# The Demonstration and Capture of an Ecosystem Service Value:

# Three Different Methodological Approaches

by

Hyun No Kim

A thesis submitted in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

in

Agricultural and Resource Economics

Department of Resource Economics and Environmental Sociology

University of Alberta

**ABSTRACT**

Water management can generate valuable ecosystem services but can be costly to implement. This dissertation examines this issue using irrigation water storage infrastructure which has provided desirable services to residential properties in the Town of Chestermere in Alberta, Canada. Based on concerns regarding fluctuations in water quality and quantity a Water Management Agreement (WMA) was struck between the irrigation agency and the town to stabilize lake conditions in 2005. The first study uses quasi-experimental hedonic property approaches to estimate the subsequent impact of the WMA on shoreline property values. We find that property values significantly increased as a result of the agreement and that the additional property tax revenues arising from these values are large enough to offset the annual service fees paid to the irrigation agency.

The second study extends discrete residential choice models by incorporating choice set formation. In this second study we explore several formulations of endogenous choice sets in which the decision maker's selection of a choice set is based on certain attributes and the final selection is made from this reduced choice set. The proposed approach is empirically applied to a housing transaction dataset and welfare measures are generated for non-marginal changes associated with a water management policy. We find that the models that approximate choice set formation improve the efficiency of estimation and influence estimated welfare measures suggesting the importance of choice set formation in the context of discrete housing choice models.

The third study extends the stated housing choice literature by examining the issue for unobserved components of utility that may arise from use of a pivot-style dataset. The particular focus of this study is on examining the influence of experimental design methods on the variance of hypothetical choice alternatives simultaneously. We find presence of heteroscedasticity across choice alternatives. However, we do not find the evidence that design differences influence the unobserved parts of the utility function. A comparison of models across different model specifications shows that model parameters and welfare measures are sensitive to how to specify the model structures suggesting the need of precautions when dealing with the data generated by pivot-style designs.

# ACKNOWLEDGEMENT

During my entire doctoral program, several people have helped me finish this dissertation. First, I would like to thank my supervisor, Dr. Peter Boxall, for his thoughtful guidance, counsel, encouragement, and support. Dr. Peter Boxall, it was my great pleasure and honor to be your student. Without your help, I could not complete my doctoral program. Thank you so much!

My special thanks go to Dr. Vic Adamowicz who has provided me with the valuable research ideas and advice throughout the process of thesis completion. I am also grateful to my advisor in Korea, Dr. Hio-Jung Shin, for training me to develop my background in agricultural and resource economics during my undergraduate and master program.

I wish to express my thanks to my best friend, Dr. Thuy Truong, and his family for providing continuous support, showing kindness and compassion, and offering unforgettable memories to my family. I am grateful to faculty and staff of the Department of Resource Economics and Environmental Sociology for their support. I also appreciate Alberta Water Research Institute for funding my research.

I cannot thank my wife, Dr. Minjeong Shin and my son, Seungbeom (Aiden) Kim enough for their understanding and support. You were always there cheering me up and stood by me through the good times and bad. I owe a profound debt of gratitude to you and hopefully I will make it up to you. I love you more than you can ever imagine.

Last but not least, I thank my parents, Daeho Kim and Insoon Kim, and my parents-in-law, Taeho Shin and Chuleung Kim. They were always supporting and encouraging me with their best wishes.

**TABLE OF CONTENTS**

## LIST OF TABLES

## LIST OF FIGURES

# CHAPTER 1: INTRODUCTION

## 1.1 Background

Water is one of the most important, essential, and valuable factors for human life in that it provides drinking water and is a vital element in the maintenance of healthy aquatic ecosystems[1] which provide humans with many beneficial services. A few of these services, for example, would be associated with controlling water quality from waste discharge, managing water level from flood and storm water, and supplying various kinds of recreational activities such as fishing, swimming, and boating etc (Millennium Ecosystem Assessment, 2006).

Because of growing recognition of the importance of water and aquatic ecosystem services, governments have been seeking policies and/or strategies to ensure a reliable supply of ecosystem goods and services (EGS) which comprise the many benefits that an ecosystem contributes to human welfare. What is needed first to design such a suitable management scheme, however, may be an understanding of the economic values of the various EGS. Since most of these services are not associated with economic markets, implementing such analysis requires employing non-market valuation techniques which are methods to assess the value of goods and services that are not transacted in formal economic markets (Grafton et al., 2004).

One such use of water to meet human needs is irrigation of crops to provide foods, fibre and income to society. This irrigation requires the

[1] An ecosystem refers to a biological environment including both all the organisms coexisting in a specific area and non-living physical components of the environment such as air, soil, water, and sunlight. An aquatic ecosystem refers to an ecosystem located in a body of water.

development of infrastructure to move and/or store water supplied by rivers, lakes, or the ground to land where crops are grown. Currently in Alberta, Canada irrigation accounts for the largest portion of water use; about 72% within the South Saskatchewan River Basin (SSRB), one of seven major basins in Alberta (Environment, Government of Alberta, 2008). In 1975 when the major water delivery head works were transferred from Federal to Provincial Government, Alberta undertook to operate this irrigation infrastructure for multi-purpose uses such as hydropower and recreation. Consequently, many recreational activities such as swimming, boating, fishing etc. (forms of EGS) are dependent today on the presence of infrastructure.

This irrigation infrastructure in the Western Irrigation District (WID)[2] was initially constructed for water storage to meet the demand for growing irrigation water use. However, portions of the WID operations involve reservoirs which have since provided more multi-purpose uses. Much of the land around this infrastructure has been developed for residential and recreational uses, and the reservoir infrastructure has become an important environmental asset supporting aquatic ecosystem services and providing residents living around or near reservoirs and visitors with non-market economic benefits such as recreation and visual amenities etc.

Chestermere Lake, located east of Calgary, Alberta, Canada is an example of the case above. It is an artificial lake built in 1880's by the Canadian Pacific

[2] WID is an organization that formed in 1944 by a group of farmers to prevent the CPR from closing the canal systems and they are now in charge of delivering water to farmers, landowners, and industrial customers as well as managing storm water and providing municipal water for most eastside of Calgary (www.wid.net).

Railway (CPR) for irrigation of the area between Calgary and Strathmore. Transfer of ownership and management of the lake to the WID took place in the 1940's and starting in the 1950's the WID permitted construction of houses along the shoreline. Since then, the Town of Chestermere developed surrounding the lake. Currently, Chestermere Lake is owned and operated by the WID and is regarded as a primary aesthetic amenity within Town of Chestermere. The lake is used mainly for recreational activities yielding positive externalities for the residents and any visitors. To ensure an adequate supply of these benefits obtained from environmental amenities, however, some conflicts between residents and the WID have arisen in terms of storm water management, water level management, and land encroachment issues.

The primary problems in the Lake were related to variation in water level during the irrigation period (May to September) which provided challenges to recreational use by Town residents and visitors. In addition, sediment accumulation causing increasing aquatic weed growth also created barriers for recreational activities in the lake (White and Biol 2001; Alberta Lake Management Society's Lakewatch Program 2010). Possible sources of the accumulating sediments in the lake were Calgary's use of the WID system as a storm water waste way, but rural sources from the surrounding town were also thought to be important contributions (Mitchell and Prepas 1990; White and Biol 2001).

In 2005 a Water Management Agreement (WMA) was signed between the WID and the Town of Chestermere to settle the conflict. The agreement allowed the Town to discharge storm drainage into the Lake and affirmed allowing Town residents and other regional users continued use of the Lake for aesthetic and recreational purposes by sustaining specific levels of water in the lake and water quality. For example the WID agreed that during the irrigation period of each year, water levels in the lake would be held between 1025.5 - 1025.6 meters above sea level (m asl) unless special circumstances occurred. In addition, maximum annual phosphorous levels entering the lake from the Town were specified to be 0.356 tonnes, and the WID agreed to monitor water quality to ensure that the required standard was met. Finally, the WID permitted the Town to dredge Chestermere Lake conditional on compliance with regulatory requirements and agreed to cooperate on moderate actions to control weed growth in the lake.

**Table 1.1: The components of the fee paid by the Town of Chestermere to the Western Irrigation District for water management**

| Service | Fee /year |
|---|---|
| Lake level management | 150,482 |
| Storm drainage discharge | 28,900 |
| Storm surge protection | 155,000 |
| Total | 334,382 |

- Source: Western Irrigation District

In return for these services the Town agreed to pay an annual fee to the WID. Table 1.1 presents the services provided by WID and the associated annual fees that the Town has paid. The town and WID also agreed to adjust the fee each year by applying the consumer price index (CPI) for the City of Calgary. To put the fee in context, the Town operating budget for 2010 was about $21,509,690 and thus the WID service fee accounted for about 1.6% of the Town total expenses. Payment of this fee serves to illustrate the capture of the economic value of the WMA and associated ecosystem service provision to the Town of Chestermere.

**1.2 Objective, Contribution and Overview of Thesis**

Reduced variation in water quantity and quality as a result of implementation of the WMA is likely to have a significant influence on changing the amount and quality of the services that the aquatic ecosystem associated with the lake provides (Phaneuf et al., 2008). Therefore, it seems that Chestermere residents and visitors have likely gained economic benefits from the lake as a consequence of the increased recreational opportunities and aesthetic amenities since the development of the WMA.

The benefits generated by environmental amenities associated with Chestermere Lake could in part be reflected in the value of properties in the Town of Chestermere since along with other structural attributes of the property and its locational attributes, environmental amenities are an important factor influencing property values (Taylor, 2003; Grafton et al., 2004; Bockstael and McConnell, 2007). Moreover, changes in water quantity and quality may have different impacts on property values depending on the location of the property with respect to the shore of the lake (i.e. different geographic locations or waterfront versus non-waterfront properties within the town).

This dissertation uses the case of estimating the value of the services provided by a particular piece of irrigation infrastructure, Chestermere Lake, to advance the property valuation literature. More specifically, this study employs three different methodological approaches to demonstrate and capture the economic value of ecosystem services provided by an artificial lake which has probably yielded positive externalities for the residents and any visitors around it. Moreover, all three studies also set out to investigate the economic impact of increases in the level of ecosystem services resulting from change in water management policy.

Among various kinds of non-market valuation methods, the hedonic pricing method is widely employed to value non-market attributes associated with marketable goods (Haab and McConnell, 2002). In particular, hedonic methods employ the hedonic price function which results from the interaction of supply and demand in the market to examine the relationship between housing-related attributes, including environmental attributes and the market price of the property (Grafton et al,. 2004; Phaneuf and Requate, forthcoming). The magnitude of the contribution of housing characteristics to the value of the property can be identified through estimation of this hedonic price function.

Using this approach it is possible to separate the value of environmental attributes from the other components of housing features. In addition, gains or losses resulting from changes in the provision of environmental attributes can be captured by changes in property values and can be quantified as monetary values. Thus, the monetary values derived can be regarded as an indicator of the values generated by change in the level of ecosystem services provided by environmental goods. Therefore, measuring the benefits resulting from changes in the level or water quality of the lake would be useful in determining the value of EGS generated by the lake. Knowledge of the relationship between these environmental attributes and property values could be valuable information in designing policies to implement strategies to secure aquatic ecosystem services.

The first study starts by investigating the impact of water stabilization on property values due to the implementation of the WMA described earlier. The monetary values obtained from this analysis can be considered an estimate of the welfare effects[3] generated by changes in environmental attributes provided by the WMA to the residents of Chestermere. In developing these estimates this study employs a particular difference-in-difference (DID) estimation which is commonly used to evaluate the impact of a policy intervention (e.g. the WMA) on an outcome (e.g. house prices) of two different groups of residents. However, there are concerns in the literature regarding potential problems raised in DID settings such as sampling error or endogeneity associated with the intervention variable (Bertrand et al., 2004). To alleviate these problems, the DID analysis was extended to a more robust analysis, referred to as difference-in-difference-in-difference (DIDID) by involving both geographically different observations and a control group within the treatment group.

The first paper makes two contributions to the literature on property value impacts from water resource infrastructure. First, it employs a quasi-experimental approach to identify the impact of irrigation infrastructure management and

[3] Note that proper welfare measure must take account of behavioral adjustments in response to the change in environmental quality and in this respect this welfare effect differs from a "pure willingness to pay" measure (see Bockstael and McConnell, 2007).

provide empirical estimates of the monetary value. Second, it explores the capture of an ecosystem service value and relates that amount to the payment for provision of service in this case study.

The hedonic price approach used in the first paper, however, would be confined to examination of marginal changes in environmental goods, and thus the welfare measures derived from this empirical approach should be interpreted with caution when evaluating non-marginal measures[4]. To estimate more precise welfare measures in relation to non-marginal changes in environmental goods, the hedonic price method can be extended to a second stage which requires particular data and challenging econometric techniques (Palmquist, 2005; Bockstael and McConnell, 2007; Phaneuf and Requate, forthcoming). Typically this second stage is ignored in many property valuation studies due to data limitations and several econometric estimation issues challenging to ensure unbiased estimation results (e.g. Leggett and Bockstael, 2000; Poor et al., 2001; Boxall et al., 2005; Chattopadhyay et al., 2005; Brasington and Hite, 2005).

Rather than applying the two-stage hedonic method to address concerns regarding the welfare measures, the second study uses an alternative approach that develops a discrete residential choice model based on random utility theory. The use of discrete choice models to examine residential choice in the context of environmental amenities has previously appeared in the literature (Palmquist and Israngkura, 1999; Banzhaf and Smith, 2007; Bayer et al., 2009; Klaiber and Phaneuf, 2010; Tra, 2010), but the second paper extends this literature through the

[4] The welfare measures should be regarded as the approximate measures in association with a large change in environmental goods.

examination of the issue of the choice set. This issue arises because one must make assumptions about the size and extent of the set of choices from which a home buyer will make a purchase. The existing literature on the use of discrete choice methods to understand the relationship between property values and environmental attributes is not well-developed. Thus in this second component we develop a discrete housing choice model which incorporates a model of the availability of properties for potential buyers. In other words, the second study proposes an approach that modifies choice sets using limited data availability, which may be a first attempt in the context of a residential choice model.

An underpinning of this research uses arms-length sales prices paid by property owners for various properties associated with Chestermere Lake. However, such revealed preference data can be limited regarding variation in water quality parameters associated with the lake as well as the individual specific characteristics of property buyers. Variation in water quality may have significant influences on housing choices (e.g. Braden et al. 2008; Phaneuf et al. 2008). Since the primary objective of this thesis is to assess the relationship between environmental amenities and households' residential choices, it is important to obtain enough information about these variables over the period that housing transactions are examined.

The deficiency of using market data could be overcome by implementing a survey to obtain supplemental information regarding households' potential housing choices. While a survey will be important in assessing the importance of water quality on residential choices, it can also be used to acquire household's characteristics. Thus, the third study focuses on understanding preferences for residential choice in association with changes in a range of water quality parameters in Chestermere Lake. Water quality attributes associated with housing choices could not be examined using the revealed preference data so the survey develops a stated preference approach. There are few studies in the literature that have used stated preference methods to examine the welfare impacts of environmental attributes on residential choice. Thus, in this case study of Chestermere water quality we employ a pivot-style experimental design which uses individual specific reference levels in the stated housing choice task. Given the application of pivot-style design, we apply two alternative design strategies to generate choice sets for respondents.

A pivot-style design (or alternatively cited as a reference design) uses individual knowledge (or experience) base to derive the attribute levels of the alternatives in the choice experiments. This design approach is well supported by a number of theories which promote the use of reference alternatives in the choice occasions such as prospect theory, case-based decision theory and minimum-regret theory (Rose et al., 2008). These theories state how individual specific knowledge or experiences can be psychologically related to the choice decisions and the advantage of using reference alternatives in the choice experiments. Because the use of reference alternatives in the choice experiments may have potentials for respondents to reveal their preference more meaningfully, a pivot design has been applied in the stated choice experiments (Hensher, 2004; Rose et al., 2008; Hess and Rose, 2009).

In the stated choice experiment literature, two alternative experimental design strategies have been used to generate choice sets. One is to adopt fractional factorial orthogonal designs and the other is to apply efficient designs. Since these two design strategies employ different criteria in the process of design construction, the efficiency of parameter estimates will be different between the models generated by these design strategies. There are few studies in the literature that have examined the impact of the experimental design strategy on the estimation results. Thus, the third study undertakes comparison of the two alternative design strategies to verify whether experimental design differences have an influence on the error components of the utility function. Put differently, this third paper extends the stated housing choice literature by examining the issue for unobserved components of utility that may arise from use of a pivot-style dataset as to potential systematic differences in unobserved parts of utility function (i.e. error terms) between alternatives in choice tasks. The particular focus of this study is on examining the influence of experimental design methods on the variance of hypothetical choice alternatives simultaneously.

The remaining chapters of the dissertation are organized as follows. The second chapter discusses the hedonic price analysis method. It provides the theoretical framework, a review of related literature, and the data employed in the analysis followed by a section that outlines our empirical model specifications. The empirical results are then presented and discussed. Chapter 3 presents a discrete house choice model which attempts to address the choice set issue in the context of revealed preference methods. Relevant literature, data, estimation methods, and results are also reviewed. Chapter 4 outlines the approaches used to examine stated preferences for houses associated with water quality changes based on attribute based stated choice methods. This chapter incorporates a review of existing literature, discusses the survey structure and experimental designs, and provides the empirical results. Chapter 5 summarizes the dissertation.

**References**


Alberta Lake Management Society's Lakewatch Program. 2010. *2010 Chestermere Lake Report,* completed with support from Government of Alberta

Banzhaf, H. S. and V. K. Smith. 2007. "Meta-analysis in model implementation: choice sets and the valuation of air quality improvements", *Journal of Applied Econometrics* 22:1013-1031

Bayer, P. J., N. Keohane, and C. Timmins. 2009. "Migration and hedonic valuation: the case of air quality", *Journal of Environmental Economics and Management* 58:1-14

Bertrand, M., E. Duflo, and S. Mullainathan. 2004. "How much should we trust differences-in-differences estimates?", *Quarterly Journal of Economics* 119 (February): 249-275

Bockstael, N. E. and K. E. McConnell. 2007. *Environmental and Resource Valuation with Revealed Preferences*. Dordrecht, The Netherlands: Springer

Boxall, P. C., W. H. Chan, and M. L. McMillan. 2005. “The impact of oil and natural gas facilities on rural residential property values: a spatial hedonic analysis”, *Resource and Energy Economics* 27:248-269

Braden, J. B., L. O. Taylor, D. Won, N. Mays, A. Cangelosi, and A. A. Patunru. 2008. “Economic Benefits of Remediating the Buffalo River, New York Area of Concern”, *Journal of Great Lakes Research* 34:631-648

Brasington, D. M. and D. Hite. 2005. “Demand for Environmental Quality: A Spatial Hedonic Analysis”, *Regional Science and Urban Economics* 35(1):57-82

Chattopadhyay, S., J. B. Braden, and A. Patunru. 2005. “Benefits of Hazardous Waste Cleanup: New Evidence from Survey- and Market-Based Property Value Approaches”, *Contemporary Economic Policy* 23(3):357-375

Environment, Government of Alberta: www.environment.alberta.ca

Grafton, Q., W.L. Adamowicz, D. Dupont, H. Nelson, R. Hill, and S. Renzetti. 2004. *The Economics of the Environment and Natural Resources*. Basil Blackwell Publishers

Haab, T. C. and K.E. McConnell. 2002. *Valuing Environmental and Natural Resources: The Econometrics of Non-Market Valuation*. Cheltenham, UK: Edward Elgar Publishers

Hensher, D. A. 2004. “Identifying the influence of stated choice design dimensionality on willingness to pay for travel time savings”, *Journal of Transport Economics and Policy* 38(3): 425-446

Hess, S. and J. M. Rose. 2009. "Should reference alternatives in pivot design SC surveys be treated differently?", *Environmental and Resource Economics* 42(3): 297-317

Klaiber, H. A. and D. J. Phaneuf. 2010. "Valuing open space in a residential sorting model of the Twin Cities", *Journal of Environmental Economics and Management* 60:57-77

Leggett, C. G. and N. E. Bockstael. 2000. "Evidence of the Effects of Water Quality on Residential Land Prices", *Journal of Environmental Economics and Management* 39:121-144

Millennium Ecosystem Assessment (2006): www.milleniumassessment.org

Mitchell, R. and E. Prepas. 1990. *Atlas of Alberta Lakes*. University of Alberta Press. Available at: http://alberta-lakes.sunsite.ualberta.ca/

Palmquist, R. B. 2005. "Property Value Models", chapter 16 in *Handbook of Environmental Economics*, volume 2, K.G. Mäler and J. Vincent, eds., Elsevier, Amsterdam

Palmquist, R. B. and A. Israngkura .1999. "Valuing Air Quality with Hedonic and Discrete Choice Models", *American Journal of Agricultural Economics* 81(5):1128-1133

Phaneuf, D. J., V. K. Smith, R. B. Palmquist, and J. C. Pope. 2008. "Integrating Property Value and Local Recreation Models to Value Ecosystem Services in Urban Watersheds", *Land Economics* 84 (3): 361-381

Phaneuf, Daniel J. and Till Requate. Forthcoming. *A Graduate Course in Environmental Economics: Theory, Policy, and Practice.* Cambridge University Press

Poor, P. J., K. J. Boyle, L. O. Taylor, and R. Bouchard. 2001. "Objective versus Subjective Measures of Water Clarity in Hedonic Property Value Models", *Land Economics* 77(Nov.): 482-93

Rose, J. M., M C. J. Bliemer, D. A. Hensher, and A. T. Collins. 2008. "Designing efficient stated choice experiments in the presence of reference alternatives", *Transportation Research Part B* 42:395-406

Taylor, L. O. 2003. The hedonic method*.* In: Champ, P. A., Boyle, K. J., Brown, T.C. (Editors.)*, A Primer on Nonmarket Valuation.* Kluwer, Dortrecht, pp. 331-393

Tra, C. I. 2010. "A discrete choice equilibrium approach to valuing large environmental changes", *Journal of Public Economics* 94: 183-196

Western Irrigation District: www.wid.net

White, J. S. and P. Biol. 2001. The water quality of Chestermere Lake: *A state of the knowledge report*. *Aqua*lity Environmental Consulting Ltd

# CHAPTER 2: THE DEMONSTRATION AND CAPTURE OF AN ECOSYSTEM SERVICE VALUE: A QUASI-EXPERIMENTAL HEDONIC PROPERTY ANALYSIS

Rosen (1974) developed the underpinnings of theoretical hedonic property model by pointing out that along with a bundle of housing characteristics, environmental attributes could also be one of the contributive factors to house prices. Properties can be regarded as quality differentiated market products in that each unit is different with respect to the components of housing-related attributes that house embodies (Palmquist, 2005). This implies in turn there will be an array of prices for the quality differentiated properties in the housing market. The price of houses sold in the market will be determined by the agreement between home buyers and sellers. In other words, hedonic property models assume that the market price of a house is the equilibrium price and is characterized as a hedonic price function (or schedule). The hedonic price function is the function connecting each point that consumer's bid and supplier's offer coincide together. Put differently, it is an envelope of the equilibrium between home buyers and sellers, which consists of a vector of housing-related attributes (Grafton et al., 2004).

