 dollars. Yu and Belcher (2011) found that the estimated WTA of landowners in Saskatchewan to adopt wetland and riparian conservation management in the Dark Brown and Black Brown soil zone for a 10-year contract period was $30.48/acre/year (2007 dollars, $34.96/acre/year in 2014 dollars). The estimates obtained in this study are considerably higher than the Yu and Belcher estimates although this is expected given the higher soil productivity and hence land values in the Black soil zone.

Hill et al. (2011) invited both cropland and forage bids and their approved forage bids ranged from $20.8-$391.2/acre/year ($22.86-$429.95/acre/year in 2014 dollars). The range of all submitted forage bids (approved and unapproved) in their study was $0-$386.64/acre/year ($0-$424.94/acre/year in 2014 dollars). Predicted pasture bids in this study obtained from the midpoint analyses range from $23.81 to $173.25/acre/year in Alberta and $88.75-$238.48/acre/year in Saskatchewan. The pasture bids obtained in this study provide a much tighter range compared to the bids received by Hill et al. (2011). The median WTA for pasture obtained from the pooled model was $103.05 per acre per year. The average compensation for restoration in marginal land elicited by Trenholm et al. (2013) was $171.86/acre/year ($177.65/acre/year in 2014 dollars).

One implication of the analysis in the current study is that it may be possible to obtain information on cost variability for adoption of the wetland restoration BMP observed by Hill et al. (2011) using a SP auction as a cheaper alternative to reverse auctions. It is also re-assuring to see that the median WTA values for cropland from the partial models corrected for social desirability bias roughly match the actual bids submitted in the reverse auction conducted by Hill et al. (2011). Even though the sample size was small, the respondents in this study spent a considerable amount of time discussing the details of the proposed wetland restoration scenarios as if they were real. This is most likely due to the fact that wetland restoration agencies such as Ducks Unlimited and Alternative Land Use Services (ALUS) are actively restoring wetlands in these areas and thus the designed scenarios seemed realistic and credible. The elicited range of farm-specific bids indicates the variability in costs of provision of the ES through wetland adoption and potentially allows a restoration agency to identify the low-cost suppliers of the service even without an EBI measure. For two out of three farms in this study that did not accept any bid for restoration in cropland, it was noted that their predicted WTA was higher than the highest bid offered. In the context of existing flat-rate policies for encouraging adoption of BMPs and the current low rate of uptake, this observed variability in cost may indicate that targeting low-cost suppliers of ES could improve the rate of adoption for these BMPs.

One of the main motivations for estimating the cost of wetland restoration BMP was to generate data for the proposed cost transfer analyses. The cost estimates generated by SP auction in this chapter also form a basis for comparison with the farm-specific estimates of opportunity cost of wetland restoration obtained using financial models of net cash flow. This is dealt with in the following chapter. The WTA estimates from the two study sites are also used to transfer the costs of BMP adoption across sites in Chapter 4.

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3 Estimation of Financial Opportunity Costs of Adopting Wetland Restoration BMP in Alberta and Saskatchewan

3.1 Introduction

An alternative approach to estimation of the impact of BMP adoption is to undertake farm-level financial analyses. The BMP of interest in this study (i.e., wetland restoration) involves setting aside productive agricultural land for production of non-market ES. This implies that producers adopting the BMP would have to forego potential revenue that they could otherwise earn from the acres now set aside as wetlands. The BMP adoption also affects cost of production. The wetlands in a field act as a “nuisance” to movement of farm machinery. This imposes additional costs on the producers in terms of inputs, time required to finish seeding and harvesting, and additional machinery repair costs. Together, the loss of revenue and the additional costs constitute the direct opportunity cost of the BMP. The impact of a BMP is not instantaneous and is spread over several years of farm operations. The opportunity cost accrued may be limited to the duration of the original contract period or may persist beyond the contract period. In a financial analysis of BMP adoption, the objective is to estimate the impact of BMP on the current and future cash flows of a farm.

The present chapter approaches the issue of estimating the costs of the wetland restoration from the financial analysis perspective. Farm-level opportunity costs of adoption of wetland restoration were calculated using a capital budgeting technique. The costs of wetland restoration were captured as the difference in cash flow and are analyzed in a net present value framework. Monte Carlo simulation methods were used to account for the risky nature of future crop yields and prices. The net present values (NPV) of cash flows of a farm with and without the BMP were compared to estimate the financial cost (FC) of wetland restoration.

Unlike previous studies that developed representative farm models to capture the costs of BMP adoption, this study undertakes a farm-specific approach. The primary data for farm operations captured in the farm-level survey were used in conjunction with secondary data on prices, historical yield and input costs to develop farm-specific models. Farm-specific information such as crop mix, area in agricultural production, yield and types of enterprises were combined with parameters that were assumed to be constant across farms in each study area such as prices and input costs. A notable aspect of developing such farm-specific models is that these models are based entirely on observable heterogeneity in farm operations and do not take into account any preference heterogeneity on the part of the producers.

The farm-specific nature of the simulation models allowed this study to capture variability in FC and estimate its distribution. In the previous chapter, the estimation of the costs of wetland restoration was explored from the perspective of welfare impact on agricultural producers. It is shown that even within the same conceptual framework of a random utility model, the estimates of WTA depend heavily on the various econometric specifications. The variability in WTA estimates is driven largely by how unobservable preference heterogeneity across the producers is modelled. The estimated FCs in this chapter allow for a comparison with elicited WTAs from the previous chapter.

While representative farm models exploring costs and benefits of agricultural BMPs have been developed by several previous studies for a multitude of BMPs, the studies used stylized data to create hypothetical farms. Jeffrey et al. (2014) summarized findings from three separate studies (Koeckhoven, 2008; Dollevoet, 2010; Trautman, 2012) that looked into the economics of adopting agricultural BMPs for protecting riparian areas in Alberta and Saskatchewan. While the representative farm simulation models are carefully developed to represent farming parameters for a typical farm in the study areas, none of the previous studies used actual farm-level data. The focus of the previous BMP impact studies was on obtaining the central tendencies of the costs or benefits of BMP adoption. The current study incorporated actual farm-specific information and developed a cost distribution that is comparable with the WTA distribution obtained in the previous chapter. This has not been attempted in the previous studies.

Given the conceptual difference between the SP study and FC simulations, it is interesting to observe the magnitude of the difference between these two estimates of cost for each farm. The author is not aware of any previous studies that attempted to compare WTA with a farm-level ‘revealed” cost of BMP adoption. The relationship of these estimated FCs and WTAs were used in an illustration of cost calibration approach explored in the following chapter.

This chapter used dynamic farm-level cash flow simulation models to identify the average farm-specific FCs of adopting wetland restoration BMP. The distributions of farm-specific FCs were used to quantify the heterogeneity in the cost of ES provision through wetland restoration within and between samples without accounting for producers’ preference heterogeneity. The FCs were estimated in order to compare to the elicited WTAs discussed in the previous chapter and investigate the relationship between these two cost estimates. The FCs were used to complement the WTAs from the previous chapter to conduct and validate a spatial cost transfer.

3.2 General Methodological Approach

This section discusses the general methodological approach used in this analysis as a precursor to the description of elements of the empirical models.

3.2.1 Capital Budgeting- Net Present Value Analysis

Capital budgeting technique can be used to measure the impact of a project on the wealth of a farm. As the decision to adopt a BMP entails an impact on the farm income and hence wealth over a period of time, capital budgeting is deemed as an appropriate technique to determine the financial viability of BMP adoption. Net present value (NPV) analysis is a type of capital budgeting technique[14] that can be used to capture the impact of a BMP on current and future cash flows for a farm. Bertolini and Viaggi (2012) employed NPV analyses to estimate the impact of delaying investment in methane digester technology on Italian farmers. Floridi et al. (2013) used NPV of future cash flow of a dynamic farm-household model to assess the impact of various levels of subsidies on adoption of automated milking system in dairy farms in the Netherlands.

The NPV of a stream of cash flow is defined as the present value of the future cash flows net of the cost of investment. The future cash flows are discounted by the opportunity cost of capital to obtain the present value. The time preference of a farm is captured in the opportunity cost of capital or the discount rate used to obtain the present value. The discount rate quantifies the marginal rate of substitution between current and future cash flows. The NPV is calculated according to the following equation:

[14] Details on various other types of capital budgeting techniques such as internal rate of return (IRR), accounting rate of return (ARR) and payback period (PP), and the advantage of using NPV over these are available in Copeland et al (2005) and were also discussed by previous representative farm simulation studies such as Cortus (2005) and Trautman (2012).

$$NPV = \sum_{t=0}^{N} \frac{(Cash flow)_t}{(1+r)^t} - I_0 \qquad 3\text{-}1$$

where *Cashflow* is net cash flow, *r* is the discount rate, I_0 is the initial investment or cash expenditure and *t* is time.

The farms receive variable income from multiple sources including the crop and/or cow-calf enterprises as well as from business risk management(BRM) programs. The BMP adoption is not likely to impact the capital structure of the farm but it would affect the revenues and costs associated with the enterprises in farm production. A Modified Net Cash Flow (MNCF) approach was undertaken to model the net cash flow from the multiple enterprises following the approach previously undertaken in studies, such as, Koeckhoven (2008) and Xie (2014). This MNCF approach accounts for the net cash flows from each farm enterprise but does not include fixed costs or payment of debt principal (Koeckhoven, 2008).

The 12-year simulation period chosen in this study is the same as the contract length specified in the SP auction described in the previous chapter. This was to allow the comparability of the findings from the welfare impact analyses and the financial opportunity costs. Assuming that the sample farms would continue production beyond the 12-year simulation period and the restored wetlands would not be drained after the contract period is over, it was necessary to develop a cash flow that would continue indefinitely beyond the simulation period.[15] This was done by calculating the NPV in perpetuity according to the following equation:

$$NPV_{Perpetuity} = \sum_{t=0}^{12} \frac{(Cash flow)_t}{(1+r)^t} + \frac{(Cashflow)_{12}}{r} * \frac{1}{(1+r)^{12}} \qquad 3\text{-}2$$

[15] The WTA values estimated in the previous chapter were based on a 12-year contract period. The preference elicitation design itself did not specify whether the producers would leave the restored wetland in place or drain it again. However, draining a wetland at the end of the specified 12-year contract period would mean that the producers would have to incur extra drainage costs. The value of the restoration would also be lost. For the purposes of FC analysis it was assumed that the restored wetland would persist beyond the contract length (i.e., the perpetuity calculation for the NPV). If the survey respondents assumed that they would re-drain the wetlands at the end of the contract period, this may lead to inconsistencies when comparing WTA and FC estimates..

For comparison of the opportunity costs across farms and also with the SP compensation estimates, the NPV in perpetuity was converted into an annualized value. The annualized NPV in perpetuity (A) was calculated using the following formula:

$$A = NPV_{Perpetuity} * r \qquad 3\text{-}3$$

3.2.2 Discount Rate

The impact of the BMP in future time periods is uncertain to a price-taker producer due to yield and price variability and hence the BMP adoption can be treated as a decision involving risk. While the WTA estimation analyses in the previous chapter treat subjective risk preference as inherent in the stated choice of the respondent, the NPV analysis treats the risk preference directly by assuming a suitable discount rate. However, it may be noted that selecting a single discount rate for all farms in the cash flow analyses imposes the restriction that producers have identical risk preferences when presented with the choice of adopting wetland restoration on their land. This simplifying assumption may prove to be a limitation in capturing the full extent of farm-level variability in financial opportunity costs of wetland restoration. However, in inter-temporal welfare analysis, the standard practice is to assume that the discount rates are the same across households and across time. Previous representative farm cash flow simulation studies used a discount rate of 10% (e.g. Trautman, 2012; Xie, 2014). This study used the same discount rate of 10% for all farms in the sample.

3.2.3 Simulation Model

In order to capture the uncertainty in cash flow of a farm that is attributable to the stochastic nature of yield and prices in future time periods, a Monte Carlo simulation model was employed. Monte Carlo simulation employs repetitive random sampling of values for stochastic variables from pre-defined distributions to compute outcomes that would depend on the stochastic variables. The @RISK 6 add-in program (Palisade Corporation, 2013) for Microsoft Excel was used to develop the simulation model.

For each random draw of the stochastic variables, the model is recalculated to generate the outcome. Since multiple draws of the stochastic variables are used, Monte Carlo simulation generates a distribution of outcomes that depend on the sets of random draws or iterations of the stochastic inputs. In this study, the NPV of a farm's cash flow was defined as a model outcome. Accuracy of the distribution of model outcome increases with the number of iterations. Without conducting a test of accuracy based on number of iterations, 5000 iterations were used in this study [16]. Prices and yields of crops and forages were defined as stochastic inputs. The stochastic price and yield models are explained in detail in section 3.3.3.

It may be noted that while prices were modelled as stochastic, farms from the same province were assumed to face the same stochastic prices for crops and forages. Given that there are 15 farms in the Alberta sample and 13 farms in the Saskatchewan sample, a total of 28 farm-specific simulation models were developed. In order to be able to compare opportunity costs of wetland restoration across farms in a particular sample and to maintain the condition that the farms from a particular province would face the same prices, it was necessary that the 15 farm simulation models in Alberta and 13 models in Saskatchewan were run simultaneously. This was done in @RISK using the RiskSimTable function.

3.2.4 Assessment of BMP

For each farm, a baseline model was calculated that generated the distribution of NPV in absence of the wetland restoration BMP. The scenario model generated the distribution of NPV when the wetland restoration BMP is adopted by the farm. Once the annualized NPVs were obtained for the baseline and the scenario models, the difference between these was calculated for each farm to obtain the impact of BMP adoption ($/year). The farm-level total cost of BMP adoption was then divided by the number of acres of wetland to obtain the opportunity cost of restoring wetlands ($/acre/year). This figure was used as an estimate of the FC of wetland restoration.

[16] The underlying sampling method for this simulation study was Latin Hypercube which requires a smaller number of iterations than the alternative Monte Carlo sampling method. For a Monte Carlo sampling method, at least 440 iterations are deemed required in general (Palisade Corporation, 2015). Hence, 5000 iterations in a Latin Hypercube sampling method were deemed sufficient and further tests of accuracy were not conducted.

3.3 Empirical Model

Each farm's cash flow model was developed using the primary data about farm operations obtained through the farm-level survey, and secondary data from various sources. As reported in the previous chapter, a sample of 29 producers in three rural municipalities in Alberta and one rural municipality in Saskatchewan were surveyed and data from 28 of these producers could be used for the FC estimation. Details of the survey implementation are provided in Appendix A2. Farm-level data were gathered on farm size, area allocated to cropping and pasture, types of crops grown in 2013 and corresponding yields, crop rotation, fertilizer and chemical costs, number of livestock and number of days of grazing and feeding. The collected data were complemented with data from secondary sources for crop and forage prices, detailed input costs and details on the cow-calf enterprise. The main components of the cash flow model are revenue and cost calculations which depend on the area allocated to cropping enterprise, types of crops grown, corresponding prices and yields, costs of production, livestock herd size and participation in public BRM programs. Each of these components is discussed in this section as a description of the model-building process with additional relevant details discussed in the associated appendices.

3.3.1 Crop and Forage Production

3.3.1.1 Size of Operations and Crop Acreage

Size of operations is a crucial factor in farm variability as differently-sized operations would vary in terms of machinery complements, time taken for field operations and input costs. The respondent farms have considerable variation in total size and crops produced as well as the size of land that they own and rent. Farms were asked to describe the details of their cropping operations based on the land that they own. However, this later proved to be a flaw in the phrasing of the question as the machinery complements and the crop rotations for any farm would be based on the total area operated (i.e., including rented land) and not just the area that they own.

Upon analyzing the responses about farming operation details it was noted that about 50% of the respondents based their detailed answers on the total farm size and not just the size of owned land. This group of respondents consists of the larger farms - the average size of the second group (total size based responses) is 30 quarter sections compared to an overall average of 17 quarter sections for the entire sample. A possible explanation of why these farms answered the cropping operations questions based on total size is that these are large operations and it was difficult for the respondents to separately describe cropping practices for land that they own versus rent.

This posed an issue of how crop production and associated costs and returns would be modelled for the two groups. For example, the machinery complement should be based on the total size of the operation. As a result, it was decided to adjust the crop and pasture acreage details for the farms that did not report the usage information for rented land, so that these two groups of responses could be treated comparably. It was also noted that some farms did not report any production of tame hay in 2013 in their crop enterprise details although they indicated acreage allocated to hay. For a few farms, the sum of the reported crop acreage was more than the total farm size or the sum of crop, pasture and non-agricultural land did not add up to the total farm size. Given these issues with the raw data, it was decided to adjust the allocation of land for relevant farms among annual crops, hay, summer-fallow (when applicable), pasture and non-agricultural usage. For this purpose, the data on total farm size, suitability percentages for cropping, pasture and non-agricultural usage, and type of enterprise and livestock data were used on a case-by-case basis to obtain the adjusted allocation of total farm acreage for cropping, pasture and non-agricultural usage. For the farms with an aggregation error in the crop and pasture acreage allocation or no pasture and livestock, a case-by-case ad hoc correction was undertaken. Once the allocation between crop, pasture and non-agricultural land was adjusted, the adjusted crop area needed to be allocated among the annual crops and tame hay grown by the farms. For each farm requiring this adjustment, the excess crop acreage was distributed among annual crops in the exact proportion of the originally reported annual crop acreage. The farm-specific adjustments in acreage are detailed in Appendix E (Table E1 through Table E4). The final allocations after the adjustments are reported in Table E5 and Table E6.[17]

[17] For the purposes of the simulation analysis it is assumed that the area to be restored to wetland has been capable of producing a crop each year since originally being drained; that is, there is no risk of natural events (e.g., flooding) causing a loss of productive area.

3.3.1.2 Crop Rotations

Crop rotation refers to growing a specific crop from a rotation cycle in a specific year on each field. Crop rotations are used by farms to optimize water and nutrient usage, minimize risks of diseases, manage weeds and maximize the rate of return from crop production (SAF, 2005). SAF (2005) noted that although the term “crop rotation” is familiar to the producers, in practice they often refer to the sequence of crops grown from year to year. The farms were asked to indicate what the long term rotation was on their "best field". Upon analyzing the responses it was noted that the long term rotations seemed considerably different from the mix of crops grown in 2013 for many of the respondents. It was noted that some of the reported long term rotations might not be viable as they might increase the risk of diseases (Saskatchewan Agriculture, 2015; AARD, 1999). It was decided to take the crop mix grown by the producers in 2013 as the crop rotation used to model the cash-flow analyses. Also, it was noted that while the 2013 crop mix itself may not be viable as a long run crop rotation, it may be likely that the respondents would anchor their responses to the WTA questions based on the crops produced and cash flow for 2013. The crop rotation for each farm based on their 2013 production is summarized in Appendix F.

Note that this approach is different from how crop rotation is typically determined for a representative farm analysis (e.g., Trautman, 2012; Xie, 2014). In a representative farm analysis the crop rotation is based on desirable agronomic practices, representativeness of the rotation practice followed in the study area and given sales revenue objective. It was assumed that the allocated area for each crop would remain unchanged over the simulation period while the farms would internally conduct rotations across specific fields.

3.3.1.3 Forage Production

Production of tame hay was assumed to be a part of the cropping operation and crop rotation. This has been done previously by Dollevoet (2010) and Koeckhoven (2008) in the course of modelling a representative mixed cropping and beef farm. In this study it was assumed that for the farms that indicated to have area allocated to hay, the forage stand is established in the first year and followed by seven years of alfalfa-grass mix growth. After the eighth year, the field is utilized for annual crop production. To incorporate this in the simulation model it was assumed that at any time 7/8th of the area under hay was generating revenue and the rest was in establishment. Note that while in reality the yield from a forage stand would depend on the age of the stand (Leyshon et al., 1981), in this study it was assumed that the hay yield followed the stochastic yield pattern and the dependency on the age of the stand was therefore not modelled explicitly. This is because at any point each farm might have alfalfa-hay stands of various ages which would cause yield to average out over the entire area and hence, the assumption of an average hay yield at a particular time seemed justified.

3.3.1.4 Livestock Production and Pasture

3.3.1.4.1 Livestock Production

The sampled farms indicated if a livestock enterprise was a part of their farm operations. Production of livestock in a cow-calf or mixed operation was assumed to be deterministic in this study. For each farm, the total number of livestock, number of grazing days and the number of feeding days, were obtained from the survey. For each farm, the total number of livestock was converted into the animal unit equivalent (AUE) referred to hereafter as herd size. An animal unit is defined as 1000 pounds of beef cow with or without a calf. The AUE for a beef-cow is 1.0, that of a bull is 1.3 and AUE of a yearling heifer or steer is 0.67. In the present study it was assumed that the herd size of 2013 was the steady state herd size and hence stayed constant throughout the simulation period.

The cow-calf production cycle was discussed in detail by Koeckhoven (2008) and Dollevoet (2010) for a stochastic model that linked forage availability with calf weaning weight and the number of weaned calves. It was assumed in this study that the pasture and forage availability does not impact the weaning weight of the calves.

The parameters of the cow-calf production model (i.e., conception rate, calving rate, weaning rate, culling rate and death loss), and the average income from sales of weaned calves were obtained from the AgriProfit$ Cost and Returns Report (AARD, 2012-a). The cow-calf production parameters for the Saskatchewan farms were taken from Dollevoet (2010). The weaning weight and the average income from sale of weaned calves for Saskatchewan were obtained from the Western Beef Development Corporation (WBDC, 2013). The cow-calf production parameters are summarized in Table G1 and Table G2 and the steady state herd size is reported in Table G3 in Appendix G.

3.3.1.4.2 Pasture Rental

For the farms that reported pasture land but no livestock, it was assumed that pasture land is rented out by these farms. The pasture land rental rates for Alberta was obtained from the provincial Pasture Lease and Rental Survey (AARD, 2013-a). Since a pasture lease agreement in the study site was not available, the nearest location and soil type match were used. For a 4.5 months (135 days) season in the thin Black soil region in Minburn, an adjacent RM, a verbal contract for grazing 80 cows with calves for $6000 was reported in the rental survey of 2013. This implied an average pasture rental rate of $0.5556 per animal per grazing day in the study area in Alberta.

The pastureland rental rate for the Southeast Saskatchewan (CD 1 and 2) for arms-length agreements is obtained from Saskatchewan Agriculture (2013-a). The pasture cash rental rate for this region was $0.6759 per animal per grazing day for an average season of 135 days for grazing cows with calves.

Pasture capacity (in AU) was determined for farms with no livestock following the procedure described in Appendix A assuming the stocking rate for tame-seeded pasture to be 1.3 AUM and that for natural pasture to be 0.65 AUM. This was multiplied by the number of grazing days assumed for an average season and the cash rental rate ($/AU/day) to obtain the total cash rental amount for the season.

3.3.2 Machinery Complements

Cortus (2005), Trautman (2012) and Koeckhoven (2008) provided detailed discussions about developing machinery complements (MC) for representative farm simulation analyses. MC is an important component in modelling the cash flow of an actual farm or a representative farm. The specific MC determines variable machinery cost and impacts cash flow through machinery replacement costs, fuel use and machinery repair. MC depends on the soil zone, farm size, crops produced and type of enterprise. Past studies have built MCs for representative farms in specific soil zones by invoking assumptions about soil characteristics, annual hours of use for each piece of machinery and time available for cropping operations, such as, tilling, seeding and harvesting. In reality, the replacement of farm machinery for commercial farms depends on economic feasibility and hence modelling the exact replacement schedule in a simulation analyses is difficult. However, if machinery replacement is not done regularly to maintain the asset base, farming operations might be impacted given the time-sensitive nature of the cropping operations that require specific machinery. Previous representative farm simulation studies, therefore, designed MC by identifying the types and size of machinery required for cropping operations and determined a constant annual cost that would be incurred by the farm to maintain the initial asset value of the MC throughout the simulation period.

In the present study, the constant yearly machinery replacement cost has been determined on the basis of the farm operations and the machinery complements developed by the previous studies (Koeckhoven, 2008; Dollevoet, 2010; and Trautman, 2012). Machinery complements for annual crop production, forage production and cow-calf operation were considered in the present study.

3.3.2.1 Machinery Complement for Crop and Forage Production

Trautman (2012) developed MC for a representative 2560 acres farm in the Black soil zone of Alberta. Assuming market values for the machinery required for cropping operations of this representative farm and assuming average machinery age of five years, Trautman calculated the initial book value of the MC. Multiplying the initial book value by a depreciation rate of 8%, the machinery replacement cost per year was calculated. This was further divided by the farm acreage to obtain the machinery replacement cost per acre per year. Total annual machinery replacement cost, as developed by Trautman (2012) in the Black soil zone for a farm that grows barley, canola and spring wheat, was $21.86 per acre. In the present study, this has been assumed to be the machinery replacement cost for the crop component of a farm's enterprise irrespective of the annual crops grown except for Farm 13[18].

[18] It was noted after the development and estimation of the full simulation model for Alberta that assuming the $21.86 per acre per year machinery replacement cost for the crop enterprise led to estimation of negative baseline scenario NPV values for the Farm 13. As Farm 13 indicated that its main enterprise is cow-calf production with barley as the only annual crop grown, it was decided that the annual machinery replacement cost for the crop enterprise for this farm needed to be scaled down. The scaling factor used was equal to the percentage of annual

As the MC developed by Trautman for the Black soil zone did not include any machinery for forage production, a basic machinery complement for forage production was assumed in this study based on Jeffrey et al. (2013). The MC for forage production used in this study is presented in Table H1 in Appendix H.

The new machinery values were taken from the Farm Machinery Custom and Rental Rate Guide of Saskatchewan Agriculture (2014-a) and the machinery was depreciated to five years of age. The machinery replacement cost per acre per year was obtained by following the procedure of multiplying the depreciation rate and dividing by the total area under agricultural use for each farm. Given that the same forage machinery complement was used for all farms, this introduced significant variability in the annual forage machinery replacement cost. The forage machinery replacement cost for the farms that produced alfalfa hay and were assumed to own the machinery, ranged from $1.33 per acre per year to $27.57 per acre per year in Alberta and $1.95 per acre per year to $15.80 per acre per year in Saskatchewan.

It was noted that for some farms, area under hay production was probably too low to justify investment in ownership of high valued forage machinery. An alternative estimation was conducted using the custom rates for a self-propelled mower-conditioner and hay rake along with the annual replacement cost for a five-year-old baler owned by the farms. A comparison of the forage machinery replacement costs between full ownership and custom rental revealed that, while for bigger farms the difference between these costs were marginal, for smaller farms the difference was more pronounced (Table H2 and Table H3 in Appendix H). The minimum of the two estimates was used in this analysis.

3.3.2.2 Machinery Complement for Cow-Calf Production

Given that some of the farms in this study were primarily cow-calf operations or mixed enterprises, cow-calf MC was adapted from Koeckhoven (2008) and Dollevoet (2010) for two sizes of operations based on size of herd maintained by the farms. Dollevoet (2010) developed a cow-calf/mixed MC for a representative farm in the Lower Souris region with 116 Animal Units.

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crop acreage, i.e. barley acreage, in the total area under agricultural usage. The acreage under barley was 7.88% of the total agricultural area of the farm and hence, 7.88 was used as the scaling factor.

Koeckhoven (2008) developed MC for a mixed farm in Southern Alberta with 464 Animal Units. The cow-calf MCs developed by these two studies were considerably different.

In this study, eight farms have more than 116 Animal Units and seven farms have less than 116 Animals as their steady state herd size. Two different MCs for cow-calf operations were adapted from Koeckhoven (2008) and Dollevoet (2010) for farms with more than 116 AU and less than 116 AU respectively. These are reported in Table H4 and Table H5 in Appendix H. It was also noted that cow-calf machinery often overlaps with crop and forage machinery.

It was assumed that a farm with less than 116 animals would have a livestock trailer and machinery for the crop and/or forage components of the enterprise. For a farm with larger herd size more specific machinery was assumed, based on the MC developed by Koeckhoven (2008). The cow-calf machinery replacement cost per acre per year was calculated following the procedure described above. The cow-calf machinery replacement cost ranged from $0.21 per acre per year to $3.09 per acre per year in Alberta. For the Saskatchewan farms the cost ranged from $0.24 to $2.10 per acre per year.

3.3.2.3 Total Machinery Replacement Costs

Once the individual annual replacement costs were determined for each enterprise component for each farm, these were summed to obtain the total machinery replacement cost per acre per year. The farm-specific machinery replacement costs are given in Table H6 and Table H7 in Appendix H. The cash outflow for each farm per year was obtained by multiplying the total annual machinery replacement cost per acre per year with the total area under agricultural usage. Ideally MC for crop and forage would be developed individually for each farm in the simulation analyses in this study, given the variation in acreage and types of enterprise. Developing the MC is a detailed step for even a representative farm study and, as past studies have documented, it requires expert consultation and opinion of farmers to determine if certain machineries would actually be owned by a farm. However, for the purposes of the present analyses it was deemed acceptable to skip the rigorous and detailed development of this component of the simulation model.

3.3.3 Stochastic Model Elements

3.3.3.1 Estimation of the Stochastic Price Models

Stochastic price models are developed for the farms using provincial historical price data obtained from various sources. Detailed information on price data sources is provided in Appendix I1.

3.3.3.1.1 Tests for Stationarity of Prices

In order to develop the stochastic price models the data were first tested for stationarity to see if the means and variances of each price series were finite. Without stationarity, a price shock due to a policy change would be permanent and thus modelling current prices on lagged values would not be accurate. Three tests of stationarity for the presence of a unit root were undertaken using Limdep 10.0. These are Phillips-Perron test, augmented Dickie-Fuller (ADF) test and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) (Greene, 2007).

Metes (2005) noted that Phillips-Perron test is non-parametric, allows for serial correlation and heteroskedasticity, and does not require a lag length specification. Three specifications were used in the derivation of Phillips-Perron test statistics; no constant term (case 1), with constant term (case 2), and with constant term and time trend (case 4) with two lags. The results are reported in Table I1 in Appendix I. The null hypothesis of nonstationarity could be rejected for all cases at 1% level for all the crop prices except for peas in Saskatchewan.

The ADF test for the random walk with drift and the trend stationary models (Table I2 in Appendix I) indicated that while the simple random walk model may be inadequate, the random walk with drift and the trend stationary models perform better. In the random walk with drift model the hypothesis of the presence of a unit root could be rejected at 1% level for prices of wheat, oats, barley, canola and flaxseeds and at 5% for tame hay for both study areas, thus indicating stationarity. For price of field peas in Saskatchewan, the unit root hypothesis could not be rejected in any of the random walk with drift models. With the trend stationary model that involves both a constant and a time trend, the hypothesis of the presence of a unit root could be rejected for all the crops in Alberta and all except peas in Saskatchewan.

Based on the results of the Phillips-Perron test and the trend stationary specification of the ADF test, the crop and forage prices in Alberta and Saskatchewan are assumed to be stationary. Trautman (2012) discussed the issues of the weakness of ADF test of unit root and used the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test as an additional stronger test with the null hypothesis of stationarity. The KPSS test complements Phillips-Perron test and the ADF test as it implements the null hypothesis that data are stationary. For the crop and forage prices in Alberta and Saskatchewan, the KPSS test was conducted in Stata 10 using maximum lag length of two and quadratic spectral kernel. The test results are provided in Table I3 in Appendix I. For Alberta, stationarity of flaxseeds and peas prices was rejected by the KPSS test at 10% and 5% levels of significance, respectively. For Saskatchewan, the stationarity of the prices of flaxseeds was rejected at 5% and that of pea prices was rejected at 10% level of significance.

Despite the conflict between ADF test results and KPSS test results for select crops, stationarity of prices was assumed for the following reasons. First, the null hypothesis of KPSS for flaxseeds and peas was not rejected at higher levels of significance. Secondly, it is possible to have the KPSS test reject stationarity even when the data are stationary (Hobjin, Franses and Ooms, 2004). Thirdly, it is difficult to identify a nonstationary process with a small dataset such as the one used in this study (Dixit and Pindyck, 1994). Based on these arguments, it was decided to treat all the relevant price series in this study as stationary.

3.3.3.1.2 Determination of Optimal Lag Length

To determine the optimal number of lags for each price equation that would be used as a component of the stationary price model, each price variable was regressed on own lagged values in Limdep 10.0. As recommended in Greene (2007) the search for optimal lag length should move down to the correct value rather than up. Using this general-to-simple approach (Greene, 2007 p 676), for each price variable, OLS regressions were run using six through one lagged values and the corresponding Akaike Information Criterion (AIC) and Schwarz's Criterion (SC) were compared[19].

Based on the AIC and SC values (Table I4 and Table I5 in Appendix I), wheat and barley price equations for Alberta should optimally use two lags, flax and canola should use three lags

[19] The AIC and SC values were calculated using Equations 20-9 and 20-10 (Greene, 2007 p 677).

and the rest of the crops should use one lag. For the Alberta prices, both the AIC and SC values generate the same optimal number of lags. However, that is not the case for the Saskatchewan prices. For Saskatchewan, both the AIC and SC values indicate that the optimal number of lags for wheat and tame hay is one and that for oat and barley is two. However, for flax, canola and soybean, the SC values suggest optimum lag length of two while AIC values suggest optimal lag length of six, six and five, respectively. Also, for pea prices, both AIC and SC values suggest a lag length of six. Greene (2007) noted that AIC is likely to lead to over-fitting with an increase in lag length while SC is likely to under-fit. Given that the time series of price data spans only 30 years, it was decided to use a lag length of two for the price equations of flax, canola and soybean in Saskatchewan. As the time series for pea prices is even shorter, a lag length of three is used for the Saskatchewan peas price equation.

The stationary price equations are estimated by regressing current prices on lagged values according to the optimal lag lengths. The price equations are given in Equations 3-4 and 3-5 below:

$$\left.\begin{aligned}
P_t^{SW,AB} &= \gamma_0^{SW,AB} + \gamma_1^{SW,AB} P_{t-1}^{CWRS,AB} + \gamma_2^{SW,AB} . P_{t-2}^{SW,AB} + \varepsilon_{SW.t}^{AB} \\
P_t^{OAT,AB} &= \gamma_0^{OAT,AB} + \gamma_1^{OAT,AB} P_{t-1}^{OAT,AB} + \varepsilon_{OAT,t}^{AB} \\
P_t^{FLX,AB} &= \gamma_0^{FLX,AB} + \gamma_1^{FLX,AB} P_{t-1}^{FLX,AB} + \gamma_2^{FLX,AB} P_{t-2}^{FLX,AB} + \gamma_3^{FLX,AB} P_{t-3}^{FLX,AB} + \varepsilon_{FLX,t}^{AB} \\
P_t^{BAR,AB} &= \gamma_0^{BAR,AB} + \gamma_1^{BAR,AB} P_{t-1}^{BAR,AB} + \gamma_2^{BAR,AB} P_{t-2}^{BAR,AB} + \varepsilon_{BAR,t}^{AB} \\
P_t^{CA,AB} &= \gamma_0^{CA,AB} + \gamma_1^{CA,AB} P_{t-1}^{CA,AB} + \gamma_2^{CA,AB} P_{t-2}^{CA,AB} + \gamma_3^{CA,AB} P_{t-3}^{CA,AB} + \varepsilon_{CA,t}^{AB} \\
P_t^{PEA,AB} &= \gamma_0^{PEA,AB} + \gamma_1^{PEA,AB} P_{t-1}^{PEA,AB} + \varepsilon_{PEA,t}^{AB} \\
P_t^{HAY,AB} &= \gamma_0^{HAY,AB} + \gamma_1^{HAY,AB} P_{t-1}^{HAY,AB} + \varepsilon_{HAY,t}^{AB}
\end{aligned}\right\} \qquad 3\text{-}4$$

$$
\left.
\begin{aligned}
P_t^{SW,SK} &= \gamma_0^{SW,SK} + \gamma_1^{SW,SK} P_{t-1}^{SW,SK} + \varepsilon_{SW,t}^{SK} \\
P_t^{OAT,SK} &= \gamma_0^{OAT,SK} + \gamma_1^{OAT,SK} P_{t-1}^{OAT,SK} + \gamma_2^{OAT,SK} P_{t-2}^{OAT,SK} + \varepsilon_{OAT,t}^{SK} \\
P_t^{FLX,SK} &= \gamma_0^{FLX,SK} + \gamma_1^{FLX,SK} P_{t-1}^{FLX,SK} + \gamma_2^{FLX,SK} P_{t-2}^{FLX,SK} + \varepsilon_{FLX,t}^{SK} \\
P_t^{BAR,SK} &= \gamma_0^{BAR,SK} + \gamma_1^{BAR,SK} P_{t-1}^{BAR,SK} + \gamma_2^{BAR,SK} P_{t-2}^{BAR,SK} + \varepsilon_{BAR,t}^{SK} \\
P_t^{CA,SK} &= \gamma_0^{CA,SK} + \gamma_1^{CA,SK} P_{t-1}^{CA,SK} + \gamma_2^{CA,SK} P_{t-2}^{CA,SK} + \varepsilon_{CA,t}^{SK} \\
P_t^{PEA,SK} &= \gamma_0^{PEA,SK} + \gamma_1^{PEA,SK} P_{t-1}^{PEA,SK} + \gamma_2^{PEA,SK} P_{t-2}^{PEA,SK} + \gamma_3^{PEA,SK} P_{t-3}^{PEA,SK} + \varepsilon_{PEA,t}^{SK} \\
P_t^{HAY,SK} &= \gamma_0^{HAY,SK} + \gamma_1^{HAY,SK} P_{t-1}^{HAY,SK} + \varepsilon_{HAY,t}^{SK} \\
P_t^{SOY,SK} &= \gamma_0^{SOY,SK} + \gamma_1^{SOY,SK} P_{t-1}^{SOY,SK} + \gamma_1^{SOY,SK} P_{t-2}^{SOY,SK} + \varepsilon_{SOY,t}^{SK}
\end{aligned}
\right\} \qquad 3\text{-}5
$$

3.3.3.1.3 Incorporation of Stochastic Prices in the Simulation

The seemingly unrelated regression (SUR) model results for Alberta prices are presented in Table 3-1. Except for canola the constant terms were significant at 1% level. The first-lag price coefficients were significant at 1% or 5% level. Among the second-lagged prices, those for canola and flaxseeds were significant at 1% level. The third-lagged prices were also significant. The individual model R-squared values of goodness-of-fit were low and ranged from 0.0128 to 0.6248. However, the value of Breusch-Pagan chi-square test statistic of independence was 117.088, indicating high error correlation and that seemingly unrelated regression equations (SURE) was an appropriate model for prediction of prices. Table 3-2 presents the calculated SUR correlations between the prices for Alberta.

Table 3-1: Estimated Coefficients of SURE Price Model - Alberta[a]

	Spring wheat		Barley		Canola		Oats		Peas		Flax		Hay	
Lag 1	0.4639	***	0.2757	**	0.9861	***	0.2503		0.7549	***	0.5436	***	0.6522	***
	(0.1501)		(0.1311)		(0.1381)		(0.1605)		(0.1005)		(0.1300)		(0.1171)	
Lag 2	-0.1084		-0.1308		-0.6336	***					-0.4928	***		
	(0.1432)		(0.1137)		(0.1555)						(0.1295)			
Lag 3					0.3786	***					0.2250	*		
					(0.1179)						(0.1276)			
Constant	167.8429	***	143.9557	***	133.0535	**	128.6801	***	71.6069	***	314.2067	***	46.1710	***
	(45.0054)		(25.6784)		(65.6874)		(28.3413)		(28.1036)		(80.6227)		(14.6702)	
R-squared	0.1672		0.1853		0.5519		0.0128		0.6248		0.4108		0.5143	

[a]: Standard errors in parentheses under estimated coefficients. ***: Significant at 1% level. **: Significant at 5% level. *: Significant at 10% level.

Table 3-2: Correlations between SURE Price Equations - Alberta

	Spring wheat	Barley	Canola	Oats	Peas	Flax	Hay
Spring wheat	1						
Barley	0.7258	1					
Canola	0.3889	0.4503	1				
Oats	0.5225	0.6319	0.2998	1			
Peas	0.3188	0.4876	0.5225	0.3283	1		
Flax	0.3330	0.5618	0.5763	0.3500	0.6483	1	
Hay	0.1670	0.1874	0.5824	0.2597	0.2953	0.3395	1

All first-lag prices were significant for the Saskatchewan price series. Except for the second-lag price for flax, the second-lagged prices were also significant. The constant terms were significant at 1% or 5% level in all cases. Individual R-squared of the price models ranged from 0.047 to 0.526 (Table 3-3). The Breusch-Pagan chi-square test statistic was 93.974 indicating that SURE model was a better model in terms of robustness of coefficients and estimator of error terms than the individual price equations. Correlations between the prices in Saskatchewan are given in Table 3-4.

Table 3-3: Estimated Coefficients of SURE Price Model - Saskatchewan[a]

	Spring wheat		Barley		Canola		Oats		Peas		Flax		Hay		Soybean	
Lag 1	0.3027	**	0.3030	***	0.7339	***	0.3134	***	0.7767	***	0.2484	*	0.6174	***	0.6626	***
	(0.1345)		(0.1073)		(0.1303)		(0.1201)		(0.1640)		(0.1479)		(0.1710)		(0.1526)	
Lag 2			-0.3294	***	-0.2906	***	-0.5723	***	-0.6207	***	-0.1512				-0.2520	*
			(0.0865)		(0.1157)		(0.1191)		(0.1727)		(0.1444)				(0.1452)	
Lag 3									0.1809							
									(0.1398)							
Constant	147.7735	***	172.8313	***	245.6961	***	205.6165	***	169.7554	***	376.6046	***	36.6289	**	209.0567	***
	(31.0111)		(22.9128)		(52.9725)		(25.4520)		(49.2838)		(81.6545)		(17.3884)		(50.2523)	
R-squared	0.0470		0.2785		0.4615		0.3370		0.5260		0.1003		0.1751		0.4487	

[a]: Standard errors in italics under estimated coefficients. ***: Significant at 1% level. **: Significant at 5% level. *: Significant at 10% level.