In most hedonic property studies, however, it is generally assumed that the supply of the houses is fixed and for this reason the examination of hedonic property models concentrates on consumer behavior in the housing market (Palmquist, 2005; Bockstael and McConnell, 2007; Phaneuf and Requate, forthcoming). Thus, the following presentation of the theoretical framework of hedonic property models focuses on the consumer's utility maximization problems assuming the stock of housing in the market as given.

### 2.1 Theoretical Framework of Hedonic Property Model

The consumer's maximization problem[5] associated with choosing a housing unit subject to a budget constraint can be described as follows:

$$\max_{\{z,q\}} u(z,q)$$

$$\text{s.t } y = z + P(q)$$

where z is the numeraire good with which price is normalized to one and q is the vector of housing related attributes such as structural, locational, environmental characteristics. In the constraint y is the household's income and P(q) is the hedonic price function which is assumed to be an equilibrium price and is described as a function of a bundle of attributes, q. Assuming an interior solution, the first order condition (FOC) maximizing consumer's utility is organized as the following condition:

$$\frac{\partial u/\partial q_i}{\partial u/\partial z} = \frac{\partial P(q)}{\partial q_i} \quad i = 1, \ldots, n \qquad (2.1)$$

where left-hand side in Eq. (2.1) is the marginal rate of substitution (MRS) between $q_i$ and z and right-hand side is the slope of hedonic price function associated with an attribute, $q_i$.

Household's bid function which is defined as the maximum amount of money household would be willing to pay for a particular house and is comprised of attributes (q), income (y), and baseline utility ($u_b$) is expressed as $\varphi(q, y, u_b)$.

[5] This section is heavily taken from Grafton et al. (2004) and Bockstael and McConnell (2007)

By definition, it must be true that after purchasing a house, the amount of money left over household income can be spent on consuming composite good, z. Mathematically,

$$y - \varphi(q, y, u_b) = z \tag{2.2}$$

Holding utility constant at the baseline level ($u_b$) while other elements, z and q can vary is expressed as

$$u(z, q) = u_b \tag{2.3}$$

Substituting Eq. (2.2) into Eq. (2.3) gives the following expression:

$$u(y - \varphi(q, y, u_b), q) = u_b \tag{2.4}$$

Taking total differential of Eq. (2.4) with respect to $q_i$ can be written as:

$$\frac{du}{dq_i} = -\frac{\partial u}{\partial z}\frac{\partial \varphi}{\partial q_i} + \frac{\partial u}{\partial q_i} = 0 \tag{2.5}$$

Arranging Eq. (2.5) in terms of the slope of bid function associated with $q_i$ yields the result as follows:

$$\frac{\partial \varphi}{\partial q_i} = \frac{\partial u/\partial q_i}{\partial u/\partial z} \tag{2.6}$$

Finally, comparing two conditions, Eq. (2.1) and (2.6) provides an interesting and important result that has been used in hedonic literatures.

$$\frac{\partial P(q)}{\partial q_i} = \frac{\partial u/\partial q_i}{\partial u/\partial z} = \frac{\partial \varphi}{\partial q_i} \tag{2.7}$$

The condition, Eq. (2.7) shows that household's bid function for marginal change in $q_i$ is equal to the slope of hedonic price function at the optimum. Based on this condition, estimating hedonic price function is prevalent in hedonic literature to assess the marginal value of an attribute.

## 2.2 Review of Related Literature

Since the development of Rosen's hedonic model numerous studies have been undertaken to understand the relationship between property values and environmental goods. Property value studies in the context of environmental valuation aims mostly to assess the impact of environmental goods on property values and to derive welfare measures associated with changes in environmental quality. The application of the hedonic property studies includes, for example, various environmental factors such as air quality, open space, and water quality etc.

Since it is not practicable to examine and present all of the hedonic studies, literature review is limited to the relevant examples which employed hedonic property analysis with regard to water quality and quantity in the context of urban/recreation land and irrigation which is suited to this study. Also, presented are the studies which linked difference-in-difference estimation method with hedonic property modelling in the context of valuation of environmental policy and/or some exogenous environmental event.

There is a relatively large literature using hedonic property approaches to value water quality attributes (e.g. Boyle et al. 1999; Leggett and Bockstael 2000; Michael et al. 2000; Poor et al. 2001) but few studies examining the impact of lake levels on property values. Among the first to examine lake levels was Lansford and Jones (1995) who determined the value of water in recreational and aesthetic uses reflected in property prices around a lake in Texas. Using hedonic property methods they found that fluctuations in lake level could be uncovered in the prices of properties located around the lake. They found that the marginal values of lake level reductions were lower than marginal prices per acre foot in related agricultural water uses in the region.

Loomis and Feldman (2003) estimated economic losses to the lakeshore residents from anthropogenic reductions in water levels at a California lake where allocation of water between hydropower or irrigation operations during summer peak seasons affected lake levels which impacted recreational uses. These studies indicate that anthropogenic reductions in lake levels can constitute a significant disamenity, negatively affecting property prices of surrounding residences.

Muller (2009) compared property prices at two lakes which were managed for different purposes resulting in fluctuation of water level at one lake, and a constant level at the other. While Muller's study focused on the sensitivity of hedonic model specification, he did find that the lake with constant levels provided significant premiums to waterfront property locations due to adjacency, scenic views and access services. In contrast, at the other lake shoreline properties were associated with smaller premiums due to reduced services resulting from periodic flooding of land from high lake water levels and poor access, offensive odors and other features associated with low water levels.

These hedonic property studies, however, have not assessed the effect of stabilizing water levels on residential property values in a quasi-experimental framework that considers the water control policy as endogenous.

Employing quasi-experimental hedonic property approaches to value impacts of policy or exogenous events is relatively recent. For example, flood risks produced by Hurricanes Fran and Floyd on housing prices were examined by Bin and Polasky (2004) and Pope (2008). Bin and Polasky (2004) used property sales data from 1992 - 2002 in Pitt County, North Carolina and treated Hurricane Floyd, which occurred in September 1999, as an exogenous quasi-random experiment which was assumed to influence housing prices. Instead of designing a natural event itself as a causal factor, Pope (2008) used two sources of variation as an instrument for flood risk information. Pope used residential disclosure statements and a flood plain map provided by the Federal Emergency Management Agency in the state of North Carolina to examine the impact of commencement of a disclosure statement on house prices in flood zones.

More recently, Bin et al. (2009) investigated the influence of the imposition of riparian buffer regulations in North Carolina using quasi-experimental methods. Heintzelman (2010) conducted a difference-in-difference (DID) analysis to measure the impact of the Massachusetts Community Preservation Act, which was passed for the purpose of open space and historic preservation, on property values. Zabel and Guignet (2012) estimated the impact of leaking underground storage tank sites on property values by modeling the discovery of a leak as the experimental treatment applied to a specific treatment group. Muehlenbachs et al. (2012) developed a triple difference (DIDID) modeling strategy to identify the effect of groundwater contamination risk caused by shale gas operations.

In our analysis, we follow the quasi-experimental literature and exploit the WMA as an endogenously implemented policy (e.g. an experimental treatment).

Since we have information about the location of each property sale within the Town with respect to the lakefront, we grouped each sale into two groups; a treatment group which consists of waterfront houses, and a control group that includes non-waterfront houses. Our assumption regarding this grouping is grounded on Muller's (2009) intuition that the impacts of the WMA would likely be experienced by waterfront properties relative to non-waterfront[6]. However, this simple DID approach is extended to a DIDID analysis by including waterfront and non-waterfront sales from a different, nearby housing market as an additional control. Using these frameworks the difference in property values between these groups is estimated, both before and after the implementation of the WMA to evaluate the economic value of the WMA on the residential property value ecosystem service.

## 2.3 Data

Arms length transaction data from the Town of Chestermere and City of Calgary were obtained from the Calgary Real Estate Board from year 2000 to 2010. After removing observations which obviously involved incorrect structural, geographical information, and/or some missing information, a final sample of sales (1,798 in Chestermere and 217,336 in Calgary) was used for econometric analysis. The data for each property included structural characteristics such as residential area, lot size, the number of bedrooms and bathrooms, the information

[6] One might argue that the impacts of the WMA would not be limited to the waterfront properties because non-waterfront properties can also have water views. We visited study area and verified that unless the properties are lakeshore, one cannot simply see the lake. Thus, we assumed that the benefits due to the good water conditions resulting from the WMA would be mostly felt by waterfront houses.

regarding whether properties are waterfront or not, as well as geographical information which permitted the calculation of distances to the Chestermere Lake lakeshore.

**Table 2.1: Variable definitions and means of variables used in two hedonic property value analyses**

| Variable | Definition of variable | Mean values DID model | Mean values DIDID model |
|---|---|---|---|
| price | House sales prices (2007 $CAD) | 512,882 | 419,257 |
| area | Square meters of area not including basement | 1,911.9 | 1,371.7 |
| bed | Number of bedrooms | 3.29 | 2.61 |
| bath | Number of bathrooms | 2.34 | 1.93 |
| ac | Presence of air conditioning system (DV) | 0.09 | 0.06 |
| decbal | Deck or balcony present (DV) | 0.64 | 0.61 |
| waterf | Waterfront house (DV) | 0.05 | 0.003 |
| detgarage | Garage detached (DV) | 0.03 | 0.23 |
| sfhouse | Single family houses (DV) | 0.92 | 0.71 |
| summer | houses are sold in June through August (DV) | 0.3 | 0.27 |
| hage_d1 | 1 if house age is <= 5 years, 0 otherwise (DV) in DID model<br>1 if house age is <= 10 years, 0 otherwise(DV) in DIDID model | 0.7 | 0.41 |
| hage_d2 | 1 if house age is between 6 and 10 years, 0 otherwise (DV) in DID model<br>1 if house age is between 11 and 20 years, 0 otherwise(DV) in DIDID model | 0.18 | 0.13 |
| hage_d3 | 1 if house age is between 11 and 20 years, 0 otherwise (DV) in DID model<br>1 if house age is between 21 and 30 years, 0 otherwise(DV) in DIDID model | 0.07 | 0.22 |
| hage_d4 | 1 if house age is >= 21 years, 0 otherwise (DV) in DID model<br>1 if house age is >=31 years, 0 otherwise(DV) in DIDID model | 0.03 | 0.24 |
| housetype | House types detached or attached (DV) | 0.85 | 0.64 |
| invmtolake | Inverse of distance (meters) from each house to lake | 0.0039 | 0.00009 |
| szg_d1 | 1 if no. of cars to be stored in the garage is <= one, 0 otherwise (DV) | 0.08 | 0.52 |
| szg_d2 | 1 if no. of cars to be stored in the garage is equal to two, 0 otherwise (DV) | 0.81 | 0.47 |
| szg_d3 | 1 if no. of cars to be stored in the garage is equal to three, 0 otherwise (DV) | 0.1 | 0.02 |
| szg_d4 | 1 if no. of cars to be stored in the garage is >= four, 0 otherwise (DV) | 0.009 | 0.001 |
| fp_d1 | 1 if no. of fireplace is equal to one, 0 otherwise (DV) | 0.82 | 0.92 |
| fp_d2 | 1 if no. of fireplace is equal to two, 0 otherwise (DV) | 0.17 | 0.08 |
| fp_d3 | 1 if no. of fireplace is >= three, 0 otherwise (DV) in DID model<br>1 if no. of fireplace is equal to three, 0 otherwise (DV) in DIDID model | 0.009 | 0.007 |
| fp_d4 | 1 if no. of fireplace is equal to four, 0 otherwise (DV) | n/a | 0.001 |
| fp_d5+ | 1 if no. of fireplace is >= five, 0 otherwise (DV) | n/a | 0.0002 |
| Obs | Number of observations | 1,798 | 219,134 |

- DV denotes that the variable is a dummy variable.

Thus, for each property, minimum distances to the lake as an indicator of travel distances for recreational activities were calculated. This distance variable was transformed into inverse distance and included in the econometric analysis. Sales prices were adjusted to constant 2007 dollars by applying a New Housing Price Index (NHPI) in Calgary provided by Statistics Canada to account for inflationary effects. Table 2.1 provides the definition and mean values of the variables used in the hedonic regressions. A map showing spatial distributions of property locations and sales prices in the study area (the Town of Chestermere) is presented in Figure 2.1. It is noteworthy that the higher priced properties are located close to the shoreline of the lake.

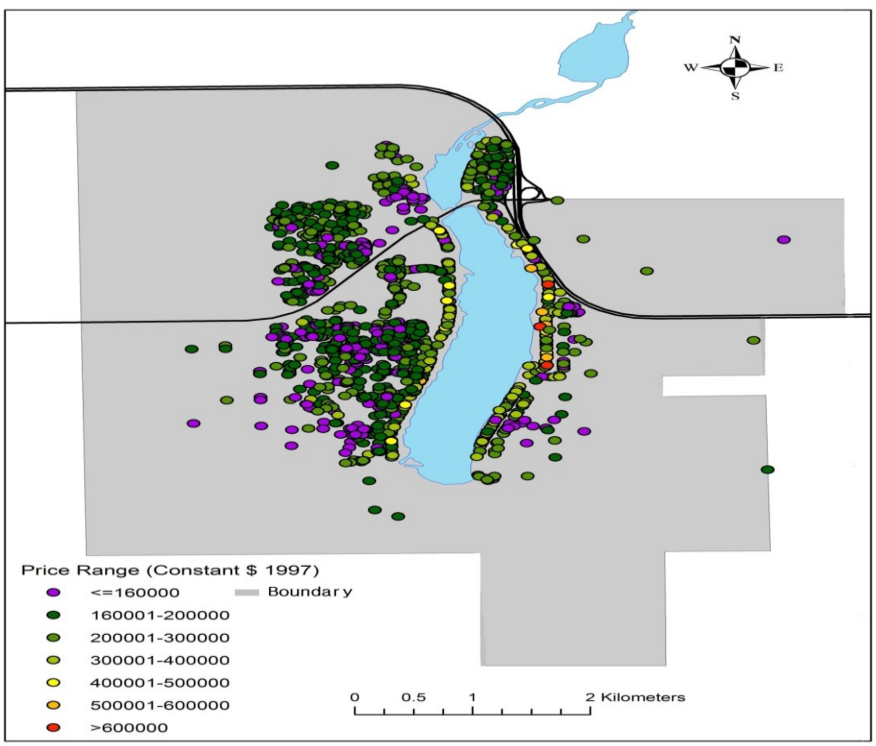



**Figure 2.1: A map of spatial distribution of housing sales price in study area**

A relatively high proportion of properties had a zero value for house age because many houses were newly built, had no garage spaces to store vehicles, or did not have fireplaces. Accordingly, we created categorical dummy variables for house age, garage spaces, and fireplaces as *hage_d1* through *hage_d4; szg_d1* through *szg_d4*; and *fp_d1* through *fp_d5+ respectively.* We included these categorical dummies in the econometric analysis rather than treating these variables as continuous to allow for non-linear effects of these attributes. We also generated dummy variables for each year during the time series of transactions in order to capture indirect effects of time on house prices. These are not included in table 2.1 for space considerations.

**Table 2.2: Proportional distribution of property transactions**

| Area | | Number of properties sold | | |
|---|---|---|---|---|
| | | Before WMA[1] | After WMA | Total |
| Chestermere | Waterfront | 44 | 47 | 91 |
| | Non-Waterfront | 608 | 1,099 | 1,707 |
| | Total | 652 | 1,146 | 1,798 |
| Calgary | Waterfront | 372 | 277 | 649 |
| | Non-Waterfront | 106,052 | 110,635 | 216,687 |
| | Total | 106,424 | 110,912 | 217,336 |
| | Grand total | 107,076 | 112,058 | 219,134 |

[1]This represents the Water Management Agreement signed between the Western Irrigation District and the Town of Chestermere in 2005.

The proportional distribution of observations for the DID and DIDID analysis are shown in table 2.2. For the DID data, out of 1,798 cases, houses sold after the WMA constitute 64% and non-water front houses comprise 95% of total sales. While the houses which are waterfront and sold before the WMA make up the least proportion (2.4%), non-waterfront houses which were sold after the WMA account for the most sales (61%). For the DIDID data, the sum of non-waterfront houses in Calgary sold before and after the WMA constitutes the largest proportion (99%) of all sales, while the proportion representing the DIDID observations (i.e. waterfront properties sold after the WMA in Town of Chestermere) make up 0.01% of sales.

In this merged data, the number of observations available to identify the impact of the WMA is quite small (i.e. the treatment group is very small relative to the overall sample). In such cases there may be too few observations to statistically capture the impacts of the policy home values (Zabel and Guignet 2012). However, in our analysis we find clear evidence that the implementation of the WMA has had an influence on the property values for waterfront houses despite the relatively few treatment observations.

### 2.4 Econometric Specifications

The first stage of the econometric analysis involved specifying the hedonic property value equation and the appropriate functional form. Based upon Box-Cox regression procedures and examination of the hedonic property literature the double log functional form of the hedonic property equation was chosen.

*Difference-in- Difference estimation*

The DID method, while widely used to analyze impacts of policy interventions, is also regarded as a suitable approach to deal with omitted variable bias[7] which is one of the econometric issues of concern in the hedonic pricing literature (Wooldridge 2002; Parmeter and Pope 2009; Heintzelman 2010). Thus, we assumed that the WMA represents the policy intervention, and that the values of Chestermere waterfront properties were significantly affected by its implementation in 2005. The treatment group was considered to be the Chestermere waterfront properties and the control group the Chestermere non-waterfront properties. To identify the sales that were affected by the WMA in our time series of sales we developed a dummy variable for the periods after the implementation of the WMA (i.e. from September 2005 to 2010).

Our first econometric specification used a group fixed effects structure to control for unobserved differences that might affect house prices between groups rather than relying on the cross sectional estimates (see Heintzelman 2010; Zabel and Guignet 2012; Muehlenbachs et al. 2012). Most of the hedonic property literature uses general census spatial patterns to deal with spatial dependencies. However, it is difficult for us to define groups by census zones or tracts because the Town of Chestermere is one census division. Alternatively, we defined spatial groups based on distances from the lake[8]. First group involved waterfront houses. Second group involved the properties which are located within 500 meters from

[7] Omitted variable bias occurs when the estimated model incorrectly misses one or more important causal factors. In other words, this problem arises if the missed (unobserved) variables are correlated with both the dependent and one or more independent variables included in the regression analysis.

[8] We also considered a different type of group-fixed effects based on geographic locations (east and west) or a different range of distances but these different specifications provided similar results.

the lake. The properties located between 500 meters and 1,000 meters from the lake belonged to the third group. Fourth group included the properties which are far away between 1,000 meters and 2,000 meters from the lake. Finally, the properties more than 2,000 meters away from the lake were placed into the fifth group.

The econometric model for DID estimation was:

$$\mathrm{lnP_{igt}} = \beta_0 + \beta_c \ln X_{it}^c + \beta_d X_{it}^d + \beta_{lake} \ln(\mathrm{invmtolake_{it}}) + \beta_{DID}\mathrm{DID_{it}} + \theta_t + \lambda_g + \mu_{gt} + \varepsilon_{igt} \qquad (2.8)$$

where $\mathrm{lnP_{igt}}$ is the log transformation of sales price for property *i* in group *g* at time *t*, $X_{it}^c$ and $X_{it}^d$ indicate property characteristics for continuous and dummy variables respectively. $\mathrm{invmtolake_{it}}$ is the inverse distance to the Chestermere Lake, $\mathrm{DID_{it}}$ represents dummy variable that is interacted with the dummy for the time periods the WMA has been in place (from September 2005 to 2010) and a dummy for each treatment group, $\theta_t$ represents a set of time dummy variables that capture any trends in sales prices over time, and $\lambda_g$ is a group fixed effect that absorbs differences that do not vary over time between groups. The terms $\beta_0$, $\beta_c$, $\beta_d$, $\beta_{lake}$, and $\beta_{DID}$ are individual or vectors of coefficients to be estimated. $\mu_{gt}$ and $\varepsilon_{igt}$ represents group and individual levels of error components, respectively.

The coefficient of interest, $\beta_{DID}$, is the difference in difference estimator for the periods WMA has been operated. More specifically:

$$\hat{\beta}_{DID} = \left(ln\bar{P}_{tr,\mathrm{WMA}=1} - ln\bar{P}_{tr,\mathrm{WMA}=0}\right) - \left(ln\bar{P}_{c,\mathrm{WMA}=1} - ln\bar{P}_{c,\mathrm{WMA}=0}\right) \qquad (2.9)$$

where $\bar{P}_{tr}$ represents the average sale price of waterfront properties, $\bar{P}_c$ is average sale price of non-waterfront properties. The first term in (2.9) is the average price difference due to the presence of the WMA with respect to waterfront houses and the second is on average price difference attributed to the WMA for non-waterfront houses. Thus, the parameter $\hat{\beta}_{\mathrm{DID}}$ captures the difference of these two terms.

Following Kennedy (1981), the average percentage change (APC) in waterfront house prices due to the WMA corresponding to Eq. (2.8) is:

$$\mathrm{APC} = \left\{\exp\left(\beta_{\mathrm{DID}} - \frac{1}{2}\mathrm{V}\big(\beta_{\mathrm{DID}}\big)\right) - 1\right\} * 100 \tag{2.10}$$

where $\mathrm{V}(\beta_{\mathrm{DID}})$ is an estimate of the variance of $\beta_{\mathrm{DID}}$.

*Difference-in-Difference-in-Difference estimation*

To address problems in DID frameworks such as potential endogeneity of the policy effect, the DID analysis was extended to a difference-in-difference-in-difference (DIDID) (see Bertrand et al. 2004). This approach represents a more robust analysis than DID in the sense that it involves other observations of property transactions which took place in a similar but different market. In our DID analysis, it was assumed that trends in sales between the two markets are not systematically different - in other words, in the absence of the WMA the price time paths of property values for lakefront and non-lakefront houses within the Town would move in parallel with those in a related market. This assumption, however, may not be assured since one cannot exclude the possibility that other factors irrelevant to the WMA could have an influence on the values of waterfront houses relative to the non-waterfront houses.

To obtain improved estimates of the impact of the WMA on waterfront property values, we use information from the Calgary housing region adjacent to the Town of Chestermere and where no such WMA policy was implemented to manage conditions of the lakes and/or reservoirs near residential areas in the region. Within Calgary several lakes and reservoirs provide residents with recreational activities and services similar to Chestermere, and one of these, Glenmore Reservoir, is a similar size. Instead of designating waterfront houses in Calgary as the control group in a different DID framework[9], we employed the triple difference estimator using both geographically distinct sales observations and a control group within the treatment group.

In essence, our DIDID estimation strategy implies that anything causing differential changes in property values for different property types (i.e. waterfront versus non-waterfront) is common to both Chestermere and Calgary. In other words, the DIDID estimator was specified to control for possible confounding trends, such as changes in property values of waterfront houses, across the two housing markets which may have no connection to the WMA at Chestermere Lake. The other component of the DIDID analysis is to control for the changes in property values of all properties within the Town of Chestermere which could be affected by town-specific factors. As in the DID model, we employed a group fixed effect model where each property was placed into one of four groups: non-waterfront houses in Calgary, waterfront houses in Calgary, non-waterfront houses in Chestermere, and waterfront houses in Chestermere. Dividing the sample into

[9] This specification could also be problematic because the changes in the waterfront property values might differ systematically between two housing markets due to other economic factors rather than the influence of the WMA.

smaller groups could be more effective in terms of controlling for more factors but doing so would be less likely to produce powerful estimates since sufficient within-group variation in each independent variable is necessary to obtain successful estimation. Increasing the range of group-fixed effects, however, would increase vulnerability to the presence of omitted variables (Heintzelman 2010).

The model structure of our DIDID estimation is expressed as follows:

$$\begin{aligned}\mathrm{lnP_{igt}} = \ & \beta_c \, \mathrm{lnX_{it}^c} + \beta_d \, \mathrm{X_{it}^d} + \beta_{\mathrm{Chestermere*wma}} \, \mathrm{Chestermere_{igt}} * \mathrm{WMA_t} \\ & + \beta_{\mathrm{wf*wma}} \, \mathrm{Wf_{it}} * \mathrm{WMA_t} + \beta_{\mathrm{lake}} \mathrm{ln(invmtolake_{it})} * \mathrm{Chestermere_{igt}} \\ & + \beta_{\mathrm{DIDID}} \mathrm{DIDID_{igt}} + \theta_t + \lambda_g + \mu_{gt} + \varepsilon_{igt} \qquad (2.11)\end{aligned}$$

where $\mathrm{lnP_{igt}}$ is the log transformation of sales price for property $i$ in group $g$ at time $t$ and $\mathrm{X_{it}^c}$ and $\mathrm{X_{it}^d}$ are the same variables defined as in Eq. (2.8). $\mathrm{Chestermere_{igt}}$ is a dummy variable for Chestermere properties, $\mathrm{Wf_{it}}$ is a dummy variable for those observations which are waterfront houses either in Calgary or in Chestermere, $\mathrm{WMA_t}$ indicates a dummy for the WMA from September 2005 to 2010, and the $\mathrm{Chestermere_{igt}} * \mathrm{WMA_t}$ term represents an additional dummy variable for Chestermere properties sold after the implementation of the WMA. Similarly, $\mathrm{Wf_{it}} * \mathrm{WMA_t}$ is a dummy variable equal to one for those observations which are waterfront properties sold in either Calgary or in Chestermere after the signing of the WMA. The variable, $\mathrm{ln(invmtolake_{it})} * \mathrm{Chestermere_{igt}}$ , represents log of the inverse of distance to the Chestermere Lake, which is interacted with a dummy variable for Chestermere properties. Finally, $\mathrm{DIDID_{igt}}$ represents the product between $\mathrm{Chestermere_{igt}}$, $\mathrm{Wf_{it}}$, and $\mathrm{WMA_t}$ and is equal to 1 only if a property type is waterfront sold in Chestermere after signing of WMA and 0 otherwise. As defined in Eq. (2.8), $\theta_t$ is a set of time dummies and $\lambda_g$ is a group fixed effect. The coefficient of interest, $\beta_{DIDID}$ is the difference in difference in difference estimator of the following expression:

$$\hat{\beta}_{DIDID} = \left(ln\bar{P}_{treatment,wf,WMA=1} - ln\bar{P}_{treatment,wf,WMA=0}\right)$$
$$- \left(ln\bar{P}_{control,wf,WMA=1} - ln\bar{P}_{control,wf,WMA=0}\right)$$
$$- \left(ln\bar{P}_{treatment,non-wf,WMA=1} - ln\bar{P}_{treatment,non-wf,WMA=0}\right) \qquad (2.12)$$

where the first term in (2.12) is interpreted as the average house price difference due to the WMA with respect to waterfront houses in Chestermere, while the second term is expressed as the house price difference resulting from the WMA in relation to waterfront houses in Calgary. The last term captures the price difference as a consequence of the WMA for non-waterfront houses in Chestermere. Note that $\beta_{DIDID}$ will collapse into the DID estimator if this middle term is excluded.

## 2.5 Results and Discussion

*DID results*

Coefficients and clustered standard errors for the DID model were estimated using the STATA10 software package. These estimates are shown in the second and third columns of table 2.3[10]. The estimates are statistically significant at the 10% level with the exception of the *bedroom, hage_d4, szg_d2, detgarage* and *sfhouse* variables, and the signs of parameters are as expected. For example,

[10] To validate the group fixed effects, we test for the hypothesis that group effects are jointly zero and the results reject the null hypothesis in favor of the group fixed effects.

the larger the area of residence and the more bathrooms in the house, the higher its price. For polychotomous binary variables, the coefficient for each variable can be interpreted in comparison to the reference category variable while controlling for the other independent variables. For instance, the coefficient on *hage_d2* implies that holding other features constant the properties which are 6 to 10 years old have about 3.5% lower prices compared to *hage_d1*. Note that the sign of *hage_d3* variable is not of the expected sign (i.e. the sign of this variable was expected to be negative suggesting older properties have lower prices but it is positive). This result probably arises from the fact that the age of waterfront houses are typically older than non-waterfront properties because in Chestermere's historical development waterfront properties were constructed first. The remaining variables, *szg_d3* through *szg_d4* and *fp_d2* through *fp_d3* can be interpreted in a similar way that is applied to the house age case.

The inverse distance to Chestermere Lake from a residence was entered in the regression (i.e. *invmtolake* variable). This transformation implies an asymptotic property for the price-distance relationship (Ihlanfeldt and Taylor 2004). The positive coefficient for the inverse of the distance to the lake indicates that property prices increase at a decreasing rate as distance from the lake decreases. In other words, the closer the property is to the shoreline, the higher its price is. Since the functional form follows a log-log specification, the estimated coefficient of the *invmtolake* variable represents the elasticity of price with respect to the inverse distance to the lake.

**Table 2.3: Parameter estimates for the DID and DIDID analysis**

| | DID model | | | DIDID model | |
|---|---|---|---|---|---|
| Variable | Coefficient [a] | Std. Err.[b] | Variable | Coefficient [a] | Std. Err [b]. |
| constant | 10.314 | 0.063 | constant | 7.975 | 0.017 |
| | | | Chestermere*WMA | -0.027 | 0.0004 |
| | | | wf*WMA* | 0.011 | 0.016 |
| DID | 0.054 | 0.023 | DIDID | 0.034 | 0.002 |
| ln(area) | 0.361 | 0.009 | ln(area) | 0.665 | 0.003 |
| ln(bed)* | -0.026 | 0.029 | ln(bed) | -0.136 | 0.001 |
| ln(bath) | 0.089 | 0.015 | ln(bath) | 0.173 | 0.001 |
| hage_d1 | | | hage_d1 | | |
| hage_d2 | -0.035 | 0.015 | hage_d2 | -0.056 | 0.001 |
| hage_d3 | 0.057 | 0.012 | hage_d3 | -0.092 | 0 |
| hage_d4* | 0.067 | 0.128 | hage_d4 | 0.104 | 0.001 |
| ln(invmtolake) | 0.045 | 0.004 | ln(invmtolake)*Chestermere | 0.029 | 0.001 |
| ac | 0.049 | 0.003 | ac | 0.109 | 0.001 |
| decbal | 0.046 | 0.006 | decbal | 0.025 | 0.0002 |
| szg_d1 | | | szg_d1 | | |
| szg_d2* | 0.076 | 0.046 | szg_d2 | 0.003 | 0.001 |
| szg_d3 | 0.196 | 0.049 | szg_d3 | 0.238 | 0.009 |
| szg_d4 | 0.234 | 0.038 | szg_d4 | 0.235 | 0.01 |
| fp_d1 | | | fp_d1 | | |
| fp_d2 | 0.086 | 0.007 | fp_d2 | 0.135 | 0.0002 |
| fp_d3 | 0.108 | 0.038 | fp_d3 | 0.31 | 0.002 |
| | | | fp_d4 | 0.416 | 0.008 |
| | | | fp_d5 | 0.565 | 0.078 |
| detgarage* | 0.036 | 0.038 | detgarage | 0.123 | 0.001 |
| sfhouse | 0.067 | 0.045 | sfhouse | 0.062 | 0.0002 |
| housetype | 0.135 | 0.015 | housetype | 0.061 | 0.001 |
| summer | 0.03 | 0.006 | summer | 0.019 | 0.0002 |
| Test for FE | F (4,1764)=67.5, P=0.000 | | Test for FE | F (3,219097)=291.2, P=0.000 | |
| N | 1,798 | | N | 219,134 | |
| Adj $R^2$ | 0.76 | | Adj $R^2$ | 0.72 | |

[a] For space considerations, the coefficients for year dummies are not reported in the table.

- Note that variables with * are NOT significant at 10%.

[b] SEs were clustered at the level of spatial fixed effects to control for potential heteroscedasticity.

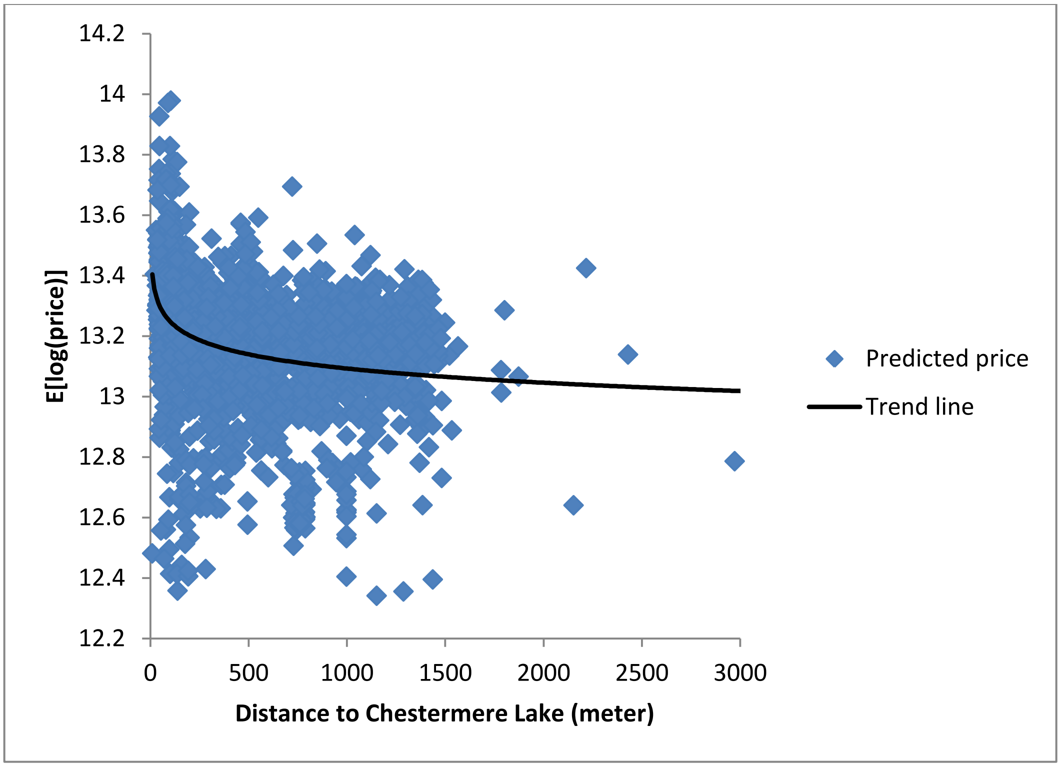



**Figure 2.2: Relationships between sales prices of properties in the Town of Chestermere and distance to Chestermere Lake**

Figure 2.2 shows the impact of distance from Chestermere Lake on predicted prices. While the trend line shows predicted prices decrease as distance to the lake increases, the gradient becomes more gradual with the increase in the distance to the lake.

The coefficient on the $DID$ variable represents the % change in prices for waterfront houses due to the WMA and since this coefficient is positive, we find evidence that the implementation of the WMA in September 2005 have had a positive and significant impact on the sales prices of waterfront home values since it has been in force. Using the formula specified in Eq. (2.10), $DID$ suggests that the WMA resulted in a 5.5% increase in property values for waterfront houses.

To illustrate the differential impact of the WMA between the control and the treatment group, the predicted mean prices of these two groups obtained are plotted by year in Figure 2.3. The sales prices in each of the two groups are quite similar prior to the implementation of the WMA. However, the sales price trends up for the waterfront properties after the signing of the WMA while prices of the non-waterfront sales remain stable.

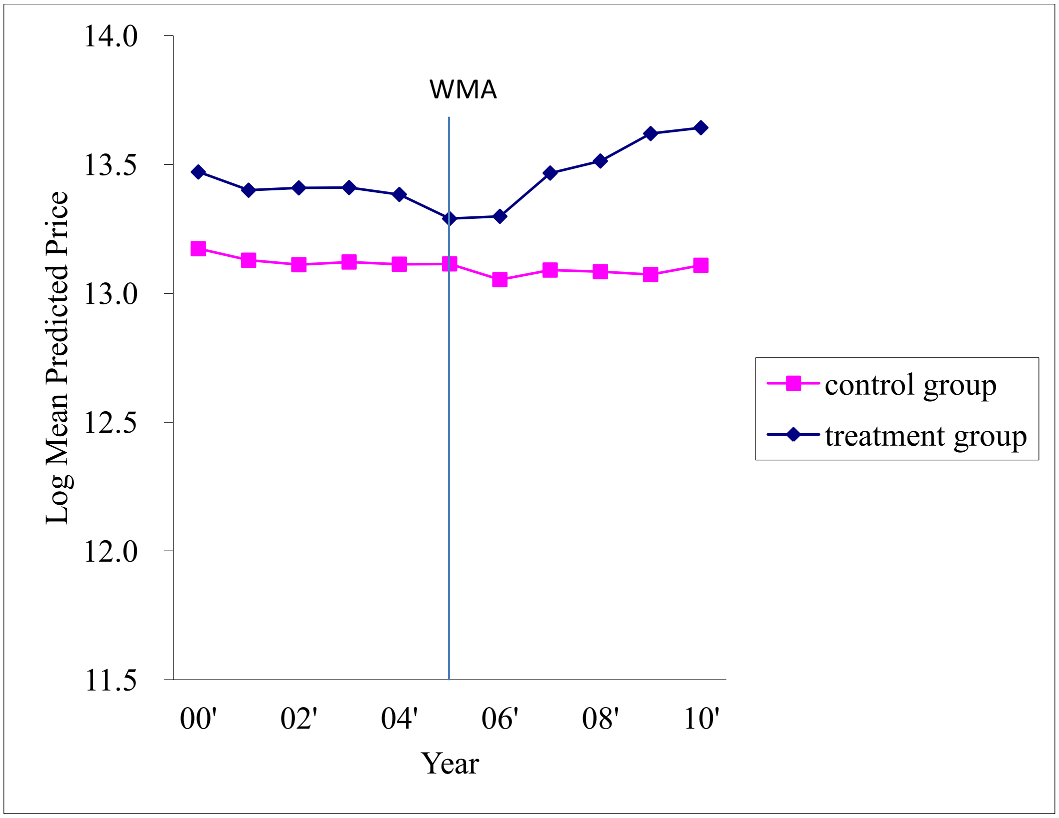



**Figure 2.3: Predicted mean price (2007 $CAD) of properties sold in Chestermere Lake from 2000 to 2010 using coefficients from the difference in difference analysis**

*DIDID results*

Coefficient estimates for the DIDID model are given in the fourth and fifth columns in table 2.3. This DIDID model does a reasonable job of explaining variation in sales price (adjusted $R^2$=0.72). Except for one variable, most of the parameters are statistically significant and are similar to the DID results as expected. The estimated coefficients for the dummy variables on house age (*hage_d2* through *hage_d3*) are negative in sign and statistically significant compared to the base category (*hage_d1*). For *szg_d2-szg_d4* and *fp_d2- fp_d5*, these variables are positive and significant in comparison to their corresponding base categories. The interpretation of these polychotomous binary variables is similar to that described above. The remaining dummy variables such as *ac*, *decbal*, and *detgarage* are positive in sign and statistically significant at the 10% level or better implying that the prices of the properties with these features are higher than those that do not have them. The inverse distance from a residence to Chestermere Lake was interacted with a dummy variable for Chestermere properties in these models (i.e. ln(*invmtolake)∗chestermere* variable) which limits the effect of the Chestermere Lake to properties in the Town of Chestermere only. As in the DID estimates, this coefficient represents the elasticity of price and it is positive and significant indicating that property prices in the Town decrease as distance from the lake increases.