Table 3-4: Correlations between SURE Price Equations - Saskatchewan

	Spring wheat	Barley	Canola	Oats	Peas	Flax	Hay	Soybean
Spring wheat	1							
Barley	0.7851	1						
Canola	0.6940	0.5583	1					
Oats	0.5850	0.7721	0.2863	1				
Peas	0.0648	0.2646	0.2734	0.0617	1			
Flax	0.6374	0.5562	0.7104	0.5082	0.1037	1		
Hay	-0.1507	-0.1597	0.1672	-0.0655	0.4110	0.1050	1	
Soybean	-0.1130	0.0319	0.2772	0.0210	0.4777	0.2544	0.4792	1

The simulation model utilises the SURE for prices (Equations 3-4 and 3-5) with stochastic error components in each individual equation. The error terms of the price equations were assumed to follow a standard normal distribution in @RISK. As the individual price equations are correlated, the error terms are also correlated and hence need to be adjusted given the standard errors. This error adjustment has been done in previous representative farm simulation studies (e.g., Trautman, 2012; Xie 2014) following Hull (2003). While the previous studies mention that it is possible to conduct the error adjustment using Cholesky decomposition, this study does not attempt that.

The error adjustment following Hull (2003) required solving for the corrected error terms from the following equations:

$$\varepsilon_i = \sum_{j=1}^{i} \alpha_{ij} . x_j$$

$$s.t. \quad \sum \alpha_{ij}^2 = 1 \qquad \text{3-6}$$

$$and \quad \sum \alpha_{ij} . \alpha_{kj} = \rho_{i,k}$$

where ε_i is the corrected error for the price of crop i, x_j is the error draw scaled to standard deviation of the corresponding price and $\rho_{i,k}$ is the correlation between errors for prices of crop i and k obtained from the SUR estimation of the price equations. By solving for the α_{ij} terms, the adjusted error is calculated. It has been noted that the above formula gets overly complicated as the number of crops increases to four or more. Previous studies (e.g., Trautman, 2012; Xie 2014) dealt with this issue by identifying sub-groups of four or less number of crops based on error correlations as obtained from the SURE analyses of prices. High positive correlation of the error terms of two or more crops indicate that extraneous factors would have similar impact on the error terms of the price equations of these crops and this should be taken into account while building a stochastic price model.

Table 3-2 and Table 3-4 present the error correlations obtained from the price SURE models for Alberta and Saskatchewan respectively. For Alberta, the error correlation based groups were spring wheat-barley-oats, canola-flax-field peas and tame hay. For Saskatchewan, the groups were spring wheat-barley-oats, canola-flax and field peas-tame hay-soybean.

The correlated error terms for prices in Alberta were obtained as follow:

$$\varepsilon_{SW}^{AB} = x_{SW}^{AB} \tag{3-7}$$

$$\varepsilon_{\mathbf{B}AR}^{AB} = \rho_{SW.BAR}^{AB}.x_{SW}^{AB} + \left(\sqrt{1-\left(\rho_{SW.BAR}^{AB}\right)^2}\right).x_{BAR}^{AB} \tag{3-8}$$

$$\varepsilon_{OAT}^{AB} = \rho_{SW.OAT}^{AB}.x_{SW} + \left(\frac{\rho_{BAR.OAT}^{AB} - \rho_{SW.BAR}^{AB}.\rho_{SW.OAT}^{AB}}{\sqrt{1-\left(\rho_{SW.BAR}^{AB}\right)^2}}\right).x_{BAR}^{AB} + \left(\sqrt{1-\left(\rho_{SW.OAT}^{AB}\right)^2 - \left(\frac{\rho_{BAR.OAT}^{AB} - \rho_{SW.BAR}^{AB}.\rho_{SW.OAT}^{AB}}{\sqrt{1-\left(\rho_{SW.BAR}^{AB}\right)^2}}\right)^2}\right).x_{OAT}^{AB} \tag{3-9}$$

$$\varepsilon_{CA}^{AB} = x_{CA}^{AB} \tag{3-10}$$

$$\varepsilon_{FLX}^{AB} = \rho_{CA.FLX}^{AB}.x_{CA}^{AB} + \left(\sqrt{1-\left(\rho_{CA.FLX}^{AB}\right)^2}\right).x_{FLX}^{AB} \tag{3-11}$$

$$\varepsilon_{PEA}^{AB} = \rho_{CA.PEA}^{AB}.x_{CA} + \left(\frac{\rho_{FLX.PEA}^{AB} - \rho_{CA.FLX}^{AB} \cdot \rho_{CA.PEA}^{AB}}{\sqrt{1-\rho_{CA.FLX}^{2}}} \right) .x_{FLX}^{AB} + \left(\sqrt{1-\left(\rho_{CA.PEA}^{AB}\right)^2 - \left(\frac{\rho_{FLX.PEA}^{AB} - \rho_{CA.FLX}^{AB} \cdot \rho_{CA.PEA}^{AB}}{\sqrt{1-\rho_{CA.FLX}^{2}}} \right)^2} \right) .x_{PEA}^{AB}$$

3-12

$$\varepsilon_{HAY}^{AB} = x_{HAY}^{AB}$$ 3-13

The correlated error terms for prices in Saskatchewan were obtained as follows:

$$\varepsilon_{SW}^{SK} = x_{SW}^{SK}$$ 3-14

$$\varepsilon_{\mathbf{B}AR}^{SK} = \rho_{SW.BAR}^{SK}.x_{SW}^{SK} + \left(\sqrt{1-\left(\rho_{SW.BAR}^{SK}\right)^2} \right) .x_{BAR}^{SK}$$ 3-15

$$\varepsilon_{OAT}^{SK} = \rho_{SW.OAT}^{SK}.x_{SW}^{SK} + \left(\frac{\rho_{BAR.OAT}^{SK} - \rho_{SW.BAR}^{SK} \cdot \rho_{SW.OAT}^{SK}}{\sqrt{1-\left(\rho_{SW.BAR}^{SK}\right)^2}} \right) .x_{BAR}^{SK} + \left(\sqrt{1-\left(\rho_{SW.OAT}^{SK}\right)^2 - \left(\frac{\rho_{BAR.OAT}^{SK} - \rho_{SW.BAR}^{SK} \cdot \rho_{SW.OAT}^{SK}}{\sqrt{1-\left(\rho_{SW.BAR}^{SK}\right)^2}} \right)^2} \right) .x_{OAT}^{SK}$$

3-16

$$\varepsilon_{CA}^{SK} = x_{CA}^{SK}$$ 3-17

$$\varepsilon_{FLX}^{SK} = \rho_{CA.FLX}^{SK}.x_{CA}^{SK} + \left(\sqrt{1-\left(\rho_{CA.FLX}^{SK}\right)^2} \right) .x_{FLX}^{SK}$$ 3-18

$$\varepsilon_{PEA}^{SK} = x_{PEA}^{SK}$$ 3-19

$$\varepsilon_{HAY}^{SK} = \rho_{PEA.HAY}^{SK}.x_{PEA}^{SK} + \left(\sqrt{1-\left(\rho_{PEA.HAY}^{SK}\right)^2} \right) .x_{HAY}^{SK}$$ 3-20

$$\varepsilon_{SOY}^{SK} = \rho_{PEA.SOY}^{SK}.x_{PEA}^{SK} + \left(\frac{\rho_{HAY.SOY}^{SK} - \rho_{PEA.HAY}^{SK} \cdot \rho_{PEA.SOY}^{SK}}{\sqrt{1-\left(\rho_{PEA.HAY}^{SK}\right)^2}} \right) .x_{HAY}^{SK} + \left(\sqrt{1-\left(\rho_{PEA.SOY}^{SK}\right)^2 - \left(\frac{\rho_{HAY.SOY}^{SK} - \rho_{PEA.HAY}^{SK} \cdot \rho_{PEA.SOY}^{SK}}{\sqrt{1-\left(\rho_{PEA.HAY}^{SK}\right)^2}} \right)^2} \right) .x_{SOY}^{SK}$$

3-21

Some of the farms in the sample reported growing organic spring wheat and oats. Typically organic crops command a price premium. However, due to the unavailability of a reported historical price series for organic crops, a price adjustment was made for these farms, given the percentage difference in prices between the non-organic and the organic varieties. The estimated price of organic spring wheat and oats was obtained from Organic Crop Planning Guide 2014 of Saskatchewan Agriculture (Saskatchewan Agriculture, 2014-b). This was compared with the 2013 estimated on-farm market price of non-organic wheat and oats obtained from the 2013 Crop Planning Guide of Saskatchewan Agriculture (Saskatchewan Agriculture, 2013-b). The estimated 2014 price of the organic wheat is $587.80 per tonne which is 123.78% higher than the price of the non-organic spring wheat. The price of organic oats is $389.11 per tonne which is approximately 106.9% higher than the price of non-organic oats. The difference in these prices was incorporated in the price model by allowing farm-specific increase in the simulated prices for spring wheat and oats by 123.78% and 106.9% respectively.

3.3.3.1.4 Validation of Simulated Prices

The simulated prices obtained from @RISK were compared against the historical prices. The means of simulated prices in year 12 were compared with the historical mean of prices over 1984-2013, assuming non-paired samples and unequal variance, using Student's t-test. The null hypothesis of historical and simulated means being equal could not be rejected for any of the crops in Alberta but it was rejected in Saskatchewan for barley at 1%. A correction in barley prices in Saskatchewan was done by obtaining the difference between the average of the mean simulation prices and the non-stochastic starting price and subtracting this difference from the constant term of the regression equation for price of barley. The corrected price of barley was used to recheck the equality of historical and simulated mean prices and the null hypothesis of equality could not be rejected. Table 3-5 and Table 3-6 present the historical and simulated mean prices and the t-statistics for equality of mean prices of the crops in Alberta and Saskatchewan. For all prices, the t-statistics indicate that the null hypothesis of equality of the means could not be rejected.

Table 3-5: Comparison of Historical Price Data and @RISK Simulated Price - Alberta

Crops	Simulated Mean	Historical Mean	t-statistic	t-Critical 5%	t-Critical 1%
Spring wheat	260.40	263.05	0.2520	1.699	2.46
Barley	168.34	170.88	0.3559	1.699	2.46
Canola	491.04	469.26	1.1748	1.699	2.46
Oats	171.65	173.74	0.3034	1.699	2.46
Peas	292.60	273.31	1.3606	1.699	2.46
Flax	433.97	444.07	0.4898	1.699	2.46
Hay	132.66	119.39	2.1124	1.699	2.46

Table 3-6: Comparison of Historical Price Data and @RISK Simulated Price - Saskatchewan

Crops	Simulated Mean	Historical Mean	t-statistic	t-Critical 5%	t-Critical 1%
Spring wheat	211.93	224.57	1.0586	1.699	2.46
Barley	163.13	167.53	0.4840	1.699	2.46
Canola	178.81	176.90	0.2032	1.699	2.46
Oats	256.37	268.28	0.6780	1.721	2.52
Peas	417.16	439.77	0.9648	1.699	2.46
Flax	441.31	462.57	1.0391	1.699	2.46
Hay	95.75	105.18	1.1979	1.699	2.46
Soybean	354.72	363.19	0.5079	1.706	2.479

3.3.3.2 Estimation of Stochastic Yield Models

The stochastic yield models were developed using historical dryland yield data at the rural municipality level available from multiple sources and adjusting them to reflect farm-level variability. The detailed information on data availability and how missing data were dealt with is reported in Appendix J1 through Appendix J4. Tests of data stationarity were conducted before de-trending the yield data. The de-trended yield data were used to identify the best-fit yield distributions.

3.3.3.2.1 Tests of Yield Stationarity

The null hypothesis of a unit root was rejected for all the crops in Alberta given the estimated values of Z(rho) or Z(tau) test statistics of the Phillips-Perron test. For Saskatchewan, the hypothesis of a unit root was rejected for all crops except soybean yield. However, it was difficult to ascertain whether this was truly due to the presence of a unit root or due to the small size of the time-series. The KPSS test was done additionally for soybean yield data. The results of the KPSS tests indicated that the null hypothesis of trend stationarity could not be rejected for soybean yields. The conflict between KPSS and Phillips-Perron test results for soybean yield data indicated that the data were not informative enough to conclude one way or the other. Given that soybean yield data were limited, it was assumed that the soybean yield data were stationary to maintain consistency with the other crops. The test statistics for the stationarity tests are summarized in Table J3 - Table J5 in Appendix J.

3.3.3.2.2 De-trending Crop Yields

Before proceeding with the estimation of the yield distribution parameters, the data were de-trended to remove the effects of technical change. The yield data were de-trended by regressing the yield data on a time trend using the following equation in NLogit 5.0.

$$Y_t = \alpha + \beta t + \varepsilon_t \qquad 3\text{-}22$$

A positive coefficient on the time variable (t) indicates progressive technical change in yield Y_t. The corresponding regression coefficients for the yield trends in Alberta and Saskatchewan are presented in Table J6 and Table J7 respectively. The time trend coefficient is positive in all cases. It is significant for all but two crops in Alberta and for two of the eight crops in Saskatchewan. The de-trending is done for all crops on the basis of obtaining a positive coefficient. The residuals are calculated by subtracting the predicted yield obtained from the above equation for each crop from the observed/historical yield. The residuals are added to the predicted yield of the base year (2013) for each crop to obtain the de-trended series. Since the farm-level survey was implemented in March 2014, 2013 yields were the most recent yields available at the time of this analysis and hence, 2013 was selected as the base year. The de-trended yield data are used to find the best-fit distributions in @RISK. The summary statistics of the de-trended yield data in the two study areas area are presented in Table J8 and Table J9 in Appendix J.

3.3.3.2.3 Weather-based SURE Models for Crop and Forage Yield

In this study, weather-based models of yield using growing season temperature and precipitation were estimated for both the study areas with unsatisfactory results[20]. The weather models of yield in the Alberta RMs showed very low significance of the weather-based yield equations. The SURE estimation results for weather-based yield equations in Saskatchewan indicated that the weather variables were not significant in most cases. As well, the expected signs were also not obtained in most cases for the major crops. This indicated that weather-based yield modelling might not be ideal in this study given the weather and yield data and alternative methods should be explored.

Trautman (2012) and Xie (2014) attempted to directly identify the best distribution that would fit the de-trended yield data using the distribution-fitting routine in @RISK. This study adopted the same methodology. A crucial point of departure was that, unlike past studies that

[20] Weather-based stochastic yield models were successfully implemented in some previous studies while some other studies observed that they had low predictive power and low statistical significance. Cortus (2005) developed and used a weather-based yield model for Emerald, Saskatchewan. The same formulation as developed by Cortus (2005) was used by Koeckhoven (2008), Dollevoet (2010) and this study although the growing season was defined to be May 1-October 31 in this study unlike Cortus. Trautman (2012) and Xie (2014) also explored this type of stochastic weather based yield modelling but observed low significance of the weather variables.

dealt with representative farms, the means and standard deviations of the fitted yield distributions in this study were adjusted for each farm specifically.

3.3.3.2.4 Fitting Yield Distributions

The de-trended data are fitted to distributions using the "Fit Distribution" routine in @RISK so that the parameter estimates pertaining to the best-fit distribution could be obtained. The selection of potential distributions under consideration was constrained by the requirement of having a zero lower bound so that negative yields would not be generated by the stochastic model. This requirement is satisfied by distributions such as Beta-general, Exponential, Gamma, LogLogistic, Lognormal, Triangle, Uniform and Weibull. Given the number of crop yields series that needed to be fitted, goodness-of-fit is determined using the Kolmogorov-Smirnov (K-S) test statistic instead of comparing the outcome using various other test statistics such as AIC, BIC and Chi-Squared test statistic. Small values of the K-S test statistic indicate better fit. The K-S test statistics for each rural municipality and each crop are presented in Table J10 through Table J14 in Appendix J.

The Weibull distribution was the best fit for most crops except oats, peas and alfalfa hay in Alberta, and canola in Saskatchewan. For peas in Beaver, the Weibull distribution results were suppressed by @RISK as it was determined to be not a good fit and the LogLogistic was determined to be the best fit. Similarly, the Weibull distribution was not determined to be the best or the second best distribution for yield data of peas for other RMs in Alberta. For all other crop series in Alberta RMs, the Weibull distribution was determined to be the best or second best distribution to fit the data except for alfalfa hay for which it is the third best distribution. Also in Saskatchewan, the Weibull distribution was determined to be among the three best distributions for five out of eight crops. Given that it was among the best three distributions for the majority of the crop yields series in both the study areas, it was decided to fit Weibull distribution to all the crop yields series. Using a single distribution simplifies the analyses of the stochastic yields to some extent in the sense that it would allow some degree of comparability among the respondent farms in various RMs if they grow the same crop.

The Weibull distribution is defined by the probability density function:

$$f(x) = \alpha x^{\alpha-1} \frac{\alpha x^{\alpha-1}}{\beta^{\alpha}} e^{-\left(\frac{x}{\beta}\right)^{\alpha}} \qquad 3\text{-}23$$

where α and β are positive shape and scale parameters (Palisade Corporation, 2013) of the density function. The fitted Weibull distributions generate the values of α and β for each crop yield series that define the mean and the standard deviations of the de-trended historical yields.

3.3.3.2.5 Crop Yield Correlations

The field-level crop yield correlations used in the stochastic yield modelling were obtained from AARD. For this study, the risk correlations for the dryland Risk Region C obtained from field-level data over 2004-2006 were used. Risk Region C includes the rural municipalities included in the Alberta study area. The same correlations were used for the farms in Saskatchewan since they are in the same soil zone. Correlations for soybean yields with other crop yields were not available and hence, the correlation coefficient was assumed to be 0.3 invoking the assumption made in the AARD yield correlation calculation for missing crop yields. Note that these field level correlations were used rather than the municipality level yield correlations since yield was modelled at the farm-level. The following tables present the correlation coefficients used in this analysis.

Table 3-7: Field Level Yield Correlation Coefficients - Alberta[a]

	Spring wheat	Barley	Canola	Oats	Peas	Flax	Hay	Triticale
Spring wheat	1							
Barley	0.7671	1						
Canola	0.6553	0.6584	1					
Oats	0.723	0.7393	0.6253	1				
Peas	0.7506	0.7566	0.6713	0.7247	1			
Flax	0.6492	0.6493	0.5974	0.6331	0.7141	1		
Hay	0.3	0.3	0.3	0.3	0.3	0.3	1	
Triticale	0.7347	0.8049	0.5943	0.7406	0.6517	0.6409	0.3	1

[a] : Source: AARD (2007).

Table 3-8: Field Level Yield Correlation Coefficients - Saskatchewan[a]

	Spring wheat	Barley	Canola	Oats	Peas	Flax	Hay	Soybean
Spring wheat	1							
Barley	0.7671	1						
Canola	0.6553	0.6584	1					
Oats	0.723	0.7393	0.6253	1				
Peas	0.7506	0.7566	0.6713	0.7247	1			
Flax	0.6492	0.6493	0.5974	0.6331	0.7141	1		
Hay	0.3	0.3	0.3	0.31	0.3	0.3	1	
Soybean	0.3	0.3	0.3	0.3	0.3	0.3	0.3	1

[a] : Source: AARD (2007).

3.3.3.2.6 Yield Adjustment for Farm-Level Variability

Various studies noted that aggregate yield data may not be representative of farm-level yield due to aggregation and resultant loss of variability (Fulton et al., 1988; Just and Weninger, 1999; Rudstrom et al., 2002, Marra and Schurle, 1994; Popp et al., 2005). Marra and Schurle (1994) developed an adjustment process to correct for aggregation bias. For each percentage difference between the county acreage and average farm acreage, Marra and Schurle (1994) increased the county level variability by 0.1%. Cortus (2005), Koeckhoven (2008) and Xie (2014) used this adjustment procedure. Trautman (2012) employed a similar adjustment process inspired by the Marra-Schurle (M-S) correction based on the total acreage grown for each crop at the county level and the representative farm level. Given the limitation of available farm-level yield data it was decided to adapt the M-S yield corrections based on the farm-level acreage and the RM-level crops and forage acreage information.[21]

RM level 2013 crop acreage information for Alberta was obtained from AFSC (2014-a) for spring wheat, barley, canola, oats and peas in the Beaver and Vermilion RMs. The crop acreage information for the Wainwright RM was available for spring wheat, barley, canola, oats, peas

[21] An alternative is to use the Bayesian framework to calibrate county level yield series to generate farm-level yield series by exploiting the relationship between these farm yield and the county average yield for the common years (Fulton et al., 1998) However, applicability of such Bayesian correction would require knowledge of the farm-level standard deviations of yield for each crop and each farm and the required data was not available.

and spring triticale. Since the acreage information for flax was not available for 2013 at the RM level, flax acreage in Risk Area 13 from AFSC (2014-b) was used. The total flax acreage in Risk Area 13 was 1637 acres in 2013. This was deemed low enough for use as RM-level acreage of flax without any adjustment for size difference between the Risk area and the RMs under study. Tame hay acreage was not available for the Alberta RMs. Substituting barley acreage in place of tame hay acreage for the calculation of farm-specific standard deviation of hay resulted in extremely high standard deviations for some farms. To avoid this, it was assumed that the increase in standard deviation of tame hay yield is equal to the increase in standard deviation of barley for the farms in Alberta as both are used as forage. No adjustment was done for corn yield.

The RM-level crop acreage information for Saskatchewan was obtained from the Saskatchewan Management Plus (SMP) Program of Saskatchewan Crop Insurance Corporation (SCIC, 2013). The 2013 number of acres for SMP was available for Risk Area 5 in Saskatchewan for hard red spring wheat, barley, canola, oats, peas, flax and soybean. The Risk Area 5 comprises 10 RMs including Moosomin. Since specific acreage information for Moosomin RM was not available, the available Risk Area acreage for each crop under SMP was divided by 10 to estimate the county level acreage for each crop for the M-S correction. Barley acreage was used as a proxy for alfalfa hay acreage at the RM level.

For each farm and for each crop, the difference in farm acreage and the RM acreage was calculated. This was multiplied by the M-S factor of 0.1% to obtain the correction factors for standard deviation. Once the correction factors were calculated for each respondent farm, the standard deviations obtained from the fitted Weibull distributions in @RISK were accordingly corrected, with the scale and shape parameters of the distribution being adjusted to maintain the same mean. Note that the corrections were farm-specific as each farm had different acreage allocated for the crops.

However, a comparison of the farm-reported yields in 2013 and the average RM-level historical yield revealed that farm-specific yield for some farms in 2013 were considerably different from the historical average in the area. Therefore, the means of the fitted yield distributions also needed to be adjusted to reflect farm-level variability. Since 2013 was the most recent year at the time of the survey in terms of actual yields, it was possible that the farms anchored their WTA responses on 2013 yields irrespective of whether 2013 was a year with higher-than-average yield across the RMs. This is known as the "recency effect" where individuals rely on smaller and recently experienced samples of information when making a decision about a risky prospect (e.g. Hertwig et al., 2004). Note that this was another point of departure from the representative farm simulation studies as the goal of those studies was to ensure that the mean simulated yield used in the model matches the average yield for the corresponding area.

In order to do the farm-specific adjustment in mean, it was determined whether the 2013 yields were relatively higher or lower than the historical average yield for the area. The ratio of the 2013 yield for the RMs and the historical average yield was calculated as the correction factor. The farm-specific corrected yield was obtained by dividing the 2013 farm-specific reported yield by the correction factor. The farm-specific corrected yield gave an approximation of farm-specific average yield[22].

$$Farm specific adjusted mean\, yield = \frac{\dfrac{Reported 2013 Farm specific\, yield}{2013 RM\ yield}}{Historical RM\ mean\, yield} \qquad 3\text{-}24$$

The farm-specific adjusted yields are reported in Table J15 and Table J16 in Appendix J. Once the farm-specific adjusted mean yield was obtained, the parameters of the fitted Weibull distribution for each crop were adjusted using an online Weibull Calculator so that the farm-specific adjusted mean yield and the M-S corrected standard deviation would be obtained as mean and standard deviation of the distribution.

A considerable amount of yield variability was noted across farms. For corn in Alberta, the respondent specified that it was for grazing and he could not report any estimate of yield. Hence, farm-specific deterministic corn yield from 2013 obtained for the Saskatchewan site was assumed to apply in this case. For grazing corn and millet in Saskatchewan, farm-specific deterministic yield from 2013 was used throughout the simulation period of 12 years. Therefore, risk in yield was not modelled for corn and millet.

[22] For farms in Vermilion River that produced barley in 2013, the reported yield was assumed to be the approximated average yield as otherwise the correction procedure generated unrealistically high levels of barley yield as average.

3.3.3.2.7 Maximum Yield Restriction

The stochastic yield model has the potential to generate unrealistically high yields. This would impact the revenue estimation and hence, generate unrealistically high estimates of NPV. To correct for this possibility, maximum yield restrictions were placed on the simulated means. Using the RiskTruncateP function in @Risk, the distribution of yield was truncated to a maximum possible value corresponding to the 90th percentile of the distribution. The yield restrictions are summarized in Table J17 and Table J18 in Appendix J.

3.3.3.2.8 Yield Simulation and Validation

With the maximum yield restrictions imposed, 15 yield models for Alberta and 13 yield models for Saskatchewan were simulated using 5000 iterations in each case. Comparison of farm-specific adjusted mean with simulated mean yield for each crop at the 12th year of the simulation was done using the RiskMean function of @Risk. The RiskMean function calculated the mean yield using 5000 iterations for each of the 13 simulation runs in the case of Saskatchewan and 15 simulation runs in the case of Alberta.

The truncation of the yield distributions at the 90th percentile caused the simulated means to be lower than the farm-specific adjusted mean as simulated yield values that were higher than the 90th percentile value were now restricted to the imposed maximum. Following the process used by Xie (2014) it was assumed that a difference of 5% between the simulated mean and the adjusted mean would be acceptable. For crops that experienced a larger decrease in simulated mean, a second stage of adjustment in standard deviation was performed such that the 5% tolerance range for the difference in the two means was achieved. The relevant tables are in Table J19 and Table J20 in Appendix J.

The simulated means and simulated standard deviations obtained after the maximum yield restriction and second stage standard deviation correction are presented in Table J21-Table J24 in Appendix J. The final values of the Weibull parameters that were used in the analyses are presented in Table J25 and Table J26 in Appendix J.

3.3.4 Revenue

A farm can earn revenue through crop sales, sales of weaned calves and from pasture rental. While sales of weaned calves and pasture rental were modelled as deterministic income, revenue from crop sales depended on stochastic yield and prices. The farms also receive cash flow through crop insurance and AgriStability.

Annual revenue from a crop operation was obtained by multiplying the stochastic yields (tonnes/acre) with the stochastic prices ($/tonne) and the area allocated to each crop. Since yields were drawn from the adjusted Weibull distribution and the stochastic nature of the crop prices arose from the random draw of the error components for each year, there was considerable variability in revenue across years. It may be noted that corn and millet were modelled in this study as crops with positive costs of production but no revenue as it was assumed that corn and millet were grown as livestock feed. Hence, the costs of production of these crops were used to adjust the variable costs of production of livestock for the relevant farms.

Revenue from a cow-calf enterprise was generated from sale of weaned calves. The net cash flow from the cow-calf enterprise was obtained by subtracting total variable costs of production of weaned calves from the revenue from the sale of weaned calves. As mentioned above, for farms that grow corn and/or millet, the net variable cost of production of weaned calves was obtained by subtracting the cost of production of corn and/or millet from the total variable cost. The net cash flow was then calculated by subtracting the net variable cost from the total revenue. For farms that have pasture land but no livestock it was assumed that they earn revenue from pasture rental, as discussed in section 3.3.1.4.2.

3.3.5 Crop Insurance and AgriStability

3.3.5.1 Crop Insurance

Crop insurance receipts represent a significant proportion of the cash flow for producers especially in the event of unexpected fall in yield due to weather events. Total receipts from direct payments constituted 4.27% and 4.66% of total farm cash receipts in 2014 in Alberta and Saskatchewan, respectively (Statistics Canada, 2015). Crop insurance was modelled in this study following the structure developed by AFSC and also used by Trautman (2012).

A fixed coverage level of 80% was assumed for baseline simulation model and the BMP scenario. The farmer receives an insurance payment if the yield in any year falls below 80% of the normal yield. The calculation of the insurance payment and the premium was done using spring insurance price (SIP), fall market price (FMP), risk area average yields, actual farm-level yields, the variable price benefit (VPB) on shortfall, and spring price endorsement (SPE).

A detailed discussion of the crop insurance payment and premium calculation was provided by Trautman (2012) and Xie (2014). SIP for spring wheat, barley, canola, oats, peas and flax in Alberta was obtained from AFSC (2013-e). SIP for triticale was assumed to be equal to SIP of barley. For Saskatchewan, SIP for spring wheat, barley, canola, oats, peas, flax, soybean and organic spring wheat and organic oats was taken to be equal to 2015 base prices (SCIC, 2015). It was assumed that for grazing corn and millet, no insurance was purchased. Note that a single SIP is used throughout the simulation period although in reality SIPs would be revised every year. The SIPs for Alberta and Saskatchewan are presented in Table K1 and Table K2 in Appendix K.

For each farm the basic level of insurance coverage was obtained by multiplying the insured yield by the SIP. For an 80% coverage level, the insured yield was 80% of the RM average yield. The insured yield depends on actual historical yields for the farm and average yields in the crop insurance risk area. For simplicity's sake, the RM average yield for each period was calculated as the average of the actual simulated farm yield for that period and the average yield for the RM from the previous period. For the first simulation period, the average yield for the RM was taken as the risk area average yield. The farm receives a crop insurance payment if there is a yield shortfall, i.e. the actual simulated yield is less than insured yield. The crop insurance payment was obtained by multiplying the yield shortfall (tonnes) with the SIP ($/tonnes).

Producers in both study areas were also assumed to have variable price benefit (VPB). VPB is an additional compensation for the events with both yield shortfall and occurrence of a 10-50% higher actual price than the SIP (Trautman, 2012; Xie, 2014). If there is a yield shortfall and the FMP is 10%-50% higher than the SIP, then the VPB payment is generated. The VPB payment was calculated as the product of the yield shortfall and the difference between the FMP and SIP.

The Spring Price Endorsement (SPE) provides additional insurance against a decrease in FMP to 10-50% lower than the SIP. With the SPE program, the SPE payment is calculated as the product of the difference between FMP and SIP and the greater of the actual and the insured yields. If FMP is less than 10% of SIP, no additional benefits are received. If FMP falls to below 50% of SIP, the benefit is calculated based on 50% of SIP. The total crop insurance benefit to a producer was calculated as the sum of the payments from the basic crop insurance coverage, VPB payments and SPE payments.

The total premium cost for each crop is defined as the dollar amount of coverage on production which is equal to the product of actual production (tonnes) and the SIP ($/tonne). It was assumed that the premium rate was equal for all crops and for all producers in this study although in reality the premium would depend on the risk area and vary across producers, risk areas and crops. Also SPE might not be purchased by all producers. Note that this might lead to loss of farm-level variability in the NPV analyses. The fixed premium rate used in this study was 10%. Out of the total premium value, it was assumed that 40% is paid by the producer and the rest was paid by the government in the form of a subsidy. In the cash flow analysis, the crop insurance premium of 40% was included as an cash outflow.

3.3.5.2 AgriStability

AgriStability is a part of the BRM programs under Growing Forward 2 (AFSC, 2015) that protect farms against a significant decline in production margin (PM). Among the past simulation studies, Xie (2014) used the new framework of AgriStability that was introduced in April 2013. This new format was also used in calculation of benefits from AgriStability in this study.

The PM of the farm is defined as the difference between the allowable income and the allowable expenses. In this study, the allowable income was the sum of total crop sales, crop insurance receipts, revenue from livestock enterprise and revenue from pasture rental, if any. The allowable expenses were the sum of the variable costs such as seed, fertilizer, chemical, fuel, utilities and custom work and labour, net variable expenses for livestock enterprise and the nuisance costs and input wastage costs associated with the wetland restoration BMP.

The producer receives an AgriStability payment if the PM of the farm falls below the set percentage of a reference margin (RM). The RM is the minimum of the conventional reference margin and the average allowable expenses for each simulation period. The conventional reference margin for the first two simulation periods in this study was calculated as a simple average of the PMs from the previous periods. From the third simulation period onwards, the conventional reference margin was calculated as an Olympic average[23] of the production margins from the previous periods. An AgriStability payment was generated if the PM was less than 70% of the RM (AFSC, 2015). The payment was equal to 70% of the difference between the actual PM and the 70% of the RM.

The participation fee for the AgriStability program is $.0045 per dollar of the reference margin multiplied by 70 % (AFSC, 2015) with a minimum fee of $45. A fixed annual administrative cost share fee of $55 is also levied on the participating producers, thus, making the total minimum fee equal to $100. AgriStability fees were included as cash outflows.

3.3.6 Input Costs

The input costs for a crop enterprise in this study include costs of seed, fertilizer, chemicals, fuel and machinery repair costs, custom work and hired labor, interest on variable expenses, license and insurance and utilities, as well as miscellaneous expenses. In order to capture complete farm-level variability in cash flow it would be ideal to have complete farm-specific input cost information. Since it was not possible to collect the full details of input costs of the respondent farms, only farm-level fertilizer and chemical costs were collected.[24]

However, the data on reported fertilizer and chemical costs indicated that for some farms, the reported input costs might not be applicable for every year of a 12-year simulation period. For example, while some farms reported very high fertilizer and chemical costs that were more than double the average costs of fertilizer and chemical for the region, some reported zero fertilizer costs or chemical costs, as a result of using manure composting. Unless the farms were growing organic crops, it was deemed unlikely that no fertilizer or chemical would be used for a 12-year period. Also, it was not clear whether the very high or low costs of fertilizer and

[23] The Olympic average is calculated using the production margins from the previous five periods excluding the highest and the lowest values.
[24] Fertilizer and chemical costs constitute approximately 44% of total direct variable costs of production for spring wheat and approximately 46.5% for canola (AARD, 2013-c).

chemical would be a result of variation in soil productivity across farms or simply due to reporting error during the survey. Given these issues with the collected data on fertilizer and chemical costs, it was decided that instead of using the farm-specific information, the average costs of production for the soil zone would be used in the simulation model unless otherwise specified.[25] The details on input costs are reported in Appendix L.

The input costs for a livestock enterprise are comprised of winter feed costs, pasture, bedding, labour, depreciation and capital lease payments and other variables costs. Total production costs per lb. of weaned calves for Alberta were obtained from the AgriProfit$ Cost and Returns Report (AARD, 2012-a). and those for Saskatchewan were obtained from the Western Beef Development Corporation (WBDC, 2013). Note that each farm with a livestock enterprise also reported pasture areas which were further adjusted on a case-by-case basis to account for rented land on the basis of pasture capacity calculations. Thus it is assumed that these farms have the required pasture capacity given the herd size. Pasture costs per pound of weaned calves were subtracted from the total production costs.

3.3.7 Wetland Restoration

The objective of the FC simulation analysis was to evaluate the farm-level costs of adopting wetland restoration BMP in active farmlands of Alberta and Saskatchewan such that it could be compared with the WTA estimates obtained from the SP auction discussed in the previous chapter. This would allow an understanding of the extent to which farm-level financial opportunity costs can be used to explain farmers' preference for compensation for adopting wetland restoration BMP. The proposed wetland restoration project in the cropland[26] involved restoring seven acres of the best cropland of the farm for 12 years. It may be noted that while the details of the proposed project is the same for all farms *ex ante*, the *ex post* impact of the project would vary significantly from farm to farm since the respondent farms vary significantly in terms

[25] Note that Farm 24 and 27 reported zero fertilizer costs. Farm 24 reported chemical costs to be zero as well, while farm 27 reported positive chemical costs that were lower than the average estimates of chemical costs from the Crop Planning Guide 2013 (Saskatchewan Agriculture, 2013-b). Using an assumption of average fertilizer and chemical costs for these two farms led to negative NPVs in the baseline model. This indicated that the assumed costs might be too high for these farms. Hence, for these two farms, fertilizer costs were assumed to be zero, as reported by the prodeucers. For both of these farms, it is assumed that organic manure composting is undertaken. Chemical costs are also assumed to be equal to the farm-reported values.
[26] In this chapter, the financial opportunity costs of restoring wetlands in pastureland are not calculated.

of size, crop rotations, enterprise details and existing number of wetlands. This section describes how adoption of the wetland restoration has been modelled in the farm-level analyses.

3.3.7.1 Impact on Acreage and Revenue

The long term crop rotations reported by respondents for their best field were adapted and used as the basis for modelling the impact of wetland restoration on crop acreage and subsequent revenue. According to the description of the wetland restoration program for the cropland presented to the respondents, the restoration would be done on their best cropland. It was assumed that the best cropland would be the most productive field of the farm and hence, would be used for growing cereals, pulses and/or oilseeds. The respondents' long term crop rotations were compared with the 2013 rotations to identify which cereals, pulses and oilseeds overlapped both rotations. It was assumed that the acreages of only these crops would be affected by the wetland restoration and these were defined as the "best field rotations". The best field rotations of the farms used in the BMP model are reported in Table 3-9.[27]

Under the BMP scenario, in each simulation period the land available for the production of crops according to the best field rotation was reduced by seven acres. For example, for Farm 16 in Saskatchewan, undertaking the wetland restoration project would reduce the number of acres under production of organic spring wheat by seven acres in each simulation period. However, the number of acres of hay produced by this farm would remain unchanged in the BMP scenario. Similarly, For Farm 21, with the wetland restoration project the acreage under production of oats would be reduced by seven acres in the first period and that under canola would be reduced by the same amount in the eighth period.

The wetland restoration BMP does not have a direct impact on crop yield. However, it has a negative impact on total crop sales through the reduction of acreage available for production. This is captured in the opportunity cost of the BMP, calculated as the difference between the

[27] The presence of organic crops was explicitly indicated by the producers. Therefore, it was assumed that only those crops identified as being organic were in fact produced using organic practices. It is unlikely that an organic crop would be grown as a part of a rotation where the other crops are non-organic, as this would likely result in the organic crop as not being "certified" as organic. For example, in the case of Farm 20 if the organic wheat followed the cultivation of non-organic canola or barley, the price premium included for organic wheat in the model may not actually be received by the producer. This would affect the NPV in perpetuity for this farm both for the baseline and for the BMP scenarios. Since both scenarios may be affected equally by this issue, it was decided to use the farm-reported best field rotation as given in Table 3-9.

NPVs from the baseline scenario and the wetland restoration scenario, discussed later in this chapter.

Table 3-9: Best Field Rotations[a]

Alberta		Saskatchewan	
Farm ID	Best field rotations	Farm ID	Best field rotations
1	W-C-W-P	16	Org_W
2	B-C	18	W-C
3	W-C	19	W-B-O-SOY
4	C-W-W-F	20	C-B-Org_W-F
5	B-T	21	O-P-W-F-B-C-W-C
6	W-C	22	W-C
7	O-O-O-C	23	W-C
8	C-W-B	24	B
9	C-B	25	W
10	C-B-O	26	W-C
11	W-C	27	B-O-M
12	W-W-C	28	W-C
13	B	29	W-C
14	W-C		
15	W-B-C-P		

[a]: W- spring wheat; B - barley; C - canola; O - oats; P - field peas; F- flax; T - triticale; M - millet; SOY - soybean; Org_W - organic spring wheat.

3.3.7.2 Wetland Restoration Costs

Wetland restoration imposes direct costs on the producers through nuisance costs and input wastage costs. It may be noted that while the actual restoration involves the cost of construction of ditch plugs and administration costs of the BMP program, the current study is interested in only the direct cost imposed on the producers. This is because the restoration agencies in the study areas generally bear the construction and administrative costs, as reported by Hill et al. (2011). Cortus (2005) discussed in detail the factors that influence the cost of adding a wetland in a field. The costs depend on the number of wetlands already existing in the field, the number of new wetlands being added, the shape and size of the added wetland(s) and their placement in the field. Respondents in the present study have indicated informally as well as in formal comments in the survey that they would be more interested in wetland restoration projects that minimize nuisance costs or help them consolidate the existing wetlands. They expressed their preference for wetlands that are located in a corner of the field or along one side, so that machinery movement in the field is not hampered to a great extent or at all. They also informally indicated that such programs would induce them to ask for very low amounts of compensation, if any. However, since the context of the present study is restoration of previously drained wetlands, there is a high likelihood that these restored wetlands would not be arranged in a convenient fashion for the producer.

The actual configuration of the restored wetland was not specified in this study. However, for modelling purposes, it was assumed that a single wetland of size seven acres would be added to a quarter section for each farm. The calculation of the nuisance costs and the input wastage cost for adding one extra wetland to a quarter section is discussed below.

3.3.7.2.1 Nuisance Costs

Nuisance costs arise out of the difficulty of moving machinery through the field around wetlands. Cortus (2005) noted that there is very little literature (Aldabagh & Beer, 1975; Desjardins, 1983 and Accutrak Systems Ltd., 1991) available on the calculation of nuisance cost. Based on the previously available studies, Cortus (2005) developed and used a methodology for estimating the nuisance cost based on farm size, machinery operating costs and the number of wetlands added to a quarter section of land. This methodology has been adapted and implemented by some of the more recent studies such as Packman (2010). The present study also adapted the methodology developed by Cortus (2005) for calculation of nuisance costs.

$$Nuisance\,cost = Nuisance\,factor * Machinery\,operating\,costs \qquad 3\text{-}25$$

The nuisance factor is the farm-specific percentage increase in machinery operating cost that is attributed to the addition of a wetland in a quarter section. The nuisance factor was assumed to increase with farm size which is a proxy for the size of farm machinery implements. The bigger the machinery implement size, the more difficult it is to maneuver it around wetlands in the field, thus generating a higher nuisance cost. For the addition of one wetland in a quarter section the farm-specific nuisance factors that increase at an increasing rate are calculated based on Cortus's (2005) calculations. There is considerable variation in nuisance factors as the respondent farms in this study have a lot of variability in farm size. The nuisance factors used in this study are presented below (Table 3-10).