The parameter for *Chestermere*∗ $WMA$ interaction term suggests that sales prices for properties in the Chestermere housing market sold since the implementation of the WMA are, on average, different from those that are not (i.e. the reference category). Thus, the negative and significant coefficients on these dummy variables imply decreases in prices for Chestermere properties sold from September 2005 to 2010. Applying the formula specified in Eq. (2.10), the result shows a 2.7% reduction in house prices. Similarly, the variable, $wf* WMA,$ which represents waterfront houses sold either in the Chestermere housing market or in the Calgary housing market interacted with WMA dummy, indicates on average the difference in house prices from those in the reference category. However, this variable is not statistically significant suggesting that the change in prices of waterfront houses sold in both regions is not different to properties which belong to the reference category.

Turning to the variables of main interest, the coefficient on the *DIDID* variable represents the % change in prices for waterfront properties sold only in Chestermere due to the WMA. Similar to the DID estimates, the result supports the hypothesis that the implementation of the WMA had a positive and significant influence on the waterfront property values. Even though the magnitude of the DIDID coefficient is smaller than in the DID model, the impacts of WMA on waterfront properties estimated between DID and DIDID models are statistically equivalent[11]. Using the same approach as in the DID model, the percentage increase in prices due to the WMA resulted, on average, in a 3.4% increase in property values for Chestermere waterfront houses.

*Discussion*

Given the positive and significant coefficients associated with the impact of the WMA on Chestermere waterfront properties, it is straightforward to calculate the increase on property values for waterfront houses generated by the

[11] We test for the equality of two coefficients, DID and DIDID using the statistical test (Z-test) discussed by Paternoster et al. (1998). The results indicate that the null hypothesis cannot be rejected implying no difference of WMA effects estimated between two models.

WMA. Some caution is required, however, when interpreting the results obtained from the DID and DIDID models. As discussed in the literature, the hedonic price approach is confined to the examination of marginal changes in environmental goods (Grafton et al. 2004). In other words, the quasi-experimental hedonic property analyses used in this study cannot normally provide the exact welfare measures associated with large changes in environmental goods but would provide a reasonable approximation of welfare effects (Phaneuf and Requate, forthcoming). Thus, the impact of the WMA estimated here would be better interpreted as an approximate welfare measure associated with the discrete change in the condition of Chestermere Lake due to the WMA. In addition, we assume that the impacts of changes in condition of Chestermere Lake are localized and are identified in properties located in the Town of Chestermere only. This exogenous change will not shift the hedonic equilibrium price function ex post in response to the change in the status of Chestermere Lake (Chattopadhyay et al. 2005; Ihlanfeldt and Taylor 2004).

To assess the influence of the WMA on waterfront houses in the Town of Chestermere, the estimated increase in property values $\Delta P$ in year 2007 dollars from the DID and DIDID estimates is given by:

$$\Delta P = \left\{ \exp\left( \beta^{i} - 0.5 * V\left(\beta^{i}\right) \right) - 1 \right\} * \mathrm{Price}_{\mathrm{median}}^{\mathrm{wf}} \qquad (2.13)$$

where i=DID and DIDID, $V\left(\beta^{i}\right)$ is the variance of $\beta^{i}$ and $\mathrm{Price}_{\mathrm{median}}^{\mathrm{wf}}$ is the median price of waterfront houses which is adjusted in \$2007 dollars. The resulting increases in property value are reported in table 2.4 and appear to be substantial. While price increases per property are about \$53,143 based on the

DID estimates, they are about $32,896 using the DIDID estimates. Note that the waterfront properties in Chestermere are of very high value even in the absence of the WMA (e.g. the median price of waterfront properties in the dataset is $963,597 in $2007 dollars) and thus the percentage value increases are considerable.

**Table 2.4: Estimates of the property value increase due to the implementation of the WMA in the Town of Chestermere at the median sales price in year 2007 dollars**

| No. of WF Properties | DID analysis | | DIDID analysis | |
|---|---|---|---|---|
| | Value increase ($/property) | Total value increase ($ millions) | Value increase ($/property) | Total value increase ($ millions) |
| 389 | 53,143 | 20.7 | 32,896 | 12.8 |

To put these values in context, the total tax revenue accruing to the Town from these property value increases can be computed annually by applying the estimates in table 2.3 to the total number of waterfront properties in the Town. Given the limited length of the shoreline in the Chestermere Lake, and that there are virtually no areas along the lake where new waterfront properties can be constructed, we used total number of waterfront properties that are based on 2010 property estimates. This revenue is about $ 20.7 million using the DID results, and about $12.8 million using the DIDID results.

When local governments assess property taxes they perform an appraisal of the monetary value of each property and annual taxation levels are based on the assessed value of each property. Since the WMA resulted in an increase in property value for waterfront properties, the Town of Chestermere would gain increased tax revenue due to the WMA. The Town could internalize the positive externalities of their investments (i.e. WMA) by means of an additional tax levied by the Town on the beneficiaries (i.e. owners of the waterfront properties). Therefore, these tax-revenue increases allow the Town to pay the WMA service fee and by comparing the benefits and the costs it would be feasible to identify how much the WID service fee was offset by tax increments. Based on this perspective, we determined whether the Town is making a sound investment in terms of their payment to the WID.

**Table 2.5: Comparison of property tax revenues and fees paid from 2006-2010 to the Western Irrigation District for the Water Management Agreement in Chestermere Lake**

| Model | Total increase in value of waterfront properties ($ millions) | Annual tax rate (%) | Total tax revenue to the Town from 2006-2010 | WMA service fee paid 2006-2010 | % of fee captured by the Town |
|---|---|---|---|---|---|
| DID | 103.4 | 0.46 | 473,372 | 1,848,978 | 25.6 |
| DIDID | 64 | 0.46 | 292,027 | 1,848,978 | 15.8 |

- The municipal residential tax rates are applied.

Using average property tax rates from year 2006 to 2010, table 2.5 shows total property value increases and total tax revenue increments captured by the Town of Chestermere since WMA has been implemented. Note that these total tax increments are the revenues captured from waterfront properties only. In table 2.5, total tax increments were calculated by multiplying total value increases and tax rates and WMA service fee in each year from 2006 to 2010 was calculated by Eq. (2.14). The percentage capture is the proportion of total tax increment to WMA service fee shown by:

$$\text{WMA fee}_t = \text{WMA fee}_{t-1} + (\text{WMA fee}_{t-1} * \text{Annual \% change in CPI in Calgary}) \quad (2.14)$$

where CPI denotes consumer price index and $\text{WMA service fee}_{\text{base,2006}} = \$334{,}381.5$.

Note that in table 2.5, WID fee is the sum of the annual fees that the Town of Chestermere has paid to the WID for the WMA-related services. These fees are converted to year 2007 dollars.

Total tax increments calculated over all waterfront properties due to the implementation of the WMA are substantial, which are calculated to be about $473,372 from the DID analysis and $292,027 based on the DIDID analysis. These estimated tax revenues cover approximately 25.6% of the Town's expenses related to the WMA service fee from the DID estimates while they offset 15.8% of the Town's costs using the DIDID estimates. Given that the WMA would affect waterfront property owners the most, the fees paid for enjoyment of services is virtually met by the increased annual tax revenues associated with the property value increase.

## 2.6 Conclusions

This study sought to understand the impact of water stabilization on property values due to the implementation of water management policy using the case of irrigation infrastructure - Chestermere Lake. More specifically, this study focused on identifying the differential effect of the stabilization of water levels and quality on the sales prices between waterfront and non-waterfront houses.

Applying hedonic property analysis in combination with quasi-experimental techniques, our results suggest that the economic value of increases in property values, an ecosystem service provided by the irrigation infrastructure, is considerable. The methodological methods utilized in this study may be a better approach to produce plausible estimates of the value captured by the infrastructure generating those services. Consequentially, these economic values were used to estimate the additional town tax revenues that resulted from the increase in the provision of services generated by water management.

We find evidence that water management had a substantial and positive impact on property values for property owners who benefited from them. This result illustrates the significance of water management in generating increased economic values of an ecosystem service. Moreover, even though the number of properties directly affected by the water stabilization policy in the study area is small, the total benefits arising from the water management policy are sufficiently large to generate tax increments that can be used to offset the costs paid by the local government to irrigators to manage water conditions in the lake. Finally, in this case one could judge that Town of Chestermere is making a reasonable investment in the agreement with the irrigators because increased taxes appear to offset the annual fee paid to obtain these services.

## References


Alberta Lake Management Society's Lakewatch Program. 2010. *2010 Chestermere Lake Report,* completed with support from Government of Alberta.

Bertrand, M., E. Duflo, and S. Mullainathan. 2004. "How much should we trust differences-in-differences estimates?" *Quarterly Journal of Economics* 119 (February): 249-275.

Bin, Okmyung, C. E. Laundry, and G. F. Mayer. 2009. "Riparian Buffers and Hedonic Prices; A Quasi-Experimental Analysis of Residential Property Values in the Neuse River Basin." *American Journal of Agricultural Economics* 91(4): 1067-1079.

Bin, Okmyung and Stephen Polasky. 2004. "Effects of Flood Hazards on Property Values: Evidence Before and After Hurricane Floyd." *Land Economics* 80 (November): 490-500.

Bockstael, N. E. and K. E. McConnell. 2007. *Environmental and Resource Valuation with Revealed Preferences*. Dordrecht, The Netherlands: Springer.

Boxall, P. C., W. H. Chan, and M. L. McMillan. 2005. "The impact of oil and natural gas facilities on rural residential property values: a spatial hedonic analysis." *Resource and Energy Economics* 27:248-269.

Boyle, K. J., P. J. Poor, and L. O. Taylor. 1999. "Estimating the Demand for Protecting Freshwater Lakes from Eutrophication." *American Journal of Agricultural Economics* 81:1118-1122.

Chattopadhyay, S., J. B. Braden, and A. Patunru. 2005. "Benefits of Hazardous Waste Cleanup: New Evidence from Survey-and Market–Based Property Value Approaches." *Contemporary Economic Policy* 23(3):357-375.

Czajkowski, Jeffrey and Okmyung Bin. 2010. "Do Homebuyers Differentiate between Technical and Non-Technical Measures of Water Quality? Evidence from a Hedonic Analysis in South Florida." Working Paper ecu1007, Department of Economics, East Carolina University.

Alberta Environment, Government of Alberta: www.environment.alberta.ca

Grafton, Q., W.L. Adamowicz, D. Dupont, H. Nelson, R. Hill, and S. Renzetti. 2004. *The Economics of the Environment and Natural Resources*. Basil Blackwell Publishers.

Heintzelman, M. D. 2010. "The Value of Land Use Patterns and Preservation Policies." *The B.E. Journal of Economic Analysis & Policy*: Vol. 10: Iss. 1 (Topics), Article 39.

Ihlanfeldt, K. R. and L. O. Taylor. 2004. "Externality effects of small-scale hazardous waste sites: evidence from urban commercial property markets." *Journal of Environmental Economics and Management* 47:117-139.

Kennedy P. E. 1981. "Estimation with Correctly Interpreted Dummy Variables in Semilogarithmic Equations." *The American Economic Review* 70(4):801.

Landford, N. H., and L. L. Jones. 1995. "Recreational and aesthetic value of water using hedonic price analysis." *Journal of Agricultural and Resource Economics* 20:341-355.

Leggett, C. G. and N. E. Bockstael. 2000. "Evidence of the Effects of Water Quality on Residential Land Prices." *Journal of Environmental Economics and Management* 39:121-144.

Loomis, J. and M. Feldman. 2003. "Estimating the benefits of maintaining adequate lake levels to homeowners using the hedonic property method." *Water Resources Research* 39(9):1259.

Michael, H. J., K. J. Boyle, and R. Bouchard. 2000. "Does the Measurement of Environmental Quality Affect Implicit Prices Estimated form Hedonic Models?" *Land Economics* 76(May): 283-298.

Millennium Ecosystem Assessment (2006): www.milleniumassessment.org

Mitchell, R. and E. Prepas. 1990. *Atlas of Alberta Lakes*. University of Alberta Press. Available at: http://alberta-lakes.sunsite.ualberta.ca/

Muehlenbachs, L., E. Spiller, and C. Timmins. 2012. "Shale Gas Development and Property Values: Differences across Drinking Water Sources." Working Paper 18390, National Bureau of Economic Research.

Muller, N. Z. 2009. "Using hedonic property models to value public water bodies: An analysis of specification issues." *Water Resources Research* 45: W01402, doi:10.1029/2008WR007281.

Palmquist, R. B. 2005. "Property Value Models", chapter 16 in *Handbook of Environmental Economics*, volume 2, K.G. Mäler and J. Vincent, eds., Elsevier, Amsterdam

Parmeter, C. F. and Jaren C. Pope. 2009. *Quasi-Experiments and Hedonic Property Value Methods*. Prepared for the Handbook on Experimental Economics and Environment: Edward Elgar Publishers.

Parternoster, R., Brame, R., Mazerolle, P., and A. Piquero. 1998. "Using the correct statistical test for the equality of regression coefficients." *Criminology* 36(4): 859-866.

Phaneuf, Daniel J. and Till Requate. Forthcoming. *A Graduate Course in Environmental Economics: Theory, Policy, and Practice.* Cambridge University Press.

Poor, P. J., K. J. Boyle, L. O. Taylor, and R. Bouchard. 2001. "Objective versus Subjective Measures of Water Clarity in Hedonic Property Value Models." *Land Economics* 77(November): 482-493.

Pope, J. C. 2008. "Do Seller Disclosures Affect Property Values? Buyer Information and the Hedonic Mode.l" *Land Economics* 84(4): 551-572.

Rogen, S. 1974. "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition", *Journal of Political Economy* 82(1):34-55

Western Irrigation District: http://www.wid.net

White, J. S. and P. Biol. 2001. The water quality of Chestermere Lake: *A state of the knowledge report*. *Aqua*lity Environmental Consulting Ltd.

Wooldridge, J. M. 2002. *Econometric Analysis of Cross Section and Panel Data*, Cambridge, Massachusetts, London, England: The MIT Press.

Zabel, J. E. and D. Guignet. 2012. "A hedonic analysis of the impact of LUST sites on house prices." *Resource and Energy Economics* 34:549-564.

# CHAPTER 3: THE ECONOMIC VALUE OF AN IMPROVEMENT IN AN AQUATIC ECOSYSTEM SERVICE: MODIFYING CHOICE SET FORMATION IN A DISCRETE HOUSE CHOICE ANALYSIS

Even though the value of changes in environmental attributes could be evaluated by marginal implicit prices obtained from the first-stage and quasi-experimental hedonic property analysis described in the previous chapter, this value would be valid only for marginal changes in property attributes (Grafton et al., 2004). Furthermore, those values would be a good approximation of welfare change only if the assumption regarding a localized impact of change in environmental attributes is met. For validating non-marginal changes in attributes, as well as identifying more precise welfare measures, two different methodologies using revealed preference data (market data) can be considered; a two-stage hedonic approach and a discrete residential choice model.

The two-stage hedonic method can be used to recover an inverse demand function and derive consumer surplus welfare measures (Boyle et al. 1999; Palmquist and Israngkura 1999; Zabel and Kiel 2000; Brasington and Hite 2005). To estimate demands for environmental attributes using this two-stage method, marginal implicit prices for the environmental variables, which can be obtained from the first stage hedonic estimation, are regressed on the quantities of environmental attributes and household socio-demographic characteristics in a second stage hedonic estimation (Palmquist, 2005; Bockstael and McConnell, 2007). This approach, however, is challenging to apply since it must deal with issues such as data availability and econometric-related issues (Phaneuf and Requate, forthcoming; Bockstael and McConnell 2007). These problems are elaborated below.

The challenges in estimating hedonic second stage models arise since the analysis of the hedonic model relies on using market data which in general do not include the home buyer's socioeconomic information that would be crucial to recover consistent parameters of preferences in the second stage estimation. To obtain consistent parameters in second stage estimation, two significant econometric-related issues to overcome have been discussed in the literature. One of which is associated with the difficulty of figuring out the appropriate instruments for the endogeneity problem, which occurs since marginal implicit prices of attributes derived from the first stage estimation are regressed on a set of explanatory variables including the quantity of own attributes in estimating inverse demand functions. Consequently, this results in environmental attributes being correlated with error terms in the second stage estimation unless a linear functional form for the hedonic price schedule is specified in the first stage estimation[12]. Otherwise, an appropriate instrument must be used for consistent estimation. Moreover, estimating demand equations require an adjustment of income which could be applied by linearizing the budget constraint, but this will be endogenous as well.

The other issue is related to discriminating inverse demand functions from the hedonic price function, which has been called the identification problem in the

[12] Other non-linear functional foams will indicate that households will choose the quantity of attributes and marginal implicit prices of attributes simultaneously (Phaneuf and Requate, forthcoming).

hedonic literature (Phaneuf and Requate, forthcoming; Palmquist, 2005; Day, 2001).

The discrete choice residential location model initially developed by McFadden (1978)[13] where the theoretical underpinnings are based on the random utility model (RUM), has been employed for the valuation of environmental goods, especially for non-marginal changes in environmental attributes. A discrete house choice model is similar to a hedonic property model in conceptual terms as the model can be developed based on the combination of attributes of a house (Grafton et al., 2004). They are, however, different with respect to various theoretical and empirical aspects. While the hedonic property method examines the relationship between attributes of a house and house price, a discrete choice model focuses on an individual's exclusive house choice decision from a given finite set of houses available to them.

Another distinction between the hedonic model and the discrete choice model would be the different approaches used to regain preference parameters (Bockstael and McConnell, 2007). While the hedonic approach depends on the precise gradient of the estimated hedonic function since it requires marginal implicit prices of attributes in order to incorporate them into a second-stage hedonic model, the discrete choice model does not require this step since preference parameters can be directly recovered from the utility function identified from parameter estimates. This advantage has appeal for the application of a discrete choice model in the environmental valuation literature.

[13] More precisely, the consumer's residential decision model he proposed is specified as the choice of dwelling unit given the choice of community.

Before proceeding to the next section, it would be useful to emphasize an important issue which has received attention in the discrete choice literature. Irrespective of any discrete choice applications of random utility theory, the requirement to define the choice set from which a consumer selects an alternative has become crucial to estimate accurate model parameters and thus generate welfare measures associated with changes in the attributes of the alternatives. Studies associated with the examination of other choice outcomes have uncovered significant impacts by applying alternatively defined choice sets, and have contributed to creating more realistic/precise estimates of choice sets. Examples include Manski (1977), Swait and Ben-Akiva (1987a, 1987b), Horowitz and Louviere (1995), Ben-Akiva and Boccara (1995), Peters et al. (1995), Haab and Hicks (1997), Cascetta and Papola (2001), Martinez et al. (2009), and Truong (2013).

In this second paper, we extend the housing choice literature through examination of the choice set issue. In the context of residential choice analysis, the choice set issue will also be important because one must make assumptions about the size and extent of the set of choices from which a home buyer will make a purchase. As discussed by Banzhaf and Smith (2007), the model parameters of attributes estimated will be affected by the assumptions regarding the choice set and thus the assessment of welfare measures associated with environmental attributes will vary depending on these assumptions.

The present study proposes an approach that modifies choice sets using limited data availability in the context of a residential choice model. We develop a discrete housing choice model which takes the availability of properties for potential home buyers into consideration by introducing an explicit approach to deal with the issue of choice set formation.

### 3.1 Theoretical Framework of Discrete House Choice

This section[14] presents a brief review of the theoretical framework associated with a discrete house (location) choice model based on random utility theory. The household's utility maximization problem associated with discrete housing choice can be described as:

$$\max_{\{h,z\}} U(h_i \dots h_m, q_i \dots q_m, z)$$

$$\text{Subject to} \quad \sum_i^m p_i \cdot h_i + z \le Y$$

$$h_i \cdot h_m = 0 \quad \forall\, i \neq m$$

$$h_i = h_i^* \quad \forall\, i$$

where the subscript *i* denotes one of *m* alternatives available to the household; *h* denotes a residential property (or its location); *q* is a vector of property-related quality attributes; *p* is the price of property *i*; *z* is the numeraire good with which price is normalized to one, and *Y* is household income. In the constraint, the second condition implies that only one unit of the $i^{th}$ house is consumed (i.e. other remaining houses are zero) and the third condition indicates that the chosen $i^{th}$ house is the optimal choice. These two conditions together mean that household's property choice is mutually exclusive (i.e. only one house can be chosen by the household).

[14] This theoretical presentation is mainly taken from Bockstael and McConnell (2007) and Grafton et al. (2004).

Conditional on the choice of the $i^{th}$ house over the other properties available, the utility maximization problem can be solved yielding an indirect utility function. Incorporating additive random components suggested by Ben-Akiva and Lerman (1985) into the indirect utility function, a stochastic indirect utility function can be described as:

$$V_i(Y - p_i, q_i, \varepsilon_i) = V_i(Y - p_i, q_i) + \varepsilon_i$$

where $\varepsilon_i$ is the error component. Because utility is stochastic, the probability that household *n* chooses property *i* over all other alternative properties in the choice set, $J_n$ can be identified as:

$$\mathrm{Pr}_{n,i} = \mathrm{Pr}\,\{ V_{n,i} + \varepsilon_{n,i} > V_{n,m} + \varepsilon_{n,m} \}$$

$$= \{V_{n,i}(y_n - p_i, q_i) - V_{n,m}(y_n - p_m, q_m) > \varepsilon_{n,m} - \varepsilon_{n,i} \}\ \forall\ i, m \in J_n, i \neq m \qquad (3.1)$$

If all error terms are assumed to follow a type I extreme value distribution (Gumbel), then Eq. (3.1) can be represented by:

$$\mathrm{Prob}_{n,i} = \frac{\exp^{\{\mu \cdot V_{n,i}\}}}{\sum_{m \in J_n} \exp^{\{\mu \cdot V_{n,m}\}}} = \frac{\exp^{\{\mu \cdot V_{n,i}(y_n - p_i, q_i)\}}}{\sum_{m \in J_n} \exp^{\{\mu \cdot V_{n,m}(y_n - p_m, q_m)\}}} \qquad (3.2)$$

where $\mu$ is a scale factor which is assumed to be one. Suppose a conditional indirect utility function is specified as:

$$V_i(Y - p_i, q_i) = \beta_1(Y - p_i) + \beta_2(q_i)$$

where $\beta_1$ and $\beta_2$ are parameters to be estimated. Then Eq.(3.2) can be re-expressed as:

$$\mathrm{Prob}_{n,i} = \frac{\exp^{\{\beta_1(Y - p_i) + \beta_2(q_i)\}}}{\sum_{m \in J_n} \exp^{\{\beta_1(Y - p_m) + \beta_2(q_m)\}}} \qquad (3.3)$$

As discussed by Banzhaf and Smith (2007), the estimation of parameters will be affected by how one specifies the choice set, *J* even though the uniform conditioning rules[15] suggested by McFadden are applied since in Eq. (3.3) the individual choice set, $J_n$ is in the denominator. Welfare measures associated with changes in attributes can be estimated based on the maximum of the stochastic indirect utility function. The compensating variation (CV) associated with a quality change for alternative $j$ in consequence of some policy implementation can be defined as:

$$\max_{j \in J_n}\{V_{n,j}(y_n - p_j, q_j^0, \varepsilon_{n,j})\} = \max_{j \in J_n}\{V_{n,j}(y_n - CV - p_j, q_j^1, \varepsilon_{n,j})\} \qquad (3.4)$$

where superscripts 0 and 1 imply before and after the quality change, respectively. Besides two assumptions about the error term structure, which are additive and follow a Gumbel distribution, if the utility function is linear in income, Eq. (3.4) has a closed form and can be expressed as:

$$E\,(CV) = \frac{1}{\beta_y}[\ln(\textstyle\sum_j^J \exp\,(V_j^1)) - \ln(\textstyle\sum_j^J \exp\,(V_j^0))].$$

### 3.2 Review of Related Literature

The discrete choice model has been popular in modelling the choice of differentiated goods such as recreational sites, transportation modes, school districts, and vehicles etc (Bockstael and McConnell 2007). Since numerous studies applying discrete choice models have been undertaken, it would be infeasible to examine and present all of these studies. Therefore, our literature review will be limited to the relevant examples where discrete choices of residences or their location based on a random utility framework have been

[15] These rules suggested by McFadden (1978) are often used as a way of constructing a subset of alternatives from the overall choice sets and to reduce the computational burdensome of empirical estimation in the context of presence of large alternatives available.

applied to assessing the economic value of changes in environmental attributes in response to the implementation of a new policy and/or exogenous environmental events.

Prior to reviewing the literature, it is worth noting that in discrete choice housing applications, there have been two different approaches in terms of the unit of choice; 1) choice of individual residential structures; and 2) choice of specific residential areas in which specific neighborhoods are defined by some criteria such as geographical boundaries (census block) and/or school districts etc. (Phaneuf and Requate forthcoming). The latter approach, known as the residential sorting model,[16] was triggered by Bayer et al. (2005)[17] and its application has been generally used in the context of urban market settings associated with environmental valuation studies.

The fundamental difference between these two approaches involves the definition of sets of housing choices that are available to home buyers. Most studies employing individual housing unit choice utilize the same number of alternative housing units for each household generated using random sampling rules (Phaneuf and Requate forthcoming). However, it seems implausible to

[16] Two different types of sorting models have been presented so far, one of which refers to a vertical sorting model and the other is called a horizontal sorting model. The latter is closely related to the standard discrete choice model framework developed by McFadden (1978). Here, we will only pay an attention to a horizontal sorting model.

[17] A locational sorting model can be regarded as the extended version of the standard location choice model. The extended features of this framework compared to the standard model can be briefly illustrated as follows. With publicly available census data, an advanced empirical model could allow for preference heterogeneity by introducing interaction terms between attributes of housing types and household's socio-demographic information and alternative specific effects (Klaiber and Phaneuf, 2010). Moreover, incorporating the equilibrium concepts, which assume house prices and other neighborhood attributes in specific locations are established endogenously, can aid in characterizing the market equilibrium condition for the corresponding location. Besides partial equilibrium welfare measures, general equilibrium welfare measures, which allow households' adjustment associated with the change in amenity levels, can be simulated.

assume that each household has the same number of alternatives in their choice set. The reason is based on the premise that households may have different searching periods; thus there would be different numbers of houses available on the market at the time each household purchased a house. In addition each household might have different criteria that they consider in selecting a property based on their preferences; thus each household would have a different number of houses applicable to their filtering criteria. For location unit choice, however, most studies in the literature assume that households would have the same set of choice alternatives conditional on judgments made by the researchers (Phaneuf and Requate forthcoming).

It is important to note that use of the location choice model to understand the importance of attributes could have some advantages and disadvantages. Advantages would be related to the capabilities of simplifying the econometric specification of the empirical model by narrowing down choice alternatives on the basis of some criterion, reducing computational burden. Choosing appropriate criteria, however, could be an arbitrary decision and thus the corresponding results can be sensitive to the assumptions about the definition of the choice set. The way of assigning the same alternatives to each choice set may also produce improved estimation results[18]. This, on the other hand, requires additional assumptions about the imputation of explanatory variables including house-related, neighborhood-related, and environment-related attributes etc. In other words, the

[18] Peters et al. (1995) compared three different empirical models in which two of them assigned the same number of choice alternatives per each respondent and the other allowed each respondent to have a different number of choice alternatives. The later model, compared to other two models, produced poorer results in terms of the number of parameters statistically significant as well as the goodness of fit.

average attribute values are computed from the group of individual properties belonging to the same location and are attached to the corresponding alternative. This might call into the judgment their accuracy for empirical application (Phaneuf and Requate forthcoming).

The choice of the appropriate application between the two different unit choice models would depend upon several circumstances which, for instance, constitute the objective of the study, the context of the study area, data availability, and types of environmental amenities to be targeted etc. For example, a location choice model could be more attractive than an individual house choice model in the case of urban market settings where the impact of changes in environmental attributes is expected to be extensive across large urban areas and the degree of its impact is observed to vary from location to location. Also, it could be more appropriate when the objective of study is to measure the heterogeneous impact of spatially discriminated public goods by locations within certain study areas.

In contrast, applying a location choice model might be less practicable in the context of a suburban housing market in that the determination of choice alternatives could be difficult because reasonable standards to divide suburban areas into several specific locations are not typically available. In addition, it may not be feasible to impute aggregate household socio-economic information in specific locations due to the absence of applicable census data at an appropriate level of aggregation in suburban areas. If the objective of the study is to examine a particular environmental commodity in a specific region and the impact of change in its amenity levels is localized to a particular housing market (i.e. the number of affected houses is small), a valid benefit measure in response to the improvement of attribute levels can be captured by partial equilibrium analysis as well.

Most of the previous studies related to examining residential sorting models are associated with the valuation of large scale changes in environmental attributes such as changes in air quality and open space in the context of large urban areas. The relevant examples above include Klaiber and Phaneuf (2010) for open space valuation and Tra (2010) and Bayer et al. (2009) for air quality valuation.

Following the model framework developed by Bayer et al. (2005), Klaiber and Phaneuf (2010) developed a residential sorting model to evaluate heterogeneous open space amenities in the Twin Cities, Minnesota. Choice alternatives in this study were determined using three main components: locational dimensions (census block group), house-related dimensions (house size), and time dimensions (four aggregate time periods), together yielding 20,444 unique housing types. In order to allow for household preference heterogeneity, all attributes except price were interacted with the approximated individual demographic characteristics obtained from public census data. Two-step econometric estimation techniques were applied, and based on these estimation results, partial and general equilibrium welfare measures were computed for various hypothetical policy interventions regarding open space expansion. Their findings suggested that since open spaces in the study area are spatially differentiated and households have different preferences for different types of open space, it is important to take such points into consideration when designing and implementing relevant policy.

A similar empirical model was proposed by Tra (2010) to investigate the benefits associated with air quality improvement in Los Angeles as a result of the implementation of the 1990 Clean Air Act Amendments (CAAA). The choice alternatives were defined by six categories and for empirical estimation a random sampling approach was used to formulate choice sets comprising one chosen alternative along with 15 non-chosen alternatives. Applying similar estimation strategies utilized by Klaiber and Phaneuf (2010), the impact of reductions in ozone levels due to the CAAA was assessed by comparing two equilibrium conditions between those observed in 1990 and the counterfactual in 2000. The empirical results indicated that partial equilibrium welfare measures, which do not account for the households' relocation of their residence, underestimated the benefits of improvement in air quality compared to general equilibrium measures. In addition, these benefits were shown to vary substantially across income groups - higher income households enjoyed the largest welfare gains.

Bayer et al. (2009) showed the influence of moving costs, which are generally assumed to be zero in traditional hedonic models, on the marginal willingness to pay (MWTP) for air quality improvement. Their study compared values estimated by a hedonic wage model with those obtained from a residential sorting model. Household mobility costs in response to the change in local amenities were included in both models. Rather than focusing on one particular area as studied by Tra (2010) this study used 242 Metropolitan Statistical Areas

(MSAs) in the USA to evaluate reductions in ambient concentrations of particular matter (PM10) for 10 years between 1990 and 2000. In the residential sorting model, the choice sets consisted of the larger US cities which comprise more than 80% of the total US metropolitan population. A considerable amount of effort was made not only to construct key variables using several public data sources, but to take account of econometric challenges such as the positive correlation between local air quality levels and local house prices. Estimation of the MWTP derived from the sorting model was in the range of $149 to $185 for a one unit reduction in PM10, while the same estimates from the hedonic model were three times lower.

Two previous studies applying an individual residential choice model were found; those by Banzhaf and Smith (2007) and Palmquist and Israngkura (1999). Both studies were concerned with the valuation of air quality improvements in urban areas.

Banzhaf and Smith (2007) stressed the importance of the definition of choice sets by conducting meta-analysis (statistical sensitivity analysis). Their study was applied to the entire city of Los Angeles (5 counties) to estimate the value of reductions in the number of days of ozone alerts using housing transaction data gathered from 1989 to 1994. Due to the absence of supplementary information regarding households' actual consideration sets, which could not be provided using available market data, judgments about the "true" choice sets were made along three main dimensions. These included two boundaries of geographic units, four boundaries of time windows, and house price ranges (4 high-end and 4 low-end boundaries), generating a total of 128 potential alternative choice sets. Because of the presence of large data sets, random sampling approaches were used and different sampling schemes between more choice occasions with fewer alternatives and fewer observations with more alternatives were compared to assess how different sampling schemes could affect the efficiency of estimation. The results indicated that the sample containing more observations with small alternatives produced better efficiency based on smaller standard errors for the coefficients estimated. Meta-analysis to assess the influence of each dimension used to define true choice sets was undertaken using a regression model in which the dependent variable was a numerical estimate of WTP and the independent variables were boundary indicators in each dimension. The results suggest that the assumptions regarding each dimension used to define choice sets tend to have an effect on the estimation of an empirical model as well as the welfare estimates.

Palmquist and Israngkura (1999) summarized the welfare gains from non-marginal changes in air quality improvement by comparing the results from a hedonic model with a housing choice model. The data employed included 13 metropolitan markets. Four air pollutants served as air quality indicators. In a housing choice model, choice sets of 40 alternatives were considered in estimation, which were formulated using a two-step sampling technique. In the first step, all houses located in the same urban area were selected and in the second stage, 40 alternative houses were sampled, which consisted of 20 houses sold in a very short time before and 20 houses sold immediately after the chosen house. Rather than estimating each of the markets separately, aggregate estimation was performed. As a result, WTP for a 20% improvement for one pollutant, Total Suspended Particulates (TSP), was higher in a house choice model than in a hedonic two-stage model.

The present study develops discrete residential choice models in which the unit of choice consists of an individual residential property. Our study is designed to investigate the impact of a water management agreement in an area where the policy impact was likely to be localized. Our application considers an alternative way of dealing with choice set formation by allowing for the *probability* of alternatives to be considered in the choice set of available properties for purchase. To the best of our knowledge, any residential choice models which have evaluated welfare impacts caused by a policy or regulation with regard to a water management scheme (i.e. improvement in water quantity and quality) have not been undertaken. Moreover, none of the studies summarized above provided an explicit approach to handling the important issue of choice set formation.

### 3.3 Choice Set Formation and Empirical Model

Following the logic of random utility theory, households are assumed to choose a property that yields the highest utility over the finite set of alternatives available to them, taking account of a collection of attributes that each property contains. The first step in making the theoretical framework practicable for empirical analysis would be to define choice sets.

Our study area is the Town of Chestermere which is a suburban community (small size) experiencing positive externalities from a primary aesthetic amenity - Chestermere Lake. Initially it would seem reasonable to assume that households could consider any properties in the study area which were available in the market during the period that households searched (Banzhaf and Smith 2007; Earnhart 2002). In addition, given the small size of the community it could be possible that not enough properties for sale were available in the market at the time that households purchased, as well as during the time that households searched. Therefore, households could also consider purchasing properties which were available in the larger region which provides amenity benefits similar to those of Chestermere Lake. Accordingly we examined adjacent housing markets and selected Glenmore Reservoir in the City of Calgary as a water body which provides similar conditions to Chestermere Lake. To use this reservoir a spatial buffering approach based on the distance from the Glenmore Reservoir was used to decide the inclusion of eligible properties in the Calgary region to geographically define choice sets. Several distance buffers (3km, 2km, 1km, 0.5km) were applied in preliminary analyses and a 0.5km buffer was found to provide the most similar housing statistics to the Chestermere properties. Table 3.1 shows means of various characteristics of property data from the two geographical areas used to make this choice.

Assuming that the regions are geographically similar, we then utilize time windows to define the choice sets in the first stage. It would be unrealistic to assume that all properties over the entire transaction period could be included in an individual's choice set. The market data used in this study do not contain household characteristics as well as supplemental information regarding household's housing consideration criteria which would be useful for determining an individual household's choice sets. Rather, lacking details on these criteria, a feasible set of alternatives was constructed based on temporal proximity around the date of the household's observed purchase. This approach is similar to that used by Phaneuf and Requate (forthcoming).

**Table 3.1: Comparison of means of housing characteristics in two areas in the Calgary region**

| Characteristics | Definition | Chestermere | Glenmore |
|---|---|---|---|
| Price | House sales price($2007) in $1,000 | 520.5 | 725.8 |
| Area | Square meters of area not including basement | 1,914.0 | 1,988.8 |
| Bedroom | Number of bedrooms | 3.29 | 3.68 |
| Bathroom | Number of bathrooms | 2.34 | 2.29 |
| Fireplace | Number of fireplaces | 0.99 | 1.29 |
| Hage | Age of house calculated by sold year-built year | 5.95 | 27.73 |
| Distances* | Distance (meters) from each property to lake or reservoir | 562 | 382 |
| Housetype | House detached (0/1) | 0.86 | 0.81 |
| Garage | Garage detached (0/1) | 0.96 | 0.83 |
| Size of garage | Number of cars to be stored in the garage | 2.00 | 1.59 |
| Ac | Presence of air conditioning system (0/1) | 0.09 | 0.12 |
| Decbal | Deck or balcony present (0/1) | 0.65 | 0.45 |
| Observations | Number of observations for the entire transaction period | 1,969 | 1,820 |

- Note that distances are calculated from the location of each house to Chestermere Lake for Chestermere properties and to Glenmore Reservoir for the properties within 500 meters from Glenmore Reservoir.

As explained by Banzhaf and Smith (2007), temporal proximity can involve either a particular time span before a household's actual choice, which is related to the length of the household's searching time, and/or could be associated with the length of time a property remained in the market for sale following a purchase. For instance, if a household's search period is assumed to be very short and a typical property remains on the market for sale for only a short time, then the set of alternative properties could be determined using a temporal buffer of 1 month in time backward and forward from the date of purchase. Since no precise temporal dimensions are available for each purchase we applied various temporal windows and compared the resulting choice model parameter estimates across the different temporal specifications.

Defining choice sets based on temporal dimensions has some challenges. Since households were engaged in a search at different times and the supply of available properties for sale was variable from time to time, each household would have a different number of choice alternatives in their choice set (Phaneuf and Requate, forthcoming). To reduce the computational burden when too many choice alternatives are presented, previous studies used the same number of alternatives per individual, which were drawn from the full set of alternatives using random sampling rules (McFadden 1978). Unlike these studies, this computational burden does not exist in our empirical case. Therefore, we allow for the number of choice alternatives to vary across households depending on their purchase date and the stock of properties for sale based on the temporal window of availability.

The choice sets determined using the two dimensions described above assume that all feasible alternatives for each individual are equally considered in modeling the household's final purchase decision. This assumption might be unrealistic in the sense that some alternatives are available, but the degree of their consideration to the purchaser could vary based on particular attributes of those alternatives. The extreme cases allowing for the availability of the alternatives can be possibly handled by incorporating logarithms of a Bernoulli variable (0,1) where 1 is assigned to the alternative if available and 0 if not in the utility function. Rather than modelling the extreme cases however, Cascetta and Papola (2001) proposed a generalized approach to choice set formation by incorporating an implicit availability/perception function into the utility function of the random utility choice model. We use their approach in this study. The availability/perception function is constrained to be between zero and one and is parameterized. This modified approach could enable an analyst to measure the degree of membership of an alternative for consideration to the purchaser and thus approximate a more precise/realistic behavioral element to determining the choice set.

To illustrate this consider household $i$ who is assumed to choose a specific property $j$ given the finite set of housing alternatives $J$ to maximize their utility. The utility function[19] is specified by:

$$U_j^i = V_j^i + \ln \tau_j^i + \varepsilon_j^i \quad \forall j,\ j = 1, 2, \dots, J,$$

where $$V_j^i = \sum_k \beta_k X_{jk}^i \quad \text{and } \tau_j^i = \frac{1}{1 + \exp(-\eta Z_j^i)} \quad \forall\, i \tag{3.5}$$

In Eq. (3.5) $V_j^i$ refers to the systematic utility of property $j$ for household $i$ and is composed of an associated collection of attributes ( $X_{jk}^i$ ) of which include continuous and dummy variables for structural attributes and environmental

[19] Because of insufficient information about household demographic characteristics in our data, the model will be estimated without observed preference heterogeneity. In addition, there are no alternative specific constants in the model because each alternative is generic (i.e. each alternative is only a function of attributes).

attributes and prices. $\beta_k$ are parameters to be estimated. $\tau_j^i$ refers to an availability function which measures the degree to which property $j$ is considered by household $i$. In other words, it can be interpreted as the average probability of property $j$ in $i$'s choice set, $J$. $\varepsilon_j^i$ is the error component associated with property $j$ for household $i$. In the availability function, $Z_j^i$ is a set of variables associated with $j$ which are assumed to have an influence on whether that property is in the choice set and $\eta$ is a vector of parameters to be estimated. Since the availability function follows a binomial logit specification, $\tau_j^i$ is constrained to be between zero and one. Note that not only does the logarithmic transformation of the binomial logit specification allow for an extreme degree of considerations $(0, -\infty)$, it also measures the intermediate level of considerations. In other words, if the value of $\tau_j^i$ is equal to 1, Eq. (3.5) collapses into a standard model specification; a lower value of $\tau_j^i$ indicates the lower possibility of an alternative $j$ to be considered.