Table 3-10: Farm-Specific Nuisance Factors

Alberta		Saskatchewan	
Farm ID	Nuisance factor	Farm ID	Nuisance factor
1	36%	16	8%
2	8%	18	86%
3	144%	19	8%
4	29%	20	23%
5	18%	21	23%
6	44%	22	86%
7	9%	23	14%
8	8%	24	23%
9	14%	25	9%
10	18%	26	53%
11	9%	27	9%
12	9%	28	18%
13	14%	29	18%
14	14%		
15	29%		

3.3.7.2.2 Input Wastage Costs

The issue of manoeuvring machinery around wetlands in a field also leads to input wastage due to overlaps. Input wastage cost was also modelled following Cortus (2005). The additional movement in the field due to the presence of a wetland leads to overlapped application of seed, fertilizer and chemical on a percentage of land. Cortus (2005) assumed that the overlapped area can be modelled using a fraction of the nuisance factor. With the use of precision farming techniques such as variable rate fertilizer spreader and global positioning system (GPS) guided seeders, the input wastage cost would be less significant. However, for the current sample of producers, it was assumed that this technology is not used. For each farm, input wastage cost for each appropriate crop according to the best field rotation was calculated using the following equation:

$$Input\ wastage cost = input cost\ per\ acre * affected\ area * nuisance\ factor * overlap\ factor \quad 3\text{-}26$$

The input cost per acre was the sum of seed, fertilizer and chemical costs. The affected area was equal to a quarter section (160 acres) where the wetland would be restored. The overlap factor was a constant percentage of the nuisance factor which indicates the extent of input wastage due to overlap in seed, fertilizer or chemical application. The overlap factor of 10% used by Cortus (2005) was also used in this study.

3.4 Results

3.4.1 Baseline Results

The baseline model generated a distribution of NPV in perpetuity under the assumption that the wetland restoration BMP was not adopted by the farms. The means and the standard deviations of these NPVs for the sample farms are presented in the following tables (Table 3-11 and Table 3-12). Annualized mean NPV in perpetuity per acre of agricultural area was also calculated. Note that while NPV calculated using MNCF is not equivalent to farm equity or net wealth as it does not include payments for debt principals, it does serve as a proxy. The NPVs calculated for each farm would be dependent on the general assumptions of the model as well as any farm-specific assumption. For the purpose of this study, the distribution of mean NPVs indicates the degree of variability of farm wealth across the sample farms and not the absolute magnitude of farm wealth. Annualized mean NPV per acre in Alberta ranged from $18.96 per acre to $264.50 per acre. For the Saskatchewan farms it ranged from $9.06 to $243.29 per acre.

Table 3-11: Summary of Baseline NPV in Perpetuity - Alberta

Farm ID	Mean	Std. dev.	Annualized mean per acre	Agricultural area (acres)[a]	Herd size (AU)[b]
1	$8,415,145.96	$942,677.57	$189.53	4440	0
2	$404,010.31	$51,038.51	$85.96	470	50
3	$25,788,723.05	$2,122,087.28	$264.50	9750	200
4	$9,780,815.74	$933,914.43	$203.77	4800	100
5	$4,654,517.49	$197,767.38	$146.83	3170	607
6	$15,252,259.07	$1,578,478.15	$246.00	6200	0
7	$324,441.05	$80,247.66	$26.16	1240	110
8	$1,306,075.19	$195,681.59	$148.42	880	0
9	$2,429,482.10	$243,694.39	$102.08	2380	250
10	$1,273,303.45	$243,933.77	$43.31	2940	169
11	$2,956,735.53	$320,424.96	$240.39	1230	0
12	$2,619,727.49	$334,810.12	$187.12	1400	0
13	$577,684.33	$54,895.33	$18.96	3047	185
14	$5,356,607.20	$617,930.21	$204.06	2625	0
15	$9,848,473.02	$984,682.73	$231.73	4250	0

[a]: Sum of crop and pasture land owned and rented by the farm. [b]: Animal Units.

Table 3-12: Summary of Baseline NPV in Perpetuity - Saskatchewan

Farm ID	Mean	Std. dev.	Annualized mean per acre	Agricultural area (acres)[a]	Herd size (AU)[b]
16	$593,640.94	$134,766.09	$72.40	820	0
18	$6,181,356.51	$1,069,692.09	$73.59	8400	0
19	$2,189,598.30	$137,800.98	$243.29	900	80
20	$378,830.95	$263,709.51	$9.47	4000	70
21	$3,169,208.27	$488,243.37	$76.77	4128	40
22	$16,577,924.76	$1,540,246.14	$197.36	8400	0
23	$6,858,119.47	$563,032.64	$233.27	2940	0
24	$654,486.73	$204,224.85	$17.98	3640	550
25	$200,458.82	$144,251.78	$14.96	1340	0
26	$11,253,054.93	$1,179,450.45	$168.96	6660	0
27	$124,084.54	$74,020.13	$9.06	1370	75
28	$3,468,352.44	$395,681.14	$99.10	3500	220
29	$3,468,352.44	$395,681.14	$99.10	3500	220

[a]: Sum of crop and pasture land owned and rented by the farm. [b]: Animal Units.

3.4.2 Validation

The farm-level simulation models were developed using a number of assumptions and a mix of actual farm-specific and secondary data. This made it difficult to assess the degree to which the estimated mean NPVs in perpetuity serves as a correct proxy of actual farm wealth. Koeckhoven (2008) noted that contribution margin relative to cash rent could be used as a check for model credibility. For renters to make profit out of their farm operation, the mean contribution margin of a farm should be at least double the cash rent in the study area (AARD, 2015). The range of cash rent for cropland in Central Alberta in 2013 is $21.25-$75 per acre (AARD, 2014-c) with an average of $52.1 per acre. Data on cash rental rates for Saskatchewan were not available. Compared to the Alberta cash rental rates, the contribution margins and hence the mean NPV in perpetuity of two farms (Farms 7 and 13) in Alberta sample and four farms in Saskatchewan (Farms 20, 24, 25, 27) were significantly lower (Table 3-13 and Table 3-14). While for some farms the contribution margins are higher than the maximum amount of cash rent, it is less of a concern as the farms appear to be profitable unlike those with very low contribution margin.

Comparing mean NPV in perpetuity to farmland values per acre is an alternative validation method undertaken in previous studies (e.g., Trautman, 2012; Xie, 2014). The mean NPV in perpetuity of four farms (Farms 2, 7, 10 and 13) in the Alberta sample and four farms in the Saskatchewan sample (Farms 20, 24, 25, 27) were significantly lower than the average farmland values in 2013 (Table 3-15 and Table 3-16). As stochastic yield validations have been conducted to approximate the yield variabilities for each farm individually, the low levels of mean NPV in perpetuity are likely attributable to the farm-specific assumptions such as machinery replacement costs and assumptions about input costs. The limited availability of farmland values may be noted as well.

Table 3-13: Comparison of Annualized Mean NPV in Perpetuity Per Acre To Contribution Margin in Year 12 - Alberta

Farm ID	Annualized mean NPV per acre	Half of mean contribution margin per acre in year 12
1	$189.53	$94.61
2	$85.96	$43.24
3	$264.50	$132.85
4	$203.77	$101.71
5	$146.83	$73.34
6	$246.00	$123.49
7	$26.16	$13.16
8	$148.42	$74.93
9	$102.08	$51.50
10	$43.31	$21.86
11	$240.39	$120.61
12	$187.12	$93.83
13	$18.96	$9.54
14	$204.06	$102.24
15	$231.73	$116.03

Table 3-14: Comparison of Annualized Mean NPV in Perpetuity Per Acre To Contribution Margin in Year 12 - Saskatchewan

Farm ID	Annualized mean NPV per acre	Half of mean contribution margin per acre in year 12
16	$72.40	$36.19
18	$73.59	$36.86
19	$243.29	$121.64
20	$9.47	$4.48
21	$76.77	$38.34
22	$197.36	$98.75
23	$233.27	$116.66
24	$17.98	$8.95
25	$14.96	$7.35
26	$168.96	$84.56
27	$9.06	$4.49
28	$99.10	$49.59
29	$99.10	$49.59

Table 3-15: Comparison of Mean Baseline NPV in Perpetuity to Farmland Values - Alberta

			Farmland values in 2013 per acre[a]		
Farm ID	RM	Mean NPV in perpetuity per acre	Min	Mean	Max
1	Beaver	$1,895.30	$150.04	$1,694.65	$3,316.91
4		$2,037.67			
5		$1,468.30			
12		$1,871.23			
2	Vermilion River	$859.60	$1,062.50	$1,799.55	$3,340.25
3		$2,645.00			
6		$2,460.04			
7		$261.65			
8		$1,484.18			
9		$1,020.79			
10		$433.10			
13		$189.59			
15		$2,317.29			
11	Wainwright	$2,403.85	$1,792.45	$1,932.83	$2,107.32
14		$2,040.61			

[a]: Source: FCC (2015).

Table 3-16: Comparison of Mean NPV in perpetuity to Farmland Values - Saskatchewan

		Farmland values in 2013 per acre[a]		
Farm ID	Mean NPV in perpetuity per acre	Min	Mean	Max
16	$723.95	$901	$1,263	$1,469
18	$735.88			
19	$2,432.89			
20	$94.71			
21	$767.73			
22	$1,973.56			
23	$2,332.69			
24	$179.80			
25	$149.60			
26	$1,689.65			
27	$90.57			
28	$990.96			
29	$990.96			

[a]: Source: FCC (2015).

While it is useful and informative to check whether the developed farm-specific models provide credible approximations of actual farm wealth, the main interest of this analysis was in the estimation of the financial opportunity cost of the BMP adoption using change in estimated farm wealth across baseline and BMP scenarios. The absolute values of the mean NPV in perpetuity, while important, are not crucial for the purpose of this study. Therefore, instead of delving in a post-estimation farm-specific adjustment of machinery replacement costs and input costs, it was decided to proceed with the analyses of the main results of interest.

3.4.3 BMP Results

The following tables (Table 3-17 and Table 3-18) summarize the mean NPV in perpetuity under the BMP scenario. The mean NPVs were less than the corresponding values obtained in the baseline scenario, thus indicating that restoration of BMP imposed a net cost on all the producers in the sample. The difference in annualized mean NPV in perpetuity between the two scenarios is the total opportunity cost of wetland restoration. The total opportunity cost was divided by the total number of wetland acres to arrive at the annual opportunity cost per acre of wetland. This is the metric of interest of this study and is comparable to the WTA values estimated in the previous chapter.

There was significant variability in FC, as noted from the tables below. The FC in Alberta ranged from $123.67/acre/year to $1958.80/acre/year. Interestingly, the highest opportunity cost in Alberta corresponded to the farm that declined the highest WTA bid presented in the study. The imputed WTA for this farm was $2520.47. The FC estimate indicated that this farm was indeed a high-cost supplier of ES and might not have provided a protest response to the preference questions. The range of FC in Saskatchewan was $137.62/acre/year-$922.18/acre/year.

Table 3-17: Summary of NPV in Perpetuity with Wetland Restoration BMP - Alberta

Farm ID	Mean	Std. dev.	Annualized mean per acre	Difference in annualized mean[a]	Opportunity cost per acre of wetland per year[b]
1	$8,371,812.72	$936,874.02	$188.55	$4,333.32	$619.05
2	$384,610.74	$49,234.97	$81.83	$1,939.96	$277.14
3	$25,651,607.04	$2,120,218.50	$263.09	$13,711.60	$1,958.80
4	$9,738,139.99	$931,838.66	$202.88	$4,267.57	$609.65
5	$4,601,733.95	$195,845.88	$145.17	$5,278.35	$754.05
6	$15,201,372.70	$1,573,455.06	$245.18	$5,088.64	$726.95
7	$315,784.48	$78,843.43	$25.47	$865.66	$123.67
8	$1,286,368.65	$191,566.40	$146.18	$1,970.65	$281.52
9	$2,403,205.16	$241,293.15	$100.98	$2,627.69	$375.38
10	$1,257,436.55	$237,965.37	$42.77	$1,586.69	$226.67
11	$2,931,935.91	$317,765.50	$238.37	$2,479.96	$354.28
12	$2,603,099.05	$330,545.62	$185.94	$1,662.84	$237.55
13	$561,730.07	$53,893.40	$18.44	$1,595.43	$227.92
14	$5,332,748.00	$613,288.69	$203.15	$2,385.92	$340.85
15	$9,809,664.01	$981,435.56	$230.82	$3,880.90	$554.41

[a]: Difference in Annualized Mean=Annualized mean in baseline-annualized mean in BMP scenario.
[b]: Difference in annualized mean/no of acres of wetland restored.

Table 3-18: Summary of NPV in Perpetuity with Wetland Restoration BMP - Saskatchewan

Farm ID	Mean	Std. dev.	Annualized mean per acre	Difference in annualized mean[a]	Opportunity cost per acre of wetland per year[b]
16	$578,137.90	$132,858.18	$72.40	$1,550.30	$221.47
18	$6,128,361.90	$1,068,185.13	$73.59	$5,299.46	$757.07
19	$2,163,916.25	$136,617.98	$243.29	$2,568.20	$366.89
20	$364,154.11	$262,483.91	$9.47	$1,467.68	$209.67
21	$3,150,163.22	$487,153.87	$76.77	$1,904.50	$272.07
22	$16,513,371.98	$1,538,914.05	$197.36	$6,455.28	$922.18
23	$6,831,373.68	$561,623.76	$233.27	$2,674.58	$382.08
24	$637,628.57	$203,467.61	$17.98	$1,685.82	$240.83
25	$183,246.92	$143,357.75	$14.96	$1,721.19	$245.88
26	$11,208,720.35	$1,177,948.88	$168.96	$4,433.46	$633.35
27	$114,450.99	$73,041.74	$9.06	$963.36	$137.62
28	$3,443,841.11	$394,238.16	$99.10	$2,451.13	$350.16
29	$3,443,841.11	$394,238.16	$99.10	$2,451.13	$350.16

[a]: Difference in Annualized Mean=Annualized mean in baseline-annualized mean in BMP scenario.
[b]: Difference in annualized mean/no of acres of wetland restored.

3.5 Discussion

The objective of this chapter was to estimate the financial opportunity costs of adopting wetland restoration BMP using farm-level simulation models so that these estimates could be compared and contrasted to producers' WTA obtained using SP methods. The FCs are estimated using observed and simulated data and hence, could be thought of as a measure of revealed cost while the WTA estimates are a measure of stated cost.

Significant variability in FC estimates was observed both within and across the samples from the two study areas. For the Alberta sample, the mean FC was $511.19/acre/year with a standard deviation of $446.43/acre/year. For the Saskatchewan sample, the mean FC was $391.49/acre/year and the standard deviation was $234.96/acre/year. The mean FC begin higher for the Alberta sample was in contrast with the findings of the previous chapter where mean or median WTA was higher in Saskatchewan.

Estimated FCs were scaled by 1000 and regressed using ordinary least square (OLS) analysis upon the following explanatory variables: (i) total agricultural area (AGAREA), (ii) number of livestock (HERDSIZE), (iii) a dummy variable for case study site (AREA) that assumes the value of one for the Alberta subsample and zero for Saskatchewan, and (iv) a dummy variable for type of enterprise (CROP) that assumes the value of one if the main enterprise of the farm is crop and zero if it is mixed or cow-calf. The OLS regression generated the following equation.[28]

$$\begin{aligned} Scaled\ FC = & \underset{(-1.31)}{-0.14093} + \underset{(6.09)}{0.00011}*AGAREA + \underset{(1.03)}{0.00036}*HERDSIZE + \underset{(2.27)}{0.17979}*AREA \\ & + \underset{(0.83)}{0.10046}*CROP \end{aligned} \qquad \text{3-27}$$

Agricultural area had a positive and significant coefficient at 1% level of significance. This implies that the estimated FC increases with farm size. This is not surprising since it was assumed that the nuisance factor and consequently the nuisance and input wastage costs increase

[28] t-statistic of estimated coefficients is in parentheses below the coefficients.

at an increasing rate with farm size. The dummy variable for the area of study had a positive and significant coefficient at 5% level of significance. This indicates that FC is higher for the Alberta sample compared to the Saskatchewan sample of farms. Herd size had a positive but not significant coefficient indicating that FC increases with number of livestock. FC thus increases with size of the operation, either crop or cow-calf, even though the revenue or costs from the cow-calf operation were modelled deterministically. Finally, the dummy variable for type of enterprise had a positive but not significant coefficient indicating that a crop enterprise has higher FC compared to a mixed or cow-calf enterprise.

Kernel density estimators[29] (KDEs) were used to describe the distributions of FC obtained from the two subsamples without imposing additional assumptions about the distributions. As done in the previous chapter to describe the distributions of farm-level WTA, logistic kernel and a bandwidth parameter of 0.337865 were used for fitting the KDEs for FC scaled by 1000. The KDEs from the two study areas are presented in Figure 3-1. There is a very high degree of overlap between the KDEs of FC between the two samples although a fairly long right tail is observed for the FC density for Alberta indicating the presence of a few farms with very high opportunity costs. The overlapping coefficient[30] of the FC distributions from the two subsamples is 0.9996 assuming equal variances and 0.6745 assuming unequal variances.

While, in principle, WTA is thought of as the "true" measure of the cost of BMP adoption, this study acknowledges that the elicited WTA estimates may not be error-free. The farm-level simulation models discussed in this chapter are also extremely dependent on specific assumptions. Comparing the estimates of FC and WTA allows this study to test for convergent validity of the measures of cost of BMP adoption in this study.[31] [32] Since direct valuation studies are resource and time-intensive to conduct, it is worth investigating if farm-specific FC estimates

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[29] A KDE is a non-parametric estimator of probability density function of a random sample.

[30] The overlapping coefficient measures the common area under two density functions (Inman and Bradley, 1989). When two distributions overlap completely, the corresponding overlap coefficient is 1.

[31] In the context of a comparison between revealed and SP WTP estimates, Cummings et al. (1986) note that revealed preference estimates of WTP depend on many technique-specific assumptions and functional forms and therefore should not be treated as necessarily representing the "truth". Carson et al. (1996) note that given two measures of a benefit, where neither can be assumed to be the "true" measure but are both capable (in principle) of capturing the desired measure, the estimates could be used to test for convergent validity.

[32] The FC estimation and subsequent comparison with WTA estimates is predicated on the assumption that restored wetlands would persist beyond the contract period specified in the hypothetical preference elicitation question. However, if the actual WTA estimates are based on producer intentions to re-drain the wetland at the end of the contract, there would be an inconsistency in these two estimates.

are close to the corresponding WTA counterparts in magnitude or provide underestimates or overestimates of WTA.

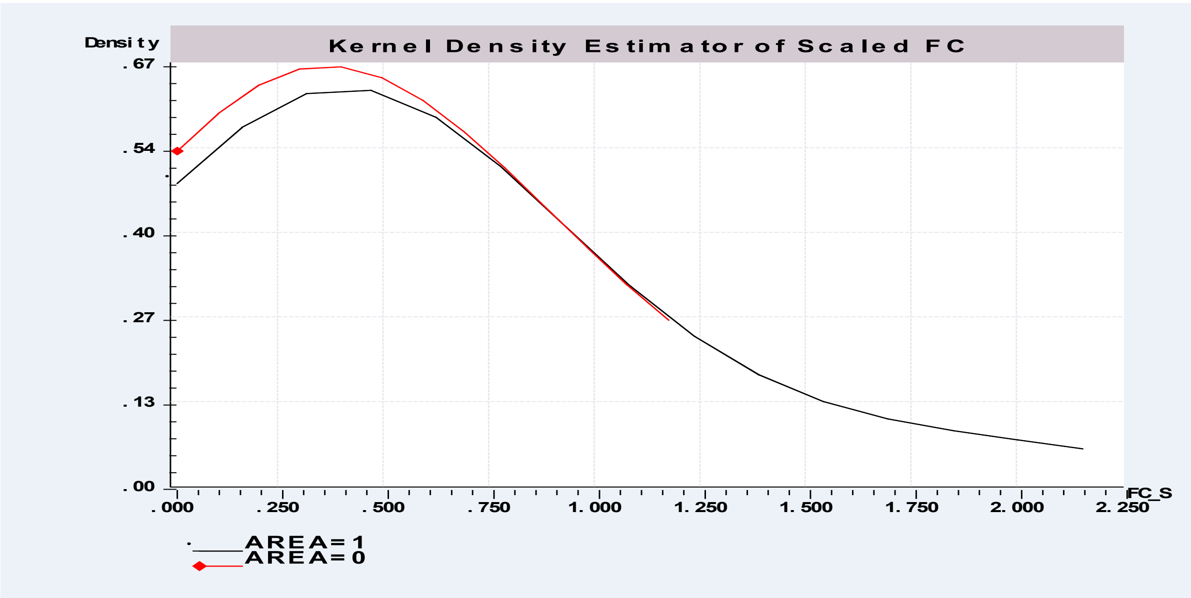

Figure 3-1: Kernel Density Estimators for Simulated Scaled Financial Opportunity Cost (FC_S) (Alberta: Area=1, Saskatchewan: Area=0; Logistic Kernel; Bandwidth = 0.337865)

Figure 3-2 presents the KDEs of the FC and predicted WTA (including imputed values) from the midpoint analyses (scaled by dividing by 1000) obtained from two study areas. The KDEs were again fitted using logistic kernel and a bandwidth parameter of 0.337865. There is a bigger gap between the FC density and the WTA density for Saskatchewan compared to that for Alberta. The overlapping coefficients of FC and WTA distributions are 0.7114 for Alberta and 0.2990 for Saskatchewan, respectively. In general, FC estimates are lower than the corresponding WTA estimates with the exception of three farms.

Figure 3-3 presents the KDEs excluding the observations with imputed WTA. Excluding the imputed WTA values affects the overlap coefficients and the shape of the WTA distributions. The overlapping coefficients of FC and WTA distributions fall to 0.67 for Alberta and increase to 0.3077 for Saskatchewan respectively.

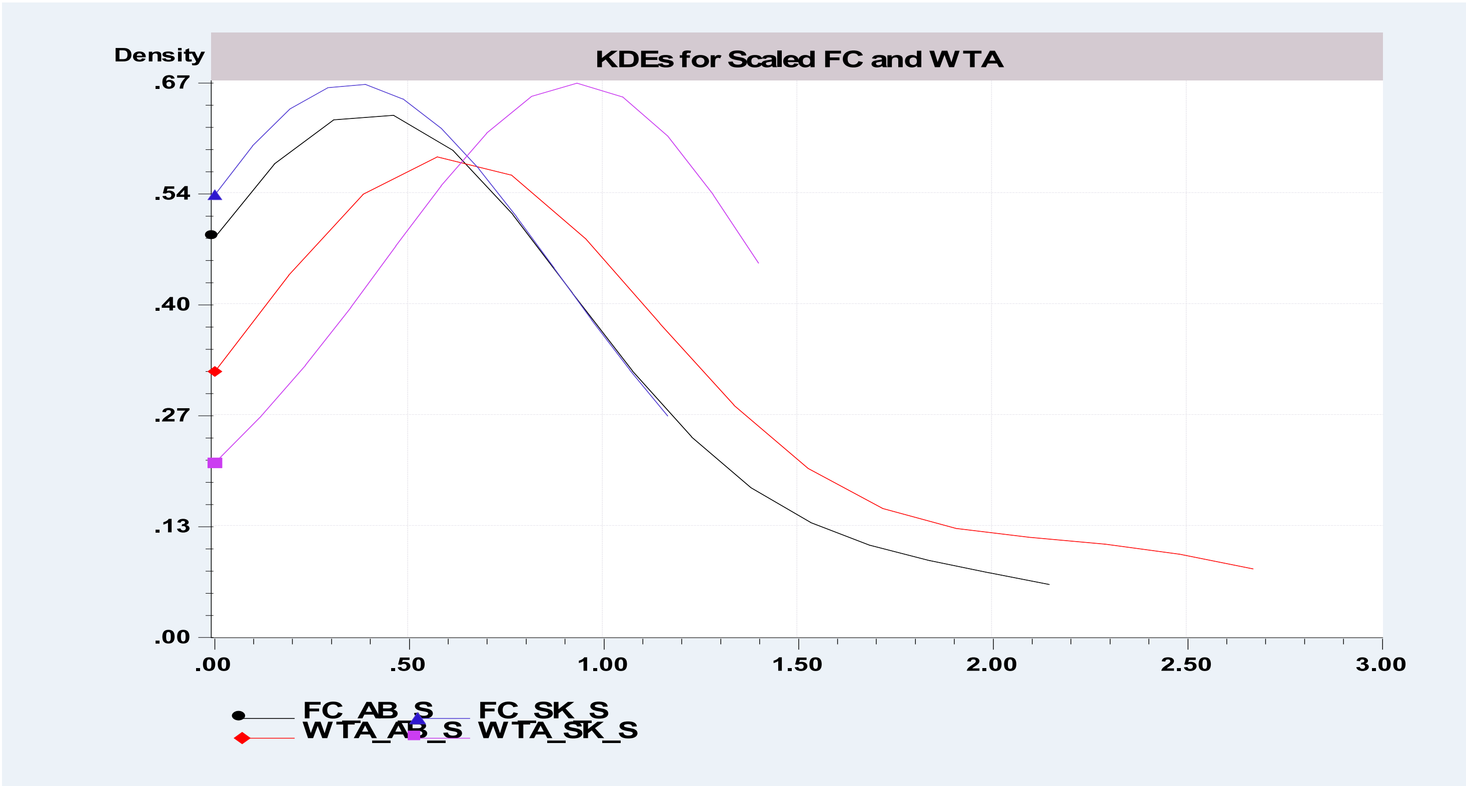

Figure 3-2: Kernel Density Estimators for Simulated Scaled Financial Opportunity Costs (FC_AB_S and FC_SK_S) and Scaled Predicted WTAs (WTA_AB_S and WTA_SK_S) Including Imputed Values of WTA

(Logistic Kernel; Bandwidth = 0.337865; AB represents Alberta and SK represents Saskatchewan)

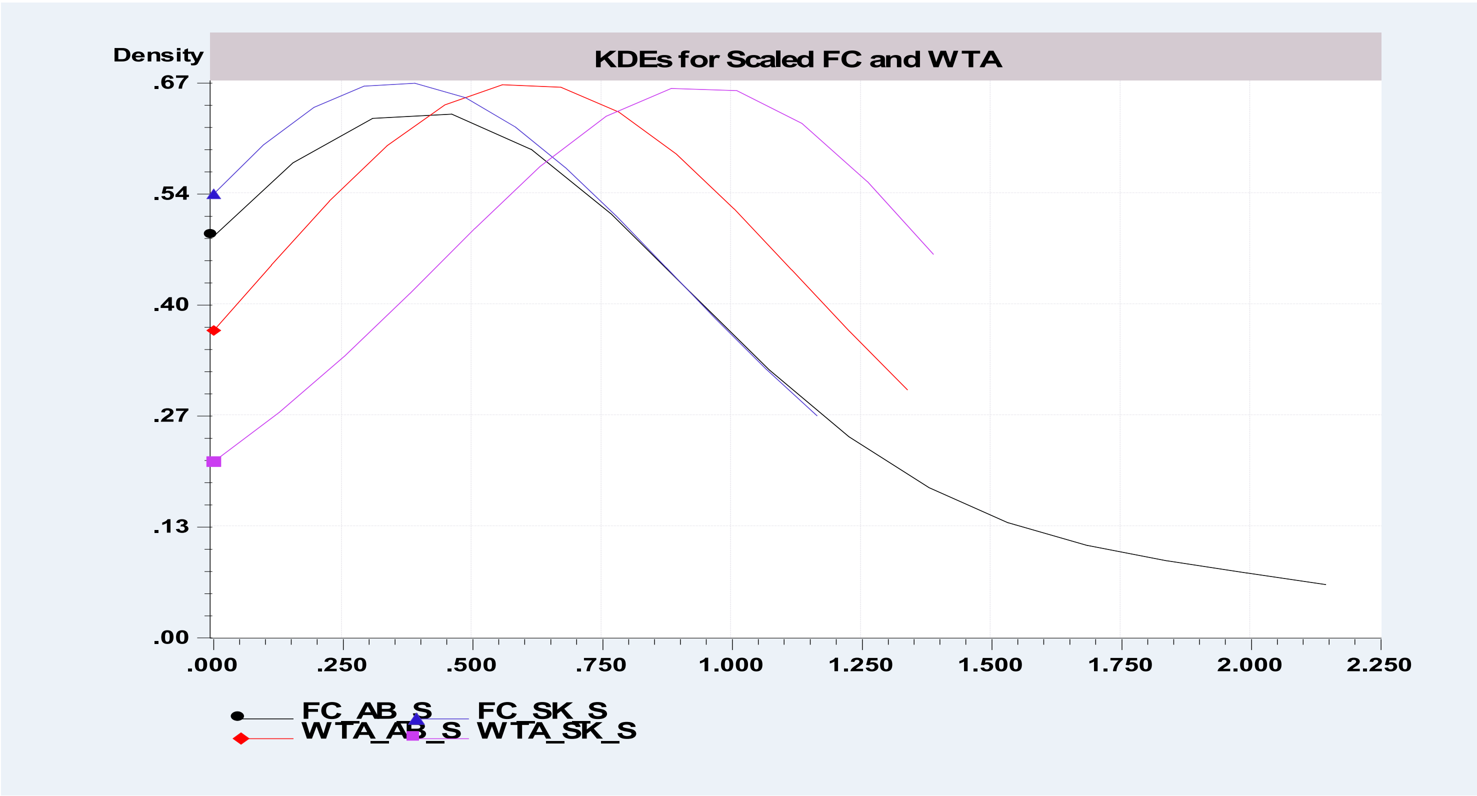

Figure 3-3: Kernel Density Estimators for Simulated Scaled Financial Opportunity Costs (FC_AB_S and FC_SK_S) and Scaled Predicted WTAs (WTA_AB_S and WTA_SK_S) Excluding Imputed Values of WTA

(Logistic Kernel; Bandwidth = 0.337865; AB represents Alberta and SK represents Saskatchewan)

Also of interest is whether FC estimates are correlated with the WTA estimates. The correlation coefficient of FC and WTA for the two samples combined was 0.467, if the imputed values of WTA were included in the sample. Excluding the observations with the imputed WTAs generated a negative correlation coefficient of -0.408 between FC and WTA indicating an inverse relation between these two measures. This is counterintuitive and might be due to the small sample size and presence of a few farms with very high WTAs compared to the FC counterparts.

Finally, a regression of the farm-specific scaled WTA estimates from the previous chapter on the scaled[33] FC estimates obtained in this chapter resulted in the following equation:[34]

$$\begin{aligned} Scaled\, WTA &= \underset{(4.18)}{0.57285} + \underset{(2.69)}{0.63725} * Scaled\ FC \end{aligned} \qquad 3\text{-}28$$

Both the constant term and the FC variable coefficient were positive. The constant term was significant at 1% level and the coefficient of the FC was significant at 5% level. This indicates that for the sampled producers in this study, the FC and WTA estimates are positively correlated.[35]

The chapter concludes with the following observations. The adoption of wetland restoration BMP imposes net costs on the producers. The positive costs of adoption indicate that without appropriate compensation, the potential for uptake of these programs would be low. The costs vary significantly across farms and their estimation would allow a policy maker or restoration agency to identify potentially low-cost suppliers of ES.

The variability in the cost of BMP adoption could be captured by using a farm-level simulation model that uses a mix of farm-specific primary data and secondary data. The farm-level simulation model does not account for producer preferences for ES or their perceived transaction costs involved in wetland restoration projects above and beyond the direct opportunity costs. Therefore, they are free from producer rent-seeking behaviour or hypothetical bias. However, precision of the estimation depends crucially on the data availability and specific model assumptions.

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[33] FC estimates are scaled by dividing by 1000.

[34] The t-statistic of estimated coefficients is given in parentheses below the coefficients.

[35] A study of the divergence between the farm-specific WTA and the FC values in terms of identifying explanatory factors remains a question to be further explored in future studies and extensions of this work.

The main drivers of the opportunity cost in the farm simulation models are loss of revenue for the acres set aside for wetland restoration and imposition of nuisance and input wastage costs. A higher precision in the estimation of FC could be obtained if actual field-specific information regarding impact on crops and nuisance costs could be obtained in the farm-level survey. Obtaining that level of precision would require developing a farm-specific restoration plan instead of using a stylized wetland restoration program. Incorporating farm-level variability in input costs would also further accentuate the estimated FC heterogeneity obtained in this study.

This study assumed that the same discount rate applies to all farms but this may not be the case in reality[36]. This implies that the degree of heterogeneity in farm-level FCs could be less in a model that assumes a single discount rate as opposed to farm-specific discount rates. This is a limitation of the current study and could be explored in future study.

Two sets of cost estimates have been derived from SP and farm simulation methods but what is the real-world use of these estimates? The current study has estimated net private costs of a select BMP in the Black soil region of Alberta and Saskatchewan. Both sets of cost estimates indicate that under the assumption that environmental benefits from wetland restoration are homogeneous across farms, it is efficient from the policy makers' perspective to target low-cost suppliers of ES and encourage them to participate in these programs through provision of incentives. This would potentially help achieve a certain environmental target at a lower overall budget.

The non-parametric density estimators of FC for the two study areas demonstrated a high degree of overlap, thus, indicating a potential for transfer across sites. FC estimates were found to be, in general, lower than WTA although they were positively correlated. The following chapter explores the relationship of these estimates further in the context of cost transfer exercise.

[36] Duquette et al. (2013) used a field experiment to elicit time preference of two samples of US farmers that are a priori known as early and late adopters of best management practices. They note that late adopters have 14% higher mean discount rate compared to the early adopters under the assumption of risk neutrality. They claim that individuals with high discount rates would be slow to adopt new conservation technologies (e.g. reduction of nitrogen application) that involve significant initial costs with benefits accruing in later periods. They note that the difference in discount rates across agricultural producers could potentially explain the low rate of uptake of conservation technologies. Yesuf (2004) and Duflo et al. (2011) also explore farmers' time preferences although in developing country contexts.

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4 Spatial Cost Transfer Analyses

4.1 Introduction[37]

Direct valuation studies are location-specific and, thus constrain policymakers in estimating the impact of a policy that would be implemented in multiple locations. However, direct valuation studies pose significant challenges, especially when such studies are undertaken to inform policy makers regarding the benefit or costs of an environmental policy or regulation within a specific timeframe. Also, the budget to conduct multiple site-specific direct valuation studies may be limited.

Benefit transfer (BT) is a methodology that has been evolving since the early 1990s as an alternative to direct valuation exercises for estimating values of environment benefits. A benefit transfer exercise attempts to address the issues posed by direct valuation exercises, such as time constraints, resource constraints and the site-specific nature limiting large scale applicability of study findings. Almost exclusively used to transfer benefits, the tool is called “benefit transfer” or “value transfer” as it involves transferring estimated benefit values (WTPs) from original valuation studies to a new application or policy context. The essence of a transfer exercise lies in using existing valuation information to predict the impact of new and/or existing policies in different locations and/or at different time periods (Boyle et al., 2010) for expedited policy evaluation.

A cost transfer methodology is, in principle, analogous to the BT as it addresses the issue of transferring elicited measures of willingness to accept (WTA). As of the time of this work, the transfer literature almost exclusively focuses on the benefit transfer (BT) methodologies, its applications and challenges with only cursory reference to the potential of application in cost transfer studies. However, the potential for applying a BT methodology to transfer costs spatially has been noted in a few benefit transfer studies. Navrud and Bergland (2005) noted that the use of cost transfer in policy contexts and especially the focus on determination of compensation payments requires a higher level of accuracy than is the case for benefit transfer and hence cost transfer has yet to achieve the same level of acceptance by the policy makers. Smith et al. (2002)

[37] Parts of this section are taken from Kanjilal and Jeffrey (2014) without rephrasing.

noted that the BT technique, specifically structural transfer using preference calibration, can be adapted and used to transfer WTA.

Cost transfer may prove to be a better alternative methodology than using ad hoc amounts for designing appropriate incentives to enhance private supply of public goods such as uptake of agricultural BMPs by agricultural producers to provide ES. It would also help to evaluate the costs of conservation programs and provide policy support within a reasonable time frame if the caveats applicable to transfer studies in general are taken into consideration.

While in principle cost and benefit transfer address the same policy need of obtaining estimates of welfare impact without conducting a complete direct valuation study, a few major differences set cost transfer apart from BT and pose challenges for a cost transfer exercise. The first major difference arises from the inherent nature of the welfare estimates that need to be transferred. WTA studies are less common than WTP studies thus leading to a lack of original studies available for cost transfer. A major issue associated with SP valuation and especially WTA studies is the existence of hypothetical bias. The implication of this issue is that in any cost transfer analysis the WTA estimates from original valuation studies would be under scrutiny regarding whether they represent the true welfare impact of the policy change in question. This, in turn, affects the quality of original data for any cost transfer studies to be undertaken. As the literature indicates that the choice of the valuation technique matters in terms of the difference between real and hypothetical WTA, it puts additional pressure on the analyst to select relevant studies with usable WTA data from an already limited pool of WTA studies. Secondly, the underlying property rights in a WTA study may not be well suited for a cost transfer, especially internationally, although it may not pose a big problem if the transfer is conducted within a small geographical scope. Thirdly, unlike WTP, WTA is not bounded by income. This implies that while in theory a cost calibration can be conducted using a WTA function by adapting the methodology of Smith et al. (2002), the advantage of consistency between multiple estimates of cost would be lost in such an adaptation. However, for empirical applications such as transferring WTA estimates for ES, the WTA values can roughly be anchored around land values at the sites concerned. A cost transfer study would have to address the challenges outlined above.

The previous chapters dealt with estimation of the cost of adopting wetland restoration BMP using two alternative methodologies – SP methods and farm-level cash-flow simulation methods. Using the SP methods, the study estimated agricultural producers' WTA compensation for restoring wetland in their active farmland in the Black soil region in Alberta and Saskatchewan. The farm-level cash-flow simulation studies estimated the farm-specific cost of adopting the BMP in terms of the impact on farm wealth under yield and price risk for the same sample of producers. Both of these methods used farm-specific data obtained using a farm-level survey designed to elicit agricultural producers' preference for compensation for adopting the BMP and data on farm operations. As discussed in the previous chapters, the availability of farm-level data for such studies can be limited as it is dependent on producers' availability and willingness to participate in such studies. Conducting the farm-level in-person surveys can be time consuming and expensive. They are also specific to the location or "site" of the environmental change under consideration and the affected population. Therefore, for time-sensitive policy need or for designing appropriate incentive schemes for agricultural producers for adopting BMPs, an alternative approach is needed. This underscores the need for a cost transfer study that would allow prediction of the cost of adopting wetland restoration BMP using existing valuation information.

The current study adapted select BT methods to transfer WTAs across the case study sites of Alberta and Saskatchewan. The cost estimation exercises described in Chapter 2 and Chapter 3 were motivated to generate data for the transfer exercises. This put the study in an advantageous position in terms of addressing the challenge of data availability for the proposed transfer exercise. Typically transfer exercises are undertaken when there is no *ex ante* valuation information available at the "policy site" (i.e., the site of interest for the policy purposes). However, policy relevant estimates of BMP adoption costs in the Canadian Prairie region are lacking. Also, given the lack of cost transfer studies in the transfer literature, it seemed justified to conduct two sets of premeditated direct valuation studies at two different but similar locations so that the transfer methods could be adapted and applied, and the errors in such a transfer exercise could be measured.

The current study elicited WTA and estimated financial opportunity cost (FC) of wetland restoration in two sites that are similar in terms of soil productivity, topographical features and enterprise mix. The choice of the sites of the original valuation exercise was not random and instead it was motivated by the ultimate objective of meeting the site similarity (Johnston et al., 2015; Johnston and Rosenberger, 2010; Johnston, 2007) criteria for the transfer exercise. Generation of the primary valuation data that were meant to be used in the transfer exercise addressed the issue of not finding an appropriate primary valuation study. The issue of hypothetical bias and social desirability bias inherent in the estimated WTA is addressed in the estimation of WTAs discussed in Chapter 2. Finally, having cost estimates available for the two sites in this study allowed the choice of picking either site as the "study site" and designating the other as the "policy site". This allowed the comparison of the originally estimated WTA and the "transferred WTA" at the policy site and thus estimation of the transfer error.

The analysis and discussion in this chapter examined the following questions. Can the WTA and FC estimates be used for point transfer? Can the estimates of cost be used for function transfer? How are the various estimates of cost obtained using behavioural methods and financial methods related given structural assumptions regarding the relationship made by the analyst? Can the relationship between various cost estimates be used to transfer costs spatially? How big are the errors?

The study transferred cost estimates through unit cost transfer and a simple cost function transfer using WTA and FC estimates. It also explored the potential of transfer using the relationship of WTA and FC estimates invoking an assumed preference structure. While exploring the structural relationship of the two types of cost estimates, the study used the "social preference" hypothesis and developed a land allocation model for an agricultural household with endogenous income. This model was used to numerically approximate preference parameters of an assumed utility function of an agricultural household which are then used in the structural cost transfer illustration. Given the gap in the transfer literature regarding cost transfer studies, the cost transfer exercise would be a significant contribution as one of the first studies to apply BT methodologies in a cost context.

4.2 Review of the BT Methods and General Methodological Approach[38]

The transfer literature deals almost exclusively with the state of the art of BT, the available methodologies, its empirical applications, issues and challenges. Therefore, it is important to briefly review the available BT methods and their merits and demerits. A detailed discussion and review of the BT methods is provided by Johnston et al. (2015). The brief review presented here

[38] Parts of this section are taken from Kanjilal and Jeffrey (2014) without rephrasing.

assists in focusing the discussion on the choice of BT methods that are explored in this study for the cost transfer. At the time that this thesis is written, the author is not aware of any existing cost transfer study.

4.1.1 General Methodological Approach

The first step of a typical transfer problem would involve a description of the policy context; that is, what is being valued. This is followed by the identification of existing valuation studies that would be relevant to the problem at hand. The locations of these original valuation studies are known as the “study sites”. The location of the policy evaluation is known as the “policy site”. The study sites and the policy site are compared to evaluate whether they have a sufficient degree of similarity regarding the ES being valued, affected population, baseline conditions and change in ES. Under favourable conditions for a transfer, WTP values from the study sites are transferred to the policy site. Note that this is the general approach in a policy-motivated study that relies entirely on existing estimates of WTP. The transferred values are then tested for convergent validity (Rosenberger, 2015).