Cascetta and Papola (2001) showed that Eq. (3.5) can be estimated with the conditional logit model (CNL) in which joint distribution of random residuals is assumed to be independent and identically distributed Gumbel. For a CNL model without an availability function (or $\tau_j^i$=1), the probability of choosing an alternative $j$ is expressed as:

$$\mathrm{Pr_j} = \frac{e^{\mu V_j}}{\sum_{k \in J} e^{\mu V_k}} \tag{3.6}$$

For a CNL model with an availability function, the probability of choosing an alternative $j$ can be defined as:

$$\Pr_j = \frac{e^{\mu(V_j + \ln\tau_j)}}{\sum_{k\in J} e^{\mu(V_k + \ln\tau_k)}} . \tag{3.7}$$

Given the probability in Eq. (3.7), the parameters of interest in Eq. (3.5) can be identified using the following log-likelihood function:

$$\text{Log L} = \sum_i \sum_j Y_j^i \ \ln(\Pr_j^i), \tag{3.8}$$

where $Y_j^i = 1$ if house $j$ is chosen by household $i$ and 0 otherwise; and $\Pr_j^i$ represents the household *i*'s choice probability shown in Eq. (3.7)

## 3.4 Data

Property transactions data from the Town of Chestermere and the area around Glenmore reservoir were obtained from the Calgary Real Estate Board from year 2000 to 2010. After deleting observations that had suspicious structural characteristics and/or some missing information, the final Chestermere data set contained 1,655 observations. For the Glenmore Reservoir market, 537 observations located within 500 meters of the reservoir remained for the analysis. Thus, 2,192 sales observations were available to construct the entire set of choice alternatives in each individual′s choice set. Information for each property includes structural characteristics such as the size of living area, the number of bedrooms and bathrooms, and house age as well as geographic location data which were used to calculate distances to the Chestermere Lake lakeshore for the Chestermere properties or to the Glenmore reservoir (see table 3.1). The distance variable and house age (*hage*) variable were transformed into inverse distance and used as explanatory variables in model estimation.

In empirical estimation, property sales prices were converted to constant

2007 dollars using the New Housing Price Index (NHPI) for Calgary provided by Statistics Canada. To evaluate the impact of policy intervention, we generated the dummy variable, *wma*, which is equal to 1 if properties are located in the Town of Chestermere and sold after the water management agreement (WMA) was implemented in September 2005, and 0 otherwise. This *wma* variable is interacted with a variable identifying waterfront properties (*wf*) variable in empirical estimation, which identifies the impact of the WMA experienced by Chestermere waterfront properties.

**Table 3.2: Means of housing attributes by temporal definition of the choice set**

| Variable | Definition | Temporal windows* | | | |
|---|---|---|---|---|---|
| | | 1B1F | 3B1F | 3B3F | 6B3F |
| price | House sales price($2007) in $1,000 | 600.44 | 599.77 | 601.57 | 602.81 |
| wma | 1 for properties sold after WMA only in Chestermere | 0.57 | 0.56 | 0.57 | 0.55 |
| wf | 1 for waterfront houses | 0.04 | 0.04 | 0.04 | 0.04 |
| distance | Distance to the lake or reservoir (meter) | 557.64 | 558.16 | 557.78 | 555.98 |
| decbal | 1 if deck or balcony present | 0.63 | 0.62 | 0.63 | 0.62 |
| bed | No. of bedrooms | 3.53 | 3.52 | 3.53 | 3.52 |
| bath | No. of bathrooms | 2.43 | 2.43 | 2.43 | 2.42 |
| fp | No. of fireplaces | 1.07 | 1.07 | 1.07 | 1.07 |
| szg | No. of cars to be stored in garage | 2.07 | 2.07 | 2.07 | 2.06 |
| area | Size of living space (ft2) | 2001.39 | 1997.51 | 2000.19 | 1997.94 |
| htype | 1 for detached house | 0.93 | 0.93 | 0.93 | 0.93 |
| ac | 1 if air conditioner present | 0.11 | 0.10 | 0.11 | 0.11 |
| hage | Age of house (yrs) | 12.96 | 13.05 | 13.08 | 13.16 |
| renovation | 1 for properties required to be renovated (i.e. if hage is greater than 30 years) | 0.18 | 0.19 | 0.19 | 0.19 |
| alt | Means of number of alternatives per households | 74 | 120 | 163 | 221 |
| N | Number of choice observations used in model estimation | 110,421 | 179,135 | 247,342 | 342,195 |

*The expression "XBYF" denotes choice alternative houses are cut off by X months in time backward from the actual property transaction by a household in the data set and Y months in time forward from the actual sale.

Since the choice sets were defined on the basis of various alternative temporal windows, the number of alternatives per household will be different as well as the number of choice observations. Table 3.2 presents the means of housing attributes by choice sets defined by different time dimensions. As the time dimension increases, the number of observations and choice alternatives for each household increases, but this variation does not result in much variation in the average characteristics of the property attributes.

In the standard model estimation without availability functions, all variables in table 3.2 were used to recover systematic utility components ($V_j^i$) in Eq. (3.5). For the estimation of the models that approximate choice set formation, we removed the price variable from the systematic utility function ($V_j^i$) and incorporated it only into the availability function. This variable was used as $Z_j^i$ in Eq. (3.5) in the first availability model. The intuition behind this is based on our judgment that when households buy properties, the most important factor that they consider in the final purchasing decision would be the price of houses. In other words, higher-priced properties for sale were less likely to be considered by a purchaser because of his/her budget constraint. Put another way, the degree to which an alternative is available for an individual's consideration would be a decay function of how high the house prices are (the higher, the less considered).

In addition to house prices, home buyers in the study area apparently consider whether a prospective property for sale requires renovation based on discussion with realtors in the study area. We do not have information regarding renovations for each property in the dataset, so we created a renovation variable based on the age of the residential structure as a proxy for the requirement of renovation in the second availability model along with the variables used in the first availability model. In other words, older properties for sale were more likely to need to be renovated and thus less likely to be considered by a purchaser because of required time and additional costs. Similar to home buyers' consideration regarding house prices, the degree to which an alternative is available for an individual's consideration would be a decay function of how old the house is (the older, the less considered).

### 3.5 Results and Welfare Measures

*Results*

The empirical model presented in Eq. (3.5) with/without the availability function was estimated using maximum likelihood estimation procedures. Including the availability function into the utility function makes the model nonlinear. Thus, we used the econometric software, BIOGEME, to generate parameter estimates. BIOGEME is designed for estimating choice models with nonlinear utility functions.

We estimated several models in which individual's choice sets were defined by different temporal windows in the first stage by changing both assumptions about the periods that households were assumed to be engaged in the market for searching (time backward) and assumptions regarding the periods that a property remained in the market for sale (time forward). The following expression "XBYF" denotes model specifications in which individual's choice alternatives consisted of houses which were cut off by X months in time backward and Y months in time forward based on the actual property transaction date by a household in the data set. We estimated various models with the choice sets defined by 1B1F, 1B3F, 3B1F, 3B3F, and 6B3F.

Table 3.3 presents the results of standard conditional logit models with the choice set defined by "1B1F", which are estimated without/with accounting for choice set formation (inclusion of the availability function). Ben-Akiva and Lerman (1985) suggested using the adjusted likelihood ratio index $\bar{\rho}^2$ for non-nested tests of model specification, and showed that for discrete choice models which utilize a large number of observations and of alternatives as in our case, if the difference of $\bar{\rho}^2$ values between two models is equal to or greater than 0.01, the model with higher $\bar{\rho}^2$ is preferred. In our study, "1B1F" model exhibited the highest $\bar{\rho}^2$ across the models defined by different temporal dimensions. In addition, $\bar{\rho}^2$ values in other models differed by more than 0.01 compared to "1B1F" model. The difference in $\bar{\rho}^2$ values becomes greater as temporal windows used to define the choice sets increase. Besides this statistical criterion, we also considered other criteria such as general intuition and the number of parameters statistically significant, and chose the "1B1F" model as the preferred model over the other specifications. First, the "1B1F" specification would be more reasonable to define the individual's choice set than other specifications which assume longer temporal windows since a shorter time window would be more likely to include house alternatives which may correspond to more true choice set (Banzhaf and Smith 2007). Second, the "1B1F" specification provided more parameter estimates which are statistically significant; in some specifications, the variables related to the distance to the lake or associated with water management policy were not statistically significant which we thought was problematic based on research reported in the previous chapter.

**Table 3.3: Parameter estimates for three conditional logit models without/with choice set formation defined by 1B1F**

| | Standard model | 1st AV model | 2nd AV model |
|---|---|---|---|
| | Coefficient | Coefficient | Coefficient |
| Variable | Av function | Av function | Av function |
| price | | -0.00252*** | -0.00115*** |
| renovation | | | -3.25*** |
| | Utility function | Utility function | Utility function |
| price | -0.0022*** | | |
| wf*wma | 0.8068*** | 0.816*** | 0.523*** |
| $hage^{-1}$ | 0.7076*** | 0.702*** | 0.215** |
| $distance^{-1}$ | 21.4*** | 21.2*** | 12.3** |
| decbal | 0.2485*** | 0.244*** | 0.0493 |
| bed | -0.1206*** | -0.124*** | -0.0309 |
| bath | 0.2235*** | 0.224*** | 0.0377 |
| fp | 0.0435 | 0.0401 | 0.0183 |
| szg | 0.2985*** | 0.293*** | 0.0444 |
| area | 0.0001*** | 0.0001*** | 0.00002 |
| htype | 0.0861 | 0.0652 | 0.0511 |
| ac | 0.0920 | 0.0886 | 0.0369 |
| N | 110,421 | 110,421 | 110,421 |
| LL | -6659.249 | -6659.7 | -6509.331 |
| $\bar{\rho}^2$ | 0.0262 | 0.026 | 0.048 |

- Significant at the ***0.01 level; **0.05 level; *0.10 level.

Most of the parameters for the main effects associated with the housing characteristics are statistically significant and their signs generally follow our prior expectations (e.g. *price*, $hage^{-1}$, $distance^{-1}$, *decbal*, *bath, szg* and *area*). The coefficient of the *price* variable is negative and statistically significant. The positive coefficients for the inverse of the house age ($hage^{-1}$) and distance

($distance^{-1}$) variables indicate that these variables had an impact on housing choices. Put differently, for the $hage^{-1}$ variable, the newer the property is, the higher its impact is on housing choices. For the $distance^{-1}$ variable, the closer the property is to the shoreline, the higher its impact is on housing choices. Concerning the impact of the WMA, the positive and significant coefficient on the *wma*wf* variable suggests that water stabilization in Chestermere Lake influenced choices for waterfront houses.

In terms of the estimated parameters in the availability function, all parameters are statistically significant at the 1% level and the effects of their consideration to the households are as expected. In the first AV model, purchasers were less likely to consider properties with higher prices. In the second AV model, homebuyers were less likely to consider properties which were more likely to need renovation as well as taking house prices into account.

We turn to comparing the three models which were estimated with and without taking account of choice set formation (Standard model versus 1st and 2nd AV model) based on the estimates in table 3.3[20]. It should be noted that including the same variables in both the systematic utility and availability functions together resulted in difficulty in identifying model parameters. We tried several different specifications but we finally removed the *price* variable from the systematic utility specification and incorporated it in the availability function only. We settled on this approach because as discussed previously we assumed that price is probably more important in determining an individual's choice set of properties

[20] For space considerations, we do not include the results of other standard model estimates (without an availability function) across the choice sets defined by different temporal windows (i.e. 1B3F, 3B1F, 3B3F, and 6B3F). The results of these models are available upon request.

rather than a component in an individual's utility function. In the first AV model, the estimated coefficients on the most of the statistically significant variables are not much different than those in standard model. However, the magnitudes of the coefficients on *price, hage*$^{-1}$ and *distance*$^{-1}$ variables in the second AV model decrease significantly in absolute value compared to these in the standard and first AV model. In terms of model performance, a likelihood ratio test between standard model and second AV model indicates that the null hypothesis can be rejected implying that the second AV model appears to be a better fit than the standard model.

However, the estimated coefficients on the other variables related to housing characteristics are no longer statistically significant in the second AV model. These results arise because the AV model is more constrained than Model 1 in the sense that an individual would face lower probabilities of possible substitution between choice alternatives. These findings are similar to those of Swait and Ben-Akiva (1987b), Peters et al. (1995), and Banzhaf and Smith (2007). Swait and Ben-Akiva (1987b) compared two discrete choice model specifications, one of which was regarded as more constrained than the other in consideration of choice set formation. According to their empirical results, the magnitude of parameters estimated changed significantly in the constrained model compared to the unconstrained model. Peters et al. (1995) found significant changes on the estimated parameters either in magnitude or in the level of significance from the restricted choice set model which used individual's perceived choice sets. Banzhaf and Smith (2007) found changes in signs of main parameters in the model in which the choice sets are more limited than other models.

Using the estimates in the availability function in the second AV model, we calculate the change in the probability of being included in the choice set using the combination of availability parameters. Figure 3.1 shows declines in the probability by house prices and difference of its degree distinguished by the requirement of renovation using 2nd AV model. In figure 3.1, the probability for the properties which need renovation is close to zero and much lower than other properties which do not require renovation. This conforms to expectations we formed in discussions with realtors in the study area.

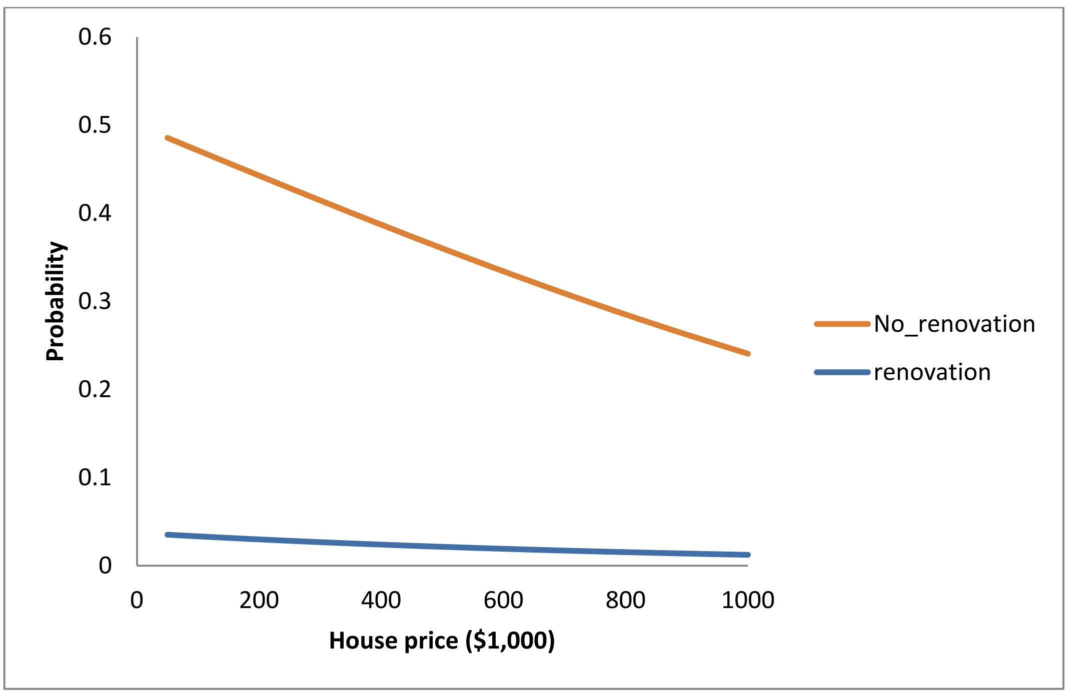



**Figure 3.1: Probability of considering houses by house prices**

*Welfare Measures*

This section evaluates the impact of changes in Chestermere Lake water levels and quality generated by the WMA on waterfront houses in Town of

Chestermere. Since the signing of the WMA, lakefront residents have experienced significant improvements with respect to stabilization of lake levels and to a certain extent, water quality in the lake. Since we focus on examining a primary environmental commodity in local area, it would be reasonable to assume that the property value impact of change in conditions of Chestermere Lake is localized to residents of the Town of Chestermere. Therefore, we utilized partial equilibrium welfare measures which exclude the possibility of households' decision to relocate in response to changes in the condition of the Lake.

To investigate the benefits of the WMA, we computed a compensating variation (CV) measure changing from a "base situation" to a "hypothetical situation". For the "hypothetical situation", no implementation of the WMA is considered. This CV can be interpreted as welfare loss associated with removing the WMA - in other words environmental conditions regarding water quantity/quality level in the lake could be worse than the current situation. The estimated welfare losses can be regarded as the economic value of betterment in the provision of aquatic ecosystem services brought by the water stabilization policy.

Welfare measures using the parameter estimates in the standard model can be estimated using well-known closed-form solutions since price was specified linearly in the utility function. In other words, the income variable is not required for the model estimation and welfare calculations because income drops out. However, in the AV models, price enters the availability function nonlinearly in which case the estimation of welfare measures are more complex because no closed-form solutions for expected CV exist (Bockstael and McConnell 2007). When income information for individual households is not available, one possible way to resolve this case would be to use an approximation of the marginal utility of money. We pursue this approach assuming price variables in the availability function can be used to approximate the marginal utility of money. An approximation of the marginal utility of money was derived by taking the derivative of the utility function with respect to prices. The overall derivative procedures are presented in the appendix A. The calculation of welfare change is given by:

$$\mathrm{E}\,(\mathrm{CV_i}) = \frac{1}{-\mathrm{MUP_i}}\left[\ln\left(\sum_{j} \exp^{V_{ji}^{1}}\right) - \ln\left(\sum_{j} \exp^{V_{ji}^{0}}\right)\right]$$

where $\mathrm{MUP_i}$ is the marginal utility of price for individual household *i*, $V_{ji}^{1}$ is the utility of alternative *j* at the "hypothetical situation", and $V_{ji}^{0}$ is the utility of alternative j at the "base situation".

The procedures to compute welfare measures are as follows. First, we calculated the current utility level for each household using the estimated parameters and the corresponding attribute levels. Second, we recalculated the utility for each household by putting a value of 0 for the dummy variable *wma*wf* to represent the "changed situation". Note that for AV models, the marginal utility of money varies by each household depending on values of attributes of their properties (See appendix A).

Table 3.4 presents the welfare impacts of moving to the hypothetical situation (removing the WMA) in the Chestermere Lake calculated from the estimation results presented in table 3.3. Note that for the individual households who purchased a house before the WMA and didn't include waterfront houses that are sold after the WMA in their choice set, welfare measures are $0 because of no difference in the utility between current and counterfactual situations.

**Table 3.4: Welfare measures associated with removing the Chestermere Lake Water Management Agreement between the Western Irrigation District and the Town of Chestermere**

| Model | No. of households affected by removing WMA | Mean measure | Median measure |
|---|---|---|---|
| Standard model | 960 | -11,472 | -9,835 |
| $1^{st}$ AV model | 960 | -12,740 | -10,658 |
| $2^{nd}$ AV model | 960 | -24,098 | -20,716 |

- Measures are in $2007/Household.

Welfare measures in table 3.4 represent per household mean and median welfare loss which takes into account of household measures in the data set in which welfare measures are nonzero. The estimated welfare losses associated with the degradation of the lake conditions range from about $11,472-$24,098 and $9,835-$20,716 based on mean and median measures, respectively. These figures illustrate the influence of the water management policy (WMA) and economic values of an increase in ecosystem services as a consequence of the WMA are non-trivial.

In terms of impact of choice set considerations on welfare measures, it would be reasonable to assume that AV models are more constrained than the standard model in the sense that an individual would face lower probability of possible substitution. In general, welfare impacts would be bigger as the probabilities of possible substitution per individual decrease. As expected, the welfare impacts calculated from standard model are smaller than that of other AV models. The differences in welfare impacts between standard model and 2nd AV models are considerable. Analogous to the previous studies examining the choice set issues in other discrete choice applications this illustrates the influence of choice set formation on the welfare measures in the context of residential choice analysis.

### 3.6 Conclusions

This study attempted to identify the issue of the choice set in residential choice models using the 2005 Water Management Agreement (WMA) in the Chestermere Lake as a case study. The particular focus of this study is on examining the choice set issue to advance the residential choice literature. We believe this study is the first attempt to estimate the impact of the choice set formation by means of approximating Manski's two-step choice set formation in the context of a residential choice analysis. Given the limited information inherent in the market data regarding the household's consideration sets, we propose an explicit approach to deal with more precise/realistic choice set formation, which measures the probability of house alternatives that households consider based on the price of the houses. In applying this approach, we incorporate the binomial logit specification of the availability function developed by Cascetta and Papola (2001) to measure the degree of membership of house alternatives to be considered by the decision maker.