BT can be done through time or space. As Johnston (2007) noted, policy context similarity or the similarity with respect to the availability of substitutes and complements across different sites is also emphasized as opposed to mere geographical similarity. The choice of non-market valuation techniques and the theoretical underpinnings of the original valuation studies also have an important bearing on the BT approach. Among the available BT methodologies this section focuses the discussion of the following: unit value transfer, simple function transfer and structural function transfer. [39]

[39] Pooled model analysis of CEs is another BT method (e.g. Johnston, 2007; Hanley et al., 2006a, 2006b; Kristofersson and Navrud, 2005; Jiang et al., 2005; Morrison et al., 2002; Morrison and Bennett, 2000). The common methodology for CE BT studies is to estimate individual choice models for each of the sites under consideration. Pooled models are estimated by imposing identical preference structure assumption across sites so that sites can be compared pair-wise. For each pair of study site-policy site, convergence validity tests are conducted to check for errors in the transfer (Moeltner et al., 2009; Johnston, 2007; Kristofersson and Navrud, 2005; Morrison et al., 2002; Morrison and Bennett, 2000; Jiang et al., 2005; Hanley et al., 2006a; 2006b; Colombo et al., 2007). Similarity of sites and policy context, attributes and their interactions as chosen by the analysts and the choice of original studies are said to affect to the result of a pooled model BT.

4.1.2 Benefit Transfer Methods

A unit value transfer involves transfer of central tendencies of WTP from a study site to a policy site. Rolfe, Windle and Johnston (2015) in their review of BT methods noted that unit value transfer can be undertaken with or without adjustments using estimates from single or multiple studies. In the case of transferring estimates from a single study, a point estimate such as mean or median WTP is used. In the case of multiple source studies, a weighted or unweighted mean of the WTP estimates is used. The transferred estimates could be adjusted ex post by exchange rates, price index or site and population characteristics depending on the requirements and context of the particular study. However, this method is seen as being too simplistic and potentially leaves large room for error in the benefit calibration across sites.

As opposed to value transfer, function transfers involve using an econometric analysis to fit a relationship of WTP as a function of study site characteristics and demographics that would be used to predict the WTP at the policy site (Rolfe, Windle and Johnston, 2015; Loomis, 1992; Rosenberger and Loomis, 2003). This value estimate is calibrated to policy-site conditions using the variables in the valuation equation (Boyle et al., 2010) given that at least a subset of the explanatory variables of valuation equation are available for the policy site (Rolfe, Windle and Johnston, 2015). A function transfer would likely be more accurate than a value transfer as it uses an estimated preference function or a meta-analysis to compute a transfer estimate (Kaul et al., 2013; Boyle et al., 2010). Kaul et al. (2013) also noted that a function transfer performs better than unit value transfer in terms of generating lower levels of error.

Function transfers can be of two different types - "simple" function transfer and "structural" function transfer. The main difference between "simple" and "structural" function transfer is that the assumed preference function in the case of a "simple" function transfer does not lend itself to mutual consistency of different welfare measures. A "simple" function transfer refers to a "single-site" function transfer that uses primary valuation data from a single study while a "structural" transfer uses multiple valuation estimates. However, a simple function transfer is expected to generate lower transfer error compared to the transfer of point estimates of value (Groothuis, 2005; DEFRA, 2010).

Structural function transfers can be of two different categories - reduced-form meta-analyses and structural transfers of preference functions. Reduced-form meta-analysis requires common value estimates from a large number of distinct study sites. Original valuation studies even in the same valuation context use different study designs, models and econometric methods. In a meta-analysis, multiple studies are used to generate a statistical summary. The common summary statistic or the measure of the value concerned (e.g., elicited WTP) from the original valuation studies is used as the dependent variable. This is regressed on dummy variables representing study design, econometric methods, valuation method employed, model specifications, quality of the publication etc. of the primary studies. The regression equation thus estimated is referred to as a meta-regression equation. In a benefit transfer exercise, this equation is used to generate an out-of-sample prediction for WTP given a set of preconditions or measures of the independent variables that are obtained from the policy site in question (Nelson and Kennedy, 2009). It may be noted that the requirement for a large number of primary valuation studies makes this particular type of structural transfer poorly suited for the present cost transfer exercise due to the lack of available WTA estimates for wetland restoration BMP from multiple sources.

The structural function transfer approach to BT uses a specification for the preference function which allows an analytical connection to be made between different concepts of value (Pattanayak et al., 2007; Smith et al., 2006; Smith et al., 2002). Smith et al. (2002) observed that transfer exercises using point estimates or a simple transfer function are primarily empirical exercises and their basis in utility theory is somewhat weak. A structural function transfer, hereby referred to as structural transfer, addresses this limitation of the simple transfers. The Preference Calibration (PC) approach is a structural function transfer approach proposed by Smith et al. (2002). The PC approach investigates whether, given a specific preference pattern, the available benefit information is sufficient to infer the parameters of the preference function. Once these preference parameters are obtained, it is possible to evaluate the welfare impacts of different policy changes using the identified preference structure. In this approach, the preference function is calibrated using all congruent and available information to estimate a common economic value.

In a PC exercise, a parametric specification for the preference function is chosen and then the relationship of the parameters to the benefit values obtained from relevant valuation studies is determined. This step is based on the theoretical concepts of value such as Roy's identity or Hicksian WTP. Appropriate mean values of the variables are selected from the original studies to calibrate the preference function parameters. The parameters are chosen to calibrate the preference function to approximately reproduce the study site values. The policy site characteristics and demographics are then substituted in the calibrated preference function to predict the welfare estimate for the policy site (Smith et al., 2002; Williamson et al., 2007). It is a theoretically consistent approach, unlike reduced form meta-analysis, although it may suffer from the same data limitation problems. This method depends on explicit assumptions regarding the specification of the utility function, selection of original studies and translation of results from different original studies to get a common unit of measurement.

Structural function transfer and preference calibration in particular is highlighted by Smith et al. (2002) as a BT method that has several advantages compared to the other methods. The main advantage of this method is in its theoretical basis that leads to consistency in the estimated welfare impact. Observable predictions of preference calibration models not only include the estimated WTP that is bounded by income but also the other predictions such as elasticities, which can be checked easily for plausibility. Finally, mutual consistency of benefit measures obtained from several studies is maintained as the single model helps reconcile between theoretically different but related measures of consumer surplus and WTP. While most other cautions and caveats about undertaking benefit transfer exercise apply for this method, its unique challenge lies in the specification of the functional form. As demonstrated by Williamson et al. (2007) the technique is complicated even without specifying a new functional form. This may explain why only a few applications of this technique are documented in the literature. In section 4.3, the unit value transfer, simple function transfer and structural function transfer are applied in transferring costs of wetland restoration BMP from Alberta to Saskatchewan.

4.1.3 Validation and Measurement of Error

Typically the error in a transfer exercise has two sources – measurement error and generalization error. Measurement error arises because of the failure of the primary valuation study to estimate the true welfare impact. Generalization error arises due to the transfer process. Convergent validity is a test for whether study-site data can be used to predict a calibrated policy-site welfare impact. A transfer is deemed valid in this context if one fails to reject the null hypothesis that the policy-site estimate from the original valuation study and the predicted value obtained by calibrating the study-site estimate(s) to policy-site conditions are equal.

The tests of convergent validity constitute tests of transfer validity and transfer reliability. Transfer validity assesses the precision of the transfer using statistical tests and thus poses a statistical issue of being able to match estimates from the study site to the data from the policy site. The measure of reliability is given by transfer error and it is characterized as being context dependent (Rosenberger, 2015). Boyle et al. (2009, 2010) suggested that transfer error can be minimized by matching the context of the transfer across the study and policy sites.

Transfer reliability is tested using Percent Transfer Error (PTE) method (Rosenberger and Stanley, 2006). The PTE method requires the knowledge of an actual welfare impact estimate for the policy site. The calibrated transfer estimate is compared to this actual estimate and PTE is calculated as a percentage difference of the calibrated estimate and the actual estimate compared to the actual estimate.

Rosenberger (2015) summarized the mean PTE observed in 38 studies that provide 1792 PTE tests for value transfer and 756 PTE tests for function transfer. The range of absolute PTE for value transfer is from less than 1% to more than 7000% and that of function transfer is from less than 1% to more than 900%. While majority of the studies are on recreational benefit transfer, Brouwer and Spaninks (1999) used a benefit transfer of farmers WTP for rare meadow bird species in agricultural areas estimated using CVM payment card and open-ended CVM. They noted that mean PTE of the transfer is in the range 30-31%. Morrison and Bennett (2000) and Morrison et al. (2002) used CEs for valuation and transfer of ecosystem service benefits and find that PTE is 45% and 56% respectively. Note that the lack of WTA transfer studies makes it difficult to assess what would be an acceptable level of PTE in a cost transfer exercise. However, Navrud and Pruckner (1997) noted that using WTA transfer for designing compensation packages would require a high level of precision indicating low levels of PTE.

4.3 Empirical Methods and Results

The protocol for undertaking a transfer of a point estimate of cost follows Rolfe, Windle and Johnston (2015). The first stage of a cost transfer exercise involves establishing the context and framework of the transfer. The transfer exercise in this study was focused on transferring the estimates of agricultural producers' private cost of provision of ecosystem services through adoption of wetland restoration BMP. The location of interest was the Black soil region of Central Alberta and South-eastern Saskatchewan. A description of the study areas was provided in Appendix A and also in the discussion in Chapters 2 and 3. It was noted that original valuation studies focusing on the estimation of the cost of BMP adoption were fairly limited in this area. Hill et al. (2011) estimated agricultural producers WTA compensation in Saskatchewan using a reverse auction. Other studies (e.g., Trautman et al., 2013) used representative-farm cash flow simulation models to estimate the economic impact of wetland restoration BMP adoption in Alberta although for a dark brown soil region. The limited availability of original valuation studies identified by the initial literature review motivated the current study to undertake WTA and FC estimation exercises that are described in the previous chapters. However, the scope of the primary valuation study was limited to the current sample of the study. For a greater policy context, a cost transfer tool would address the primary data limitation by allowing out-of-sample predictability.

Using primary valuation studies that were originally motivated to generate data for the cost transfer imposed certain similarity conditions *ex ante*. The WTA and FC were estimated using the same stylized BMP adoption program that resulted in an equal loss of acreage in cropland across all farmers in the sample. This imparted measurement similarity (loss of area), framing similarity (economic impact of agricultural BMP) and scale similarity (individual producers' cost of adoption) (Rolfe, Windle and Johnston, 2015) across the sites. The population of interest was agricultural landowners located in two different provinces in Western Canada.

The source data for the transfer were the WTA and FC estimates obtained in the previous chapters. As mentioned before, having original valuation data for both study and policy sites made it possible to check for transfer errors even in the absence of any other direct valuation study. However, that does not imply that the original source data (WTA and FC estimates in this case) were free of measurement error. Given that WTA estimates from the reverse auction (Hill et al., 2011) were available for Saskatchewan and could be used to check for transfer errors, Alberta was defined to be the "study site" and Saskatchewan was defined as the "policy site".

4.1.4 Unit Cost Transfer

A unit cost transfer method utilizes the central tendencies of welfare measures (WTA) obtained for a representative individual in the study sample. Adapting the conceptual model of unit value transfer as developed in Johnston et al. (2015) gives the following.

Suppose the central tendency (mean or median) of the WTA for adoption of wetland restoration BMP at site j and sampled population s is given by $\overline{w}_{js}$. A unit cost transfer method is applied when the welfare impact of adoption of wetland restoration BMP is required at site i $(i \neq j)$ and sampled population r $(r \neq s)$. The transferred cost is given by $\hat{w}_{ir}$.

Johnston et al. (2015) noted that it is possible to transfer a single, unadjusted estimate; an adjusted estimate or a range of estimates, if available. The transfer of a single, unadjusted estimate implies that,

$$\hat{w}_{ir} = \overline{w}_{js} \tag{4-1}$$

The unit cost transfer without adjustment assumed that the median WTA for wetland restoration obtained at the Alberta site is the required transferred cost for the Saskatchewan site. As the WTA was estimated to determine average compensation that would be required by a producer in Saskatchewan, it is not aggregated. For the same stylized wetland restoration program under consideration at both sites, there was no need to scale the transferred value up or down. Using the unit cost transfer with no adjustment, therefore, implied that the mean or median WTA for Alberta obtained using the midpoint analyses or the partial RE Probit models were equal to the calibrated WTA for the corresponding Saskatchewan models.

The calibrated WTA for the Saskatchewan policy site obtained from the midpoint analyses and the partial RE Probit models using own and inferred valuation data are presented below in Table 4-1 along with the estimated WTA obtained from each corresponding method. The absolute values of the corresponding PTE estimates are also provided for each calibrated cost. A similar exercise of cost calibration could also be undertaken using the estimates of FC obtained in Chapter 3 (Table 4-2). The mean FC from Alberta could also be transferred to calibrate average WTA at the policy site as a “cross” transfer exercise (Table 4-3). The corresponding transfer error was calculated with respect to the median WTA estimates for own and inferred valuation that were available for Saskatchewan.[40]

Table 4-1: Comparisons of Calibrated and Estimated Central Tendencies of WTA using Unit Cost Transfer without Adjustment - Saskatchewan Policy Site

Source of cost estimate	Calibrated WTA[a] ($/acre/year)	Estimated WTA[b] ($/acre/year)	Percent transfer error (PTE)[c] (%)
Mean predicted WTA from midpoint analyses including imputed values	847.17	881.69	3.91
Mean predicted WTA from midpoint analyses excluding imputed values	617.85	882.67	30.00
Median partial RE Probit with own valuation	454.56	733.32	38.01
Median partial RE Probit with inferred valuation	647.44	766.36	15.52

[a]: Calibrated WTA indicates mean or median WTA obtained at the study site of Alberta and transferred without adjustment to the policy site of Saskatchewan. [b]: Estimated WTA indicates mean or median WTA obtained at the policy site of Saskatchewan by this study. [c]: PTE=absolute value of [{(Calibrated WTA-Estimated WTA)/Estimated WTA}*100].

Table 4-2: Comparisons of Calibrated and Estimated Central Tendencies of FC using Unit Cost Transfer without Adjustment - Saskatchewan Policy Site

Source of cost estimate	Calibrated FC[a] ($/acre/year)	Estimated FC[b] ($/acre/year)	Percent transfer error (PTE)[c] (%)
Mean financial cost from cash flow simulation models	511.19	391.49	30.57

[a]: Calibrated FC indicates mean FC obtained at the study site of Alberta and transferred without adjustment to the policy site of Saskatchewan. [b]: Estimated FC indicates mean FC obtained at the policy site of Saskatchewan by this study. [c]: PTE=absolute value of [{(Calibrated WTA-Estimated WTA)/Estimated WTA}*100].

[40] As noted in the previous chapter, there may be an inconsistency between the FC and WTA estimates if the underlying assumption that the restored wetlands would not be drained at the end of the specified contract period is incorrect. This should be considered as a caveat while evaluating the transfer error for the "cross" transfer exercises.

Table 4-3: "Cross" Transfer of Mean FC Estimates to Calibrate WTA using Unit Transfer without Adjustment - Saskatchewan Policy Site

Source of cost estimate	Calibrated WTA[a] ($/acre/year)	Estimated WTA[b] ($/acre/year)	Percent transfer error (PTE)[c] (%)
Mean financial cost from cash flow simulation models	511.19	733.32[d]	30.29
		766.36[e]	33.30

[a]: Calibrated WTA at the policy site of Saskatchewan based on mean FC from the study site of Alberta. [b]:Median WTA obtained at the policy site by this study. [c]: PTE=absolute value of [{(Calibrated WTA-Estimated WTA)/Estimated WTA}*100]. [d]: Own median WTA. [e]: Inferred median WTA.

As the sampled agricultural producers were located in two different provinces, they potentially faced different prices. As noted by Rolfe, Windle and Johnston (2015), adjusting the source valuation data for price differences is common in unit value transfer studies, although they characterized this as an ad hoc adjustment depending on the context of the study. In this study, while the differences in prices between the provinces were not explicitly considered in the WTA estimation, it was a crucial assumption in the modelling of the stochastic prices in the cash flow simulation models for estimation of FC. Therefore, it was decided for the current study to adjust the unit cost transfer by the provincial all-items consumer price index (CPI). With the provincial price adjustment, the ex post cost adjustment function is given by:

$$\hat{w}_{ir} = f\left(\overline{w}_{js}\right) = \overline{w}_{js} * \frac{CPI_i}{CPI_j} \qquad 4\text{-}2$$

where CPI_i denotes the all-item consumer price index at the policy site and CPI_j is that at the study site.

The Alberta all-items CPI in 2014 (CPI_j) was 132.2 while the Saskatchewan CPI_i was 128.7 (Statistics Canada, 2015). With the price adjustment using provincial all-item CPI, the calibrated WTA, calibrated FC and the corresponding PTEs are reported in the following tables (Table 4-4, Table 4-5 and Table 4-6).

Note that the estimated WTAs for Alberta were lower than that for Saskatchewan. As the All-items CPI is higher for Alberta than Saskatchewan, the price index adjustment led to a reduction of the calibrated WTA for Saskatchewan and thus higher levels of PTE. A unit cost transfer using WTA estimates without adjustment in prices performed better in this case in terms of lower error. However, as the mean FC was higher for Alberta than Saskatchewan, the price adjustment lowered the transfer error.

Table 4-4: Comparisons of Calibrated and Estimated Central Tendencies of WTA using Unit Cost Transfer with Adjustment using Provincial All-Items CPI - Saskatchewan Policy Site

Source of cost estimate	Calibrated WTA[a] ($/acre/year)	Estimated WTA[b] ($/acre/year)	Percent transfer error(PTE)[c] (%)
Mean predicted WTA including imputed values	824.74	881.69	6.46
Mean predicted WTA excluding imputed values	601.49	882.67	31.86
Median partial RE Probit with own valuation	442.53	733.32	39.65
Median partial RE Probit with inferred valuation	630.30	766.36	17.75

[a]: Calibrated WTA indicates mean or median WTA obtained at the study site of Alberta and transferred after CPI adjustment to the policy site of Saskatchewan. [b]: Estimated WTA indicates mean or median WTA obtained at the policy site of Saskatchewan by this study. [c]: PTE=absolute value of [{(Calibrated WTA-Estimated WTA)/Estimated WTA}*100].

Table 4-5: Comparisons of Calibrated and Estimated Central Tendencies of FC using Unit Cost Transfer with Adjustment using Provincial All-Items CPI - Saskatchewan Policy Site

Source of cost estimate	Calibrated FC[a] ($/acre/year)	Estimated FC[b] ($/acre/year)	Percent transfer error (PTE)[c] (%)
Mean financial cost from cash flow simulation models	494.63	390.94	26.52

[a]: Calibrated FC indicates mean FC obtained at the study site of Alberta and transferred after CPI adjustment to the policy site of Saskatchewan. [b]: Estimated FC indicates mean FC obtained at the policy site of Saskatchewan by this study. [c]: PTE=absolute value of [{(Calibrated WTA-Estimated WTA)/Estimated WTA}*100].

Table 4-6: "Cross" transfer of Mean FC Estimates to Calibrate WTA using Unit Transfer with Adjustment using Provincial All-Items CPI - Saskatchewan Policy Site

Source of cost estimate	Calibrated WTA[a] ($/acre/year)	Estimated WTA[b] ($/acre/year)	Percent transfer error (PTE)[c] (%)
Mean financial cost from cash flow simulation models	497.66	733.32[d]	32.14
		766.36[e]	35.06

[a]: Calibrated WTA at the policy site of Saskatchewan based on mean FC from the study site of Alberta. [b]:Median WTA obtained at the policy site by this study. [c]: PTE=absolute value of [{(Calibrated WTA-Estimated WTA)/Estimated WTA}*100]. [d]: Own median WTA. [e]: Inferred median WTA.

4.1.5 Simple Cost Function Transfer

In a simple cost function transfer, the cost function derived from a primary study is used to calculate the WTA estimate at a policy site. The cost function needed for the analysis is such that the parameters of the function are calibrated using information from the study site. Once parameterized, the function is then evaluated using the values of the specified observable determinants of cost from the policy site. It may be noted that sometimes only a subset of the full set of explanatory variables of cost could be observed at the policy site. In such cases, the policy site information is used for the variables for which data are available from the policy site and study site information is used for the rest of the explanatory variables (Johnston et al., 2015; Rosenberger and Loomis, 2003; Loomis, 1992). The simple cost function transfer uses the cost estimates obtained from CVM, CE or recreational demand models of a single primary study to estimate the transfer function and is also known as a single-site function transfer.

Using the same notation described above, the cost function was defined as follows:

$$w_{js} = g(x_{js}, \hat{\beta}_{js}) \quad \text{4-3}$$

where w_{js} denoted the estimated cost at the study site j, x_{js} denoted the vector of variables specified as the determinants of cost at the study site and $\hat{\beta}_{js}$ was the vector of estimated parameters corresponding to the vector of explanatory variables in the cost equation. $\hat{\beta}_{js}$ was estimated using the information about w_{js} and x_{js} available from the selected primary valuation study. The reduced form of Equation 4-3 could be linear in its simplest form or could be non-linear to accommodate complexity in the relationship of the explanatory variables and the cost estimates (Johnston et al., 2015).

The essence of the simple cost transfer was the assumption that the $\hat{\beta}_{js}$ estimated from the study site is applicable in describing the relationship between the explanatory variables and cost estimates at the policy site. A successful transfer requires equality of coefficients at the study site and the "true" coefficients at the policy site.

The transferred cost using a simple function transfer was obtained as follows:

$$\hat{w}_{ir} = g(x_{ir}, \hat{\beta}_{js}) \quad \text{4-4}$$

To illustrate the simple cost function transfer approach, it was assumed that estimated farm-specific WTA is a linear function of observable farm and producer characteristics. Following Equation 4-3, the estimated farm-specific WTAs[41] obtained from the midpoint regression model were regressed on producer age (AGE), acres under agricultural production (AGAREA), number of seasonal wetlands on their farms (SEASWET) and a dummy variable signifying the main type of enterprise on the farm (CROP, where a value of one indicated that the main enterprise was crop and a zero value represented cow-calf or mixed). WTA estimates were regressed using various combinations of select explanatory variables in four different model specifications and survey data on the explanatory variables from Alberta. The model specifications used for simple cost function transfer were as follow.

Specification 1:

$$w_{js} = \alpha_{js} + \beta_{AGE_{js}} * AGE_{js} + \beta_{AGAREA_{js}} * AGAREA_{js} + \beta_{SEASWET_{js}} * SEASWET_{js} + \beta_{CROP_{js}} * CROP_{js} \quad \text{4-5}$$

Specification 2:

$$w_{js} = \alpha_{js} + \beta_{AGAREA_{js}} * AGAREA_{js} + \beta_{SEASWET_{js}} * SEASWET_{js} + \beta_{CROP_{js}} * CROP_{js} \quad \text{4-6}$$

Specification 3:

$$w_{js} = \alpha_{js} + \beta_{AGAREA_{js}} * AGAREA_{js} + \beta_{CROP_{js}} * CROP_{js} \quad \text{4-7}$$

Specification 4:

$$w_{js} = \alpha_{js} + \beta_{AGE_{js}} * AGE_{js} + \beta_{AGAREA_{js}} * AGAREA_{js} + \beta_{CROP_{js}} * CROP_{js} \quad \text{4-8}$$

The estimation was done in Stata 10 IC. The regression results are presented in Table M1 through Table M4 in Appendix M. The highest degree of significance of the coefficients for the Alberta subsample was obtained for Specification 2 (Table M2). To test for equality of

[41] The simple function transfer approach was undertaken using the farm-specific own WTAs. The inferred WTAs were not used in this instance as some of the sampled producers responded that they were unable to indicate the amount of compensation that a typical producer in their area would be willing to accept for wetland restoration. Thus, using the inferred WTA values would mean conducting the regression analyses for function transfer with an even smaller sample size. To avoid that issue, only the own WTA values from midpoint analysis were used.

coefficients of the explanatory variables across the two subsamples, the corresponding linear regression model for Saskatchewan was also estimated and presented alongside each WTA model specification for Alberta. The coefficients for the explanatory variables were noticeably different in magnitude and significance level across the subsamples.

To formally test model coefficients for convergent validity, a Chow test statistic for equality of the coefficients of the explanatory variables across the subsamples from the two sites was calculated. Using the notation developed for the conceptual model of simple function transfer, the null hypothesis of the Chow test was given by: $H_0 : \hat{\beta}_{js} = \hat{\beta}_{ir}$. A summary of the χ^2 test statistic for each of the WTA model specifications is provided in Table 4-7.

For Specifications 1 and 2 that generated very high significance of the variables for the Alberta sample, the null hypotheses of equality for all but one of the coefficients were rejected at 1% level of significance. For Specifications 3 and 4, the null hypotheses of equality of the coefficients of AGAREA were rejected at 1% of significance and that of the rest of the variables were rejected at 5% or 10% level. The convergent validity tests, therefore, indicate that even though the WTA models for the Alberta subsample indicate high degree of significance of the coefficients, the statistical validity of transferring these coefficients is extremely low. This is not surprising as the coefficients of the explanatory variables of the WTA function often switched signs across the samples. The convergent validity test indicated that in a cost transfer exercise where cost estimates from a primary study conducted at the policy site are not available, relying on coefficient significance only for the simple function transfer could be problematic.

Table 4-7: Chi-square ($\chi^2(1)$) Test Statistic of Chow Tests for Coefficient Equality Across Alberta and Saskatchewan Subsamples - Including Observations with Imputed WTA[a]

Explanatory variables	Specification 1	Specification 2	Specification 3	Specification 4
AGE	1.64			6.39
AGAREA	16.74	17.80	25.51	35.59
SEASWET	305.12	511.00		
CROP	20.22	13.40	3.02	2.64

[a:] 1% critical value: 6.63, 5% critical value: 3.84, 10% critical value: 2.71.

Even though the estimated coefficients were statistically different across the two sites, the estimated coefficients in the simple cost transfer functions for Alberta could be used to calibrate mean WTA at Saskatchewan using the sample average of the explanatory variables for Saskatchewan.

Table 4-8 reports the calibrated mean WTA using all four specifications of the simple transfer function and the estimated mean WTA from the midpoint regression model for Saskatchewan. The corresponding PTEs are also reported.

Despite the low statistical validity of the coefficient transfer, the PTE ranged from 2.74% to 11.3%. This is an unexpected result. It is possible that the coefficients of the linear transfer functions were biased due to the presence of a few respondents that switched from no to yes answers for very high bid amounts. The predicted WTAs for the producers in the Saskatchewan sample were higher than those in Alberta. The observable farm and producer characteristics varied considerably across the subsamples as well. It is possible that the net effect of these differences resulted in a comparatively low PTE.

Table 4-8: Comparisons of Calibrated WTA and Estimated Mean WTA using Simple Function Transfer - Saskatchewan Policy Site (Including Observations with Imputed WTA)

Source of estimated coefficients for WTA calibration - Alberta[a]	Calibrated mean WTA - Saskatchewan ($/acre/year)[b]	Estimated mean WTA from Midpoint Analyses - Saskatchewan ($/acre/year)	PTE(%)[c]
Specification 1 (AGE, AGAREA, SEASWET, CROP)	782.92	881.69	11.20%
Specification 2 (AGAREA, SEASWET, CROP)	782.04		11.30%
Specification 3 (AGAREA, CROP)	951.95		7.97%
Specification 4 (AGE, AGAREA, CROP)	905.86		2.74%

[a]: Explanatory variables of the WTA function in parentheses. [b]: Calibrated WTA using estimated coefficients of the WTA function from the study site of Alberta and mean of explanatory variables from the policy site Saskatchewan. [c]: PTE=absolute value of [{(Calibrated WTA-Estimated WTA)/Estimated WTA}*100].

To determine if including the imputed WTA values significantly affected the significance and the magnitude of the coefficients of the explanatory variables in the transfer equation, the above set of four specifications were estimated without including the farms that did not accept any compensation amounts. The linear WTA transfer models are provided in Table N1 through

Table N4 in Appendix N. Specification 2 for the simple cost function of Alberta was maintained to be the best model in terms of the degree of significance of the coefficients.

The corresponding χ^2 test statistic results for the Chow test of equality of coefficients across two subsamples for each of the WTA model specifications are provided in Table 4-9.

Table 4-9: Chi-square ($\chi^2(1)$) Test Statistic of Chow Tests for Coefficient Equality Across Alberta and Saskatchewan Subsamples - Excluding Observations with Imputed WTA[a]

Explanatory variables	Specification 1	Specification 2	Specification 3	Specification 4
AGE	1.52			5.55
AGAREA	11.99	11.88	7.92	8.28
SEASWET	117.19	146.36		
CROP	19.42	12.11	2.92	3.72

[a]: 1% critical value: 6.63, 5% critical value: 3.84, 10% critical value: 2.71.

Again the same qualitative results were obtained. The simple cost function specifications (Specifications 1 and 2) that seemed to have a better fit in terms of coefficient significance and R^2 had test results indicating that the coefficients were significantly different across the two sites. However, for the models that were not the best-fit it was harder to reject the null hypothesis of coefficient equality (e.g. Specification 4 of Table 4-9). The estimated coefficients were again used to calibrate WTA for the Saskatchewan site and calculate the PTEs. The calibrated mean WTA obtained from the four specifications are reported in Table 4-10.

Table 4-10: Comparisons of Calibrated WTA and Estimated Mean WTA using Simple Function Transfer - Saskatchewan Policy Site (Excluding Observations with Imputed WTA)

Source of estimated coefficients for WTA calibration - Alberta[a]	Calibrated mean WTA - Saskatchewan ($/acre/year)[b]	Estimated mean WTA from Midpoint Analyses -Saskatchewan ($/acre/year)	PTE(%)[c]
Specification 1 (AGE, AGAREA, SEASWET, CROP)	797.12	882.67	9.69%
Specification 2 (AGAREA, SEASWET, CROP)	795.53		9.87%
Specification 3 (AGAREA, CROP)	668.55		24.26%
Specification 4 (AGE, AGAREA, CROP)	668.13		24.31%

[a]: Explanatory variables of the WTA function in parentheses. [b]: Calibrated WTA using estimated coefficients of the WTA function from the study site of Alberta and mean of explanatory variables from the policy site Saskatchewan. [c]: PTE=absolute value of [{(Calibrated WTA-Estimated WTA)/Estimated WTA}*100.

The PTE ranged from 9.69% to 24.31% when the observations with imputed WTAs were excluded. It appears that the exclusion of these observations generated a lower cost transfer error for the model specifications that also have high coefficient significance level for the study site[42]. However, excluding them reduced the χ^2 test statistics values for all the specifications, thus implying that these observations behave as outliers (in terms of WTA, area under agricultural production and number of seasonal wetlands) and excluding them led to a higher degree of coefficient equality across the two subsamples.

The varying degrees of PTE and coefficient equality across the subsamples made it difficult to select a particular specification for simple function transfer. In the absence of any farm-specific WTA data for the Saskatchewan subsample it would not be possible to estimate an equation regressing WTA on sample covariates from Saskatchewan, thus making the Chow test of coefficient inequality infeasible. In such a case it is likely that the choice of the best-fit transfer equation would be made on the basis of high levels of coefficient significance for the Alberta subsample only. Based on that criterion, Specification 2 would seem to be the best fit and the range of corresponding PTEs would be 9.87-11.30%.

[42] The transfer of the site-specific "full" RE Probit models was also attempted. However, using the full RE model with covariates led to negative values of calibrated WTA for Saskatchewan. This is likely attributable to the fact that the coefficients in the "full" RE models are biased due to potential endogeneity of some of the explanatory variables.

4.1.6 Structural Function Transfer

A structural transfer utilizes a formal structure by explicitly identifying the utility function that is asserted to correspond to the underlying preference of the sampled population relevant for the transfer study. Following the principle of a structural benefit transfer, a structural cost transfer uses multiple estimates of cost to calibrate the parameters of a utility function posited by the analyst (Smith et al., 2002). Once the parameters are calibrated, the estimated preference structure is used to transfer costs across the sites.

A structural transfer of cost of BMP adoption based on this principle was attempted using the estimates of cost obtained from the two different valuation methods. The goal of the exercise was to estimate the parameters of an assumed preference function given the estimates of WTA and FC. Once the preference function structure was identified, it was used to transfer cost from the study site to the policy site. The structural transfer depended on the significant assumption that estimated preference function applied to the sampled population at both sites.

The simplistic structural cost transfer model started with the search for an appropriate conceptual framework that would help establish a connection between the change in NPV of a farm's cash flow (FC) and the producers' WTA. It was noted in Chapter 3 that the estimates of FC and WTA were positively correlated for the pooled sample of producers in this study. However, no utility theoretic connection was made between these two estimates of cost. An agricultural household model with endogenous income was employed to formalize the relationship of the FC of BMP adoption and the WTA of the agricultural producers by invoking the social preference hypothesis.

The idea of other-regarding behaviour or social preference arose from the "warm glow" theory. The "warm glow" is the utility received by an agent through their choice of contributing to the public good (Andreoni, 1990). The evidence from the experimental economics literature is mixed in terms of support for the social preference hypothesis. Andreoni and Miller (2002) explored whether observed altruism under experimental conditions can be rationalized or modelled. It was observed that 98% of the choices made by the subjects were rational according to the general axiom of revealed preference (GARP) and 75% of the subjects were found to show altruism. The preferences revealed under laboratory conditions concerning altruism or justice also depend crucially on the experimental design. Rutström and Williams (2000) addressed the gap between the theoretical predictions of self-interested behavior of subjects regarding redistribution of income and the observed other-regarding behavior of the subjects in experimental settings. Controlling for strategic considerations and randomizing the decision-making power, preferences over income distribution were elicited in an incentive-compatible manner under high opportunity cost situations. They observed that 99% of the subjects behave in a self-interested manner.

In the context of agricultural and environmental issues, a number of studies explore farmer stewardship ethics and the social preference hypothesis (Wallace and Clearfield, 1997; Supalla, 2003; Chouinard et al., 2008; Ovchinnikova, 2006; and Sheeder and Lynne, 2011). Wallace and Clearfield (1997) observed that the producers may adopt stewardship practices and voluntarily install conservation practices because it is the "right thing to do", thus indicating a way of life among farmers. A similar argument was offered by Supalla (2003) based on the findings that 85% of a sample of producers were willing to forego profit to undertake BMPs to reduce groundwater pollution because they have a stewardship ethic. Chouinard et al. (2008) investigated the trade-off between farm profit and environmental stewardship using an expanded utility framework based on production technology. Using CVM, they elicited WTP for environmental stewardship. Their study found support for the social preference assertion in that some producers are actually willing to pay for stewardship activities. Ovchinnikova (2006) investigated the social context of farmer behaviour to explain adoption of carbon sequestering technology for a sample of US farmers and observed that the null hypothesis of farmers exhibiting other-regarding behaviour could not be rejected. Sheeder and Lynne (2011) used a dual-interest theoretical framework to explore the conservation tillage adoption decision.

It may be noted that the studies dealing with the social preference hypothesis focus more on the behavioral assertion than on the analytical derivation of the theoretical relationships. For example, the behavioural model used by Chouinard et al. (2008) does not directly connect to the RUM framework. However, a common approach undertaken in these studies is joint maximization of utility from production or yield or farm profit and utility from improved environmental quality.

Singh, Squire and Strauss (1986) showed that, if utility is independent of factors in the profit maximization decisions, then agricultural household utility maximization problem can be thought of as a two stage problem. They claimed that if the household is a price-taker in all markets, then even a simultaneous decision making problem involving household's production and consumption can be modelled recursively. This was consistent with earlier work by Nakajima (1969) and Jorgenson and Lau (1969) and also posited as a separable consumption and production model for an agricultural household model by Bockstael and McConnell (2007). In a recursive agricultural household model the producer maximizes profit at stage 1 while at stage 2 the producer maximizes utility subject to the budget constraint that arises out of the profit function obtained from stage 1.

If the utility function is only defined over in terms of consumption then the land/land related environmental service does not affect utility. However, if it is asserted that social preference or stewardship activity is a part of the producer’s preference then it is implicitly assumed that provision of environmental service gives some utility to the producer. Therefore, a separable model of consumption and production is not sufficient or appropriate to capture this interlinkage.

If consumption and production are non-separable and allocating land to a BMP, such as, wetland restoration, affects utility directly as well as through the budget constraint of the producer then the choice problem could be formalized as an endogenous income problem. The simplest endogenous income problem is labor-leisure choice which could be adapted to address the problem of allocation of land into productive uses such as crop production and environmental uses such as production of environmental goods and services. The land allocation problem analogous to a labor-leisure problem was cast in a framework where the household has a fixed quantity of land to allocate between productive use (cropland) and leisure/environmental use (wetland).

If the household consumes composite good z which has price p, then the utility maximisation problem of this agricultural household is given by:

$$Max\ U(z,T-x) \quad subject\ to \quad pz = \bar{Y} + \theta \cdot x \qquad 4\text{-}9$$

where T denotes farm size, x denotes the share of land allocated to production, $T-x$ is the share of land allocated to the non-market ecosystem services (ES), θ denotes annual earning per acre from the land allocated to production, and $\bar{Y}$ denotes exogenous income (e.g. non-farm income).

The Lagrangian of the maximization problem is given by:

$$\Lambda = U(z,T-x) + \lambda\left[\bar{Y} + \theta x - pz\right] \qquad 4\text{-}10$$

The first order conditions are:

$$\frac{\partial \Lambda}{\partial z} = U_z - \lambda p = 0 \qquad 4\text{-}11$$

$$\frac{\partial \Lambda}{\partial x} = U_x + \lambda \theta = 0 \qquad 4\text{-}12$$

$$\frac{\partial \Lambda}{\partial \lambda} = \left[\bar{Y} + \theta x - pz\right] = 0 \qquad 4\text{-}13$$

Given the form of the utility function, from the first two FOCs it is possible to solve for z^* and x^*; that is, the optimal consumption of composite market good and the optimal allocation of land for private productive uses. For simplicity, it was assumed that the utility function was of Cobb-Douglas form. Therefore, the utility function was assumed to be given by:

$$U(z,T-x) = z^{\alpha}(T-x)^{1-\alpha} \qquad 4\text{-}14$$

Given this form of the utility function the optimal allocation of cropland is:

$$x^* = \frac{\alpha T\theta - (1-\alpha)\bar{Y}}{\theta} \qquad 4\text{-}15$$

The optimal supply of wetland is:

$$T - x^* = \frac{(1-\alpha)T\theta + (1-\alpha)\bar{Y}}{\theta} \qquad 4\text{-}16$$

The assumption of the preference structure indicates that the optimal supply of wetland is a function of the preference parameter α, farm size T, non-farm income $\bar{Y}$ and the per acre farm income θ. Optimal consumption of market goods is given by:

$$
\begin{aligned}
z^* &= \frac{\alpha}{(1-\alpha)} \cdot \frac{\theta}{p} \cdot (T - x_m^*) \\
&= \frac{\alpha}{(1-\alpha)} \cdot \frac{\theta}{p} \cdot \frac{(1-\alpha)T\theta + (1-\alpha)\overline{Y}}{\theta} \\
&= \frac{\alpha}{p(1-\alpha)} \cdot \left[(1-\alpha)T\theta + (1-\alpha)\overline{Y}\right]
\end{aligned} \quad \text{4-17}
$$

The indirect utility function $V(\cdot)$ is obtained by substituting z^* and x^* into the direct utility function $U(\cdot)$.

$$
\begin{aligned}
V &= (z^*)^{\alpha}(T - x^*)^{1-\alpha} \\
&= \frac{\alpha^{\alpha}}{p^{\alpha}(1-\alpha)^{\alpha-1}} \cdot \left(T\theta^{\alpha} + \overline{Y}\theta^{\alpha-1}\right)
\end{aligned} \quad \text{4-18}
$$

The term $T\theta + \overline{Y}$ is the "full income" (agricultural value of the total land plus the non-farm income) (Becker, 1965; Singh, Squire and Strauss, 1986; Bockstael and McConnell, 2007). A reduction in total farm size reduces indirect utility since both land allocated to non-market ES and productive land falls.

$$
\frac{\partial V}{\partial T} = \frac{\alpha^{\alpha}}{(1-\alpha)^{\alpha}} \cdot \frac{1}{p^{\alpha}} \cdot \frac{1}{\theta^{1-\alpha}} \cdot \theta \cdot (1-\alpha) = \frac{\alpha^{\alpha}}{(1-\alpha)^{\alpha-1}} \cdot \frac{\theta^{\alpha}}{p^{\alpha}} > 0
$$

An increase in non-farm income increases indirect utility.

$$
\frac{\partial V}{\partial \overline{Y}} = \frac{\alpha^{\alpha}}{(1-\alpha)^{\alpha}} \cdot \frac{1}{p^{\alpha}} \cdot \frac{1}{\theta^{1-\alpha}} \cdot (1-\alpha) > 0
$$

The main comparative static of interest in the context of the transfer exercise is the change in indirect utility with respect to change in opportunity cost of land. The direct cost of adoption of the wetland restoration program could be conceptualized as a parametric change in opportunity cost of land allocation. The corresponding comparative static expression is given by:

$$
\frac{\partial V}{\partial \theta} = \frac{\alpha^{\alpha}}{p^{\alpha}(1-\alpha)^{\alpha-1}} \cdot \left(T\alpha\theta^{\alpha-1} + \overline{Y}(1-\alpha)\theta^{\alpha-2}\right) \quad \text{4-19}
$$

The WTA for BMP adoption by definition can be formulated as

$$
V(\alpha, p, T, \overline{Y}, \theta_0) = V(\alpha, p, T, \overline{Y}, \theta_1, WTA)
$$

where θ_0 represents farm income per acre in state 0 without BMP adoption and θ_1 represents that in state 1 with BMP adoption.

Note that the change in indirect utility (∂V) due to adoption of wetland restoration BMP is captured by the estimated WTA from the SP models ($\hat{WTA}$) and the change in opportunity cost of land allocation ($\partial\theta$) is obtained from the farm simulation models ($\hat{FC}$). These two estimates could be linked using the above comparative static relationship.

$$\hat{WTA} = \frac{\alpha^{\alpha}}{p^{\alpha}(1-\alpha)^{\alpha-1}} \cdot \left(T\alpha\theta^{\alpha-1} + \bar{Y}(1-\alpha)\theta^{\alpha-2}\right) \cdot \hat{FC} \qquad 4\text{-}20$$

The above equation shows that under the assertion of non-separable consumption and production using an endogenous farm income model, Equation 4-16 could be used to estimate the preference parameter α using the estimated WTA from SP models and financial opportunity cost from modified net cash-flow models. The above model serves as an illustration of the structural transfer method by assuming a preference structure for an agricultural household that is used to connect the various measures of welfare impact of BMP adoption in an attempt to measure the preference parameters.

If the sampled producers or a subset of them were indeed motivated by social preference, it would imply that low levels of elicited WTA would be expected according to the social preference literature. However, as such, the above model does not elicit social preference and serves as a mere illustration of the effect of imposing a particular preference structure for the purpose of the cost transfer.

For each farm in the sampled population in this study, farm-specific WTA estimates were available from the midpoint regression model in Chapter 2 and farm-specific FC estimates were available from the simulation models in Chapter 3. Thus, Equation 4-16 can be solved for farm-specific α given the values of the other explanatory variables. The all-items provincial CPI for Alberta and Saskatchewan were used as proxies for the price of the composite good consumed. While the farm-level survey did not explicitly solicit information on the amount of non-farm income from the respondents, it gathered information on the percentage of the non-farm income in their total household income. Using the percentage of non-farm income indicated by the respondents and their baseline NPV in perpetuity the nonfarm income was approximated for each respondent. The parameter θ was defined in the conceptual model as a per acre income parameter. The annualized mean NPV in perpetuity per acre was initially used as a measure of θ.

The total farm size for each farm was available from the farm-level survey. Given these values, Equation 4-16 was solved using the Evolutionary engine[43] in Excel Solver, and a fixed random seed.

The optimization function for the *n*th sampled farm in Solver was defined as

$$\hat{WTA}_n - \frac{\alpha_n^{\alpha_n}}{p^{\alpha_n}(1-\alpha_n)^{\alpha_n - 1}} \cdot \left(T_n \alpha_n \theta_n^{\alpha_n - 1} + \bar{Y}_n (1-\alpha_n)\theta_n^{\alpha_n - 2}\right) \cdot \hat{FC}_n = 0 \qquad \text{4-21}$$

subject to $0 \le \alpha_n \le 1$.

However, using the annualized mean NPV in perpetuity per acre led to infeasible solutions for alpha. This could be due to scaling issue of the numerical values. To avoid this problem, the baseline annualized mean NPV from farm simulation models was used instead as a measure of θ.

It may be noted that a limitation of this approach was that Solver solutions are very much dependent on the numerical values of the variables in the model. There was a numerical difference of several orders of magnitude between the baseline annualized mean NPV and the corresponding per acre value. Ideally, it would be preferable to obtain solutions of the farm-specific preference parameter $\hat{\alpha}_n$ for per acre farm income data. The infeasibility of the solution based on per acre income data, therefore, stresses the point that this exercise should be treated more as an illustration of the structural transfer method and not as an elicitation of preference parameter.

A two-sample t-test of equality of means of $\hat{\alpha}_n$ was conducted across the site-specific samples. The null hypothesis of equality of means of $\hat{\alpha}_n$ across site-specific samples could not be rejected (Appendix O). The mean of $\hat{\alpha}_n$ in Alberta sample was 0.7844 and that in Saskatchewan was 0.7940 if the farms with imputed WTA estimates were included in the analyses. After removing the farms that did not indicate a preferred bid (Farms 3, 4 and 20), the mean of $\hat{\alpha}_n$ in the Alberta sample was 0.7902 and that in Saskatchewan was 0.7953. The farm-specific estimated values of $\hat{\alpha}_n$ are presented in Appendix P and Appendix Q. The three lowest values of $\hat{\alpha}_n$ were observed for the farms that had a higher FC than WTA. Given the asserted

[43] The Evolutionary engine in Excel Solver uses random sampling to find a pool of candidate solutions to a solver problem and then uses natural evolutionary principles such as mutation, crossover and selection to narrow down the pool of candidate solutions to the "best fit" solutions.

preference structure used in this analysis, a lower value of $\hat{\alpha}_n$ would indicate preference for higher levels of non-market ES.

As the value of α was calibrated, Equation 4-16 could be used to transfer WTA across sites given that information on FC and other observable variables are available for the policy site. As noted earlier, the assumption was that the estimated preference parameter value for the study site, in this case Alberta, applied to the policy site of Saskatchewan.

Given the estimated preference parameter α_{js} for site *j* and population *s*, the calibrated WTA for the site i and population *r* was, therefore, given by:

$$\hat{w}_{ir} = \frac{\alpha_{js}^{\alpha_{js}}}{p_{ir}^{\alpha_{js}}(1-\alpha_{js})^{\alpha_{js}-1}} \cdot \left(T_{ir}\alpha_{js}\theta_{ir}^{\alpha_{js}-1} + \bar{Y}_{ir}(1-\alpha_{js})\theta^{\alpha_{js}-2}\right) \cdot \hat{FC}_{ir} \qquad \text{4-22}$$

Table 4-11 presents the average values of the variables at the policy site, the estimated preference parameter from the study site used in Equation 4-17, the calibrated mean WTA for the study site and the PTE excluding the farms for which estimated WTA was not available due to protest response or a high WTA greater than the highest offered bid in the study. Table 4-12 presents the same calibration after including farms for which only imputed WTA values were available. The PTE ranges from 11.98% to 21.71%.

Table 4-11: Calibration of Mean WTA for Saskatchewan using Sample Averages from Saskatchewan and Preference Structural Parameter from Alberta - Excluding Farms with Imputed WTA

Annualized mean NPV in perpetuity ($/year)	450488.00
Farm size (acres)	3984.83
Non-farm income($/year)	266010.83
Estimated mean WTA from midpoint regression ($/acre/year)	882.67
Mean FC from cash-flow simulation ($/acre/year)	406.65
Mean alpha for Alberta	0.7902
Calibrated WTA for Saskatchewan ($/acre/year)	1074.26
Percent transfer error (PTE)(%)[a]	21.71

[a]: PTE=absolute value of [{(Calibrated WTA-Estimated WTA)/Estimated WTA}*100].

Table 4-12: Calibration of Mean WTA for Saskatchewan using Sample Averages from Saskatchewan and Preference Structural Parameter from Alberta - Including Farms with Imputed WTA

Annualized mean NPV in perpetuity ($/year)	418468.93
Farm size (acres)	3986.00
Non-farm income($/year)	245548.46
Estimated mean WTA from midpoint regression ($/acre/year)	881.69
Mean FC from cash-flow simulation ($/acre/year)	391.49
Mean alpha for Alberta	0.7844
Calibrated WTA for Saskatchewan ($/acre/year)	987.34
Percent transfer error (PTE)(%)[a]	11.98

[a]: PTE=absolute value of [{(Calibrated WTA-Estimated WTA)/Estimated WTA}*100].

The same calibration exercise was done using the median WTA estimates obtained from the partial RE Probit models discussed in Chapter 2 and corresponding sample averages. The partial RE Probit models were estimated excluding the farms that did not accept any compensation amount. Using the own median WTA from the partial RE Probit model for the calibration resulted in a PTE of 20.33% (Table 4-13). Using the inferred median WTA resulted in a PTE of 7.72% (Table 4-14). The structural transfer allowed a "cross" transfer between two different estimates of cost as it utilizes the FC estimates at the study site to calibrate the WTA at the policy site.

Table 4-13: Structural Calibration of Own WTA for Saskatchewan using RE Probit Estimates

Annualized mean NPV in perpetuity ($/year)	450488
Farm size (acres)	3984.833
Non-farm income($/year)	266010.8
Estimated mean WTA from RE Probit	733.32
Mean FC from cash-flow simulation ($/acre/year)	406.6467
Mean alpha for Alberta	0.732935
Calibrated WTA for Saskatchewan ($/acre/year)	584.255
Percent transfer error (PTE)(%)[a]	20.33

[a]: PTE=absolute value of [{(Calibrated WTA-Estimated WTA)/Estimated WTA}*100].

Table 4-14: Structural Calibration of Inferred WTA for Saskatchewan using RE Probit Estimates

Annualized mean NPV in perpetuity ($/year)	450488
Farm size (acres)	3984.833
Non-farm income($/year)	266010.8
Estimated mean WTA from RE Probit	766.36
Mean FC from cash-flow simulation ($/acre/year)	406.6467
Mean alpha for Alberta	0.765578
Calibrated WTA for Saskatchewan ($/acre/year)	825.5442
Percent transfer error (PTE)(%)[a]	7.72

[a]: PTE=absolute value of [{(Calibrated WTA-Estimated WTA)/Estimated WTA}*100].

4.1.7 Distribution Transfer

The transfer methods described above utilized the central tendencies of estimated cost of BMP adoption obtained using various methodologies. However, as discussed in the previous chapters, a considerable amount of variability was observed in estimated WTA and FC within the sampled populations from the study area and the designated policy area of this study. It was, therefore, relevant to revisit how the distributions of WTA and FC compared across sites. Three sets of estimated cost distributions were available to this study. These are - (i) WTA distributions for Alberta and Saskatchewan, (ii) FC distributions for Alberta and Saskatchewan and (iii) salient bid distributions[44] from the reverse auction conducted in Saskatchewan by Hill et al. (2011). The degree of similarity across these distributions would suggest whether or not the distributions themselves could be transferred. Equality of the distribution of welfare impact at study and policy sites was claimed by Brouwer and Spaninks (1999) to be an even more rigorous null hypothesis of transfer validity than equality of the corresponding central tendencies.

To test for pairwise equality of various distributions of cost, the kernel density estimators (KDEs), Epps-Singleton test statistics of equality of distributions and overlapping coefficients were obtained for the following pairs of cost distributions:

1. WTA distribution for Alberta - WTA distribution for Saskatchewan
2. WTA distribution for Alberta - WTA distribution for Saskatchewan obtained by Hill et al. (2011)
3. FC distribution for Alberta - FC distribution for Saskatchewan

[44] Note that for the distribution transfers, the bid amounts obtained from Hill et al.(2011) are not adjusted by the all-items CPI for Saskatchewan.

4. FC distribution for Alberta - WTA distribution for Saskatchewan
5. FC distribution for Alberta - WTA distribution for Saskatchewan obtained by Hill et al. (2011)
6. FC distribution for Saskatchewan - WTA distribution for Saskatchewan
7. FC distribution for Saskatchewan - WTA distribution for Saskatchewan obtained by Hill et al. (2011).

The Epps-Singleton test of characteristic functions is a formal validity test conducted as an alternative to Kolmogorov-Smirnov two-sample test of equality of distributions. Using the Kolmogorov-Smirnov test was deemed not ideal for small samples like this (Goerg and Kaiser, 2009). The Epps-Singleton test statistics and the overlapping coefficients corresponding to each distribution transfer are summarized in the following table (Table 4-15).

The Epps-Singleton test conducted using Stata 10 IC resulted in a rejection of the null hypothesis of identical distributions for the WTAs obtained from the Alberta site and the WTA obtained in the reverse auction conducted by Hill et al. (2011) at a 10% significance level. The null hypothesis of identical FC distributions obtained by this study across Alberta and Saskatchewan could not be rejected by Epps-Singleton test. Also, the null hypothesis of equality of the FC distribution for Alberta and the WTA distribution obtained by Hill et al. (2011) at Saskatchewan could not be rejected by this test.

Table 4-15: Summary of Test Statistic for Equality of Cost Distributions

Transferred cost distribution	Primary study cost distribution	Epps-Singleton test statistic (W2)[a]	Overlapping coefficient (OC)[b]
WTA_Alberta	WTA_Saskatchewan	17.319	0.5823
WTA_Alberta	WTA_Hill et al. (2011)	9.083	0.5789
FC_Alberta	FC_Saskatchewan	2.449	0.6745
FC_Alberta	WTA_Saskatchewan	33.754	0.5520
FC_Alberta	WTA_Hill et al. (2011)	4.875	0.8390
FC_Saskatchewan	WTA_Saskatchewan	23.067	0.3184
FC_Saskatchewan	WTA_Hill et al.(2011)	15.46	0.8299

[a]: Critical value for W2 at 10%: 7.779. Critical value for W2 at 5%: 9.488. Critical value for W2 at 1%: 13.277. [b]: $0 \leq OC \leq 1$ with higher values of OC indicating higher degrees of similarity between the distributions. Note: the WTA distributions include the imputed values.

The overlapping coefficients were all higher than 0.5, with the exception of the FC and WTA distributions for Saskatchewan. For this pair, the coefficient value indicated that there is a significant difference between these two cost estimates for Saskatchewan as obtained by this study. The highest value of overlapping coefficient was obtained for the distributions of FC in Alberta and WTA as obtained by Hill et al. (2011). This complements the corresponding Epps-Singleton test results. The second highest value of the overlapping coefficient was obtained between FC for Saskatchewan obtained in this study and the WTA distribution obtained by Hill et al. (2011). However, the Epps-Singleton test rejected this similarity. The overlapping coefficient of the two FC distributions was 0.6745, the third largest value among the pairwise comparisons.

It may be noted that the kernel bandwidth used in these analyses was optimized for the Alberta subsample and then imposed on the Saskatchewan distribution for the sake of comparability. The bandwidth is essentially the continuous data analogue of bin size used for drawing histograms for discrete data. While using the same bandwidth allows comparability and ease of visualization, an element of subjectivity remains in the choice of bandwidth. The complete set of pairwise comparisons of the KDEs of various cost distributions is presented in Appendix R. The KDEs of the distributions that exhibit a high degree of equality according to Epps-Singleton test or high values of the overlapping coefficient are highlighted here.

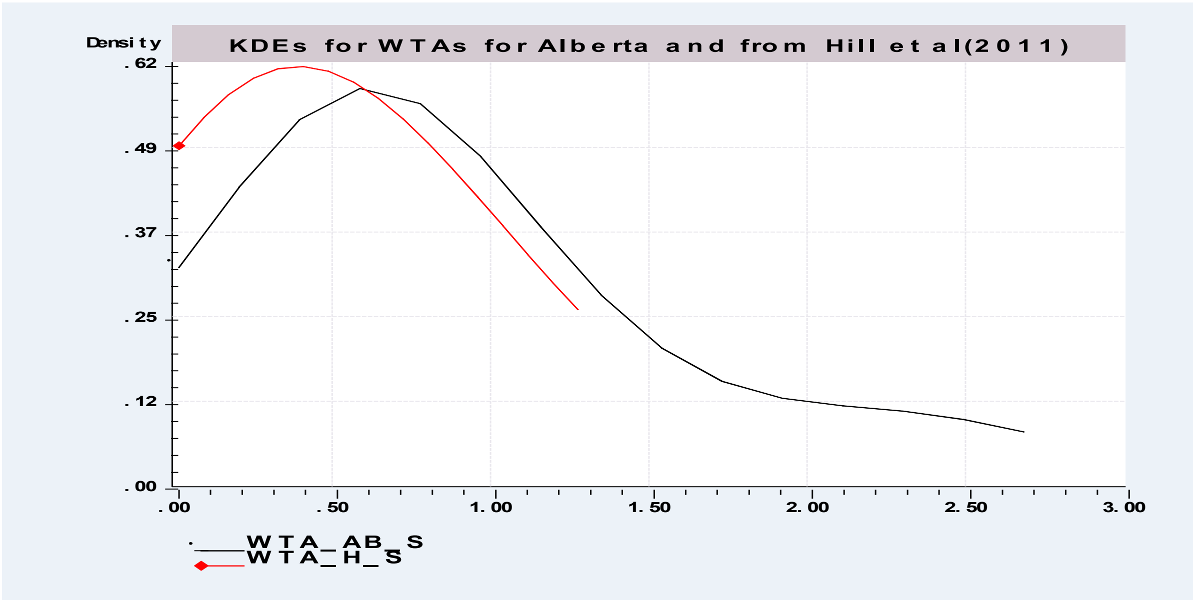

Figure 4-1: Kernel Density Estimators of Scaled WTAs for Alberta (WTA_AB_S) and from Hill et al. (2011) (WTA_H_S) (Logistic Kernel; Bandwidth = 0.337865)

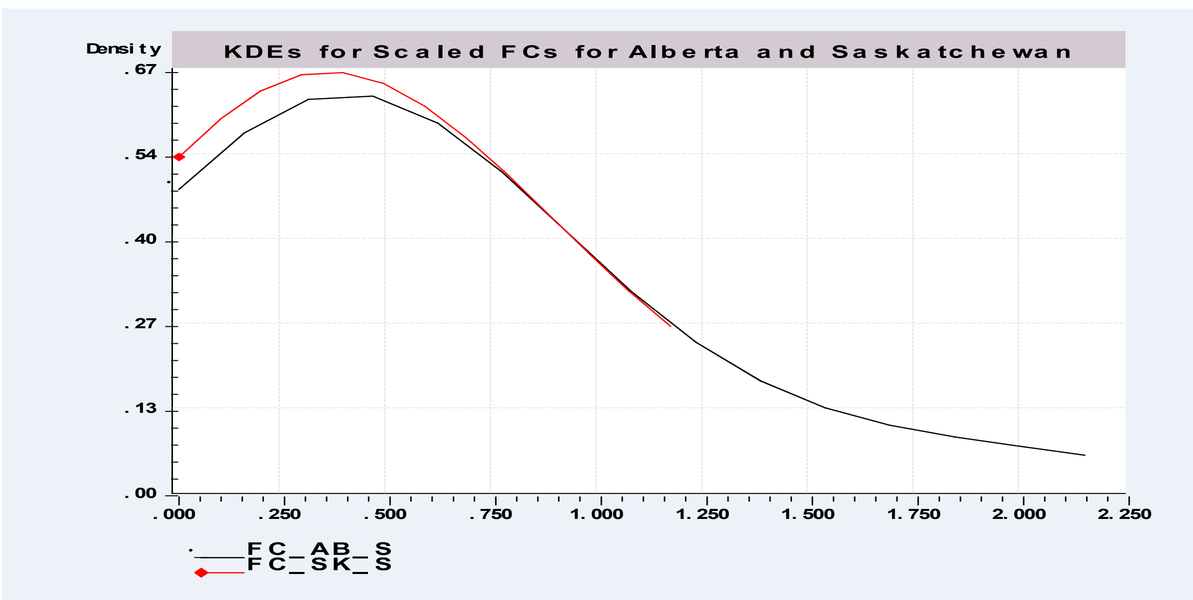

Figure 4-2: Kernel Density Estimators of Scaled FCs for Alberta (FC_AB_S) and for Saskatchewan (FC_SK_S) (Logistic Kernel; Bandwidth = 0.337865)

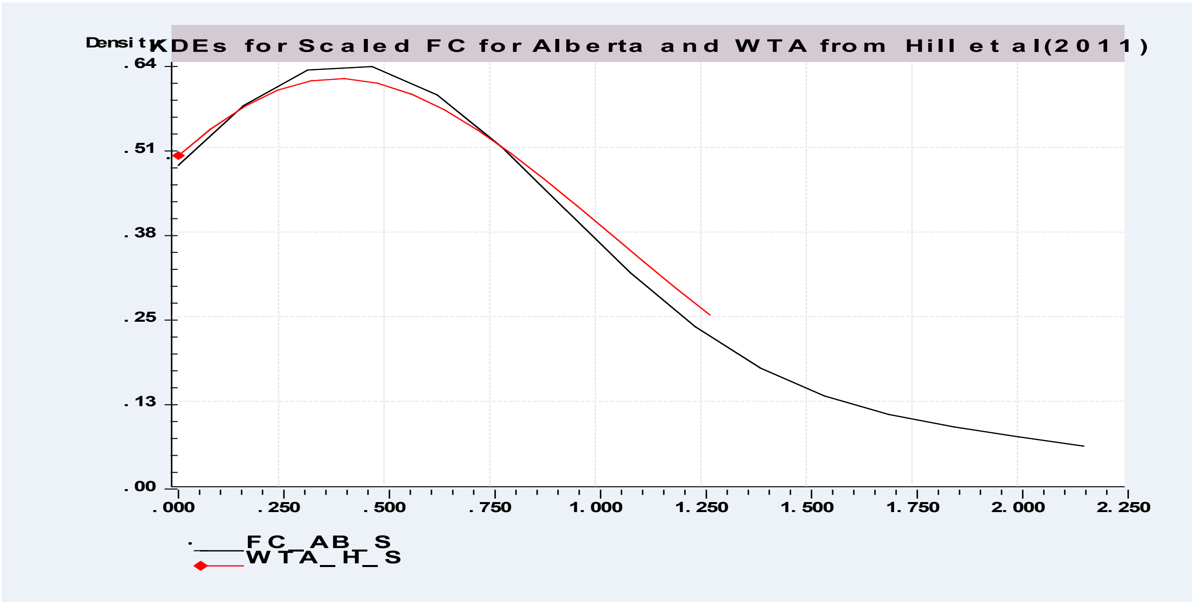

Figure 4-3: Kernel Density Estimators of Scaled Simulated Financial Opportunity Cost for Alberta (FC_AB_S) and Scaled WTA (WTA_H_S) from Hill et al. (2011) (Logistic Kernel; Bandwidth = 0.337865)

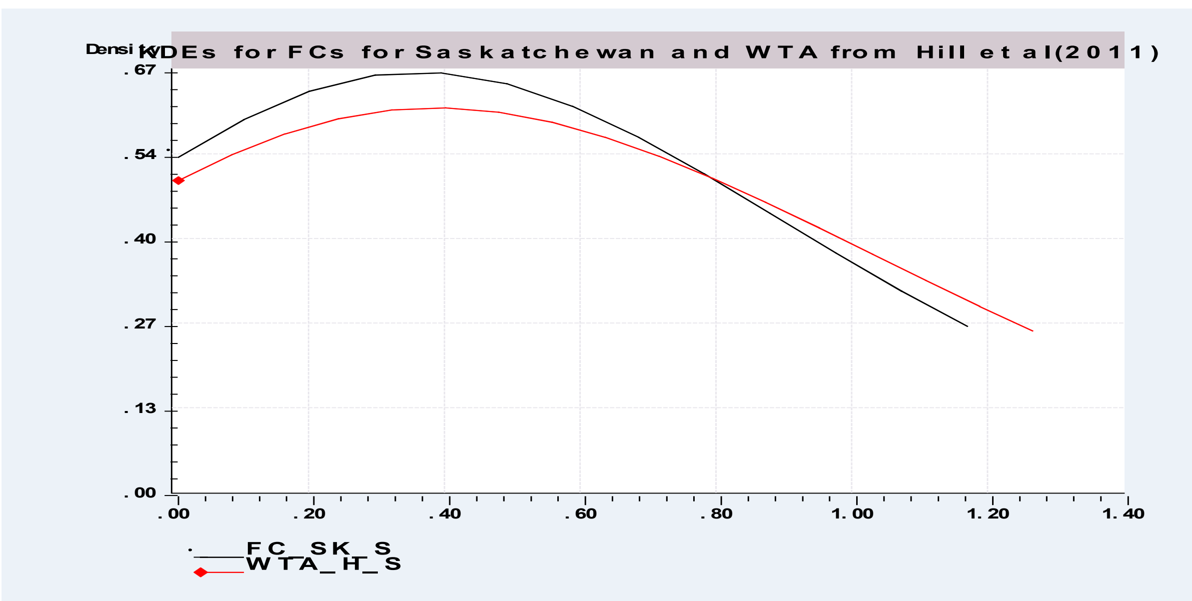

Figure 4-4: Kernel Density Estimators of Scaled Simulated Financial Opportunity Cost for Saskatchewan (FC_SK_S) and Scaled WTA (WTA_H_S) from Hill et al. (2011) (Logistic Kernel; Bandwidth = 0.337865)

4.4 Discussion

The current chapter used WTA estimates from the SP study and financial opportunity cost (FC) estimates from farm-level cash flow simulation models to transfer estimates of cost of adoption of wetland restoration BMP across two sites in the Western Canadian Prairie region. The transfer exercise was conducted between two sites that were chosen for this study based on a high degree of similarity in terms of population characteristics, enterprise mix and physical site characteristics. The data collection for the primary valuation studies that were used as the source of the valuation data used in this chapter was done within a span of few weeks in 2014. This implied that data from dated studies were not used for the cost transfer and ensured that the valuation data across the two sites had temporal stability. While these pre-conditions were fulfilled, it was observed that the success of a cost transfer exercise is very much dependent on the transfer methodology just like a benefit transfer exercise.

The study conducted non-parametric as well as parametric transfers of various estimates of cost. The non-parametric distribution transfer suggested that the distributions of WTA across the two sites may not be identical but could not reject the null hypothesis of FC distributions being identical across sites. The parametric transfer methods using central tendencies and farm-specific WTA and FC indicated that transferring cost estimates across sites would generate errors in the range of 2.74%-38.01% if the imputed WTA values are included and 8.44%-38.01% if not (Table 4-16). Note that the initial comparison was between the calibrated costs and the costs estimated in the direct valuation components by this study. In the second step, the calibrated costs were compared to the bids[45] obtained in the reverse auction conducted by Hill et al. (2011) for wetland restoration in cropland.

[45] The bids received by Hill et al (2011) were adjusted for inflation using the provincial all-items CPI.

Table 4-16: Summary of Transfer Methods, Estimated and Calibrated Central Tendencies of Costs and the Corresponding Transfer Errors

Transfer method	Source of estimated WTA/FC	Type of estimated cost	Calibrated cost ($/acre/year)	Estimated cost ($/acre/year)	PTE(%)	PTE w.r.t. CPI-adjusted Hill bids[a]
Unit Cost Transfer	Midpoint Regression	Mean Predicted WTA w/ Imputed Values	847.17	881.69	3.91	19.89
		Mean Predicted WTA w/o Imputed Values	617.85	882.67	30.00	12.57
	Partial RE Probit (Own valuation)	Median WTA	454.56	733.32	38.01	35.67
	Partial RE Probit (Inferred valuation)	Median WTA	647.44	766.36	15.52	8.38
	Cash Flow Simulation Models	Mean FC	511.19	391.49	30.57	27.66
Simple Function Transfer						
Specification 1	Midpoint Regression	Farm-Specific Predicted WTA w/ Imputed Values	782.92	881.69	11.20	10.79
Specification 2			782.04		11.30	10.67
Specification 3			951.95		7.97	34.71
Specification 4			905.86		2.74	28.19
Specification 1	Midpoint Regression	Farm-Specific Predicted WTA w/o Imputed Values	797.12	882.67	9.69	12.80
Specification 2			795.53		9.87	12.58
Specification 3			668.55		24.26	5.39
Specification 4			668.13		24.31	5.45
Structural Transfer	Midpoint Regression	Farm-Specific Predicted WTA w/ Imputed Values	987.34	881.69	11.98	39.72
		Farm-Specific Predicted WTA w/o Imputed Values	1074.26	882.67	21.71	52.02
	Partial RE Probit (Own valuation)	Median WTA	584.25	733.32	20.33	17.32
	Partial RE Probit (Inferred valuation)	Median WTA	825.54	766.36	7.72	16.83

[a] : The average submitted bid for cropland in the reverse auction conducted by Hill et al. (2011) was $642.95/acre/year(range $619.2-$666.7/acre/year) in 2009 dollars. The PTE in this case was calculated with respect to the average submitted bid in their study adjusted for inflation using all-items CPI for Saskatchewan. Hence the PTE was calculated with respect to an adjusted average of $706.64/acre/year in 2014 dollars.

A quick observation can be made regarding the effect of including the observations with imputed WTA in the models that used farm-specific predicted WTA obtained from the midpoint regression. The high values of the imputed WTA had the effect of increasing the average predicted WTA of the Alberta subsample and, thus, lowering the transfer error in case of unit cost transfer. The simple function transfer and the structural function transfer also performed better in terms of lower PTE from inclusion of these observations even though they seem to be outliers compared to the average sample characteristics.

A comparison of transfer errors obtained from the various transfer methods is relevant. A frequent observation in the BT literature is that a simple function transfer performs better than a unit cost transfer in terms of generating lower error. This observation is confirmed in the current study except for the transfer of median WTA obtained using inferred valuation. The unit cost transfer generated transfer errors in the range 15.52% to 38.01% (Table 4-16). The range of PTE for the simple cost function transfer was 9.69% to 24.31%.

Four different specifications of simple cost function transfer were tried using various combinations of observable farm and producer characteristics (producer age, area under agricultural production, number of seasonal wetlands and whether the main enterprise of the farm is crop production). As noted earlier, Specification 1 and Specification 2 generated very high significance of the independent variables for Alberta and also had R-squared values of more than 0.80. These two specifications were, however, data-intensive. It is difficult to make a choice between these model specifications as the best-fit model. A future potential application of these simple cost transfer functions (e.g. for a different set of RMs in the Black soil region of Alberta and Saskatchewan) would likely depend on the availability of study site and policy site data.

This study also attempted an illustration of the structural transfer method by assuming that agricultural producer preferences were defined over private consumption and provision of public goods and services such as ES through wetland restoration. The structural transfer in the BT literature, especially as developed by Smith et al. (2002), utilizes the conceptual and analytical linkage between two estimates of WTP. The structural transfer exercise in this study maintained the idea of using two different estimates of cost in the transfer. However, a major point of departure from Smith's calibration exercise is that the conceptual linkage between WTA and FC was fairly weak. While both were measures of agricultural producers' private cost of supplying a particular ES, unlike FC the estimated WTA is rooted in RUM framework of latent choice. The

FC estimation is entirely dependent on modelling each farm's enterprise components as realistically as possible so that the cash flow of the farm can be simulated. The producer's preference plays no role in the FC estimation as it has been approached in this study. Also, the results were very much dependent on (i) the assumed preference structure and (ii) the numerical values of the variables used in the calibration. The dependence of the structural transfer on the assumed preference structure has been discussed at length in the BT literature as well (Johnston et al., 2015). This has also been cited as one of the reasons explaining the relatively low number of empirical applications of this method. The above-mentioned points, therefore, should be used as caveats while interpreting the results from the structural transfer. The range of the PTEs in the structural transfer was 7.72% to 21.71%. This is consistent with and marginally lower than the PTEs obtained in the simple function transfer.

The transfer errors from the analysis in the current study are lower, when compared to transfer errors reported in some of the BT literature. The PTEs are expressed as the absolute difference in magnitude between the calibrated and the estimated costs from the original valuation studies at the policy site. While there is no precedence in the literature regarding what would be an observed or acceptable level of error in a cost transfer, the error levels obtained in this study are encouraging. The existing literature indicates that for a cost transfer exercise, a very high precision is ideal as the estimated numbers could be used to design compensation packages for producers to induce a higher rate of adoption of agricultural BMPs such as wetland restoration (Navrud and Bergland, 2005).

Rolfe et al. (2015) noted that there may be measurement errors inherent in a transfer exercise due to the inability of the original valuation studies to estimate the "true" welfare impact. In the context of the current exercise, it would mean that any measurement error would arise due to a divergence between the estimated costs from previous chapters and the "true cost". Johnston et al. (2015) also suggested that quality of the primary data sources would be an important factor in the success of transfer exercise. Rosenberger and Johnston (2009) noted that selection error may arise because of methodology selection and publication selection bias in the original valuation studies.

Methodology selection bias arises when estimated costs or benefits are systematically influenced by methodological choices made by the analysts. Publication selection bias occurs when a non-random sample of estimates get published due to the reviewers and editors' predisposition towards conventionally accepted results or views or the researchers unwillingness to report results that might fall outside the previously known range of values. The upshot of these two types of biases is that using estimates that suffer from these biases would impact the success of the transfer exercise.

Given these various sources of biases that can impact the transfer, it would be interesting to compare the calibrated costs obtained in this study with the results of Hill et al. (2011). Hill et al. (2011) conducted a reverse auction to identify the costs of adopting wetland restoration BMP by agricultural producers in Saskatchewan. A reverse auction is thought to be incentive-compatible as the participating producers have no incentive to bid higher than their true WTA. Therefore, it makes sense to compare the calibrated costs with their results. The PTEs were calculated after adjusting the Hill et al. (2011) average bid for cropland for inflation using all-item CPI for Saskatchewan. These are reported in the last column of Table 4-16. It is also encouraging to note the high degree of overlap between the FC distributions obtained in this study and the distributions of salient bids received by Hill et al. (2011).

It may be argued that a transferred cost estimate would be effective in achieving the policy goal of incentivising producers to adopt BMPs if it is at least equal to or higher than the “true” estimate of their private cost. Most of the calibrated costs were higher than the corresponding estimate of average WTA obtained from the reverse auction conducted by Hill et al. (2011). In general, the PTEs for unit cost transfer and simple function transfer were lower when calculated with respect to the Hill et al. (2011) data than the original cost estimated obtained by this study. The calibrated costs from structural transfer were noticeably higher than the average bid from Hill et al. (2011).

The range of calibrated cost of wetland restoration BMP in Saskatchewan across all the methods undertaken in this study was $454.56-$1087.80/acre/year. From the KDEs of the distribution of WTA in Saskatchewan it is apparent that these distributions were characterized by a longer left tail. A large proportion of the density function falls roughly to the left of the WTA value of $1000/acre/year. Juxtaposing this observation with the obtained range of calibrated cost indicated that the transfer exercise is generating values that are at the lower end of the WTA distribution in Saskatchewan obtained in this study. The data from Hill et al. (2011) indicated that the bids received by them for wetland restoration in cropland ranged from $83.33/acre/year to $1000/acre/year (2009 dollars, $91.58-$1099.06/acre/year in 2014 dollars). The calibrated costs, therefore, provided a much narrower range while being comparable to the reverse auction bids. In other words, it might be possible to use the calibrated estimates to develop an incentive scheme that would be attractive to the low-cost suppliers of ES to adopt wetland restoration.

Johnston et al. (2015) noted the gap between transfers for “research versus practice”. They also noted that in absence of a resource constraint, direct valuation studies would be preferable. However, with limited time and budget for direct valuation studies, cost transfer studies could contribute significantly to the policy dialogue such as by providing the estimates of private cost of providing ES. When compared to the original distribution of WTAs at the policy site, the calibrated costs seemed to trace out the lower end of the range of WTAs. This is re-assuring as these producers could be thought of as the main target group for incentive provision assuming that environmental benefits of wetland restoration are not field-specific. For example, if the main benefit of wetland restoration was reduction of runoff and downstream load reduction, an incentive provision policy would be cost-effective if it targets the producers with low private cost of restoring wetlands.

The objective of this chapter was to demonstrate whether it is possible to obtain credible estimates of private cost of BMP adoption using cost transfer methodologies. Keeping the caveats associated with a transfer exercise in mind, the results indicate that it is possible to adapt BT methods to predict the costs of ES provision at a policy site based on available information from a similar study site. The current chapter contributes to the transfer literature as one of the first studies to explore the potential for cost transfer using commonly used BT methodologies. As Phaneuf and Van Houtven (2015) summarized, the results in a transfer exercise would depend on the model assumptions, data availability and the quality of available data. The overall error margin as obtained in the cost transfer exercises in this chapter was approximately 2.74% to 38.01% (Table 4-16). The calibrated costs demonstrated a high degree of overlap with the bids obtained in the reverse auction for wetland restoration conducted in Saskatchewan. The results suggest that there is potential for use of cost transfer methods as a valid and cheaper option compared to actual reverse auction for discovering the price of ES provision by agricultural producers. It is relevant here to note that the total budget of the reverse auction conducted by Hill et al. (2011) was $240,000 (AWSA 2015). Finally, using these estimates as a guide for designing incentive schemes would address the issue of using ad hoc amounts as compensation payments for wetland restoration.

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5 Conclusion

The objectives of this study were to estimate agricultural producers' WTA and farm-level FCs associated with adopting a wetland restoration BMP. This was done in order to assess if FCs could be used to approximate the "true" costs of wetland restoration and to investigate the spatial transferability of the cost estimates from a study site to a policy site in the Western Canadian Prairie region. This final chapter of the thesis summarizes the findings of the study and the potential implications for wetland policy in the Western Canadian Prairie provinces. The limitations of the study are then discussed. The chapter concludes with a discussion of the scope of future research that might address some of the limitations and also be of interest as an extension of the findings of this research.

5.1 Summary of Results

Agricultural BMPs that are targeted to reduce the negative impact of agricultural activities on the environment often involve a private cost of adoption and thus require incentive programs to encourage adoption among the producers. As the cost of a BMP is often not known the existing incentive programs often offer ad hoc amounts of compensation. Interestingly, these programs often fail to achieve the environmental goal due to low uptake indicating that the existing incentive programs are not sufficiently attractive to producers. This indicates that the private costs of adoption of the BMPs might be different from the level of compensation provided by existing flat-rate or cost-sharing incentive programs. However, the number of studies that look into the cost of BMP adoption in Canada is fairly limited. For a specified BMP, such as wetland restoration that would be adopted in a specific area of a province, the available studies become even more sparse. The existing cost discovery literature indicates that estimates of BMP adoption costs may be dependent on available data and the methodology adopted in the study. Also, it would depend on the case study sites in question. The impact of BMP adoption would depend on the enterprise details and farm productivity specific to a particular soil zone. Therefore, it is important to address the issue of heterogeneity in cost of BMP adoption and location-specificity in cost discovery studies in order to assist in the design of appropriate policy or incentive scheme. However, conducting direct valuation studies is expensive and time-intensive. This makes it difficult to address the site-specific nature of the findings of the direct valuation studies.

The current study attempted to address the issue of a lack of empirical findings by estimating the cost of adoption of a wetland restoration BMP in two provinces in Western Canada, Alberta and Saskatchewan. The current study estimated the distributions and central tendencies of private costs of wetland restoration using two conceptually different but comparable methodologies. Using a farm-level in-person survey that collected data on producer preferences for compensation for restoring wetlands in cropland and pasture, producer WTAs for wetland restoration in the two case study sites were elicited using SP methods. To elicit preferences, a SP auction design, with options to indicate uncertainty in response, was used. The multiple-bounded choice questions provided the ability to collect considerably more information about the latent WTA than a typical DC SP study. Producers' own WTA and their inferred WTA (i.e., what they thought a typical producer in their area could ask as compensation if presented with the same restoration proposal) were elicited to account for social desirability bias. Instead of focusing purely on the central tendencies of the WTA, distributions of WTAs were estimated to account for the aforementioned heterogeneity within and across sites.

Farm-specific financial opportunity costs (FCs) of wetland restoration in cropland were then estimated using the farm-specific enterprise details (e.g., crop yield, acreage and crop rotation) collected in the farm-level survey in conjunction with provincial crop prices and rural municipality-level historical yield information obtained from various secondary agricultural data sources. To account for yield and price risk, a Monte Carlo dynamic stochastic simulation model was developed for each farm in the sample. The farm-specific impact of BMP adoption was calculated by estimating the change in farm wealth captured by the difference in NPVs of cash flow from the baseline scenario (without restoration) to the BMP scenario (with restoration) over the proposed contract period. The farm-specific change in wealth gives the FCs of BMP adoption, and is comparable to the welfare theoretic measure of cost captured in the producers' WTAs. The distribution of the farm-specific FCs again allowed the quantification of the heterogeneity of the cost of wetland restoration.

Finally, the discovery of the distributions of cost of wetland restoration in cropland at two different but comparable sites in Western Canadian Prairie region allowed this study to address the limitation of site-specificity that is characteristic of direct valuation studies. The current study adopted and applied various benefit transfer methods to transfer costs from the designated "study site" of Alberta to the "policy site" of Saskatchewan. The estimated costs for the Saskatchewan site made it possible to assess the error involved in the cost transfer exercise using estimated cost information from the current study as well as the salient compensation amounts paid out in a reverse auction (Hill et al., 2011) conducted in the area.

A few patterns emerged out of the cost elicitation or estimation exercises. The key findings from the WTA elicitation are summarized first followed by that from the FC estimation. The median WTA for wetland restoration in cropland in the Alberta subsample was found to be less than that in the Saskatchewan subsample and own WTA was found to be less than inferred WTA. These observations were consistent across the fitted models. Significant heterogeneity in WTA was observed within each subsample which was expected as the sampled farms were quite heterogeneous in nature.

The mean predicted WTA for a 12-year contract period, estimated using midpoint regression and based on the own valuation, was \$617.85/acre/year (std. dev. of \$292.67) in Alberta and \$882.67/acre/year (std. dev. of \$375.66) in Saskatchewan. The corresponding mean predicted WTA from the inferred valuation was \$720/acre/year (std. dev. of \$142.03) in Alberta and \$894.40/acre/year (std. dev. of \$316.55) in Saskatchewan. The median WTA from partial RE Probit models fitted with only the bid variable and no covariates was \$454.56/acre/year in Alberta and \$733.32/acre/year in Saskatchewan, again based on the own valuation. The median WTAs based on inferred valuation were \$647.44/acre/year and \$766.36/acre/year in Alberta and Saskatchewan, respectively. Predicted pasture bids obtained from the midpoint regression ranged from \$23.81 to \$173.25/acre/year in Alberta and \$88.75 to \$238.48/acre/year in Saskatchewan. The average cropland bids obtained in this study were comparable to the salient cropland bids received by Hill et al. (2011) in the second round of the reverse auction for wetland restoration conducted in Saskatchewan and the average cropland bids obtained in Trenholm et al. (2013).

Significant within- and between-sample heterogeneity in FC estimates was observed. The mean FC in Alberta was \$511.19/acre/year (std. dev. of \$446.43/acre/year) and that in Saskatchewan was \$391.49/acre/year (std. dev. of \$234.96/acre/year). While the mean FC is higher in Alberta, a very high degree of overlap between the kernel densities of FC for the two subsamples was obtained. The relationship between the FC and WTA was also explored. FC and WTA were found to be positively correlated if the observations with imputed values of WTA were included. In general, farm-specific FC estimates are lower than the corresponding WTA estimates except for three farms, where the reverse is observed.

Several BT methods were adapted for the cost transfer exercise using the estimated average WTAs and the WTA distributions from midpoint regressions and partial RE Probit model. The transfer error is expressed as the absolute percentage difference in magnitude between the calibrated and the estimated costs from the original valuation studies at the policy site. The unit cost transfer resulted in transfer errors of 3.91% to 38.01% including observations with imputed WTA and 15.52 to 38.01% excluding those. As often observed in the benefit transfer literature, the simple function transfer resulted in lower level of errors; 2.74% to 11.30% including observations with imputed WTA and 9.69% to 24.31% excluding observations with imputed WTA. The structural transfer exercise was conducted as a demonstration of the method under strict assumptions about producers' preferences. The corresponding errors ranged from 7.72% to 21.71%. Compared to the median transfer errors reported in the BT literature (45% for unit value transfer and 36% for function transfer) (Rosenberger, 2015), the transfer errors in this study are quite low.