We use two criteria which are based on the geographic similarity and temporal dimensions to define the choice sets from the universal choice alternatives. Our choice set specifications not only allow for the number of choice alternatives to vary per households depending on the households' searching time and the availability of houses in the market but account for the degree of the consideration of the choice alternatives. Our approach to construct the choice sets can be regarded as two step choice set formation processes. In the first stage, temporal windows are determined using statistical criteria and in the second stage, the endogenous choice set formation process is used to determine the set of houses examined within the predetermined temporal window. Given the choice sets defined with different temporal dimensions, we estimated models with/without the choice set formation using one sample of choice sets that we chose as a preferred model and compare welfare measures to examine the impact of choice set considerations on welfare measures.

Our model results indicate that the impacts of WMA which aims to increase ecosystem service provisions are substantial. In terms of the effects of temporal dimensions used to define the choice set, they have a significant influence on the parameters estimated. The model with availability function indicates households were less likely to consider properties with higher prices. In addition, households are less likely to consider the older houses that are more likely to be renovated. For the comparison between models with/without accounting for choice set formation, the choice set formation models outperform the standard model and affect welfare measures. The difference of welfare impacts between standard model and choice set formation model are non-trivial. This would imply standard choice models which ignore the process of choice set formation would lead to inaccurate estimation of welfare impacts. Therefore, it is suggested that the choice set formation should be considered for better welfare analysis in the case of a discrete housing choice model as well.

The present paper, however, has some limitations. The major concern relates to the approaches that deal with the choice set formation. This paper applies Cascetta and Papola (CP)'s approach to modify choice set formation. The CP approach is not an explicit method to handle individual's two-step choice set decision process but an approximation to measure the probability of each alternative in the choice set to be considered by decision makers. However, the CP approach may be more practical than other approaches, especially when the size of choice sets that a decision maker can face with is potentially so large that determining the set of alternatives from universal choice sets is non-trivial. Another limitation is associated with the computation of welfare measures using the model estimated with price in the availability function. Because of lack of individual household's income data, we used approximation of the marginal utility of money when evaluating welfare measures. So, our welfare measures should be considered as an approximation measure of E(CV).

In addition, as discussed by Banzhaf and Smith (2007), households might not take into account the properties which were either too high-priced or too low-priced. This implies that households only consider the properties which correspond to certain price ranges. In other words, including price variables distinguished by each price group can be used to identify a different scale of consideration of alternatives by price ranges to the home buyers. To take account of this fact, we also estimated different models using multiple price variables instead of using one price variable to allow for the degree of availability of properties by house price ranges. We created categorical dummy variables for the three price groups which were defined based on the price percentiles in each individual's choice set. These discrete variables were interacted with price variable and were used as explanatory variables to understand the difference of preferences by the effect of the price categories. This model, however, produced some implausible results. First, we tested the equality of coefficients on price variables and the results indicated that coefficients on these price variables are not statistically different. Moreover, as price increases the magnitude of the coefficient in absolute value in general decreases (i.e. the marginal utility of price decreases). However, the models using multiple price variables showed opposite direction of price effects, which is inconsistent with diminishing marginal utility of money.

## Appendix A

In this section, we present the derivative procedures that approximate marginal utility of money from the model estimated with the availability function.

In the first AV model, Utility function is specified as follows.

$$U_j = V_j + \ln\tau_j + \varepsilon_j \quad \forall j,\ j = 1, 2, \dots, J,$$

Where $V_j = \sum_k \beta_k X_{jk}$ and $\tau_j = \frac{1}{1+\exp(\mathrm{price}_j)}$

Utility function can be re-expressed as follows.

$$U = \sum_k \beta_k X_{jk} + \ln(1) - \{\ln 1 + \exp(\beta_{price} * \mathrm{price}_j)\}$$

$$= \sum_k \beta_k X_{jk} - \{\ln 1 + \exp(\beta_{price} * \mathrm{price}_j)\} \quad \text{since } \ln(1)=0$$

Now, taking derivative of utility function with respect to $price_j$ is equal to

$$\frac{\partial U}{\partial(price_j)} = -\frac{-\beta_{price} * \exp\{-\beta_{price} * \mathrm{price}_j\}}{1 + \exp\{-\beta_{price} * \mathrm{price}_j\}} = \frac{\beta_{price}}{\exp\{\beta_{price} * \mathrm{price}_j\} + 1}$$

For the second AV model, $\tau_j = \frac{1}{1+\exp\{\beta_{price} * \mathrm{price}_j - \beta_{hage} * \mathrm{hage}_j\}}$ and

$$\frac{\partial U}{\partial(price_j)} = \frac{\beta_{price}}{\exp\{\beta_{price} * \mathrm{price}_j + \beta_{hage} * \mathrm{hage}_j\} + 1}$$

Note that marginal utility of price (MUP) is a function of $price_j$ for the first AV model and $price_j$ and $hage_j$ for the second AV model (in the denominator). So MUP will vary depending on the value of these variables of alternative *j*. We applied average values of these variables in each individual's choice set.

## References


Banzhaf, H. S. and V. K. Smith. 2007. “Meta-analysis in model implementation: choice sets and the valuation of air quality improvements”, *Journal of Applied Econometrics* 22:1013-1031

Bayer, P. J., N. Keohane, and C. Timmins. 2009. “Migration and hedonic valuation: the case of air quality”, *Journal of Environmental Economics and Management* 58:1-14

Bayer, P. J., R. McMillan, and K. S. Rueben. 2005. “An equilibrium model of sorting in an urban housing market”, NBER working paper series no. 10865

Bayer, P. and C. Timmins. 2005. “On the equilibrium properties of locational sorting models”, *Journal of Urban Economics* 57:462-477

Ben-Akiva, M. and B. Boccara. 1995. “Discrete Choice Models with Latent Choice Sets”, *International Journal of Research in Marketing* 12(1): 9-24

Ben-Akiva, M. and S. R. Lerman. 1985. *Discrete Choice Analysis: Theory and Application to Travel Demand*. MIT Press: Cambridge, MA.

Bockstael, N. E. and K. E. McConnell. 2007. *Environmental and Resource Valuation with Revealed Preferences*. Dordrecht, The Netherlands: Springer

Boyle, K. J., P. J. Poor, and L. O. Taylor. 1999. “Estimating the Demand for Protecting Freshwater Lakes from Eutrophication”, *American Journal of Agricultural Economics* 81:1118-1122

Brasington, D. M. and D. Hite. 2005. “Demand for Environmental Quality: A Spatial Hedonic Analysis”, *Regional Science and Urban Economics* 35(1):57-82

Cascetta, E. and A. Papola. 2001. “Random utility models with implicit availability/perception of choice alternatives for the simulation of travel demand”, *Transportation Research Part C* 9(4): 249–263

Earnhart, D. 2002. “Combining Revealed and Stated Data to Examine Housing Decisions Using Discrete Choice Analysis”, *Journal of Urban Economics* 51: 143-169

Grafton, Q., W.L. Adamowicz, D. Dupont, H. Nelson, R. Hill, and S. Renzetti. 2004. *The Economics of the Environment and Natural Resources*. Basil Blackwell Publishers

Haab, T. C., and R. L. Hicks. 1997. “Accounting for Choice Set Endogeneity in Random Utility Models of Recreation Demand.” *Journal of Environmental Economics and Management* 34(2): 127-147.

Horowitz J. L. and J. J. Louviere. 1995. “What is the role of consideration sets in choice modelling?”, *International Journal of Research in Marketing* 12: 39-54

Klaiber, H. A. and D. J. Phaneuf. 2010. “Valuing open space in a residential sorting model of the Twin Cities”, *Journal of Environmental Economics and Management* 60:57-77

Manski, C. 1977. “The Structure of random utility model”, *Theory and Decision* 8: 229-254

Martinez, F., F. Aguila and R. Hurtubia. 2009. “The constrained multinomial logit: A semi-compensatory choice model”, *Transportation Research Part B* 43: 365-377

McFadden, D. 1978. “Modeling the choice of residential location” in A. Karlqvit, L. Lundqvist, F. Snickars and J.W. Weibull, eds., *Spatial Interaction Theory and Planning Models*: 75-96

Morey, E. R., V. R. Sharma, and A. Karlstrom. 2003. “A simple method of incorporating income effects into logit and nested-logit models: theory and application”, *American Journal of Agricultural Economics* 85(1):248-253

Palmquist, R. B. and A. Israngkura .1999. “Valuing Air Quality with Hedonic and Discrete Choice Models”, *American Journal of Agricultural Economics* 81(5):1128-1133

Peters, T., W. Adamowicz and P. Boxall. 1995. “The Influence of choice set consideration in modelling the benefits of improved water quality”, *Water Resources Research* 613: 1781-7

Phaneuf, D. J., V. K. Smith, R. B. Palmquist, and J. C. Pope. 2008. “Integrating Property Value and Local Recreation Models to Value Ecosystem Services in Urban Watersheds”, *Land Economics* 84 (3): 361-381

Phaneuf, Daniel J. and Till Requate. Forthcoming. *A Graduate Course in Environmental Economics: Theory, Policy, and Practice.* Cambridge University Press

Swait, J. and M. Ben-Akiva. 1987a. "Incorporating random constraints in discrete choice models of choice set generation", *Transportation Research Part B* 21(2): 91-102

Swait, J. and M. Ben-Akiva. 1987b. "Empirical test of a constrained choice discrete model: mode choice in Sao Paulo, Brazil", *Transportation Research Part B* 21(2): 103-115

Truong, Thuy Dang. 2013. "Economic Analysis of Choice Behavior: Incorporating Choice Set Formation, Non-compensatory Preferences and Perceptions into the Random Utility Framework, PhD Thesis, University of Alberta.

Tra, C. I. 2010. "A discrete choice equilibrium approach to valuing large environmental changes", *Journal of Public Economics* 94: 183-196

Western Irrigation District: http://www.wid.net

Zabel, J. E. and K. A. Kiel. 2000. "Estimating the Demand for Air Quality in For U. S. Cities", *Land Economics* 76(2): 174-194

# CHAPTER 4: THE ECONOMIC ASSESSMENT OF AN AQUACTIC ECOSYSTEM SERVICE: STATAED PREFERENCE ANLAYSIS OF WATER QUALITY CHANGES

One aspect of environmental quality affecting the properties along Chestermere Lake that was not addressed in the previous chapters is the variation in levels of water quality. Since this could be an important attribute explaining households' residential choice decisions around this irrigation infrastructure, it will be important to understand preferences for a residential choice in connection with water quality changes.

Since its creation, Chestermere Lake has played a dual role as a recreational facility and water-balancing reservoir for agricultural irrigation. Water quality in Chestermere Lake has been classified as being moderate since the lake is considered mesotrophic state in terms of its trophic state[21] and has showed little variation in measured water quality parameters over time (White and Biol 2001). White and Biol included in their historical summary several physical measures of water quality over a 30-year sampling period using data combined from a variety of sources. Even though water quality has been invariant on the basis of annual trends, there have been seasonal trends in water quality largely resulting from fluctuating water levels during the summer period when water starts being used for the irrigation (White and Biol, 2001; Alberta Lake Management Society's Lakewatch Program, 2010).

[21] Trophic state is the index to rate and compare lakes based upon the level of nutrient and algal biomass. The trophic states are classified into oligotrophic, mesotrophic, eutrophic, and hyperentrophic (Alberta Lake Management Society's Lakewatch Program, 2010).

The primary problems in Chestermere Lake have been related to sediment accumulation which can cause of increasing aquatic weed growth. Aquatic weeds have been a barrier for recreational activities in the lake (White and Biol, 2001; Alberta Lake Management Society's Lakewatch Program, 2010). One significant source of the accumulating sediments in the lake could be associated with the City of Calgary's use of the WID system as a storm water waste way. Another source could stem from the input from the Nose Creek watershed where both urban and rural land uses occur and have affected water quality in the watershed (Mitchell and Prepas, 1990; White and Biol, 2001). Nose Creek is connected upstream to the Bow River, which is the main source of water entering Chestermere Lake. In addition, since Chestermere Lake has been heavily used for recreational activities, not only for the residents but for others from nearby neighborhoods over the course of the summer, there are concerns with respect to water quality degradation in the lake during this period. So, these contexts have raised some concerns in regard to administering water quality levels in the lake high enough for the maintenance of recreational activities and other aesthetic purposes. As a result, the Water Management Agreement (WMA) between WID and the Town of Chestermere included aspects of water quality stabilization in addition to level stabilization.

The previous chapters examined the property value benefits of the presence of irrigation infrastructure and additional benefits associated with water level stabilization through the WMA. These analyses utilized revealed preference (RP) data in the form of actual sales of properties gathered from the Calgary Real

Estate Board. However, there can be concerns associated with the use of RP data, particularly as they relate to linkages to environmental quality. A major concern is that the environmental variables hypothesized to relate to the housing purchases typically exhibit little variability within the length of time the actual purchases took place. In other words if one is interested in assessing the value of a change in water level outside of the range actually experienced by current home buyers, actual sales will not be able to provide the necessary information required to evaluate this change.

This is the case with water quality information in Chestermere. There is currently very little information available on the changes in water quality during the period of the home purchases under study and thus it is difficult to relate actual sales to water quality parameters. Given that water quality is an issue for residents in the town of Chestermere, however, assessing the importance of water quality on residential choices requires the use of stated preference information. This approach requires buyers or prospective buyers of properties in Chestermere to respond to hypothetical changes in water quality posed in a questionnaire. Administering a questionnaire in a survey of home owners would thus be required to identify households' preferences with respect to changes in water quality levels holding other housing attributes constant. In an absence of information on water quality parameters in Chestermere Lake, and a general lack of knowledge about how homeowners perceive water quality in the lake, stated preference (SP) methods are the only reliable method that can elicit household's preferences to identify the values of environmental quality change. Earnhart (2001, 2002), Chattopadhyay et al. (2005), Braden et al. (2008) etc. have used stated preference methods to examine households' preferences for residential housing attributes including associated environmental amenities.

The primary objective of this chapter in the thesis is to understand households' preferences in the town of Chestermere for water quality improvements. Put differently, this third study focuses on valuing the range of change in the level of water quality in Chestermere Lake, along with change in some other housing-related attributes.

For the variation in water quality in Chestermere Lake, homebuyers may not correctly understand the level of water quality at the time they purchased their residences. Moreover, little information regarding historical scientific measures of water quality level in the lake is available. Given this context, this study tries to measure homeowners' perceptions about water quality when they bought their homes using the water quality ladder proposed by Mitchell and Carson (1986), and the linkage of this ladder to the few actual scientific measurements of water pollution in the Lake. These include levels of fecal coliform bacteria (FCB), dissolved oxygen (DO), and total suspended solids (TSSs) and their linkage uses the procedures used by Russell et al (2001). Using this information we try and link these perceptions to hypothetical changes in water quality and ask respondents if the water quality was at a particular level at the time of purchase, if they would have bought their current house, or an alternate one with alternate various characteristics provided.

More specifically, this task presented respondents with a set of three housing alternatives in which one is their current property and the others two additional hypothetical properties. Each property provided was represented by a combination of one or more different levels of housing-related attributes (e.g. structural, locational, and environmental attributes) and water quality levels. Respondents were asked to consider the three alternatives and were required to choose one of these in the choice set; this process was repeated sixteen times based on various changes in housing characteristics and counterfactual scenarios involving changes in water quality. Using this approach, homeowners' willingness to pay (WTP) for changes in water quality levels in the lake was estimated.

This third study applied Attribute-Based Stated Choice Methods (ABSCM) to understand preferences for residential choice in association with changes in water quality. In developing the choice experiments, we employed a pivot-style experimental design (or alternatively cited as a reference design), which used individual knowledge (or experience) to derive the attribute levels of the alternatives in the choice tasks. A few studies have pursued this design approach in the context of housing choices (Chattopadhyay et al. 2005; Braden et al. 2008), but none of them tested for issues that may arise through use of a pivot-style design as to potential systematic differences in unobserved parts of utility function (i.e. error terms) between alternatives in choice tasks. We extend the housing choice literature by applying advanced econometric approaches that go beyond simple conditional logit models. Following choice model frameworks proposed by Hess and Rose (2009) we estimate extensions that allow for flexible structures in unobserved components of the utility function and examine improvements in model fit compared to a base model.

Given the application of pivot-style experimental designs, we applied two alternative design strategies that have appeared in the choice experiment literature to generate choice sets for respondents. The two designs we employed are the fractional factorial design and an efficient design. Since these two design strategies employed different design criteria in the process of hypothetical choice alternatives (Rose et al. 2008), we also examine the influence of design differences on the variance of hypothetical choice alternatives. To the best of our knowledge, no studies have empirically explored the influence of experimental design issues based on the dataset generated by pivot-style designs on the error component variances[22].

This third study tries to discover more details about the economic value of providing this irrigation infrastructure, and in particular, the economic impacts of water stabilization through its effect on water quality changes. This information would provide further insights in understanding the values of residential property, an important ecosystem service, resulting from the water management scheme in the lake.

### 4.1 Review of Related Literature

In this section we summarize existing studies which examined household

[22] There are several studies which examined the topics on the influence of difference of experimental designs but these studies used different design styles (i.e. non-pivot style). For example, we found one recent paper studied by Domínguez-Torreiro (2014), which examined the effects of two different experimental design methods on parameter estimates in beef choice analysis. His study used the dataset generated by non-pivot style designs and tested the hypothesis of heterogeneous parameters estimated between two datasets generated by two alternative design strategies. Our study, on the other hand, differs from his study in terms of data style applied and econometric approaches used to compare two competing design paradigms.

preferences for primary environmental amenities around residential locations that employed stated housing choice analyses.

The first application, by Earnhart (2001), combined two different discrete housing choice models based on revealed preference (RP) and stated preference (SP) data. The study was undertaken to investigate the aesthetic benefits generated by coastal wetlands in Fairfield, Connecticut where the restoration of the Pine Creek Marsh was undertaken by the local government in 1980s. Earnhart focused on residential location choice among three different nature-based alternatives, which include water-based, land-based, and no amenity (backyard lawn). In the survey the stated preference design[23] consisted of nine attributes, each at various levels, resulting in 81 choice sets that were generated by applying an orthogonal main effects design. The 81 choice sets were partitioned into nine questionnaire versions with nine choice tasks in each version. Based on separate econometric estimation for the RP and SP data the compensating variation for a change from initial environmental conditions (either without natural features or disturbed marsh) to "new" conditions (either with natural features or restored marsh) were estimated. Earnhart found that the welfare measures calculated using the SP data were significantly higher than those generated using the RP data. This result was due possibly to the small magnitude of price coefficients arising from the econometric estimations.

Chattopadhyay et al. (2005) also used RP and SP data to study the effects of environmental amenities on property values in Waukegan Harbor, a Superfund

---

[23] Note that Earnhart (2002) used the same data obtained from this survey design and so is excluded in this examination of related literature.

site on the US side of the Great Lakes. The RP method used hedonic pricing while the SP method utilized ABSCM procedures. For the experimental design[24], they used six attributes with four levels each which were presented as a percentage increase or decrease compared to the current situation. This design yielded 128 choice sets which were blocked into eight groups of 16 choice sets. In each choice occasion, households were provided with two alternatives and were asked to choose between their current home and a hypothetical home. Each respondent was required to make 16 choices over alternatives with different configurations of attribute levels. The empirical results showed that in terms of welfare measures associated with harbor cleanup, the aggregate WTP in the Waukegan community for partial and full cleanup based on estimation results from the stated choice analysis was estimated to be $249 million and $535 million, respectively. With some assumptions that allowed for evaluating welfare measures from the first-stage hedonic price analysis, these welfare benefits were found to be comparable between the SP and RP methods regardless of the level of harbor restoration.

Similar to Chattopadhyay et al. (2005) in terms of empirical methods utilized in the analysis, Braden et al. (2008) examined the economic gains from improving the conditions of the Buffalo River, in the New York Area of Concern which is one of the contaminated areas in the Laurentian Great Lakes. Braden et al. used both hedonic pricing models and hypothetical housing choice models. To reduce the cognitive burden that respondents might encounter, four attributes which included house size, river conditions, proximity to river, and house price,

[24] In a similar fashion, the same SP data generated by this survey design was described by Patunru et al. (2007).

each at four levels, were used in the survey design[25]. Similar to Chattopadhyay et al. (2005), respondents were presented with two alternatives to choose from, one of which was their current home and the other was a modified home. Random-effects panel estimation techniques were applied to take advantage of allowing potential correlations to vary between individuals, but saving degrees of freedom. Relying on the estimation results from random-effects conditional logit models, several aggregated WTP measures were derived based on scenarios involving distance from the river and geographical division. The results indicated that the shorter distances and smaller divisions yielded lower WTPs measures. In addition, while taking only account of the areas which were discovered to have significant impacts in both analyses, welfare benefits between the two methods were compared. As a result, for some cases where all houses in the farther areas from the AOC were included, a relatively large discrepancy in terms of WTP estimates was found indicating that WTP estimates based on survey analysis were two to three times larger than those obtained from the RP market analysis.