The Epps-Singleton test was conducted to test for pair-wise equality of FC and WTA distributions obtained by the current study and the bid distribution received by Hill et al. (2011). The null hypothesis of identical FC distributions obtained by this study across Alberta and Saskatchewan could not be rejected by this test. Also, the null hypothesis of equality of the FC distribution for Alberta obtained in this study and the WTA distribution obtained by Hill et al. (2011) at Saskatchewan could not be rejected by this test. The distribution overlapping coefficients were also the highest for FC distributions for Alberta and Saskatchewan and the WTA distributions obtained by Hill et al. (2011).

5.2 Conclusions and Policy Implications

The empirical findings in this study confirm that there is need for positive incentives in the form of compensations to encourage uptake of a wetland restoration BMP in Alberta and Saskatchewan. Wetland restoration imposes positive private costs on agricultural producers. The average compensation needed for restoration in cropland is significantly higher than that for pasture. This is expected as cropland is significantly more productive.

The heterogeneity in private costs indicates that a flat-rate compensation policy may not be efficient or effective. A high flat-rate compensation policy would be inefficient as it would over-compensate the relatively low-cost suppliers. A low flat-rate compensation policy would fail to attract relatively high-cost suppliers of ES. For example, a one-time payment of $2000/acre (equivalent to approximately $166.67/acre/year for a 12-year contract period) as provided by the Lower Souris Watershed Committee might fail to attract many producers (LSW, 2015) as it is significantly lower than the median inferred WTA elicited by this study for the Saskatchewan subsample as well as that for the Alberta subsample. The observed heterogeneity in estimated costs also indicates that it would be an efficient strategy from the policy makers' perspective to identify the low-cost suppliers of ES through wetland restoration so that the optimal investment required for wetland conservation could be determined.

The policy relevance of a cost discovery study lies in its ability to inform public policy with regard to design, targeting and implementation. PES or conservation auctions are highlighted as market-based instruments (MBIs) that encourage economic agents' behaviour to achieve environmental goals. Kroeger and Casey (2007), in their investigation of whether MBI can provide agricultural landowners with incentives to produce ES, pointed out that a lack of low-cost approaches to quantification and valuation of ES poses a major barrier to having a widespread ecosystem market. The findings of the current study address this issue.
The high degree of comparability between the salient bids received by Hill et al. (2011) and the inferred WTA estimates obtained in this study indicates that the SP auctions could act as an alternative and a cheaper cost discovery method compared to reverse auctions. If the policy goal is to obtain estimates of the cost of BMP adoption for a site for which no pre-existing cost discovery studies are available, an SP auction could address the policy need.

The FC estimates reveal the low-cost and high-cost suppliers of ES. This study assessed the usability of FC estimates as a starting point for estimating the compensation required for wetland restoration. The observation that the FC estimates were in general smaller than the WTA estimates indicates that the FC estimates, as obtained in this study, might underestimate the true costs of wetland restoration, given the model assumptions and data availability constraints. A positive correlation of farm-level FC and WTA would indicate that FC estimates are able to partially predict the true costs. While this study obtained a positive correlation between FC and WTA, it was only for the full sample, including observations with imputed values of WTA. The positive correlation was not obtained for site-specific subsample analysis or after excluding the observations with imputed values of WTAs, thus indicating the limitation posed by the small sample size available for this analysis. However, the distribution of FC estimates demonstrated a high degree of comparability to the bid distribution obtained in the first round of the reverse auction conducted by Hill et al. (2011). This indicates that with precise assumptions about farm operations and/or detailed farm-specific data, FC estimates have the potential for approximating the "true" cost of wetland restoration. Therefore, existing FC estimates from BMP evaluation studies could be used as a starting point for designing compensation and estimating conservation budget.

Comparison of the transferred cost estimates with the average second-round bid received by Hill et al. (2011) allows an important conclusion regarding the use and applicability of transferred cost estimates to be drawn. While low values of the absolute transfer errors are desirable, the relative magnitudes of the transferred costs compared to the salient bids are also important especially in the context of compensation design. If transferred costs are higher than the average salient bids and hence the "true" costs of BMP adoption at the policy site, then even if these are associated with high transfer errors, these still have the potential to be accepted as compensation. The high calibrated costs would not be efficient from the policymaker's perspective even if they succeed in attracting producers. Of course, without any pre-existing cost discovery studies for a particular site, it would be difficult to ascertain if calibrated costs are indeed higher than true costs. In that case, producers' response towards the program might be used as an indicator of the effectiveness of the compensation program. It would be effective in attracting producers to wetland restoration programs if calibrated costs are either equal or marginally higher than the true costs. It would be efficient if transfer errors are minimized.

The cost transfer analyses indicate that with sufficient similarity of study and policy sites, a cost transfer could be undertaken to achieve policy evaluation in a low-cost manner. The low transfer errors obtained in this study are encouraging especially when compared to the median transfer errors found in the BT literature. The low transfer errors and high degree of overlap between the cost estimates obtained in this study and the salient bids received by Hill et al. (2011) indicate that a cost transfer method using findings from existing studies has the potential to serve as a cheap and alternative cost discovery method compared to reverse auctions, given the caveats associated with such a transfer.

The current study has not explored the context similarity of study and policy sites to a great extent. However, historical and current policy differences in the two case study areas as well as availability of the oil and wind turbine leases may contribute to potentially significant differences in producer preferences for wetland restoration projects across the two sites. For example, the county of Vermilion River, one of the RMs at the Alberta site of this study was authorized in 2013 as the first municipal wetland restoration agency in Alberta by Alberta Environment and Sustainable Resource Development (CVR, 2013). Producers' involvement in or familiarity with the wetland restoration activities in this RM might be a reason for the lower levels of WTA observed in this study area, compared to the Saskatchewan site. *The World-Spectator*, a local weekly newspaper in Saskatchewan that serves Moosomin and nearby rural communities, reported that in April 2014, the highest price paid for oil exploration licenses in the region was $9313/hectare($3768.84/acre) (*The World Spectator*, 2014). The availability of such high-valued leases potentially could affect producer and landowner willingness to participate in wetland restoration programs. These types of factors would affect the degree of transferability of the cost estimates at the implementation level.

It may be noted that many of the respondents in this study indicated that they would ask for lower amounts of compensation if they had the option to consolidate the restored wetlands with existing ones such that their nuisance cost was minimized or reduced. As restoration projects are implemented in consultation with each interested landowner, in absence of direct non-market valuation studies, it might be possible for a restoration agency to make use of FC estimates or transferred WTA estimates to reduce the information asymmetry underlying the costs of private provision of ES. It may help design a compensation package that would interest the producers to initiate the restoration dialogue. It may also help reduce interested producers' transaction costs associated with developing their preferred bid price.

5.3 Limitations of the Study

Data limitations stand out as one of the main challenges faced by this study and this has impacted the analyses described in the previous chapters considerably. The small sample size limited the exploration of the producers' preference and motivation for participating in restoration programs. It restricted the analyses to relatively simple models that accounted for the heterogeneity in preference for compensation but could not tease out the source of the heterogeneity. The partial RE Probit models allowed the estimation of the median WTA. However, the "full" model with covariates did not provide reliable results as some of the covariates were potentially endogenous. With sufficient data, it would be worth exploring the underlying source of the heterogeneity by implementing more complex econometric models such as a random coefficients model or latent class model, as it would help target a specific population of agricultural producers based on their preference and farm-level characteristics that impact the cost of provision of ES.

The FC estimation is limited by its heavy reliance on model assumptions and detailed data availability regarding farming operations. While sample size per se was not an issue for the estimation of FC for each farm, it would have been preferable to collect more detailed farm-specific information about the enterprises for each farm. As it was necessary to collect data for both producer preferences for compensation and about the farm operations, a compromise had to be made regarding the amount of detail gathered in the farm information section. A number of farm-specific assumptions had to be made in order to be able to model farm operations consistently across the sample as certain respondents presented farm operations details based on the area that they own versus the total farm size that they own and rent.

The farm-specific FC estimation exercise faced certain unique challenges compared to a representative farm analysis exploring the same issue. Since data were not available on how rental land was used - whether for crop or pasture - the rental cost was not included in the model. The entire farm size was treated as being owned. This simplification potentially results in an underestimation of the total cost of production in both the baseline and BMP scenarios. In the absence of farm-specific historical yields, it was difficult to simulate and validate farm-specific yield distributions and again required specific assumptions. Although data on fertilizer and pesticide costs were collected for each farm, in the end they could not be used in the model for most farms. For example, for some farms the fertilizer and pesticide costs for the 2013 farming season seemed significantly higher than the corresponding average costs of production and for others it was significantly lower, or even zero. However, it was deemed unlikely that a farm would continue to apply a very high level of chemicals or apply none for every year over the contract period. In the end, it was decided to use average costs of production from secondary sources with farm-specific adjustments made in certain cases to avoid a negative baseline NPV.

Similar concerns with farm-specific model assumptions apply regarding machinery replacement costs, since developing the full machinery complements for each farm in the sample seemed challenging. The assumed discount rate was also common to all farms in the sample and, thus, the study does not elicit or incorporate farm-specific discount rates. The sample size affected the investigation of the relationship between farm-level FC and WTA estimates.

It may also be noted that for the farms that have cow-calf enterprise component in their farm operation, the revenue from the sales of calves was assumed to have no link with the availability of forage. Also, the price of weaned calves was assumed to be deterministic. This is not realistic and is only assumed to maintain a relatively simple model. The only variability in revenue enters the simulation models from the crop component of the farm enterprises through crop and forage yield and price variability.

A lot of these assumptions directly affected the FC estimates. The main drivers of the FC as modelled in this study were the lost revenue from the crops that could have been grown in the seven acres of area restored, the nuisance costs and the input wastage costs. Using the average fertilizer and pesticide costs dampened the heterogeneity in input wastage costs and thus the FC estimates, even if only marginally. The nuisance costs were also modelled in a relatively simplistic manner. It was assumed that a single wetland of seven acres would be restored in a field without making any specific assumptions about how many wetlands are already there in that field or the shape and location of the restored wetland. In reality, these would be highly significant factors in the determination of the actual nuisance cost and would vary not only across farms but across fields.

While a demonstration of structural cost transfer was presented using the social preference hypothesis, this study did not elicit agricultural producers' social preference. Thus a true cost calibration as per the preference calibration method developed by Smith et al. (2002) that would theoretically and analytically connect the two estimates of WTA and FC could not be implemented.

5.4 Scope of Future Research

Needless to say a future study would benefit from a larger sample size so that the factors motivating agricultural producers to undertake wetland restoration could be better explored.

More in-depth data availability for each farm in the sample would allow the components of the cash flow to be modelled better. Several simplifying assumptions used in this study to model the farm enterprises could be relaxed in order to obtain estimates of the FC of restoration under more realistic scenarios. For example, it would be interesting to see how incorporation of yield benefits and reduced risk of diseases associated with certain crop rotations affects the cash flow and, thus, the estimation of FC. A future cost transfer study could focus on elicitation of social preference and exploring the analytical link between WTA, FC and producers' social preference or warm glow.

The cost estimation exercise in this study was based on a stylized wetland restoration program. While this allowed for a comparison of the cost estimates with the existing studies and across the farms in the current sample, it would be interesting to study the cost of BMP adoption with a farm-specific and/or field specific wetland restoration program. Of course, this would also require a significantly larger amount of data. However, at the implementation level, a wetland restoration program is highly farm-specific and hence precision of the cost discovery exercise would improve with field-specific data.

The current study addresses the issue of estimation of private costs of wetland restoration in the Western Canadian Prairie region. As Pannell (2008) noted, the identification of an appropriate policy would require knowledge of the public benefits of wetland restoration as well. Estimation of public benefits of restoring wetlands in the Prairie Pothole region of Canada would require identification of beneficiaries and evaluation of ecosystem functions and services of wetland. A direct valuation study or a benefit transfer study has the potential to address this research gap and generate benefit estimates that are comparable to the findings of this study.

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Appendix A Survey Methods - Survey Design and Implementation

Appendix A1 Survey Instrument Development

The questionnaire for the survey was divided into three sections. The first section was based on the questions about the respondents agricultural practices and enterprise details. The second section focused on the hypothetical wetland restoration scenarios and the respondent's preference for the compensation amounts associated with each scenario. Respondents' own valuation questions were followed by inferred valuation questions about what they think a typical producer in their area would do if faced with the same set of wetland restoration choices. The third section included basic demographic characteristics of the respondents. The elicited preference data were used to estimate the median WTA of the sample and also the individual WTA for each producer. The data on the enterprise details were used to develop the farm-level Monte Carlo simulations that would generate the estimated opportunity cost of wetland restoration. Given the objective of the study, that the estimated opportunity cost for each farm would be compared to and used in conjunction with the respective estimated WTA for the transfer analysis, a basic trade-off faced in the questionnaire development was between the gathering of enough farm-level data as well as minimizing the length and cognitive burden of the questionnaire. Several iterations and modifications were undertaken after consulting researchers familiar with the study areas as to what would be minimum in terms of data requirement for farm-level simulation analysis.

The focus group helped identify questions about enterprise details that could be difficult to answer off-the-cuff for many producers – especially for the ones with big operation size. It was also pointed out that the WTA for restoration would depend on the location of the restored wetland and, hence, more detail regarding the actual restoration might be useful. It was also noted that the ideally the wetland restoration questions should be specific to each farm and they should specify location (corner or centre), alignment with machinery movement direction in the field, consolidation option etc. While the farm-specific details were deemed important, for the purpose and scope of the present study it was decided that the description of the hypothetical restoration project would be maintained to a single unit of 7 acres size without the location or consolidation option details. The rationale for this stylized choice was that developing a farm-specific restoration program would require a large amount of data and the data regarding the exact location of the original drained wetland in the present landscape may not even be known to the farmer – especially if the draining was conducted several decades ago. Consolidation options or machinery movement facilitation details were also not explicitly mentioned while presenting the wetland restoration choice questions. It was assumed that these factors would underlie the choices made by the farmers as they would pick the area that best combines the economic and conservation interest, if any. Developing meaningful farm-specific restoration choices would involve knowledge of the original and current wetland distribution in the study area for each farm. It would also be more resource-intensive and, hence, could be taken up as a future study.

Appendix A2 Sampling Plan and Execution

It was decided that an in-person survey would be more effective in terms of getting quality data compared to a telephone survey or online survey as that would allow the researcher to attract the respondents' attention to the minute details of the questionnaire that might otherwise have been missed. Also, discussions with experts indicated that farmers in Canada are surveyed extensively by various organizations and they might not respond to an online survey very well in this case. As Carson (2012) commented, in-person interviews are considerably more expensive than online or telephone surveys but they have a potential advantage of motivating the respondents to answer more carefully. Carson (2012) also indicated that in-person interviews help to execute the sampling plan. In the course of the focus group as well as the survey for the present study it was informally observed by many respondents that the in-person nature of the interviews piqued or sustained their interest. However, in-person surveys are susceptible to inducing potential interviewer bias or social desirability bias. Hence, to control for this potential bias, the inferred valuation approach undertaken seemed warranted.

The sites in this study were located in the Black soil regions of Central Alberta and Southeastern Saskatchewan. These two areas were picked due to the similarity of enterprise mix and soil zone – thus indicating sufficient amount of comparability for the transfer analysis (Unterschultz, 2013).

The first step of the recruitment strategy for the study involved contacting local government and conservation agencies for a list of potential participants. For Alberta, this request for contacts generated approximately 73 names of landowners. The second step of the recruitment involved contacting these landowners for a telephone screening to determine their eligibility, willingness and availability for the survey. After repeated calling over several days, contact could be established with 38 landowners and the rest of the 35 contact numbers yielded no response. Out of the 38 producers contacted, 4 were not eligible for the study and 6 producers were not available on the scheduled interview dates. Note that the producers were given an option of picking any date for the interviews in the two weeks following the phone call. A total of 14 producers were recruited for the in-person interviews and rest were not interested. Even though the actual number of recruited producers is not large, it constitutes 40% of the total numbers of producers in Alberta contacted for the study. Specifically, in Alberta, the respondents were spread across the counties of Vermilion River, Wainwright and Beaver.

For the survey in Saskatchewan, the request for contacts from the local agencies was not successful and thus a different sampling and recruitment strategy had to be adopted. The first step was to identify the rural municipalities belonging to the Lower Souris Watershed area. The Lower Souris Watershed area covers approximately 20 rural municipalities, 19 urban municipalities and three First Nations lands (LSW, 2014). Given the size of the watershed area and the time and logistic constraints of the survey, it was decided that it would be more effective to focus instead on the Pipestone Creek sub-watershed area in the Rural Municipality #121 of Moosomin for the survey. A total of 202 contact numbers marked as “Farm” were collected from the SaskTel phonebook. The list of the contacts were randomized using random number generator in MS Excel before the telephone screening. Out of the 202 contacts, 195 numbers were found to be active and these numbers were again called multiple times at different times of the day. Contact could be established with only 99 numbers, out of which 59 were eligible for the study. Among the 59 producers contacted and screened, 41 producers were not interested to participate and 4 producers were not available on the scheduled interview dates. A total of 14 producers were recruited for the in-person interviews. This constituted approximately 23.7% response rate in Saskatchewan.

To elicit WTA of the sampled producers in the study areas, it was decided to employ a multiple-bounded polychotomous choice SP survey. This was done to collect more data than a typical DC CVM would provide so that the bid interval containing the true WTA may be narrowed down. To avoid the possibility of intransitivity of choice and to reduce cognitive burden and possible noise in the choices the amounts were listed in an increasing order. Since the ordering of the bids were not varied, potential ordering effect was not testable.

The bid amounts were designed on the basis of average bid values as reported in Hill et al. (2011). The design of bid values is crucial for SP studies as the amounts presented can often have anchoring effect. Hill et al. (2011) reported the mean and range of the bids submitted and accepted for crop and forage enterprise. For a crop enterprise, the average bid was $643 per acre per year and for a forage enterprise the average bid was $118.52 per acre per year. In the present study these bid amounts are rounded off to $640 per acre per year and $120 per acre per year respectively to be used as baseline values that are used to design the list of bid amounts for restoration in cropland and pasture. Anderson et al. (2007) used a multiple price list model in a WTP study based on lab experiments with market goods and used both the "skew high" and "skew low" designs for the price lists. Shivan and Mahmood (2012) in a WTA study with market goods used market price for pulpwood as the baseline and used a "skew high" design for list of bid amounts. In a "skew high" design, the presented values are skewed towards the highest WTP or WTA amount presented such that the amount presented in the middle row of the list is higher than the mean of the list. In the present study, the bids were presented with a "no skew" design such that the presented bid amounts were: baseline, 100% higher and lower than baseline, 75% higher and lower than baseline, 50% higher and lower than baseline, 25% higher and lower than baseline and 10% higher and lower than baseline.

The uncertain response options were introduced to control for strategic response. Response formats that allow for uncertainty are used by many authors (e.g., Li and Mattsson, 1995; Ready et al., 1995; Wang, 1997; Welsh and Poe, 1998). Alberini et al. (2003) noted that respondents' uncertainty about a choice is a valid concern for SP studies. It may be noted that in the present study the restoration choice questions involved uncertainty regarding the exact nature of the good in question (e.g. exact location of the restored wetland in the field, consolidation option) and impact on the total value of the land for future saleability. This justified the inclusion of uncertain response categories.

The own valuation question was prefaced with a cheap talk script. The question and the cheap talk script for restoration in the best cropland were phrased as follows:

"Suppose you were asked to submit a sealed bid that represents the amount that you will be willing to accept in compensation for participating in the program. The agency would select the

*winning bids by choosing the lowest bids according to their budget. Please indicate whether you would be interested in restoring wetlands on 7 acres of your best cropland for each of the following compensation amounts in Table 1.1. Please note that the land given up for wetland restoration would not be available for agricultural purposes for the next **12 years**.*
Please consider each compensation amount individually. For each amount please indicate if you would definitely accept, probably accept, probably not accept or definitely not accept, in exchange for the restoration of the wetland. It is important that you treat these choices as choices with real consequences even though the above conditions presented to you may not be real. We urge you to consider what you would really do if presented with such a situation in real life and choose accordingly."

Due to the in-person nature of the interview, respondents had a fair chance of debriefing. Each set of own valuation questions in crop and pasture scenarios was followed by debriefing questions and questions about respondent's perception of what impression his choices would make on others. These were followed by the inferred valuation questions where each respondent were asked if they thought a typical farmer in their area would be willing to participate in the program and the amounts of compensation they might require. They were also asked if a typical farmer would be certain in their responses or might overstate or understate the willingness to participate in wetland restoration projects.

Appendix B Survey Questionnaire

I. Agriculture and agri-food system plays a huge role in provincial and federal economy. Agriculture is a major land use that is important not only for the food production but also for the provision of environmental services such as wildlife habitat, carbon sequestration. Agriculture also impacts the environment and specifically water quality and quantity through the effects of nutrients, pesticides and water usage practices. Wetlands in agricultural land provide a variety of ecosystem functions but at the same time pose challenges for producers during tillage, seeding and harvesting. We are interested to understand the true cost of restoring natural wetlands from your point of view as a producer. In this section, we would like to know about your agricultural practices.

What is the farm size (in acres) in 2013?
Owned ___________
Rented ___________

Among the total land that you own, please indicate

most suitable for growing annual crops such as wheat, canola etc ___________%
most suitable for pasture ___________%
not suitable for any agriculture ___________%

Please indicate how the total area that you own, was used in 2013.

Usage	Acres
Annual Crops	
Hay	
Summerfallow	
Tame or seeded pasture (not harvested for hay, silage or seed)	
Natural pasture (including native pasture and woodland used as pasture)	
Woodland (woodlots, tree windbreaks, bush)	
Still waterbodies/ Wetlands (bogs, fens, marshes, sloughs)	
Flowing waterbodies (stream, creeks)	
Bufferstrips	
All other land (building, barnyard, lane, home garden, waste areas etc)	

What is the main enterprise on your farm? Please select one.

Crop _______
Cow-calf _______
Other (Please describe) __________________________

For a crop enterprise (owned):

Crops grown in 2013	Acres	Yield tonnes/acre (or bales/acre for hay)	Estimated pesticide cost ($/acre)	Cost of fertilizer ($/acre)	Type of fertilizer used (NPK composition)*	Rate of fertilizer used (lb/acre)*

*Note: please provide type and rate of fertilizer is cost of fertilizer is not available.

What is your general long-term rotation on your best field? _______________

What is the yield difference (in %) between your best and worst field? _______________

For a cow-calf enterprise:

What was the total number of livestock as of May 1, 2013? _______
Number of days of grazing _______
Number of days of feeding/supplementing _______

How many wetlands are there in your property?

Number of permanent ponds and lakes (flooded year-round except during extreme droughts): ____
Number of seasonal wetlands (water present until mid-summer): ___________
Number of ephemeral/temporary wetlands (flooded for a short time after precipitation or in the spring): _______

In the past 12 years have you made any land use changes (for example, conversion of cropland into residential area, restoration of previously drained wetlands or draining of wetlands) in your land? Yes/No

If Yes, please indicate the acres of the said land use change(s):
Annual cropland to wetland: ___________ acres
Annual cropland to buffer strips or shelterbelts: _____ acres
Annual cropland to tame forage or pasture: _______ acres
Annual cropland to other (please specify): ______acres
Wetland to annual cropland: ___________ acres
Wetland to tame forage or pasture: ______ acres
Woodland to cropland or pasture: _____ acres
Any other (please specify) ____ acres

II. Wetland restoration choices

A wetland is land having water at, near or above the land surface and it can take many forms depending on the duration of the water cover, water depth and common vegetation. According to Canadian Wetland Classification System, natural wetlands include bogs, fens, swamps, marshes and shallow open water. Wetlands provide environmental benefits such as flood mitigation, water quality improvement, groundwater recharge, wildlife habitat provision and carbon sequestration. Wetlands help conserve soil and control erosion, retain sediments, absorb nutrients and degrade pesticides. Wetland benefits apply to landowners as well as to society as a whole. However, more than 70% of the original wetlands in Canada's Prairie region have been lost due to infilling, altering or physically draining the wetlands (Environment Canada, 2013). We are interested in your views regarding wetland restoration as a landowner. We also want to know the cost of restoring these wetlands from your perspective.

Suppose a watershed agency is introducing a program to cover the costs of restoring wetlands that have been previously drained. The details of the program are as follows: The program would pay for the administrative and construction costs of restoring wetlands in 7 acres of the best cropland or pasture (if applicable) that you own. The wetlands would be restored by the watershed agency by plugging drainage ditches under your supervision. A lump sum payment would be made to compensate you for loss of production and any other costs. You must sign an agreement that you would not drain the restored wetlands for 12 years. Annual monitoring and compliance evaluation would be conducted by the agency.

Suppose you were asked to submit a sealed bid that represents the amount that you will be willing to accept in compensation for participating in the program. The agency would select the winning bids by choosing the lowest bids according to their budget.

1.1. Please indicate whether you would be interested in restoring wetlands on 7 acres of your best cropland for each of the following compensation amounts in Table 1.1. Please note that the land given up for wetland restoration would not be available for agricultural purposes for the next **12 years**.

Please consider each compensation amount individually. For each amount please indicate if you would definitely accept, probably accept, probably not accept or definitely not accept, in exchange for the restoration of the wetland. It is important that you treat these choices as choices with real consequences even though the above conditions presented to you may not be real. We urge you to consider what you would really do if presented with such a situation in real life and choose accordingly.

You may use the supplementary practice worksheet to identify the cost and benefit components of this land use change decision that would help you determine your final bid.

Table 1.1. For **7 acres** of wetland in your **annual cropland**

Amount	Definitely not accept	Probably not accept	Probably accept	Definitely accept
$0 /acre/year				
$160 /acre/year				
$320 /acre/year				
$480 /acre/year				
$576 /acre/year				
$640 /acre/year				
$704 /acre/year				
$800 /acre/year				
$960 /acre/year				
$1120 /acre/year				
$1280 /acre/year				

1.2. **If you didn't pick Probably accept or Definitely accept** for **any** of the amounts listed above, please indicate which of the following would describe your reason or reasons for doing so:

Such projects would interfere with farming operation ________
The payment amounts offered are too low ____________
Contract period is too long __________________
Not enough information to evaluate contract ______________
If there are any other reasons, please specify ___________________
If you had to pick **only one** reason for not participating, which one would you pick? **a/b/c/d/e**

If you picked Probably accept or Definitely accept for some compensation amounts presented above, please indicate which of the following describe your reason for participation:

The payment amount provides sufficient financial compensation ___________

Improved water quality would improve livestock health _______________
Improvement in farm aesthetics ________________
The payments would be a nice constant source of income _________________
It's a good idea to restore wetlands for environmental reasons ____________
I would do it anyway as a stewardship activity _______________
If there are any other reasons, please specify ____________

If you had to pick **only one** reason for participating, which one would you pick? **a/b/c/d/e/f/g**

1.3. Would others (other producers or your neighbours) have a positive or negative impression of you if they knew your decision to participate? (assuming they would not be directly impacted by your land use decisions) Positive/Negative/Neutral/Don't Know

1.4. Do you think a typical farmer in your area would be willing to participate in such a program? Yes/No

1.5. How much compensation do you think they would be willing to accept if you think they would participate in restoring 7 acres of wetland in their best cropland? For each amount please indicate if you think **a typical farmer in your area** would definitely accept, probably accept, probably not accept or definitely not accept, in exchange for the restoration of the wetland.

Table 1.5. For **7 acres** of wetland in the **annual cropland of a typical farmer**

Amount	Definitely not accept	Probably not accept	Probably accept	Definitely accept
$0 /acre/year				
$160 /acre/year				
$320 /acre/year				
$480 /acre/year				
$576 /acre/year				
$640 /acre/year				
$704 /acre/year				
$800 /acre/year				
$960 /acre/year				
$1120 /acre/year				
$1280 /acre/year				

1.6. Do you think people are likely to understate their inclination in participating in wetland restoration programs? Yes/No

1.7. Do you think people are likely to overstate in their inclination in participating in wetland restoration programs? Yes/No

2.1. **If you have pastureland**, please indicate whether you would be interested in restoring wetlands on 7 acres of your pastureland for each of the following compensation amounts in Table 2.1. Please note that the land given up for wetland restoration would not be available for agricultural purposes for the next **12 years**.

Please consider each compensation amount individually. For each amount please indicate if you would definitely accept, probably accept, probably not accept or definitely not accept, in exchange for the restoration of the wetland. It is important that you treat these choices as choices with real consequences even though the above conditions presented to you may not be real. We urge you to consider what you would really do if presented with such a situation in real life and choose accordingly. You may use the supplementary practice worksheet to identify the cost and benefit components of this land use change decision that would help you determine your final bid.

Table 2.1. For **7 acres** of wetland in your **pastureland (if applicable)**

Amount	Definitely not accept	Probably not accept	Probably accept	Definitely accept
$0 /acre/year				
$30 /acre/year				
$60 /acre/year				
$90 /acre/year				
$108 /acre/year				
$120 /acre/year				
$132 /acre/year				
$150 /acre/year				
$180 /acre/year				
$210 /acre/year				
$240 /acre/year				

2.2. **If you didn't pick Probably accept or Definitely accept** for **any** of the amounts listed above, please indicate which of the following describe your reason or reasons for doing so:
Such projects would interfere with farming operation ___________
The payment amounts offered are too low ___________
Contract period is too long ___________
Not enough information to evaluate contract ___________
If there are any other reasons, please specify ___________

If you had to pick **only one** reason for not participating, which one would you pick? **a/b/c/d/e**

If you picked Probably accept or Definitely accept for some compensation amounts presented above, please indicate which of the following describe your reason for participation:
The payment amount provides sufficient financial compensation __________
Improved water quality would improve livestock health __________
Improvement in farm aesthetics __________
The payments would be a nice constant source of income __________

It's a good idea to restore wetlands for environmental reasons __________
I would do it anyway as a stewardship activity __________
If there are any other reasons, please specify __________

If you had to pick **only one** reason for participating, which one would you pick? **a/b/c/d/e/f/g**

2.3. Would others have a positive or negative impression of you if they knew your decision to participate? Positive/Negative/Neutral/Don't Know

2.4. Do you think a typical farmer in your area would be willing to participate in such a program? Yes/No

2.5. How much compensation do you think they might be willing to accept if you think they would participate in restoring 7 acres of wetland in their pastureland? For each amount please indicate if you think **a typical farmer in your area** would definitely accept, probably accept, probably not accept or definitely not accept, in exchange for the restoration of the wetland.

Table 2.5. For **7 acres** of wetland in pastureland **of a typical farmer**

Amount	Definitely not accept	Probably not accept	Probably accept	Definitely accept
$0 /acre/year				
$30 /acre/year				
$60 /acre/year				
$90 /acre/year				
$108 /acre/year				
$120 /acre/year				
$132 /acre/year				
$150 /acre/year				
$180 /acre/year				
$210 /acre/year				
$240 /acre/year				

2.6. Do you think people are likely to understate their inclination in participating in wetland restoration programs? Yes/No

2.7. Do you think people are likely to overstate their interest in participating in wetland restoration programs? Yes/No

3. If you would like to leave a comment about the wetland restoration choices you made above, please use this space:

____
____
____
____

III. Landowner's Characteristics

What is your age? _______ Years
What is your gender? Male/ Female
What is your highest completed level of education?
No formal education
Elementary
High School
Bachelors degree or diploma
Masters or PhD
Do you use computers for the farm business? Yes/No
Do you use internet for the farm business? Yes/No
Do you have access to high-speed internet? Yes/No

What was your approximate household income (including all members of the household) before tax in the last year?
Less than $10,000 _____
$10,000 to $19,999 _______
$20,000 to $29,999 _______
$30,000 to $39,999 _______
$40,000 to $49,999 _______
$50,000 to $59,999 _______
$60,000 to $69,999 _______
$70,000 to $79,999 _______
$80,000 to $89,999 _______
$90,000 to $99,999 _______
$100,000 to $124,999 _____
$125,000 to $149,999 _____
$150,000 to $199,999 ______
$200,000 or Greater_____

Approximately what percentage of your total household income is from farming? ____ %
What is your employment status?
Working full time on farm ____
Working part time on farm____

Has an Environmental Farm plan been completed for your farm?

Are you a member of the following types of organizations?
Farm (e.g., Central Alberta Agricultural Society, Alberta Federation of Agriculture, Agricultural Producers Association of Saskatchewan, SaskCanola, Saskatchewan Association of Agricultural Societies and Exhibitions etc.) Yes/No
Conservation and environmental stewardship (e.g. Local watershed stewardship groups, Stewards of Saskatchewan, Agri-Environmental Group Plan etc.) Yes/No
Recreational hunting, fishing (e.g. Saskatchewan Wildlife Federation) Yes/No

Supplementary Worksheets: to be presented by the interviewer at the time of interview.

Practice Worksheet for Table 1.1

	Crop area (acres) (a)	Crop area set aside for wetland restoration (acres) (d)	Production (tonnes/acre) (b)	Price ($/tonne) (c)	Current gross income (a)x(b)x(c)	Expected loss in gross income (d)x(b)x(c)
Canola						
Spring wheat						
Winter wheat						
Oats						
Barley						
Rye						
Corn						
Alfalfa and Alfalfa-grass mixtures						
Tame hay						
TOTAL change in gross income (A)						
Added machinery cost of farming around the wetlands (B)						
Reduced operating costs (C)						
Any other cost reduction/ benefits (D)						
Total estimated cost of restoration (A+B-C-D)						

Practice Worksheet for Table 2.1

	Crop area (acres) (a)	Crop area set aside for wetland restoration (acres) (d)	Production (tonnes/acre) (b)	Price ($/tonne) (c)	Current gross income (a)x(b)x(c)	Expected loss in gross income (d)x(b)x(c)
Alfalfa and Alfalfa-grass mixtures						
Tame hay						
TOTAL change in gross income (A)						
Added machinery cost of farming around the wetlands (B)						
Reduced operating cost (C)						
Any other cost reduction/ benefits (D)						
Total estimated cost of restoration (A+B-C-D)						

Appendix C Distribution of Valuation Responses

Table C1 Actual Response Distribution - Alberta-Crop-Own (ABCO) Scenario

Crop bids (Own)[a]	Definitely no	Probably no	Probably yes	Definitely yes	NA
0	100%	0%	0%	0%	0%
160	53%	33%	13%	0%	0%
320	47%	20%	20%	13%	0%
480	27%	27%	13%	33%	0%
576	20%	20%	27%	33%	0%
640	20%	7%	27%	47%	0%
704	13%	7%	20%	60%	0%
800	13%	0%	20%	67%	0%
960	13%	0%	7%	80%	0%
1120	13%	0%	7%	80%	0%
1280	13%	0%	7%	80%	0%

[a]: Bids are in $/acre/year. "Own" refers to restoration scenario in the respondent's best cropland or pasture.

Table C2 Actual Response Distribution - Alberta-Crop-Inferred (ABCI) Scenario

Crop bids (Inferred)[a]	Definitely no	Probably no	Probably yes	Definitely yes	NA
0	80%	0%	0%	0%	20%
160	53%	27%	0%	0%	20%
320	47%	20%	13%	0%	20%
480	13%	40%	20%	7%	20%
576	13%	20%	40%	7%	20%
640	7%	13%	47%	13%	20%
704	7%	7%	33%	33%	20%
800	7%	0%	20%	53%	20%
960	7%	0%	0%	73%	20%
1120	7%	0%	0%	73%	20%
1280	7%	0%	0%	73%	20%

[a]: Bids are in $/acre/year. " Inferred " refers to what the respondent thinks a typical farmer in the area would do if presented with the same restoration scenario.

Table C3 Actual Response Distribution - Alberta-Pasture-Own(ABPO) Scenario

Pasture bids (Own)[a]	Definitely no	Probably no	Probably yes	Definitely yes	NA
0	47%	7%	7%	0%	40%
30	47%	7%	0%	7%	40%
60	40%	7%	7%	7%	40%
90	33%	13%	7%	7%	40%
108	33%	7%	7%	13%	40%
120	33%	0%	13%	13%	40%
132	27%	0%	20%	13%	40%
150	20%	7%	7%	27%	40%
180	13%	7%	7%	33%	40%
210	13%	0%	7%	40%	40%
240	7%	7%	0%	47%	40%

[a]: Bids are in $/acre/year. "Own" refers to restoration scenario in the respondent's best cropland or pasture.

Table C4 Actual Response Distribution - Alberta-Pasture-Inferred(ABPI) Scenario

Pasture bids (Inferred)[a]	Definitely no	Probably no	Probably yes	Definitely yes	NA
0	33%	7%	0%	0%	60%
30	27%	7%	7%	0%	60%
60	27%	7%	7%	0%	60%
90	13%	13%	7%	7%	60%
108	13%	0%	20%	7%	60%
120	13%	0%	13%	13%	60%
132	13%	0%	13%	13%	60%
150	13%	0%	0%	27%	60%
180	7%	7%	0%	27%	60%
210	7%	0%	7%	27%	60%
240	7%	0%	0%	33%	60%

[a]: Bids are in $/acre/year. "Inferred" refers to what the respondent thinks a typical farmer in the area would do if presented with the same restoration scenario.

Table C5 **Actual Response Distribution - Saskatchewan-Crop-Own (SKCO) Scenario**

Crop bids (Own)[a]	Definitely no	Probably no	Probably yes	Definitely yes	NA
0	100%	0%	0%	0%	0%
160	71%	21%	0%	7%	0%
320	50%	21%	14%	14%	0%
480	36%	21%	14%	29%	0%
576	29%	29%	14%	29%	0%
640	29%	7%	36%	29%	0%
704	21%	14%	36%	29%	0%
800	14%	14%	36%	36%	0%
960	14%	14%	14%	57%	0%
1120	14%	14%	7%	64%	0%
1280	7%	0%	29%	64%	0%

[a]: Bids are in $/acre/year. "Own" refers to restoration scenario in the respondent's best cropland or pasture.

Table C6 **Actual Response Distribution - Saskatchewan-Crop-Inferred (SKCI) Scenario**

Crop bids (Inferred)[a]	Definitely no	Probably no	Probably yes	Definitely yes	NA
0	100%	0%	0%	0%	0%
160	71%	21%	7%	0%	0%
320	64%	14%	21%	0%	0%
480	57%	14%	21%	7%	0%
576	43%	14%	29%	14%	0%
640	36%	14%	36%	14%	0%
704	21%	14%	43%	21%	0%
800	21%	14%	29%	36%	0%
960	21%	14%	29%	36%	0%
1120	21%	14%	14%	50%	0%
1280	21%	0%	21%	57%	0%

[a]: Bids are in $/acre/year. "Inferred" refers to what the respondent thinks a typical farmer in the area would do if presented with the same restoration scenario.

Table C7 **Actual Response Distribution - Saskatchewan-Pasture-Own (SKPO) Scenario**

Pasture bids (Own)[a]	Definitely no	Probably no	Probably yes	Definitely yes	NA
0	93%	0%	0%	0%	7%
30	71%	21%	0%	0%	7%
60	57%	14%	21%	0%	7%
90	43%	21%	14%	14%	7%
108	43%	14%	14%	21%	7%
120	36%	21%	7%	29%	7%
132	36%	21%	7%	29%	7%
150	36%	7%	21%	29%	7%
180	29%	14%	14%	36%	7%
210	29%	14%	14%	36%	7%
240	21%	7%	21%	43%	7%

[a]: Bids are in $/acre/year. "Own" refers to restoration scenario in the respondent's best cropland or pasture.

Table C8 **Actual Response Distribution - Saskatchewan-Pasture-Inferred (SKPI) Scenario**

Pasture bids (Inferred)[a]	Definitely no	Probably no	Probably yes	Definitely yes	NA
0	100%	0%	0%	0%	0%
30	71%	29%	0%	0%	0%
60	50%	36%	14%	0%	0%
90	29%	36%	21%	14%	0%
108	29%	29%	21%	21%	0%
120	29%	21%	29%	21%	0%
132	21%	14%	43%	21%	0%
150	21%	14%	29%	36%	0%
180	21%	14%	21%	43%	0%
210	14%	21%	14%	50%	0%
240	7%	0%	36%	57%	0%

[a]: Bids are in $/acre/year. "Inferred" refers to what the respondent thinks a typical farmer in the area would do if presented with the same restoration scenario.

Appendix D Midpoint Regression Results

Table D1 Midpoint Analyses - Crop

	ABCO[a]			ABCI[b]			SKCO[c]			SKCI[d]	
	Coefficients		St. error	Coefficients		St. error	Coefficients		St. error	Coefficients	St. error
Constant	0.5439		0.32936	0.76355	**	0.24535	1.43055	*	0.69389	1.23674	0.67869
AGE	-0.00475		0.00651	-0.00377		0.00505	-0.00752		0.01278	-0.00735	0.01177
SEASWET	0.01726	**	0.00637	0.0064		0.00447	-0.00248		0.00548	0.00231	0.00467
ENVTOAG	0.00488		0.00815	0.00257		0.0055	-0.00035		0.00101	-0.00054	0.00101
ANNCROP	.56936D-04		.6964D-04	.23632D-04		.4662D-04	-.29409D-04		0.00012	-.96525D-05	0.00012
TOTALCOW	-0.00015		0.00025	0.00012		0.00016	0.00011		0.00071	0.00144	0.00131
No. of obs.	13			11			12			10	
R-squared	0.6171			0.38664			0.50967			0.59561	

[a]: Alberta-Crop-Own scenario. [b]: Alberta-Crop-Inferred scenario. [c]: Saskatchewan-Crop-Own scenario. [d]: Saskatchewan-Crop-Inferred scenario.
***: Significant at 1% level. **: Significant at 5% level. *: Significant at 10% level.

Table D2 Midpoint Analyses - Pasture

	ABPO[a]			ABPI[b]		SKPO[c]			SKPI[d]		
	Coefficients		St. error	Coefficients	St. error	Coefficients		St. error	Coefficients		St. error
Constant	0.1587	**	0.04654	0.21933	0.08281	0.16096	***	0.03593	0.14928	***	0.02757
SEASWET	0.00145		0.00303	-0.00723	0.0096	-0.00057		0.00067	-0.00061		0.00052
TOTALCOW	-0.00013	*	.5840D-04	-.59200D-04	.6167D-04	0.00037		0.00036	0.00047		0.00028
No. of obs.	7			5		9			9		
R-squared	0.57986			0.51036		0.28942			0.48976		

[a]: Alberta-Pasture-Own scenario. [b]: Alberta-Pasture-Inferred scenario. [c]: Saskatchewan-Pasture-Own scenario. [d]: Saskatchewan-Pasture-Inferred scenario. ***: Significant at 1% level. **: Significant at 5% level. *: Significant at 10% level

Appendix E Acreage Adjustment

Appendix E1 Identification of Farms Needing Acreage Adjustment

As the first step in the rental acreage allocation, the farms that based their responses regarding crop operation details on owned land were identified. These were Farms 2, 5, 16, 21, 23, 26, 28 and 29[46]. It was assumed that ideally almost all of the rented land would be used for agricultural usage. A concern with this kind of acreage adjustment is that since there is no data on whether the rented land is used for pasture or for annual crops, there is a possibility of overestimating or underestimating pasture land area. The following table reports the farms for which the acreage adjustment needed to be done based on the suitability of land for various agricultural and non-agricultural purposes and the herd size they own. Once the farms were identified, it was decided to cross-check if the pasture area reported by these farms are adequate to support their reported size of herd. This would help justify any adjustment done in pasture acreage.

Table E1 Comparison of Herd Size and Reported Pasture Capacity

Farm ID	Farm size (acres)	Reported pasture based on own land (acres)			Herd size (AU)[a]	Pasture capacity (based on reported acreage) (AU)
		Total	Tame/Seeded	Natural		
2	500	200	0	200	50	25
5	3300	770	400	370	607	58
16	960	0	0	0	0	-
21	4200	328	0	328	40	40
23	2980	100	0	100	0	-
26	6740	345	0	345	0	-
28	3814	370	210	160	220	50
29	3814	370	210	160	220	50

[a]: AU - Animal Unit.

[46] Note that Farm 28 and Farm 29 were identical in all respects except how the respective respondents dealt with the WTA questions and hence they were treated as different entities.

Appendix E2 Determination of Pasture Capacity and Adjustment in Acreage

For validation of adjustment in pasture acreage, pasture capacity (in Animal Units) was calculated based on the reported total pasture area (tame-seeded as well as natural). Total number of Animal Units for each relevant farm was calculated based on the numbers of mature cows, mature bulls and yearling heifers in 2013 (AARD, 2014-a). The number of calves, when available, were assumed not weaned for calculation of Animal Units. This is because the survey was conducted in April-May and the winter calving season is January-March (MAFRD, 2014-a). Given the average annual precipitation (302 mm for the Alberta RMs and 332 mm in the Saskatchewan site) and assuming average inputs, rotational grazing and excellent pasture condition, the stocking rate for tame seeded pasture is determined to be 1.25 Animal Unit Month/acre (AUM/acre) (AARD, 2014-a). Based on the stocking rate, months of grazing reported by each farm and pasture acreage, the pasture capacity (in AU) is determined using the equation:

$$Pasture\ capacity(AU) = \frac{Pasture\ acres * Stocking\ rate(AUM / acre)}{Months\ of\ grazing}$$

The reported number of grazing days varied from 165 to 300 days. Specifically, for farms 5 and 13 the number of grazing days were reported to be 300 days and 275 days respectively. However, for the pasture capacity calculation for acreage adjustment it was assumed that the number of pasture grazing days for these two farms is 180 days.

From Table E1 comparing the existing number of AU equivalents and reported pasture capacity it was noted that for Farm 21 these two values match exactly indicating that no adjustment in pasture was needed. For Farms 16, 23 and 26 it was assumed that pasture adjustment was not needed since the farms did not report any livestock. For Farms 2, 5, 28 and 29, the reported pasture capacity was considerably less than existing herd size thus justifying the adjustment in total pasture acreage.

Using the reported suitability of the land for different types of uses and the total farm size, it was determined what percentage of the total farm size would be under pasture and crops for Farms 2, 5, 28 and 29. The calculated acreage was further adjusted ad hoc to approximate the pasture area required to support the reported herd size. Note that for Farm 5, the size of herd was still considerably greater than what the adjusted pasture area could support. For Farms 28 and 29, it was assumed that there would be no increase in the area of non-agricultural land.

Table E2 Adjusted Acreage for Farms with Reported Pasture Capacity Less Than Herd Size

Farm ID	Farm size (acres)	Calculated acreage (acres)			Adjusted acreage (acres)			Total number of AU[a]	Pasture capacity (based on adjusted acreage)
		Crop	Pasture	Non-agricultural use	Crop	Pasture	Non-agricultural use		
2	500	240	229	31	240	230	30	50	48
5	3300	800	2370	130	800	2370	130	607	494
28	3814	2403	954	458	2544	956	314	220	217
29	3814	2403	954	458	2544	956	314	220	217

[a]: AU- Animal Unit.

Table E3 Acreage Adjustment Summary - Alberta

Farm ID	Acreage Adjustment Summary
1	The reported annual crop acreage in 2013 was less than the total land usage data for annual crops. The unreported acreage of 190 acres was distributed proportionally among annual crops. Hay acreage was included.
2	The crop and pasture acreage was adjusted based on suitability percentage and pasture capacity.
3	The total usage of land exceeded the total farm size by five acres. The non-agricultural acreage is adjusted by five acres.
4	The non-agricultural area was adjusted as more acreage than the total farm-size was reported. Hay acreage was included.
5	The crop and pasture acreage was adjusted based on suitability percentage and pasture capacity. Hay acreage was included.
6	The non-agricultural area was adjusted to zero as more acreage than the total farm-size was reported. The respondent reported the entire farm area available for crop production in 2013.
7	No adjustment was required.
8	No adjustment was required.
9	The pasture capacity calculation indicated that the farm has excess pasture capacity. Hence the excess acreage (160 acres) was distributed among the annual crops proportionally.
10	The pasture capacity calculation indicated that the farm has excess pasture capacity. Hence the excess acreage (320 acres) was distributed among the annual crops proportionally.
11	No adjustment was required.
12	No adjustment was required.
13	Adjustment was based on reported usage of total farm size.
14	Adjustment was based on reported usage of total farm size. Hay acreage was included.
15	No adjustment was required.

Table E4 Acreage Adjustment Summary - Saskatchewan

Farm ID	Acreage Adjustment Summary
16	The farm has no livestock and reported no pasture. The excess crop area is allocated to the only annual crop it produced.
18	No adjustment was required.
19	No adjustment was required.
20	No adjustment was required except inclusion of hay acreage.
21	The excess acreage was distributed proportionally among annual crops as the pasture capacity calculation indicated that the farm had just enough pasture capacity to support the herd.
22	No adjustment was required.
23	Excess acreage was distributed proportionally among annual crops since the farm has no livestock.
24	Adjustment was based on reported usage of total farm size. Hay acreage was included.
25	No adjustment was required.
26	The adjustment based on suitability percentage added 674 acres of non-agricultural usage. This was deemed unrealistic as a farmer would not rent unproductive land of that size. The original pasture and non-agricultural acreage are used and the rest of the land is assumed to be used for crops and hay. The excess acreage is distributed proportionally among annual crops.
27	Based on the suitability percentage and pasture capacity, the farm had approximately the required pasture capacity based on reported pasture area. However, the reported total usage was more than farm-size. To correct for that non-agricultural area is assumed to be less than reported. Millet acreage is assumed to be 100 acres rather than the reported 130 acres. Hay acreage was included.
28	Pasture area adjusted based on suitability percentage and pasture capacity. It is assumed that reported non-agricultural acreage is unchanged since the farm is unlikely to rent land with a lot of non-agricultural usage. The excess acreage is distributed among annual crops proportionally.
29	Pasture area adjusted based on suitability percentage and pasture capacity. It is assumed that reported non-agricultural acreage is unchanged since the farm is unlikely to rent land with a lot of non-agricultural usage. The excess acreage is distributed among annual crops proportionally.

Table E5 Adjusted Acreage and Allocation of Area Among Crops (acres) - Alberta

Farm ID	Spring wheat	Barley	Canola	Peas	Corn	Triticale	Oats	Hay	Flax	Summer-fallow	Crop use	Pasture	Non-agricultural use	Farm size
1	1131	419	953	681	0	471	545	60	0	0	4260	180	1000	5440
2	0	110	110	0	0	0	0	20	0	0	240	230	30	500
3	4000	0	3900	0	0	0	140	400	0	0	8440	1310	1290	11040
4	800	800	800	800	0	0	0	50	800	700	4750	50	100	4900
5	0	400	0	0	0	300	0	100	0	0	800	2370	130	3300
6	3000	0	3200	0	0	0	0	0	0	0	6200	0	0	6200
7	0	0	140	0	0	0	280	0	0	0	420	820	40	1280
8	100	200	300	0	0	0	50	200	0	0	850	30	80	960
9	0	331	343	0	0	0	245	240	0	0	1160	1220	280	2660
10	0	192	546	0	115	0	287	100	0	600	1840	1100	280	3220
11	630	0	600	0	0	0	0	0	0	0	1230	0	50	1280
12	900	0	500	0	0	0	0	0	0	0	1400	0	200	1600
13	0	240	0	0	0	0	0	195	0	0	435	2612	108	3155
14	1785	0	815	0	0	0	0	25	0	0	2625	0	205	2830
15	1500	500	1500	500	0	0	0	0	0	0	4000	250	250	4500

Table E6 **Adjusted Acreage and Allocation of Area among Crops (acres) - Saskatchewan**

Farm ID	Spring wheat	Barley	Canola	Peas	Corn	Oats	Hay	Flax	Millet	Soybean	Summer-fallow	Crop use	Pasture	Non-agricultural use	Farm size
16	570	0	0	0	0	0	250	0	0	0	0	820	0	140	960
18	4400	0	3000	0	0	0	0	0	0	0	0	7400	1000	400	8800
19	100	100	0	0	0	300	0	0	0	100	100	700	200	60	960
20	1000	300	400	0	0	300	600	200	0	0	400	3200	800	0	4000
21	917	364	917	461	0	255	400	486	0	0	0	3800	328	72	4200
22	4700	0	3300	0	0	0	0	0	0	0	0	8000	400	400	8800
23	2093	0	747	0	0	0	0	0	0	0	0	2840	100	40	2980
24	0	550	0	0	0	0	800	0	0	0	0	1350	2290	200	3840
25	300	0	0	0	0	0	950	0	0	0	0	1250	90	100	1440
26	2960	0	3135	0	0	0	220	0	0	0	0	6315	345	80	6740
27	0	200	0	0	0	100	250	0	100	0	400	1050	320	100	1470
28	768	391	908	0	87	126	265	0	0	0	0	2544	956	314	3814
29	768	391	908	0	87	126	265	0	0	0	0	2544	956	314	3814

Appendix F Crop Rotation Summary Based on 2013 Production

Alberta			Saskatchewan		
Farm ID	Main enterprise[a]	2013 Rotations[b]	Farm ID	Main enterprise[a]	2013 Rotations[b]
1	1	W-B-C-P-T-O-HAY	16	1	Org_W-HAY
2	3	B-C-HAY	18	1	W-C
3	1	W-C-O-HAY	19	3	W-B-O-SOY-SUMM
4	1	W-B-C-P-F-HAY-SUMM	20	1	Org_W-B-C-Org_O-HAY-FLAX-SUMM
5	2	B-T-HAY	21	1	W-B-C-P-O-F-HAY
6	1	W-C	22	1	W-C
7	2	C-O	23	1	W-C
8	1	W-B-C-O-HAY	24	3	NO ROTATION
9	2	B-C-O-HAY	25	1	W-HAY
10	3	B-C-O-CO-SUMM	26	1	W-C
11	1	W-C	27	3	B-O-M-HAY-SUMM
12	1	W-C	28	3	W-B-C-O-CO-HAY
13	2	B-HAY	29	3	W-B-C-O-CO-HAY
14	1	W-C-HAY			
15	1	W-B-C-P			

[a]: 1- Crop, 2 - Cow-Calf, 3 - Mixed.
[b]: W - spring wheat; B - barley; C - canola; O - oats; P - field peas; F - flax; T - triticale; CO - grazing corn; M - millet; SOY - soybean; HAY - alfalfa hay; SUMM - summer-fallow; Org_W - organic spring wheat; Org_O - organic oats.

Appendix G Cow-Calf Production Parameters and Steady State Herd Size

Table G1 Cow-Calf Production Parameters - Alberta[a]

Cows per bull	23
Conception rate	86.50%
Calving rate	98.40%
Death loss	4%
Weaning rate	97.20%
Culling rate	16%
Herd expansion	0%
Weaning weight (lbs.)	597.5
Average income ($/lb of weaned calf)	1.45
Total variable costs (winter feed, bedding, pasture, labour, other)	
$/lb of weaned calf	1.237

[a]: Source: AARD (2012-a).

Table G2 Cow-Calf Production Parameters - Saskatchewan

Cows per bull[a]	30
Conception rate[a]	89%
Calving rate[a]	98%
Death loss[a]	1%
Weaning rate[a]	97%
Culling rate[a]	16%
Herd expansion[a]	0
Weaning weight (lbs.)[b]	510
Average income ($/lb.)[b]	1.51
Total variable costs (winter feed, bedding, pasture, labour, other)	
$/lb. of weaned calf[b]	1.36

[a]: Source: Dollevoet (2010). [b]: Source: WBDC (2013).

Table G3 Steady State Herd Size

Alberta		Saskatchewan	
Farm ID	Herd size (AU[a])	Farm ID	Herd size (AU[a])
1	0	16	0
2	50	18	0
3	200	19	80
4	100	20	70
5	607	21	40
6	0	22	0
7	110	23	0
8	0	24	550
9	250	25	0
10	169	26	0
11	0	27	75
12	0	28	220
13	185	29	220
14	0		
15	0		

[a]: AU - Animal Unit.

Appendix H Machinery Complements and Machinery Replacement Costs

Table H1 Machinery Complement - Forage

Description	Size	Quantity
S.P. Mower conditioner	13-19 ft.	1
Hay rake	16-20 ft.	1
Baler	5' × 6'	1

Table H2 Comparison of Forage Machinery Replacement Costs for Owned and Partially Custom Rented Equipment (per acre per year) - Alberta

Farm ID	Agricultural area (acres)	Area under hay (acres)	Machinery replacement cost with custom rented mower conditioner and hay rake	Machinery replacement cost with own machinery
1	4440	60	$2.45	$2.92
2	470	20	$8.05	$27.57
3	9750	400	$2.09	$1.33
4	4800	50	$2.40	$2.70
5	3170	100	$2.72	$4.09
6	6200	0	$0.00	$0.00
7	1240	0	$0.00	$0.00
8	880	200	$5.13	$14.73
9	2380	240	$3.03	$5.44
10	2940	100	$2.79	$4.41
11	1230	0	$0.00	$0.00
12	1400	0	$0.00	$0.00
13	3047	195	$2.76	$4.25
14	2625	25	$2.91	$4.94
15	4250	0	$0.00	$0.00

Table H3 **Comparison of Forage Machinery Replacement Costs for Owned and Partially Custom Rented Equipment (per acre per year) - Saskatchewan**

Farm ID	Agricultural area (acres)	Area under hay (acres)	Machinery replacement cost with custom rented mower conditioner and hay rake	Machinery replacement cost with own machinery
16	820	250	$5.38	$15.80
18	8400	0	$0.00	$0.00
19	900	0	$0.00	$0.00
20	4000	600	$2.53	$3.24
21	4128	400	$2.50	$3.14
22	8400	0	$0.00	$0.00
23	2940	0	$0.00	$0.00
24	3640	800	$2.60	$3.56
25	1340	950	$3.99	$9.67
26	6660	220	$2.23	$1.95
27	1370	250	$3.94	$9.46
28	3500	265	$2.63	$3.70
29	3500	265	$2.63	$3.70

Table H4 **Machinery Complement - Cow-Calf operations - Big (>116 AU)[a]**

Description	Size	Quantity
Livestock trailer	24 ft. gooseneck	1
Feed wagon	1000 cu. ft.	1
Bale processor	2 6ft. round bale	1
Feed mixer	2 6ft. bale, 40 bu. grain	1

[a]: AU - Animal Unit.

Table H5 **Machinery Complement - Cow-Calf operations - Small (<116 AU)[a]**

Description	Size	Quantity
Livestock trailer	24 ft. gooseneck	1

[a]: AU - Animal Unit.

Table H6 Machinery Replacement Costs ($/acre/year) - Alberta

Farm ID	Crop	Forage	Cow-calf	Total
1	$21.86	$2.45	$0.00	$24.31
2	$21.86	$8.05	$2.14	$32.05
3	$21.86	$1.33	$0.76	$23.94
4	$21.86	$2.40	$0.21	$24.47
5	$21.86	$2.72	$2.32	$26.90
6	$21.86	$0.00	$0.00	$21.86
7	$21.86	$0.00	$0.81	$22.67
8	$21.86	$5.13	$0.00	$26.99
9	$21.86	$3.03	$3.09	$27.98
10	$21.86	$2.79	$2.50	$27.16
11	$21.86	$0.00	$0.00	$21.86
12	$21.86	$0.00	$0.00	$21.86
13	$1.72 [a]	$2.76	$2.42	$6.89
14	$21.86	$2.91	$0.00	$24.77
15	$21.86	$0.00	$0.00	$21.86

[a]: Scaled down to avoid negative net present value as this is a farm with cow-calf as its main enterprise. The scaling factor used is equal to the percentage of annual crop acreage grown by the farm , i.e. barley acreage, in the total area under agricultural usage. The acreage under barley is only 7.88% of the total agricultural area of the farm and hence 7.88 is used as the scaling factor.

Table H7 Machinery Replacement Costs ($/acre/year) - Saskatchewan

Farm ID	Crop	Forage	Cow-calf	Total
16	$21.86	$5.38	$0.00	$27.24
18	$21.86	$0.00	$0.00	$21.86
19	$21.86	$0.00	$1.12	$22.98
20	$21.86	$2.53	$0.25	$24.64
21	$21.86	$2.50	$0.24	$24.61
22	$21.86	$0.00	$0.00	$21.86
23	$21.86	$0.00	$0.00	$21.86
24	$21.86	$2.60	$2.02	$26.48
25	$21.86	$3.99	$0.00	$25.85
26	$21.86	$1.95	$0.00	$23.81
27	$21.86	$3.94	$0.74	$26.53
28	$21.86	$2.63	$2.10	$26.59
29	$21.86	$2.63	$2.10	$26.59

Appendix I Stochastic Price Model – Price Data Sources, Determination of Optimal Lag Lengths

Appendix I1 Crop and Forage Prices Data Sources

Price data of oats, barley, flaxseed and canola for Alberta for (1984-2012) were obtained from Alberta Agriculture Statistics Yearbook (ASY) 2012 (AARD, 2013-b). The price data of these crops for 2013 were obtained from AFSC (2013-a, 2013-b, 2013-c). Price data for wheat for the period 1984-2007 were obtained from Trautman (2012) which were the Canadian Wheat Board (CWB) price data for Grade 1 Canadian hard red spring with 13.5% protein content. Wheat price data for the same grade and type over 2008-2010 were obtained from the realized total payments of CWB published in ASY (AARD, 2013-b). Wheat price data for 2011-2013 were obtained from the final payments of CWB. Price of field peas for the period 1984-2008 were obtained from AARD (Trautman, 2012). Average farm value of field peas were obtained from ASY (AARD, 2013-b) for the period 2009-2012 and price of field peas in 2013 were obtained from the special crop cash bids of the weekly crop market review of AARD. The tame hay prices for the period 1984-2008 were obtained from Trautman (2012). 2009 and 2010 tame hay prices were obtained from AARD (2012-b). The tame hay prices for 2011 and 2012 were obtained from ASY (AARD, 2013-b) and 2013 prices of tame hay were obtained from AFSC (2013-d). Triticale prices were not available for Alberta and hence barley prices were used as a proxy. Also, since corn was indicated as being grown for livestock grazing, corn prices were not modelled.

Prices of spring wheat, oats, barley, flaxseeds and canola in Saskatchewan for the period 1984-2013 were obtained from Saskatchewan Agriculture (2014-c). Field peas prices were available for only the period 1992-2013. It was decided that since only one farm produced organic oats and two farms produced organic spring wheat, farm-specific adjustment based on the difference between organic and non-organic prices would be done in the stochastic prices of spring wheat and oats instead of developing a full price model for organic spring wheat and organic oats. Tame hay prices for the period 1984-2004 were obtained from Saskatchewan Agriculture (2010). Tame hay prices for 2005-2013 were obtained from Saskatchewan Forage Council (SFC) (SFC, 2005, 2009, 2010, 2011, 2012, 2013-a). As no yield and price data were available for soybean production in Saskatchewan, available soybean price data from Manitoba is used. Soybean price data were available for 1987-2013 period (MAFRI, 2009, 2011, 2013-a). The compiled price data were deflated using 2013 all-items consumer price index (Statistics Canada, 2014) for Alberta and Saskatchewan respectively. Again corn prices were not modelled as it was grown for livestock grazing. Millet prices were not available for Saskatchewan.

Table I1 Phillips-Perron Tests of Stationarity of Crop and Forage Prices

	Crops	Z(rho)
Alberta	Spring wheat	-29.111
	Barley	-29.524
	Canola	-26.257
	Oats	-30.595
	Peas	-30.659
	Flax	-29.561
	Hay	-28.733
Saskatchewan	Spring wheat	-19.135
	Barley	-17.628
	Canola	-11.990
	Oats	-17.441
	Peas	-1.496
	Flax	-15.494
	Hay	-13.817
	Soybean	-11.962
	1% critical value: case 1[a]	-11.9
	1% critical value: case 2[b]	-17.2
	1% critical value: case 4[c]	-22.5

[a]: Case 1- no constant term. [b]: Case 2 - with constant term. [c]: Case 4 - with constant term and time trend.

Table I2 Augmented Dickie Fuller Tests of Stationarity of Crop and Forage Prices

		DF(gamma)		
	Crops	random walk	random walk with drift	trend stationary
Alberta	Spring wheat	-0.414	-42.095	-41.925
	Barley	-1.206	-45.947	-57.231
	Canola	-0.593	-26.021	-26.024
	Oats	-0.554	-51.862	-51.561
	Peas	0.297	-8.259	-17.804
	Flax	-1.486	-65.608	-71.420
	Hay	0.666	-13.595	-27.026
Saskatchewan	Spring wheat	-0.678	-39.594	-39.230
	Barley	-0.959	-45.168	-46.550
	Canola	-0.492	-31.650	-30.862
	Oats	-0.684	-92.128	-138.687
	Peas	-2.427	-1.623	-6.452
	Flax	-1.388	-40.064	-58.031
	Hay	-0.418	-32.126	-38.350
	Soybean	-0.866	-33.844	-35.071
	1% critical value	-11.8	-17.2	-22.5
	5% critical value	-7.3	-12.5	-17.9
	10% critical value	-5.3	-10.2	-15.6

Table I3 KPSS Tests of Stationarity of Crop and Forage Prices

	Crops	Test statistics	
Alberta	Spring wheat	0.110	
	Barley	0.099	
	Canola	0.080	
	Oats	0.054	
	Peas	0.214	**
	Flax	0.134	*
	Hay	0.087	
Saskatchewan	Spring wheat	0.110	
	Barley	0.105	
	Canola	0.111	
	Oats	0.089	
	Peas	0.125	*
	Flax	0.147	**
	Hay	0.084	
	Soybean	0.093	
	1% critical value	0.216	
	5% critical value	0.146	
	10% critical value	0.119	

***: Significant at 1% level. **: Significant at 5% level. *: Significant at 10% level.

Table I4 AIC, SC Values for Determination of Optimal Lag Lengths for Price Model – Alberta

	AIC							SC						
Lags	Spring wheat	Barley	Canola	Oats	Peas	Flax	Hay	Spring wheat	Barley	Canola	Oats	Peas	Flax	Hay
6	8.27	7.39	8.89	7.64	7.95	9.29	6.64	8.57	7.69	9.19	7.94	8.25	9.59	6.93
5	8.27	7.33	8.81	7.54	7.84	9.35	6.60	8.51	7.57	9.06	7.78	8.08	9.60	6.84
4	8.20	7.30	8.70	7.54	7.82	9.22	6.51	8.40	7.50	8.90	7.73	8.02	9.42	6.71
3	8.10	7.18	8.60	7.43	7.87	9.13	6.43	8.24	7.33	8.75	7.57	8.02	9.27	6.57
2	8.02	7.07	8.71	7.35	7.86	9.20	6.32	8.12	7.17	8.81	7.44	7.96	9.29	6.42
1	8.10	7.35	8.99	7.35	7.82	9.42	6.30	8.15	7.39	9.04	7.40	7.87	9.47	6.35

Table I5 AIC, SC Values for Determination of Optimal Lag Lengths for Price Model – Saskatchewan

	AIC								SC							
Lags	Spring wheat	Barley	Canola	Oats	Peas	Flax	Hay	Soybean	Spring wheat	Barley	Canola	Oats	Peas	Flax	Hay	Soybean
6	8.20	7.40	8.54	7.49	6.62	9.40	6.62	7.67	8.49	7.69	8.84	7.78	6.92	9.70	6.91	7.96
5	8.27	7.47	8.70	7.40	7.02	9.54	6.51	7.64	8.52	7.72	8.95	7.64	7.27	9.78	6.76	7.89
4	8.29	7.36	8.71	7.33	7.17	9.47	6.45	7.91	8.48	7.55	8.90	7.52	7.37	9.66	6.65	8.10
3	8.23	7.31	8.64	7.25	7.08	9.41	6.44	7.79	8.38	7.45	8.79	7.39	7.23	9.56	6.59	7.93
2	8.13	7.26	8.61	7.14	7.13	9.43	6.33	7.67	8.23	7.36	8.71	7.23	7.23	9.53	6.42	7.77
1	8.13	7.51	8.79	7.28	7.51	9.51	6.29	7.97	8.18	7.55	8.83	7.32	7.55	9.55	6.34	8.02

Appendix J Stochastic Yield Model

Appendix J1 Alberta Crop and Forage Yield: Data Availability

For Alberta, dryland crop yield data by rural municipality for hard red spring wheat, barley, canola and oats were available for the period 1984-2013 from AFSC (2014-a). Yield data on tame hay were available by rural municipality although for a shorter time period (1991-2008). Yield data for field peas were also available from AFSC for the period 1995-2013 for each rural municipality in Alberta study area. Missing data for alfalfa hay and field peas were calculated following Trautman (2012) based on the average yield of alfalfa hay and field peas from available data, de-trended yield of a reference crop and the yield correlation coefficient of the reference crop and the crops of interest in this case. The crop yield correlation coefficients were obtained from AARD (2007) for the specific risk areas and risk region that the study area falls under. Trautman (2012) used barley as the reference crop for missing yield calculation for the dryland farms. In the present case, the yield correlation coefficient of barley and alfalfa hay is 0.3 in the risk areas 12 and 13 (risk region C) and that of barley and field peas is 0.757 for the same region.

Appendix J2 Handling of Missing Data for Alberta - Flax

The data on flax yield across the Alberta RMs were sparse since the yield data were only reported by AFSC if more than five producers in an RM grew a particular crop in a given year. To generate a usable time series on flax yield, the average flax yield across the Alberta RMs was calculated for each year. The resulting series still had eight years of data missing (1985, 1988, 1996, 2007, 2010-2013). Since flax yield data were not available for the neighbouring RMs for the missing years, the search was broadened to cover the AFSC risk areas that the study area falls under. The weighted average of flax yield in the risk areas 12 and 13 was used for the years 2007 and 2013. Imputation of flax yield data for the years that were still missing followed the following steps.

Given that the yield data for canola were complete and available for all the RMs in Alberta over 1984-2013, the collinearity of flax yield and canola yield was tested by estimating simple OLS regressions. The average yield of flax across the RMs for the available years were regressed on the individual rural municipality-wise yields of canola as well as the average yield of canola across the RMs in the study area.

Table J1 Collinearity Tests of Flax and Canola Yield in Alberta

Area		Coefficient		Std. error	t	P
	Constant	0.03713		0.06784	0.55	0.5897
	Canola[a]	0.7745	***	0.11255	6.88	0.0000
Beaver	R-squared	0.68279				
	Constant	0.03559		0.05112	0.7	0.4936
	Canola[b]	0.77628	***	0.084	9.24	0.0000
Vermilion River	R-squared	0.7952				
	Constant	0.02311		0.05894	0.39	0.6988
	Canola[c]	0.82003	***	0.10014	8.19	0.0000
Wainwright	R-squared	0.75298				
	Constant	0.01689		0.05552	0.3	0.7638
	Canola[d]	0.81082	***	0.09198	8.81	0.0000
All RMs	R-squared	0.77934				

[a]: Canola yield at Beaver RM. [b]: Canola yield at Vermilion River RM. [c]: Canola yield at Wainwright RM. [d]: Average canola yield across study area RMs. ***: Significant at 1% level. **: Significant at 5% level. *: Significant at 10% level.

The results are reported in the above table. The yield of flax and canola had a positive and very highly significant relationship at 1% level for the study area. The R-squared value was also high with a range of (0.68-0.79). This indicated that canola yield data might be used for imputation in the missing flax yield observations. While the canola yield from Vermilion River has the highest R-squared, the coefficient of the canola yield was the highest for Wainwright. The coefficient of average canola yield across the RMs as well as the R-squared value is marginally smaller than the respective highest values obtained from individual RMs. The average yield of canola is used to predict the missing values in the flax yield series using OLS regression.

Appendix J3 Handling of Missing Data for Alberta - Triticale

Data available for triticale yield in the Alberta RMs were extremely sparse. However, yield of spring triticale could be estimated as a percentage of CPS wheat (AARD, 2001). Using the estimated yield difference between triticale, CPS wheat and CWRS wheat in the Black soil region of Alberta (AARD, 2014-b), the average yield of triticale was calculated for the period 1984-2013. It may be noted that as yield of triticale was calculated as a percentage increase over CWRS wheat, then this might introduce collinearity in the SURE estimations of the weather-based yield equations.

Table J2 Yield of Triticale Varieties as a Percentage Increase of CWRS Wheat in Black Soil Region of Alberta[a]

	% Increase over CWRS		
	Low	High	Average
CPS Wheat	15.00	20.00	17.50
Triticale Pronghorn	36.85	42.8	39.825
Triticale AC Alta	36.85	42.8	39.825
Triticale AC Ultima	66.75	74.0	70.375

[a]: Source: AARD (2001).

Appendix J4 Saskatchewan Crop and Forage Yield: Data Availability and Handling of Missing Data

For Saskatchewan, the yield data were available on a rural municipality basis from Saskatchewan Agriculture (2014-c). The yield data for spring wheat, barley, canola and oats were available for 1984-2013. Yield data for peas were available for the period 1992-2013 with the yield for 2011 missing. Yield data for flax were available for 1984-2013 with missing data for 2011 and 2012. For missing peas and flax yield data in Moosomin series, yield data from the neighbouring RM of Rocanville were substituted if available. However, data on the yield of peas were not available before 1992 even from the Rocanville series. Dollevoet (2010) used yield data from RM of Silverwood which is in the Lower Souris watershed region. The Silverwood series also did not have any data on yield of peas before 1992, thus, indicating that commercial production of peas might not have started in the region before 1992. Missing yield data for field peas were calculated following Trautman (2012).

Although some yield data for tame hay were available for Moosomin (1984-1993, 1995-1998), the series has gaps. Tame hay data (1971-2006) for RM 123-Silverwood were used to substitute for missing data in the Moosomin series. For 2006-2013, the estimated average dryland hay yields for Crop District 1 of Southeastern Saskatchewan were obtained from Saskatchewan Agriculture (2014-e). Soybean yield data are taken from MAFRD (2014-b). Note that there was no commercial soybean production in Manitoba before 1998. Hence, soybean yield data were available for 1998-2013 period.

Table J3 Phillips-Perron Tests of Yield Stationarity - Alberta

Area	Crops	Newey-West Lags	Z(rho)	Z(tau)	MacKinnon approximate p-value for Z(t)
Beaver	Spring wheat	2	-30.516	-6.501	0.0000
	Barley	2	-30.700	-5.578	0.0000
	Canola	2	-30.865	-5.35	0.0000
	Oats	2	-26.422	-4.489	0.0016
	Peas	2	-30.944	-9.500	0.0000
	Triticale	2	-30.517	-6.501	0.0000
Vermilion River	Spring wheat	2	-26.964	-4.84	0.0004
	Barley	2	-25.744	-4.727	0.0006
	Canola	2	-24.743	-4.192	0.0046
	Oats	2	-22.183	-3.952	0.0103
	Peas	2	-29.985	-8.004	0.0000
	Triticale	2	-26.964	-4.84	0.0004
Wainwright	Spring wheat	2	-29.306	-5.527	0.0000
	Barley	2	-28.662	-5.178	0.0001
	Canola	2	-25.246	-4.237	0.0039
	Oats	2	-26.494	-4.671	0.0008
	Peas	2	-31.439	-9.034	0.0000
	Triticale	2	-29.307	-5.527	0.0000
All RMs	Flax	2	-22.862	-3.976	0.0095
	Hay	2	-23.516	-4.316	0.0030
	1% critical value		-23.012	-4.343	
	5% critical value		-18.204	-3.584	
	10% critical value		-15.792	-3.23	

Table J4 Phillips-Perron Tests of Yield Stationarity - Saskatchewan

Area	Crops	Newey-West Lags	Z(rho)	Z(tau)	MacKinnon approximate p-value for Z(t)
Saskatchewan	Spring wheat	2	-25.459	-4.174	0.0049
	Barley	2	-26.92	-5.161	0.0001
	Canola	2	-24.911	-4.213	0.0043
	Oats	2	-21.466	-4.037	0.0078
	Peas	2	-26.390	-5.570	0.0000
	Flax	2	-23.772	-5.669	0.0000
	Hay	2	-18.139	-3.544	0.0349
	Soybean	2	-7.526	-1.947	0.6300
	1% critical value		-23.012	-4.343	
	5% critical value		-18.204	-3.584	
	10% critical value		-15.792	-3.23	

Table J5 KPSS Test of Soybean Yield Stationarity - Saskatchewan

Crops	Test statistic
Soybean	0.111
1% critical value	0.216
5% critical value	0.146
10% critical value	0.119

Table J6 Yield Trend Regression Coefficients - Alberta

Crops	Constant		Time	
Spring wheat	0.67763	***	0.01657	***
Barley	0.87458	***	0.01505	**
Canola	0.34534	***	0.01572	***
Oats	0.47553	***	0.02428	***
Peas	0.54186	**	0.01771	
Triticale	1.0165	***	0.02485	***
Spring wheat	0.69638	***	0.01789	***
Barley	0.90892	***	0.01422	*
Canola	0.36857	***	0.01404	***
Oats	0.49833	***	0.02764	***
Peas	0.46249		0.02338	
Triticale	1.04463	***	0.02684	***
Spring wheat	0.65565	***	0.01696	***
Barley	0.8725	***	0.01581	**
Canola	0.36021	***	0.01359	***
Oats	0.64382	***	0.01588	**
Peas	0.28168		0.02973	**
Triticale	0.98352	***	0.02545	***
Flax	0.29765	***	0.01249	***

***: Significant at 1% level. **: Significant at 5% level. *Significant at 10% level.

Table J7 Yield Trend Regression Coefficients - Saskatchewan

Crops	Constant		Time	
Spring wheat	0.69468	***	0.00921	**
Barley	1.10161	***	0.00149	
Canola	0.48534	***	0.0037	
Oats	0.71612	***	0.01294	***
Peas	0.75589	***	0.00203	
Flax	0.40526	***	0.00153	
Hay	1.34307	***	0.00168	
Soybean	0.52446	**	0.01166	

***: Significant at 1% level. **: Significant at 5% level. *Significant at 10% level.

Table J8 **Summary of De-trended Crop Yield Data (tonnes/acre) - Alberta (1984-2013)**

Area	Crops	Mean	Std. dev.	Minimum	Maximum
Beaver	Spring wheat	1.165	0.217	0.271	1.460
	Barley	1.317	0.267	0.252	1.772
	Canola	0.809	0.149	0.205	1.049
	Oats	1.191	0.255	0.337	1.612
	Peas	1.106	0.332	0.287	2.397
	Triticale	1.747	0.326	0.406	2.190
Vermilion River	Spring wheat	1.220	0.238	0.246	1.563
	Barley	2.420	0.233	1.335	2.657
	Canola	0.780	0.159	0.160	1.000
	Oats	1.313	0.289	0.360	1.814
	Peas	1.191	0.372	0.290	2.583
	Triticale	1.829	0.357	0.369	2.345
Wainwright	Spring wheat	1.155	0.222	0.233	1.464
	Barley	1.334	0.288	0.219	1.808
	Canola	0.758	0.150	0.155	0.997
	Oats	1.106	0.273	0.211	1.543
	Peas	1.199	0.363	0.344	2.601
	Triticale	1.733	0.333	0.349	2.196
All RMs	Flax	0.666	0.145	0.149	0.887
	Hay	1.022	0.391	0.044	2.040

Table J9 Summary of De-trended Crop Yield Data (tonnes/acre) - Saskatchewan (1984-2013)

Crops	Mean	Std. dev.	Minimum	Maximum
Spring wheat	0.954	0.133	0.686	1.279
Barley	1.129	0.221	0.659	1.573
Canola	0.586	0.109	0.361	0.810
Oats	1.091	0.197	0.714	1.561
Peas	0.834	0.214	0.412	1.238
Flax	0.451	0.099	0.271	0.635
Hay	1.389	0.487	0.651	2.505
Soybean	0.865	0.129	0.513	1.014

Table J10 Kolmogorov-Smirnov Distribution Fit Statistic - Beaver, Alberta[a]

Distribution	Spring wheat	Barley	Canola	Oats	Peas	Triticale
Betageneral	0.1295	0.1949	0.1765	0.0939		0.1294
Exponential	0.4911	0.5321	0.514	0.4607	0.4716	0.4911
Gamma	0.217	0.254	0.2421	0.1481	0.1421	0.217
LogLogistic					0.0896	
Lognormal	0.2499	0.2954	0.2763	0.1678	0.162	0.2499
Triangle	0.3704	0.3503	0.3822	0.24	0.2724	0.3704
Uniform	0.5627	0.5654	0.581	0.4686	0.3882	0.5627
Weibull	0.1019	0.1634	0.1682	0.0795		0.1019

[a]: Missing values for each crop indicate that the corresponding distribution was determined as not a good fit and the test statistics were suppressed by @Risk.

Table J11 Kolmogorov-Smirnov Distribution Fit Statistic - Vermilion River, Alberta[a]

Distribution	Spring wheat	Barley	Canola	Oats	Peas	Triticale
Betageneral	0.1953	0.1628	0.1891	0.0997		0.1953
Exponential	0.4656	0.5734	0.4911	0.4581	0.4551	0.4656
Gamma	0.2837	0.2474	0.2133	0.1689	0.1475	0.2837
LogLogistic					0.1252	
Lognormal	0.3063	0.2653	0.251	0.1912	0.1705	0.3063
Triangle	0.4127	0.6894	0.3431	0.2665	0.2634	0.4127
Uniform	0.5497	0.7885	0.5435	0.4536	0.3567	0.5497
Weibull	0.181	0.1204	0.1127	0.1095	0.1764	0.181

[a]: Missing values for each crop indicate that the corresponding distribution was determined as not a good fit and the test statistics were suppressed by @Risk.

Table J12 Kolmogorov-Smirnov Distribution Fit Statistic - Wainwright, Alberta[a]

Distribution	Spring wheat	Barley	Canola	Oats	Peas	Triticale
Betageneral	0.1804	0.1651	0.1617	0.0941		0.1804
Exponential	0.4996	0.4905	0.5033	0.4444	0.4758	0.4996
Gamma	0.2775	0.2433	0.2291	0.1665	0.1337	0.2775
LogLogistic					0.0857	
Lognormal	0.3057	0.274	0.2687	0.1983	0.1436	0.3057
Triangle	0.3944	0.2945	0.3458	0.2147	0.2724	0.3944
Uniform	0.5705	0.5143	0.5542	0.4289	0.362	0.5705
Weibull	0.1731	0.1527	0.1311	0.0982	0.1833	0.1731

[a]: Missing values for each crop indicate that the corresponding distribution was determined as not a good fit and the test statistics were suppressed by @Risk.

Table J13 Kolmogorov-Smirnov Distribution Fit Statistic - All RM, Alberta[a]

Distribution	Flax	Hay
Betageneral	0.1137	0.2377
Exponential	0.4863	0.4067
Gamma	0.185	0.2802
LogLogistic		0.2193
Lognormal	0.2068	0.3159
Triangle	0.2698	0.2208
Uniform	0.4989	0.2814
Weibull	0.1079	0.2332

[a]: Missing values for each crop indicate that the corresponding distribution was determined as not a good fit and the test statistics were suppressed by @Risk.

Table J14 Kolmogorov-Smirnov Distribution Fit Statistic - Saskatchewan[a]

Distribution	Spring wheat	Barley	Canola	Oats	Peas	Flax	Hay	Soybean
Betageneral		0.1189	0.0674		0.0911	0.105		0.1266
Exponential	0.513	0.442	0.4674	0.488	0.3901	0.452	0.3884	0.4825
Gamma	0.0974	0.158	0.093	0.0928	0.1009	0.1371	0.0997	0.1728
LogLogistic	0.083			0.0827			0.0962	
Lognormal	0.0958	0.1716	0.1042	0.0958	0.1196	0.1529	0.1068	0.1809
Triangle	0.3703	0.2729	0.2817	0.2993	0.135	0.1873	0.1661	0.4299
Uniform	0.5306	0.4426	0.4676	0.4644	0.3361	0.413	0.2619	0.5682
Weibull	0.1359	0.1263		0.1422	0.0774	0.0969	0.1264	0.1599

[a]: Missing values for each crop indicate that the corresponding distribution was determined as not a good fit and the test statistics were suppressed by @Risk.

Table J15 Farm-Specific Adjusted Mean Yield (tonnes/acre) - Alberta[a]

Farm ID	Spring wheat	Barley	Canola	Oats	Peas	Flax	Hay	Triticale
1	1.88964	1.73026	0.89804	2.28905	1.54189		1.11963	1.87136
2		2.2	0.74056				1.88973	
3	1.66897		1.34366	1.90581			1.51178	
4	1.61969	1.73026	1.12255		1.68206	1.00642	1.11963	
5		3.97396					1.11963	3.96690
6	1.83048		0.98535					
7			0.76702	1.34547				
8	1.48053	1.7416	1.00775	1.21972			1.51178	
9		1.9593	0.94057	1.82958			3.02356	
10		1.9593	0.78380	1.21972			1.11963	
11	1.83599		0.96312					
12	1.48759		0.98990					
13		1.5					1.11963	
14	1.56599		1.05271				1.11963	
15	1.74972	2.06815	1.09733		1.53215			

[a]: Missing values for each crop indicate that the corresponding farm did not grow the crop in 2013.

Table J16 Farm-Specific Adjusted Mean Yield (tonnes/acre) - Saskatchewan[a]

Farm ID	Spring wheat	Barley	Canola	Oats	Peas	Flax	Hay	Soy bean	Corn	Millet
16	0.80238						0.22604			
18	1.20357		0.78001							
19	1.96517	2.95622		3.95331				0.85925		
20	0.40119	0.75083	0.60172	0.30480		0.25384	1.38555			
21	1.49353	1.39928	0.84506	1.30459	0.96986	0.50965	0.99665			
22	1.60162		1.19881							
23	1.96517		1.17916							
24		1.11233					1.38555			
25	1.71174						0.90415			
26	1.71953		0.98263				1.99331			
27		1.35149		1.06680			1.38555			0.27216
28	1.73849	1.39439	1.00287	1.82880			1.24582		2.2607	
29	1.73849	1.39439	1.00287	1.82880			1.24582		2.2607	

[a]: Missing values for each crop indicate that the corresponding farm did not grow the crop in 2013.

Table J17 Maximum Yield Restrictions (tonnes/acre) - Alberta[a]

Farm ID	Spring wheat	Barley	Canola	Oats	Peas	Flax	Hay	Triticale
1	2.13252	2.05917	1.08673	2.57493	2.02124		1.66573	2.23302
2		2.53709	1.31742				2.40544	
3	1.91634		1.52277	2.24489			2.03985	
4	1.87712	2.04584	1.31318		2.15591	1.16795	1.66576	
5		4.28791					1.66576	4.31307
6	2.07953		1.17078					
7			1.25642	1.68603				
8	2.14349	2.03591	1.31743	1.60684			2.03985	
9		2.20009	1.23449	2.16219			3.50556	
10		2.23396	1.03691	1.56340			1.66561	
11	2.10299		1.15774					
12	1.74206		1.20269					
13		1.76371					1.66561	
14	1.81076		1.23717				1.66561	
15	2.01247	2.29268	1.29516		2.08054			

[a]: Missing values for each crop indicate that the corresponding farm did not grow the crop in 2013.

Table J18 Maximum Yield Restriction (tonnes/acre) - Saskatchewan[a]

Farm ID	Spring wheat	Barley	Canola	Oats	Peas	Flax	Hay	Soybean
16	0.99573						0.59829	
18	1.38618		0.91574					
19	2.16919	3.22098		4.19912				0.99279
20	0.60689	1.04143	0.74462	0.60027		0.38894	2.04608	
21	1.67595	1.67188	0.98131	1.56660	1.23440	0.63442	1.67976	
22	1.78088		1.33061					
23	2.14327		1.31291					
24		1.38998					2.04531	
25	1.89889						1.58879	
26	1.89845		1.11605				2.63272	
27		1.62654		1.33515			2.05018	
28	1.91992	1.66692	1.13752	2.08509			1.91764	
29	1.91992	1.66692	1.13752	2.08509			1.91764	

[a] Missing values for each crop indicate that the corresponding farm did not grow the crop in 2013.

Table J19 Comparison of Farm-Specific Adjusted Mean Yield with Simulated Mean Yield after Maximum Yield Restriction and Adjustment in Std. Dev. – Alberta[a]

Farm ID	Spring wheat	Barley	Canola	Oats	Peas	Flax	Hay	Triticale
1	-1.8%	-2.8%	-3.1%	-1.8%	-4.8%		-4.6%	-2.8%
2		-2.0%	-4.4%				-4.1%	
3	-2.1%		-1.9%	-2.6%			-3.6%	
4	-2.3%	-2.7%	-2.5%		-4.3%	-2.3%	-4.6%	
5		-1.1%					-4.6%	-1.2%
6	-2.0%		-2.7%					
7			-4.6%	-3.8%				
8	-4.3%	-2.5%	-4.7%	-4.9%			-4.8%	
9		-1.8%	-4.8%	-2.6%			-2.3%	
10		-2.0%	-5.0%	-4.3%			-4.6%	
11	-2.1%		-3.0%					
12	-2.5%		-3.2%					
13		-2.5%					-4.6%	
14	-2.3%		-2.5%				-4.6%	
15	-2.2%	-1.5%	-2.6%		-4.6%			

[a]: Missing values for each crop indicate that the corresponding farm did not grow the crop in 2013. The difference in yield is calculated as {(simulated mean yield-adjusted mean yield)/simulated mean yield}*100.

Table J20 Comparison of Farm-Specific Adjusted Mean Yield with Simulated Mean Yield after Maximum Yield Restriction and Adjustment in Std. Dev. – Saskatchewan[a]

Farm ID	Spring wheat	Barley	Canola	Oats	Peas	Flax	Hay	Soybean
16	-3.59%						-4.45%	
18	-2.19%		-2.52%					
19	-1.47%	-1.26%		-0.87%				-2.24%
20	-4.97%	-4.71%	-3.53%	-4.67%		-4.66%	-4.93%	
21	-1.74%	-2.85%	-2.33%	-2.95%	-4.11%	-3.65%	-4.73%	
22	-1.59%		-1.56%					
23	-1.28%		-1.61%					
24		-3.73%					-4.93%	
25	-1.55%						-4.92%	
26	-1.47%		-1.95%				-4.93%	
27		-2.99%		-3.76%			-4.93%	
28	-1.48%	-2.86%	-1.92%	-2.01%			-4.48%	
29	-1.48%	-2.86%	-1.92%	-2.01%			-4.48%	

[a]: Missing values for each crop indicate that the corresponding farm did not grow the crop in 2013. The difference in yield is calculated as {(simulated mean yield-adjusted mean yield)/simulated mean yield}*100.

Table J21 Farm-Specific Simulated Mean Yields with Maximum Yield Restriction and 2nd Stage Std. Dev. Correction (tonnes/acre) - Alberta[a]

Farm ID	Spring wheat	Barley	Canola	Oats	Peas	Flax	Hay	Triticale
1	1.85555	1.68349	0.87108	2.24899	1.47187		1.0704	1.81993
2		2.15775	0.70938				1.81504	
3	1.63411		1.31848	1.85775			1.45947	
4	1.58333	1.68539	1.09562		1.61328	0.98356	1.0704	
5		3.93037					1.0704	3.91878
6	1.79547		0.95899					
7			0.73329	1.29639				
8	1.41956	1.69995	0.96257	1.16311			1.44249	
9		1.92558	0.89763	1.78238			2.95547	
10		1.92067	0.74675	1.16988			1.0704	
11	1.79838		0.93537					
12	1.45154		0.95948					
13		1.46308					1.0704	
14	1.53144		1.02656				1.0704	
15	1.71267	2.03676	1.06922		1.46518			

[a]: Missing values for each crop indicate that the corresponding farm did not grow the crop in 2013.

Table J22 Farm-Specific Simulated Std. Dev. of Yields with Maximum Yield Restriction and 2nd Stage Std. Dev. Correction (tonnes/acre) - Alberta[a]

Farm ID	Spring wheat	Barley	Canola	Oats	Peas	Flax	Hay	Triticale
1	0.18809	0.24446	0.13849	0.22179	0.33129		0.23465	0.26817
2		0.25354	0.15001				0.36426	
3	0.18900		0.13829	0.25389			0.26192	
4	0.19528	0.23575	0.14357		0.33308	0.12254	0.23465	
5		0.25173					0.23465	0.27585
6	0.19187		0.13801					
7			0.16073	0.24331				
8	0.29483	0.22175	0.21439	0.26642			0.32721	
9		0.18713	0.20288	0.24844			0.36547	
10		0.21096	0.17368	0.24141			0.23464	
11	0.20439		0.14357					
12	0.19150		0.15570					
13		0.19756					0.23465	
14	0.18600		0.13846				0.23465	
15	0.20049	0.17627	0.14802		0.31966			

[a]: Missing values for each crop indicate that the corresponding farm did not grow the crop in 2013.

Table J23 **Farm-Specific Simulated Mean Yields with Maximum Yield Restriction and 2nd Stage Std. Dev. Correction (tonnes/acre) - Saskatchewan[a]**

Farm ID	Spring wheat	Barley	Canola	Oats	Peas	Flax	Hay	Soybean
16	0.7746						0.2164	
18	1.1778		0.7609					
19	1.9368	2.9194		3.9193				0.8404
20	0.3822	0.7170	0.5812	0.2912		0.2425	1.3204	
21	1.4680	1.3605	0.8258	1.2672	0.9316	0.4917	0.9516	
22	1.5766		1.1804					
23	1.9404		1.1604					
24		1.0723					1.3204	
25	1.6856						0.8618	
26	1.6946		0.9639				1.8997	
27		1.3122		1.0281			1.3204	
28	1.7132	1.3556	0.9840	1.7927			1.1924	
29	1.7132	1.3556	0.9840	1.7927			1.1924	

[a]: Missing values for each crop indicate that the corresponding farm did not grow the crop in 2013.

Table J24 **Farm-Specific Simulated Std. Dev. of Yields with Maximum Yield Restriction and 2nd Stage Std. Dev. Correction (tonnes/acre) - Saskatchewan[a]**

Farm ID	Spring wheat	Barley	Canola	Oats	Peas	Flax	Hay	Soybean
16	0.13915						0.04626	
18	0.13912		0.10189					
19	0.16061	0.21085		0.19970				0.10151
20	0.08904	0.16027	0.10309	0.06461		0.05379	0.30577	
21	0.14180	0.20209	0.10319	0.19346	0.18688	0.08965	0.21340	
22	0.14033		0.10338					
23	0.14155		0.10466					
24		0.19894					0.30577	
25	0.14679						0.19897	
26	0.14085		0.10278				0.43937	
27		0.20278		0.19202			0.30577	
28	0.14280	0.20196	0.10384	0.19694			0.25611	
29	0.14280	0.20196	0.10384	0.19694			0.25611	

[a]: Missing values for each crop indicate that the corresponding farm did not grow the crop in 2013.

Table J25 Adjusted Weibull Distribution Parameters with Maximum Yield Restriction - Alberta[a]

	α														
Farm ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Spring Wheat	11.0817		9.6209	8.977		10.47345		5.053			9.8039	8.34535		9.1272	9.497
Barley	7.513	9.452		7.826	17.9632			8.443	11.58	10.1625			8.1325		13.096
Canola	6.8073	4.95	10.6892	8.41		7.5936	4.755	4.6693	4.592	4.4448	7.076	6.6551		8.15	7.9222
Oats	11.4035		8.0275				5.66	4.5215	7.858	5.0888					
Peas	4.6136			5.08766											4.78
Flax				8.8848											
Hay	4.75	5.25	5.95	4.75	4.75			4.57	8.95	4.75			4.75	4.75	
Triticale	7.40				16.28										
	β														
Farm ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Spring Wheat	1.97793		1.757228	1.7106		1.92037		1.6115			1.931503	1.5764		1.652651	1.84329
Barley	1.843	2.323		1.83921	4.09355			1.84458	2.047	2.0581			1.59195		2.15135
Canola	0.96142	0.81	1.40847	1.1892		1.049	0.8378	1.10193	1.029	0.85951	1.02902	1.06104		1.11683	1.16574
Oats	2.39333		2.023369				1.45503	1.33618	1.944	1.32707					
Peas	1.687166			1.83013											1.67306
Flax				1.0634											
Hay	1.2230	2.05	1.63	1.2230	1.2230			1.66	3.19	1.2230			1.2230	1.2230	
Triticale	1.99				4.10										

[a]: Missing values for each crop indicate that the corresponding farm did not grow the crop in 2013.

Table J26 Adjusted Weibull Distribution Parameters with Maximum Yield Restriction - Saskatchewan[a]

	α												
Farm ID	16	18	19	20	21	22	23	24	25	26	27	28	29
Spring Wheat	5.9430	9.4010	13.7030	4.435	11.6585	12.715	15.6807		13.013	13.67		13.629	13.629
Barley			15.857	4.65	7.3324			5.735			7.0217	7.309	7.309
Canola		8.2100		6.0286	8.85	12.941	12.545			10.495		10.612	10.612
Oats			22.8	4.689	7.1154						5.692	10.1665	10.1665
Peas					5.2537								
Flax				4.6910	5.847								
Hay	4.8900			4.4657	4.632			4.4657	4.481	4.4723	4.4657	4.864	4.864
Soybean			9.178										

	β												
Farm ID	16	18	19	20	21	22	23	24	25	26	27	28	29
Spring Wheat	0.86535	1.2685	2.0411	0.44	1.560241	1.66781	2.03225		1.78101	1.78608		1.805955	1.805955
Barley			3.0561	0.8212	1.49229			1.20202			1.44454	1.48733	1.48733
Canola		0.8273		0.648431	0.89307	1.24757	1.22848			1.0308		1.05156	1.05156
Oats			4.0484	0.3332	1.39345						1.1533	1.92099	1.92099
Peas					1.05329								
Flax				0.2775	0.55015								
Hay	0.2465			1.51895	1.0903			1.51895	0.991	2.18506	1.51895	1.359	1.359
Soybean			0.90657										

[a]: Missing values for each crop indicate that the corresponding farm did not grow the crop in 2013.

Appendix K Spring Insurance Prices for Crop Insurance

Table K1 Spring Insurance Prices ($/tonne) - Alberta[a]

Spring Wheat	270
Barley	200
Canola	555
Oats	170
Peas	265
Flax	515
Triticale	200

[a]: Source: AFSC (2013-e).

Table K2 Spring Insurance Prices ($/tonne) - Saskatchewan[a]

Spring Wheat	205
Barley	150
Canola	410
Oats	165
Peas	230
Flax	460
Soybean	355
Organic spring wheat	390
Organic oats	297

[a]: Source: SCIC (2015).

Appendix L Data Sources and Modelling of Input Costs

For the farms in Alberta, the input costs for stubble-seeded crops, such as, spring wheat, barley, canola, oats, peas, flax and alfalfa hay were taken from 2013 Production Costs and Returns of AARD (2013-c) for the Black soil region. The input costs for fallow-seeded spring wheat, canola and barley were not available for Alberta and hence, were assumed to be equal to the fallow-seeded costs for Saskatchewan Black soil region.

For non-organic spring wheat, barley, canola, oats, peas and flax in Saskatchewan, both the stubble-seeded and fallow-seeded input costs were taken from the 2013 Crop Planning Guide of Saskatchewan Agriculture (Saskatchewan Agriculture, 2013-b). Input costs for organic spring wheat and organic oats were taken from the 2014 Organic Planning Guide (Saskatchewan Agriculture, 2014-b). The cost of production of alfalfa hay in Saskatchewan was assumed to be the same as that in the Black soil zone in Alberta as it was not available for Saskatchewan Black soil zone.

Input costs were not available for triticale in Alberta and hence, were assumed to be equal to the input costs of stubble-seeded barley in Alberta. Input costs were also not available for soybean in Saskatchewan, grazing corn in Alberta and Saskatchewan and millet in Saskatchewan. The soybean input costs were taken from the Guidelines for Estimating Cost of Production in Western Manitoba (MAFRI, 2013-b). Silage corn production costs obtained from MAFRI (2015) were assumed to apply for grazing corn production.

While costs of millet production were not available specifically for different types of inputs, an estimate of total cost of production ($/acre) of Golden German millet in 2012 was available from an annual forage species demonstration project of Saskatchewan Forage Council (SFC, 2013-b). The total costs of production of Golden German Millet was estimated to be $96.70 per acre. It may be noted that since no information was available regarding the type of millet grown by the respondent farm, using this estimate in the simulation model would lead to an approximation at best. Based on the total cost, farm-reported fertilizer cost and chemical costs and using input costs for barley as proxies for fuel and machinery repair costs, custom work and hired labor, interest on variable expenses, license and insurance and utilities and miscellaneous, the cost of millet seed was estimated.

Given that some farms reported to have summer-fallow as a part of the 2013 rotation, it was necessary to identify which crops would be stubble-seeded and which would be fallow-seeded as these would have different implications regarding input costs. Also, for farms that reported summer-fallow, it was assumed that chem-fallow was conducted thus involving input costs.

If the farms indicated to have both summer-fallow and spring wheat, it was assumed that spring wheat is grown after the fallow year. Therefore, for Farm 4, 700 acres of spring wheat is fallow-seeded and the rest is assumed to be stubble-seeded. For Farm 19, 100 acres of spring wheat is assumed to be fallow-seeded.

If spring wheat was not a part of the 2013 rotation for a farm with summer-fallow, it was assumed that the main cereal or oilseed crops would be fallow-seeded, such that, the fallow-seeded acreage for these crops match the number of acres under summer-fallow. Therefore, for Farm 10, 546 acres of canola and 54 acres of barley is assumed to be fallow-seeded. For Farm 20, canola was assumed to be fallow-seeded entirely. For Farm 27, barley, oats and millet were assumed to be fallow-seeded as the sum of the acreage under these crops was equal to the acres under summer-fallow.

The costs pertaining to chemfallow consist of the variable input costs except seed and fertilizer costs. In this study, the chemfallow costs for Saskatchewan Black soil region was used for both the sites. These were also obtained from the 2013 Crop Planner of Saskatchewan Agriculture (2013-b).

Appendix M Linear WTA Transfer Models Including Observations with Imputed WTA

Table M1 Linear WTA Transfer Model - Specification 1 - Including Observations with Imputed WTA

	Alberta			Saskatchewan		
	Coefficients		St. error	Coefficients		St. error
Constant	0.253085	*	0.123352	1.39295	***	0.140013
AGE[a]	-0.00113		0.002216	-0.00463	*	0.002446
AGAREA[b]	0.000043	***	1.29E-05	-3.5E-05	**	0.000014
SEASWET[c]	0.016138	***	0.001018	-0.00468	***	0.001025
CROP[d]	0.169185	***	0.048339	-0.07334		0.053881
No. of Indiv.	15			13		
R-squared	0.9877			0.9246		
Adj. R-squared	0.9827			0.8869		

[a]: Age. [b]: Acres under agricultural production. [c]: Number of seasonal wetlands in the farm. [d]: Dummy variable for type of main enterprise (1 if the main enterprise is crop, 0 otherwise). ***: Significant at 1% level. **: Significant at 5% level. *: Significant at 10% level.

Table M2 Linear WTA Transfer Model - Specification 2 - Including Observations with Imputed WTA

	Alberta			Saskatchewan		
	Coefficients		St. error	Coefficients		St. error
Constant	0.193835	***	0.040038	1.144219	***	0.054684
AGAREA[a]	4.42E-05	***	1.22E-05	-2.9E-05	*	1.55E-05
SEASWET[b]	0.015893	***	0.000868	-0.00515	***	0.001127
CROP[c]	0.169249	***	0.046684	-0.07947		0.061008
No. of Indiv.	15			13		
R-squared	0.9873			0.8908		
Adj. R-squared	0.9839			0.8544		

[a]: Acres under agricultural production. [b]: Number of seasonal wetlands in the farm. [c]: Dummy variable for type of main enterprise (1 if the main enterprise is crop, 0 otherwise). ***: Significant at 1% level. **: Significant at 5% level. *: Significant at 10% level.

Table M3 **Linear WTA Transfer Model - Specification 3 - Including Observations with Imputed WTA**

	Alberta			Saskatchewan		
	Coefficients		St. error	Coefficients		St. error
Constant	0.101757		0.213426	1.197503	***	0.092385
AGAREA[a]	0.00018	***	5.22E-05	-7.5E-05	***	2.05E-05
CROP[b]	0.268707		0.249135	-0.05088		0.104937
No. of Indiv.	15			13		
R-squared	0.6015			0.6373		
Adj. R-squared	0.5351			0.5647		

[a]: Acres under agricultural production. [b]: Dummy variable for type of main enterprise (1 if the main enterprise is crop, 0 otherwise).***: Significant at 1% level. **: Significant at 5% level. *: Significant at 10% level.

Table M4 **Linear WTA Transfer Model - Specification 4 - Including Observations with Imputed WTA**

	Alberta			Saskatchewan		
	Coefficients		St. error	Coefficients		St. error
Constant	-0.68555		0.52735	1.584992	***	0.239146
AGE[a]	0.015387		0.009533	-0.00736		0.004248
AGAREA[b]	0.000168	***	4.96E-05	-7.7E-05	***	1.87E-05
CROP[c]	0.248778		0.234302	-0.0453		0.095855
No. of Indiv.	15			13		
R-squared	0.6778			0.7279		
Adj. R-squared	0.5899			0.6372		

[a]: Age. [b]: Acres under agricultural production. [c]: Dummy variable for type of main enterprise (1 if the main enterprise is crop, 0 otherwise). ***: Significant at 1% level. **: Significant at 5% level. *: Significant at 10% level.

Appendix N Linear WTA Transfer Models Excluding Observations with Imputed WTA

Table N1 Linear WTA Transfer Model - Specification 1 - Excluding Observations with Imputed WTA

	Alberta			Saskatchewan		
	Coefficients		St. error	Coefficients		St. error
Constant	0.2612544		0.1483112	1.403015	***	0.16842
AGE[a]	-0.0011573		0.0024803	-0.0048159		0.002984
AGAREA[b]	0.000041	**	0.0000175	-0.0000353	**	1.52E-05
SEASWET[c]	0.0159592	***	0.0025083	-0.0046288	***	0.001164
CROP[d]	0.1707074	***	0.0544693	-0.0750386		0.059004
No. of indiv.	13			12		
R-squared	0.8872			0.9247		
Adj. R-squared	0.8309			0.8817		

[a]: Age. [b]: Acres under agricultural production. [c]: Number of seasonal wetlands in the farm. [d]: Dummy variable for type of main enterprise (1 if the main enterprise is crop, 0 otherwise). ***: Significant at 1% level. **: Significant at 5% level. *: Significant at 10% level.

Table N2 Linear WTA Transfer Model - Specification 2 - Excluding Observations with Imputed WTA

	Alberta			Saskatchewan		
	Coefficients		St. error	Coefficients		St. error
Constant	0.1988676	***	0.0613306	1.144199	***	0.056402
AGAREA[a]	0.0000425	**	0.0000164	-0.0000284		0.000016
SEASWET[b]	0.0157943	***	0.0023729	-0.0053159	***	0.001187
CROP[c]	0.1706397	***	0.0520481	-0.0697089		0.06455
No. of indiv.	13			12		
R-squared	0.8842			0.8967		
Adj. R-squared	0.8456			0.858		

[a]: Acres under agricultural production. [b]: Number of seasonal wetlands in the farm. [c]: Dummy variable for type of main enterprise (1 if the main enterprise is crop, 0 otherwise). ***: Significant at 1% level. **: Significant at 5% level. *: Significant at 10% level.

Table N3 **Linear WTA Transfer Model - Specification 3 - Excluding Observations with Imputed WTA**

	Alberta			Saskatchewan		
	Coefficients		St. error	Coefficients		St. error
Constant	0.4186446	***	0.1193232	1.196955	***	0.097383
AGAREA[a]	0.000036		0.0000379	-0.0000744	***	2.16E-05
CROP[b]	0.1938988		0.1198942	-0.0544043		0.113806
No. of indiv.	13			12		
R-squared	0.3141			0.6379		
Adj. R-squared	0.1769			0.5574		

[a]: Acres under agricultural production. [b]: Dummy variable for type of main enterprise (1 if the main enterprise is crop, 0 otherwise).***: Significant at 1% level. **: Significant at 5% level. *: Significant at 10% level.

Table N4 **Linear WTA Transfer Model - Specification 4 - Excluding Observations with Imputed WTA**

	Alberta		Saskatchewan		
	Coefficients	St. error	Coefficients		St. error
Constant	0.3590462	0.3423685	1.676028	***	0.259707
AGE[a]	0.0010663	0.0056991	-0.0091555	*	0.00469
AGAREA[b]	0.0000374	0.0000406	-0.0000762	***	1.89E-05
CROP[c]	0.1936127	0.1261437	-0.0682972		0.099598
No. of indiv.	13		12		
R-squared	0.3167		0.7547		
Adj. R-squared	0.089		0.6627		

[a]: Age. [b]: Acres under agricultural production. [c]: Dummy variable for type of main enterprise (1 if the main enterprise is crop, 0 otherwise). ***: Significant at 1% level. **: Significant at 5% level. *: Significant at 10% level.

Appendix O t-Test to Check for Equality of Means of the Estimated Preference Structural Parameter (Alpha) across Alberta and Saskatchewan

	Alpha	
	Alberta	Saskatchewan
Mean	0.784361956	0.794015567
Variance	0.007537375	0.016258421
Observations	15	13
Hypothesized mean difference	0	
df	21	
t Stat	-0.230558728	
P(T<=t) one-tail	0.409944448	
t Critical one-tail	1.720742903	
P(T<=t) two-tail	0.819888895	
t Critical two-tail	2.079613845	

Appendix P Estimated Farm-Specific Preference Structural Parameters ($\hat{\alpha}_n$) using Farm-Specific WTAs from Midpoint Regressions - Alberta

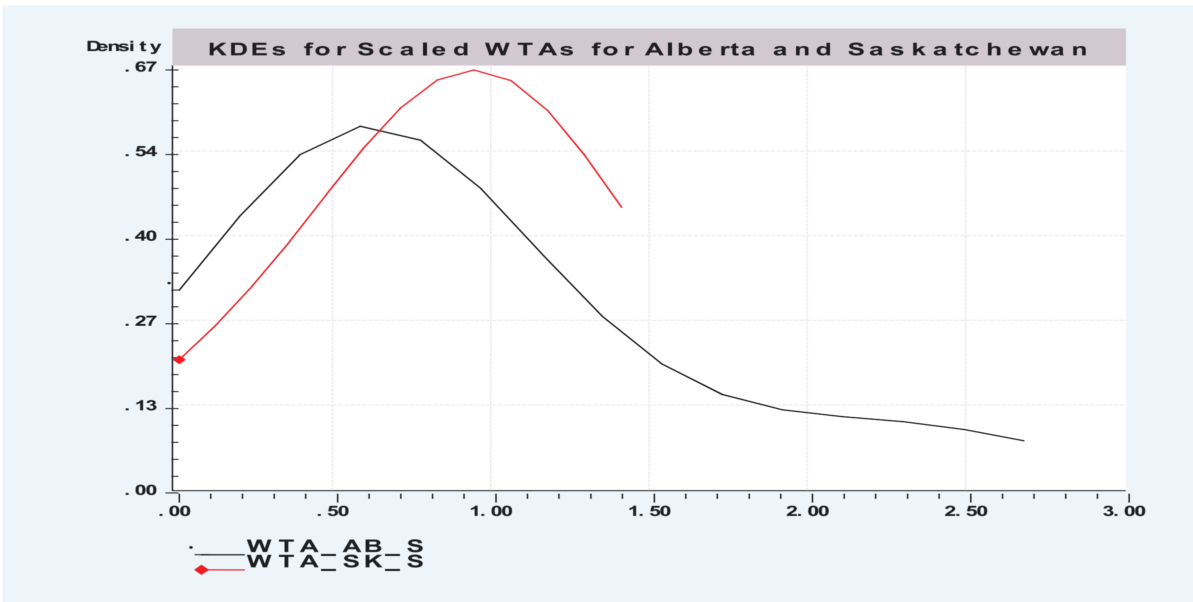
Farm ID	FC	Predicted WTA	$\hat{\alpha}_n$	Objective Function
1	619.05	702.21	0.700358	-0.00032
2	277.14	382.25	0.89724	-0.00049
3	1958.8	2520.47	0.679772	0.000526
4	609.65	2155.11	0.813184	-0.00024
5	754.05	320.72	0.629374	-0.00035
6	726.95	859.39	0.707982	-0.00049
7	123.67	427.13	0.886206	0.000638
8	281.52	454.18	0.861692	-0.00015
9	375.38	562.43	0.759426	-8.3E-05
10	226.67	744.56	0.806085	0.00047
11	354.28	417.6	0.815427	0.000154
12	237.55	1111.01	0.921678	0.000807
13	227.92	551.1	0.741328	0.000808
14	340.85	850.26	0.821401	0.000894
15	554.41	649.15	0.724279	-0.00037

Appendix Q Estimated Farm-Specific Preference Structural Parameters ($\hat{\alpha}_n$) using Farm-Specific WTAs from Midpoint Regressions - Saskatchewan

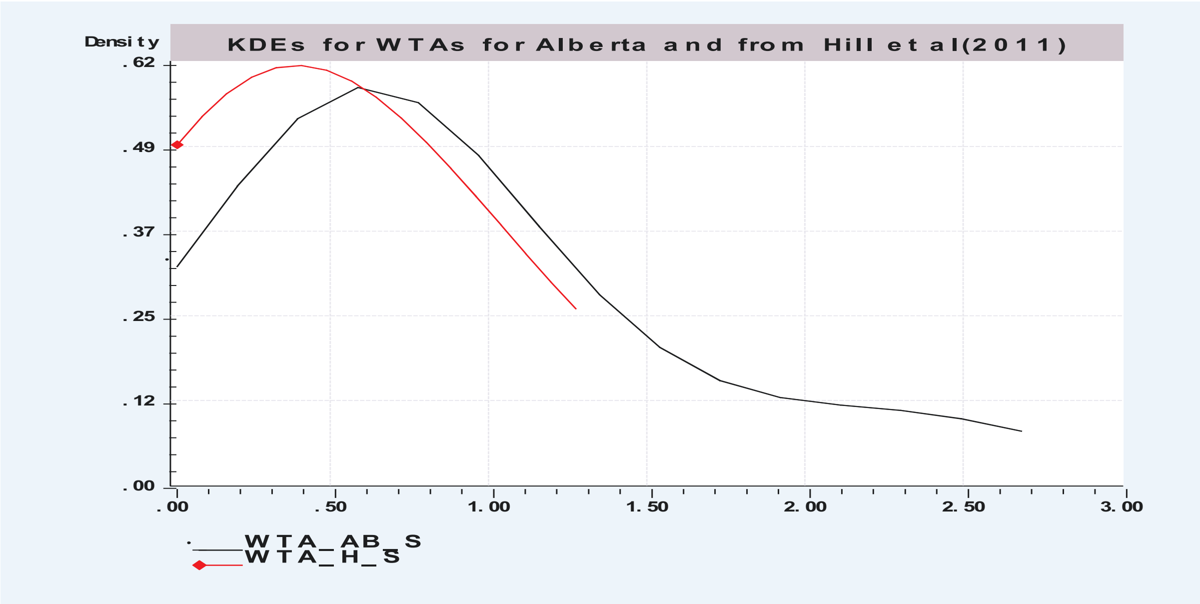
Farm ID	FC	Predicted WTA	$\hat{\alpha}_n$	Objective Function
16	221.47	1024.33	0.957692	-0.00098
18	757.07	558.39	0.604285	0.00044
19	366.89	1013.61	0.916539	-0.00041
20	209.67	869.93	0.778781	-4.4E-05
21	272.07	1054.53	0.81464	0.000768
22	922.18	178.22	0.521746	0.000686
23	382.08	957.08	0.819157	0.000377
24	240.83	953.55	0.777618	0.000654
25	245.88	996.6	0.890316	-0.00052
26	633.35	798.06	0.696742	0.000661
27	137.62	949	0.944218	-0.00082
28	350.16	933.97	0.789315	-0.00016
29	350.16	1174.67	0.811154	0.000801

Appendix R Pairwise Comparisons of Kernel Density Estimators (KDEs) of Cost of Wetland Restoration BMP

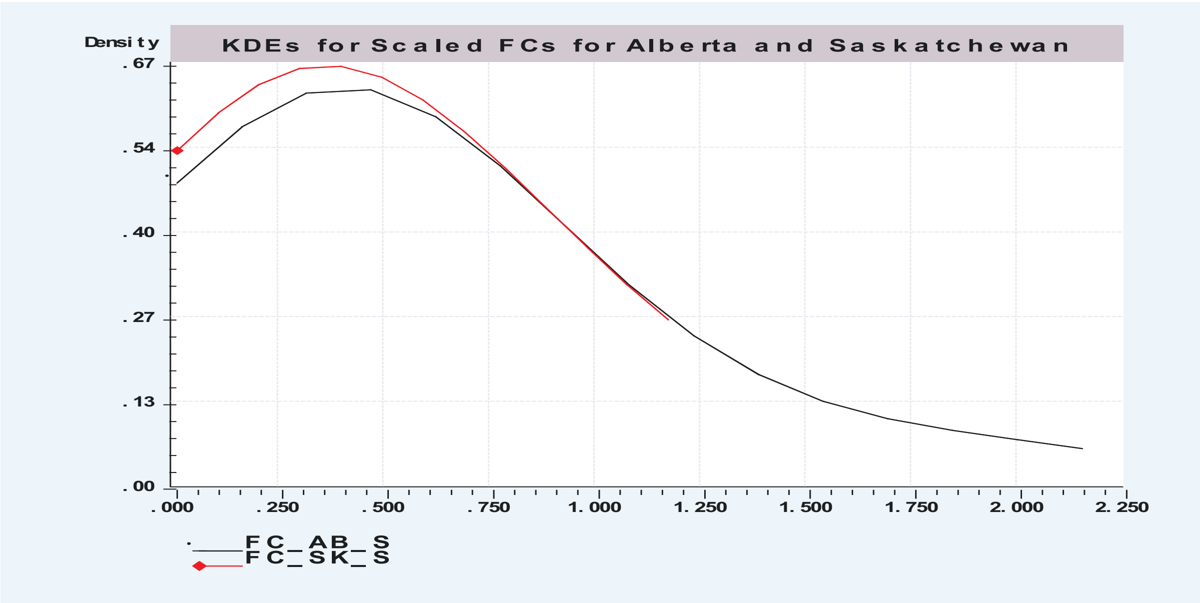
Appendix R1 Kernel Density Estimators for Scaled Predicted WTA for Alberta (WTA_AB_S) and Saskatchewan (WTA_SK_S) (Logistic Kernel; Bandwidth=0.337865)



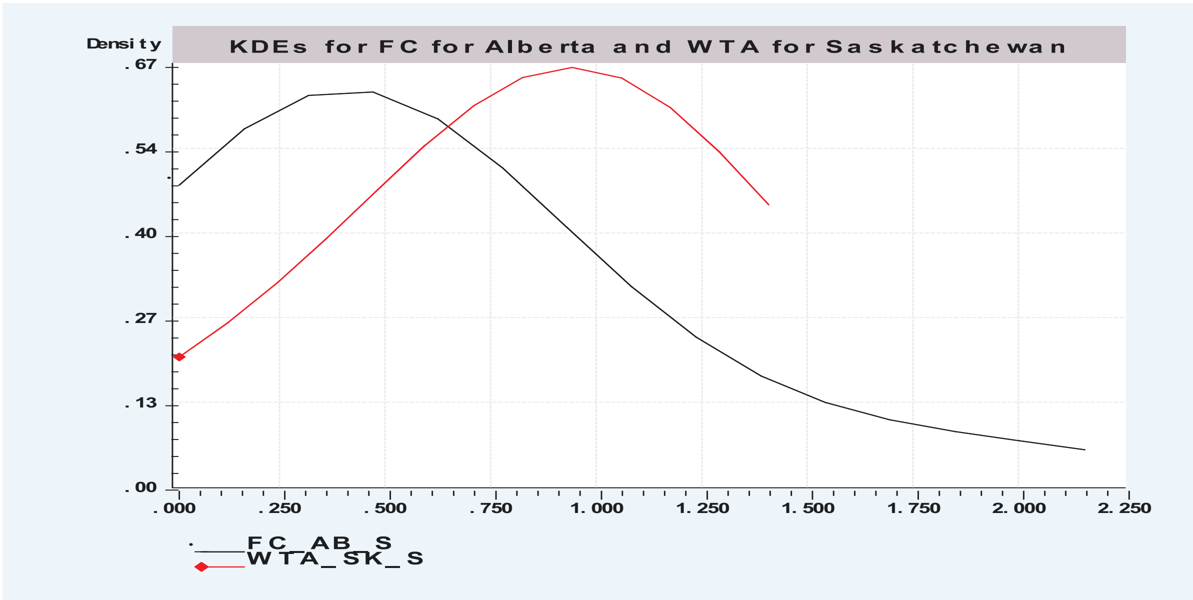
Appendix R2 **Kernel Density Estimators for Scaled Predicted WTA for Alberta (WTA_AB_S) and Scaled WTA for Saskatchewan Obtained by Hill et al. (2011) (WTA_H_S) (Logistic Kernel; Bandwidth=0.337865)**



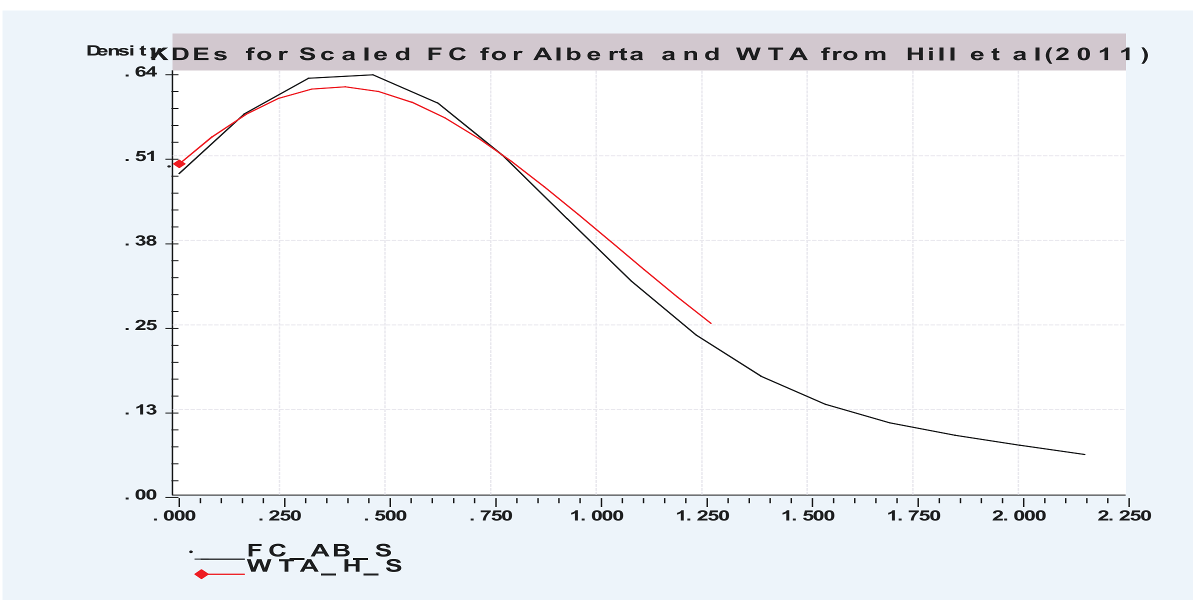
Appendix R3 **Kernel Density Estimators for Scaled FC for Alberta (FC_AB_S) and for Saskatchewan (FC_SK_S) (Logistic Kernel; Bandwidth=0.337865)**



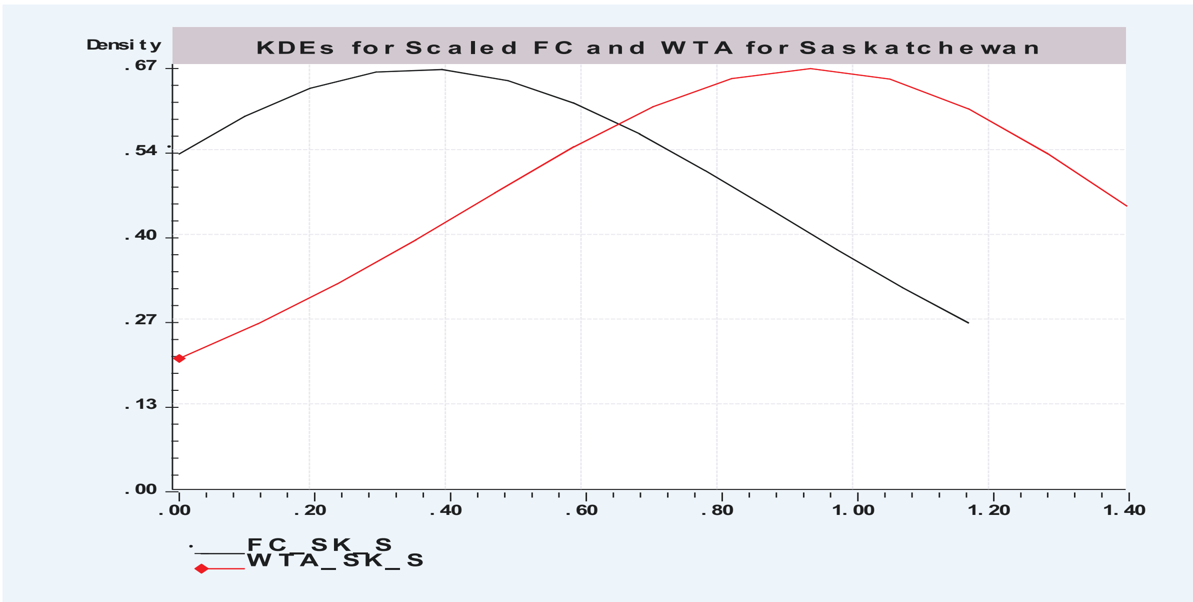
Appendix R4 **Kernel Density Estimators for Scaled FC for Alberta (FC_AB_S) and Scaled WTA for Saskatchewan (WTA_SK_S) (Logistic Kernel; Bandwidth=0.337865)**



Appendix R5 **Kernel Density Estimators for Scaled FC for Alberta (FC_AB_S) and Scaled WTA for Saskatchewan Obtained by Hill et al. (2011) (WTA_H_S) (Logistic Kernel; Bandwidth=0.337865)**



Appendix R6 **Kernel Density Estimators for Scaled FC for Saskatchewan (FC_SK_S) and Scaled WTA for Saskatchewan (WTA_SK_S) (Logistic Kernel; Bandwidth=0.337865)**



Appendix R7 **Kernel Density Estimators for FC for Saskatchewan (FC_SK_S) and WTA for Saskatchewan Obtained by Hill et al. (2011) (WTA_H_S) (Logistic Kernel; Bandwidth=0.337865)**