The present study differs from those described above in that the choice sets used in the SP tasks were generated by applying two different design strategies. This study may be the first attempt to examine the influence of alternative experimental design issues in stated housing choice experiments. In addition, we could not locate any SP-based housing choice literature associated with measuring the economic impacts of water management policy on residential neighborhoods. Thus, to the best of our knowledge, this study is the first to

[25] Again, the same data acquired by this study are applied to Phaneuf et al. (forthcoming) for one of the empirical analyses.

empirically examine the value of services arising from water stabilization on residential property values using the WMA as a case study.

### 4.2 Method and Experimental Design

The most common stated preference methods include referendum Contingent Valuation (CVM) and Attribute-Based Stated Choice (ABSCM). While both methods are fundamentally based on random utility theory (RUM), and can be employed to measure the economic welfare corresponding to the changes in the environmental amenities, they differ in some aspects (Carson and Louviere, 2011). A principal difference is the number of attributes employed in designing hypothetical choice situations. Referendum CVM typically focuses on examining monetary attributes (price or tax changes) in detail whereas ABSCM typically considers varying several attributes in addition to a monetary attribute jointly in eliciting choices between alternatives. They also differ with respect to the number of alternatives presented to respondents - referendum CVM usually involves two alternatives and asks respondents to decide whether or not they would be willing to vote to trade income in return for improvements in environmental conditions. In ABSCM respondents are presented with sets of alternatives in which each alternative consists of a bundle of attributes with different levels including a monetary attribute. Applications of ABSCM have increased in the environmental valuation literature since researchers recognized advantages associated with ABSCM, in particular the approach where a sequence of choice scenarios are provided to respondents (Adamowicz et al. 1998; Louviere et al. 2000).

This paper applied ABSCM in which housing choice experiments were generated by the design approach known as the reference or pivot-style design. In this design approach, attribute levels used in the choice experiment are derived based on the individual respondent specific experience or knowledge (Rose et al., 2008; Hess and Rose, 2009). In other words, the respondents were presented with choice alternatives where one is associated with their current situation (the reference alternative) and the others are related to hypothetical new or modified alternatives in which some of the characteristics of the attributes are pivoted from the reference alternative. To put it another way, the respondents faced individually customized choice scenarios according to their status quo or reference level. This is a distinct feature of this approach and is different from other design approaches reported in the residential choice literature. Supported by a number of theories such as prospect theory, case-based decision theory and minimum-regret theory, the use of pivot-style designs may have advantages in allowing respondents to reveal their preferences more effectively (Rose et al. 2008).

In developing the housing choice experiment, five housing-related attributes were chosen. The set of attributes and their levels used to create the choice experiment are presented in table 4.1. The selection of attributes and the levels for each attribute was based upon search from similar studies (i.e. Chattopadhyay et al., 2005; Braden et al., 2008); searches from various websites focusing on housing sale advertisements in the study area; and the assumption that these variables are most likely to be important to the decision maker among housing features including the mixture of structural, locational, and environmental characteristics. The levels of each attribute were "pivoted" as relative or absolute differences from the value of their existing property (the status quo), which were provided by the respondents. For "Distance from the lake" attributes, different levels were applied to waterfront houses and non-waterfront houses since it would not be reasonable to apply the same levels of proportional difference to both houses.

**Table 4.1: Attributes and levels used in the choice experiment**

| Characteristics | Level | Compared to your current house |
|---|---|---|
| **House size:** The amount of living space in your house usually measured in square feet | 30% larger | ☞House size is 30% larger |
| | 15% larger | ☞House size is 15% larger |
| | No change | ☞No change |
| | 15% smaller | ☞House size is 15% smaller |
| | 30% smaller | ☞House size is 30% smaller |
| **House age:** How old a house is, usually measured in years | Newer | ☞House is newer than your current house |
| | No change | ☞No change |
| | 10 years older | ☞House is 10 years older |
| | 20 years older | ☞House is 20 years older |
| **Distance from the lake for waterfront house:** How far the house is from the lake, usually measured in meters | No change | ☞No change |
| | 100 meters farther | ☞House is 100 meters farther away from the lake |
| | 250 meters farther | ☞House is 250 meters farther away from the lake |
| | >= 500 meters farther | ☞House is more than 500 meters farther away |
| **Distance from the lake for non-waterfront house:** How far the house is from the lake, usually measured in meters | 100 meters closer | ☞House is 100 meters closer to the lake |
| | No change | ☞No change |
| | 100 meters farther | ☞House is 100 meters farther away from the lake |
| | >= 250 meters farther | ☞House is more than 250 meters farther away |
| **Water quality in the lake:** The level of water quality in the lake | 20% better | ☞Water quality is 20% better |
| | 10% better | ☞Water quality is 10% better |
| | No change | ☞No change |
| | 10% worse | ☞Water quality is 10% worse |
| | 20% worse | ☞Water quality is 20% worse |
| **House price:** The dollar amount that the different house costs relative to the price you paid for your current house | 30% more | ☞House price is 30% more |
| | 15% more | ☞House price is 15% more |
| | No change | ☞No change |
| | 15% less | ☞House price is 15% less |
| | 30% less | ☞House price is 30% less |

For "Water quality" attributes, there was very little information available for historical sales data regarding objective (scientific) measures of water quality in Chestermere Lake. Therefore, we utilized the water quality ladder proposed by Mitchell and Carson (1986) to measure respondents' perception of water quality in the lake at the time they purchased their property. The images and the detailed descriptions of the water quality ladder were provided in order for respondents to clearly understand and best describe their opinion. This approach linked water quality to assessments of the ability to use the water for drinking, swimming, fishing and boating using "rungs" which range from 10 to 0. This ladder is shown in figure 4.1.

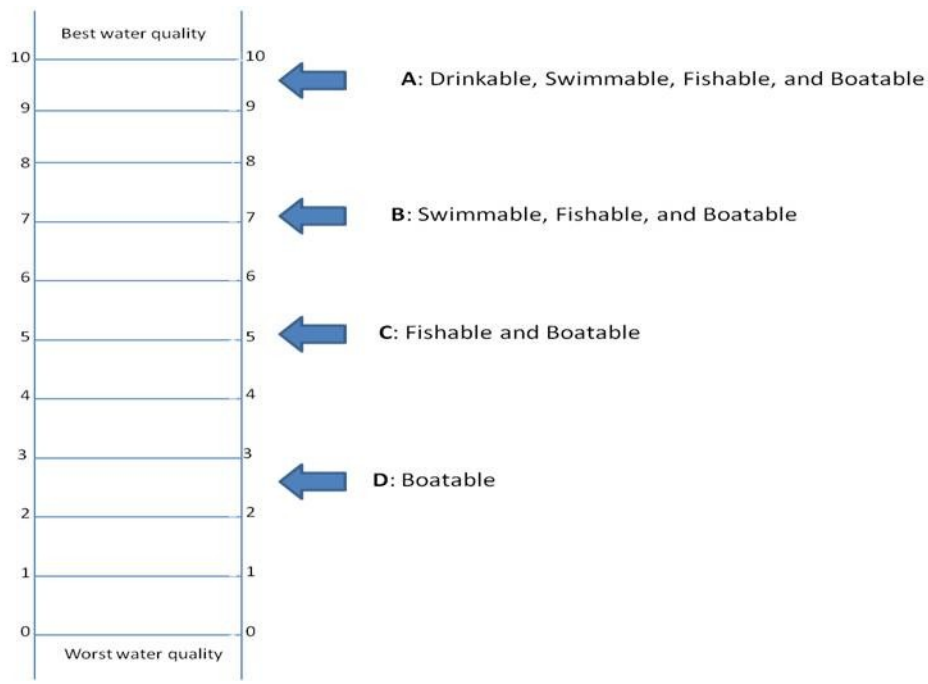



**Figure 4.1: The Water quality ladder from Mitchell and Carson (1986)**

The values provided by the respondents served as reference knowledge for the water quality variable. The levels of this water quality attribute were depicted as percentages better or worse than their reference level of knowledge in the hypothetical choice options. In addition, we linked respondents' perception to several physical measures of water quality. Unlike previous studies which investigated the valuation for the conceptual change in environmental conditions, this approach may have the advantage of estimating the welfare effect in association with a variety of change in scientific water quality measures. The relationship between water quality ladder and scientific pollution levels and the description of these scientific characteristics are displayed in table 4.2 and 4.3, respectively.

**Table 4.2: Linkage between water quality ladder and scientific pollution measures**

| Water quality ladder | | Scientific measure of water quality | | |
|---|---|---|---|---|
| Acceptable for | Point | Fecal Coliform Bacteria (No./100ml) | Dissolved Oxygen (mg/L) | Total Suspended Solids (mg/L) |
| A | 9.5 | 0 | 7 | 5 |
| B | 7 | 200 | 6.5 | 10 |
| C | 5 | 1000 | 5 | 50 |
| D | 2.5 | 2000 | 3.5 | 100 |

Source: Russell et al. (2001), "Investigating Water Quality: Measuring Benefits, Costs, and Risks", Inter-American Development Bank.

Given the use of the reference alternative provided by respondents, we generated experimental designs by applying two different design strategies and two segmentations based on property types to generate choice sets. Two design strategies used were the main-effects fractional factorial orthogonal design and the efficient design method. The main difference between these two approaches is that the fractional factorial orthogonal design allows for an independent estimation of some effects of individual attributes by ensuring no correlation between attributes (i.e. orthogonality), whereas the efficient design is one which minimizes the variances of parameters to be estimated (Louviere, 2000; Rose et al., 2008).

**Table 4.3: Description of scientific characteristics**

| Characteristics | Description |
|---|---|
| Fecal Coliform Bacteria (FCB) | FCB is used as a surrogate indicator for waterborne pathogens that are known to cause a variety of human illnesses. Low densities of FCB are characteristic of good water quality and low risk of waterborne diseases. High concentrations of FCB indicate poor water quality and a high risk of waterborne diseases |
| Dissolved Oxygen (DO) | Levels of DO in surface water are commonly used as an indicator of aquatic health. High levels of oxygen are characteristic of good water quality that can support a high-quality fishery and diverse aquatic biota. Conversely, low or depleted oxygen concentrations indicate poor water quality and an inability to support a diverse population of aquatic biota |
| Total suspended solids (TSSs) | TSSs are used as a surrogate indicator of water transparency to characterize recreational service flows provided by a water body. Low TSS concentrations are associated with a high degree of water clarity. High concentrations of TSS are generally associated with murky or turbid waters and are therefore important contributors to perceptions of poor water quality |

Source: "Environmental Assessment of Proposed Effluent Limitations Guidelines and Standards for the Meat and Poultry Products Industry Point Source", January 2002, U.S. Environmental Protection Agency Office of Science and Technology Engineering and Analysis Division.

**Table 4.4: Average attribute levels for reference alternative**

| Attributes | Unit | Waterfront | Non-waterfront |
|---|---|---|---|
| House size[1] | $ft^2$ | 2339.1 | 1898.9 |
| House age | years | 18 | 14 |
| Distance from the lake | meters | 10 | 550 |
| Water quality[1] | TSSs(mg/L) [1] | 7.5 | 7.5 |
| House price | $2007 | 996,539 | 569,256 |

[1]The unit of house size in available market data was $m^2$ and was converted to $ft^2$ because respondents were more familiar with this measurement. Water quality data were provided by Environment Canada. Total Suspended Solids (TSSs) is the average value measured from June to September, 2007.

To construct the efficient design, we used actual sales data[26] in the study area to obtain average levels for each of the attributes for the reference alternative. Table 4.4 presents the average attribute levels for waterfront and non-waterfront houses applied in the generation of efficient designs. In measuring the statistical efficiency of experimental designs, the use of D-error of a design has gained popularity in the stated choice literature (Rose et al., 2008). The approaches to compute D-error of a design comprise the $D_z$-error design approach, which assumes zero prior parameters, and the $D_p$-error design, which requires non-zero prior parameter values. Since the reference attribute levels for waterfront and non-waterfront houses are quite different (see table 4.4), we used segment-specific $D_p$-error (or D-efficient) designs for waterfront and non-waterfront properties. These designs were assigned to the survey respondents based on their property types. For the prior parameter values for each attribute, we obtained these values from

[26] We obtained arms length transaction data for the Town of Chestermere and City of Calgary from the Calgary Real Estate Board for 27 years from 1984 to 2010, which was used in another study for the hedonic analysis. We used average values of each attribute from these data.

preliminary analysis using data gathered from the focus group meetings[27].

Each version of designs contained 64 choice sets which were blocked into four groups of 16 choice scenarios each. Each respondent was asked to provide their property type (waterfront or not) and was randomly assigned to a version. In addition, the versions generated by the two different design methods were equally distributed within the same property type. Each choice task consisted of three house alternatives and asked respondents to choose between their current house (the reference alternative) and two hypothetical houses (labeled House A and B). An example of choice scenario is presented in table 4.5.

**Table 4.5: Example choice scenario**

| **Characteristics** | **Your current house** | **House A** | **House B** |
|---|---|---|---|
| House size | | 30% smaller | 30% larger |
| House age | | Newer | 20 years older |
| Distance from the lake | | More than 500 meters farther | 250 meters farther |
| Water quality | | 10% worse | 20% better |
| House price | | 30% more | 30% less |
| **Which house would you prefer to choose?** | ○ | ○ | ○ |

## 4.3 Data

Our study involved residents of the Town of Chestermere. The survey was administered to residents who purchased their house between years 1990 and

[27] We hold focus group discussions which involved recent home buyers and local realtors (separately) randomly recruited from the town to gain detailed information about home buyer preferences and the real estate markets around the lake.

2013 in the study area. With feedback from focus group participants, the survey instrument was revised to adjust question wording as well as format and flow of the questions in order to optimize responses and ensure accuracy prior to implementing the questionnaire samples.

**Table 4.6: Respondents' consideration factor and attitudes toward Chestermere Lake when purchasing their current home**

| **A. Importance of each of the factors in house purchase decision (% response)** | | | |
|---|---|---|---|
| Factor | Not at all important | Somewhat important | Very important |
| House price | 1.14 | 25.57 | 73.3 |
| Lot size | 5.11 | 46.59 | 48.3 |
| House size | 0.57 | 43.18 | 56.25 |
| Garage size | 3.98 | 52.27 | 43.75 |
| House age | 10.8 | 46.59 | 42.61 |
| Waterfront or not | 74.43 | 14.77 | 10.8 |
| Nature, recreation, and boating in the lake | 38.64 | 40.34 | 21.02 |
| Distance to the lake | 56.82 | 28.98 | 14.2 |
| Water quality of the lake | 28.98 | 44.89 | 26.14 |

| **B. Description of Chestermere lake at the time you bought your current house (% response)** | | | | | |
|---|---|---|---|---|---|
| The lake | Strongly disagree | Somewhat disagree | Somewhat agree | Strongly agree | No opinion |
| was attractive | 5.68 | 3.98 | 48.86 | 39.77 | 1.7 |
| was an important local amenity | 8.52 | 19.32 | 40.34 | 30.68 | 1.14 |
| would improve the quality of the life | 11.93 | 16.48 | 39.2 | 30.11 | 2.27 |
| would be a good place for recreation | 6.25 | 9.09 | 39.2 | 42.61 | 2.84 |
| was major factor in my home purchase decision | 22.73 | 17.05 | 31.82 | 26.7 | 1.7 |

The recruitment of potential survey respondents took place through contact by a market research survey firm, Advanis Inc. using random digit dialing methods. The initial contact outlined the intent and purpose of the survey and then the recipient was invited to participate. Interested participants were asked to go to a web link to obtain a login for the online survey, which was programmed and hosted by Advanis Inc. For incentives to respond to the survey, $20 online gift cards were provided only to those who completed the survey. Using this procedure we collected 180 completed responses which involved respondents who owned properties from a variety of distances to Chestermere Lake[28]. After deleting 4 responses because of some missing information in choice questions, the remaining 176 respondents (8,446 choice observations) were used for analysis.

In addition to inquiring about property characteristics of respondents' current residences and their demographic information, we also collected information regarding the purchase of their current home. This included questions about the factors they might have taken into consideration and their attitudes toward Chestermere Lake when searching and making a decision to purchase their current home. The summary of respondents' consideration factors for house purchase decision and their attitudes toward Chestermere Lake is provided in table 4.6. As shown in panel A, more than 70% respondents indicated the price of property as a very important element when purchasing a home. Lot size and house size were very important to about 48 and 56% of respondents, respectively. The size of garage and house age were somewhat important for about 52 and 47%.

[28] With the limited amount of phone numbers available to contact, Advanis Inc. initially aimed to collect 250 completes but the response rates were lower than they expected.

Nearly 74% of respondents answered that the location of the house on the lakefront was not an important factor. This is probably due to the fact that prices for the waterfront properties are considerably more expensive than other properties and this fact would have an influence on budget constraint when purchasing a house. Proximity to the lake was not important to 57% of respondents. Recreational activities and water quality in the lake were somewhat important matters to about 40 and 45% of respondents, respectively. As summarized in panel B, respondents' attitudes toward Chestermere Lake were dominated by "somewhat agree" and "strongly agree".

The definition of the variables used in the analysis of housing choices is provided in table 4.7. The *current* variable is an alternative specific constant (ASC) equal to one for a respondent′s current house and zero for the two other alternative house choices. In empirical estimation, house sales prices were converted to constant 2007 dollars using the New Housing Price Index (NHPI) for Calgary, Alberta provided by Statistics Canada. To incorporate the income effect, we created categorical dummy variables denoted as *low*, *med*, and *high* for three income groups which were generated based on the reported income percentiles in the sample[29]. These three dummy variables for each income category were interacted with the attributes (*price, hage, size, distance, and wq* variables) using a two-way interaction and were used as explanatory variables to understand difference in preferences by income category. The two-way interaction term, *wf***wq* measures the preference for water quality differentiated between

[29] Respondents were asked to indicate household's income ranges rather than their actual incomes. We took the midpoints of each income range and converted these values to constant 2002 dollars using consumer price index (CPI) for Calgary, Alberta provided by Statistics Canada.

waterfront properties and non-waterfront properties.

**Table 4.7: Definition of the variables used in housing choice analysis**

| Variable | Definition |
|---|---|
| current | alternative specific constant; 1 for current house, 0 otherwise |
| price | house sale prices ($1,000) in year 2007; housing price index applied |
| low | 1 for low income level(less than 33rd centiles of real income), 0 otherwise |
| mid | 1 for middle income level(between 33rd centiles and 66th centiles), 0 otherwise |
| high | 1 for high income level(more than 66th centiles), 0 otherwise |
| size | size of living space in the house (square feet) |
| hage | house age (years) |
| distance | distance from the lake (meters) |
| distancesq | $\text{distance}^2$ (1,000 meters) |
| wq | water quality |
| wf | 1 for waterfront properties, 0 otherwise |
| wf*wq | interaction between waterfront properties and water quality |
| low*wq | interaction between low income level and water quality |
| mid*wq | interaction between middle income level and water quality |
| high*wq | interaction between high income level and water quality |
| ef | 1 for efficient design, 0 otherwise |

### 4.4 Empirical Analysis

Random Utility Theory assumes a respondent is a utility maximizer choosing one alternative $j$ which renders him the greatest utility among a finite set of alternatives $J$. The stochastic utility function ($U_j$) associated with alternative $j$ can be specified as having two components, where $V_j$ is observed utility components and $\varepsilon_j$ is the unobservable component in Eq. (4.1).

$$\mathrm{U_j} = \mathrm{V_j} + \varepsilon_\mathrm{j} \tag{4.1}$$

where $\mathrm{V_j} = \sum_\mathrm{k} \beta_\mathrm{k}\, \mathrm{X_{jk}}$ and where $X_{jk}$ are a set of the attributes of alternative $j$ which include an alternative specific constant (ASC) and the attributes displayed in table 4.7. $\beta_k$ are the parameters to be estimated.

Hess and Rose (2009) stressed that in a pivot style dataset, the attributes of the reference alternative are invariant across choice occasions for the same respondent. More specifically, in the case where respondent i is given three alternatives ($\mathrm{j} = 1, 2, 3$) where one of which is their current home (j=1) and the others are hypothetical homes ($\mathrm{j} = 2, 3$) in choice occasions $(\mathrm{n} = 1, \ldots, 16)$, the utility function ($\mathrm{U}^{\mathrm{i}}_{\mathrm{j,n}}$) can be expressed as:

$$\mathrm{U}^{\mathrm{i}}_{1,\mathrm{n}} = \mathrm{V}^{\mathrm{i}}_{1} + \varepsilon^{\mathrm{i}}_{1,\mathrm{n}} \text{ where } \mathrm{V}^{\mathrm{i}}_{1} = \sum_{\mathrm{k}} \beta_{\mathrm{k}}\, \mathrm{X}^{\mathrm{i}}_{1,\mathrm{k}}$$

$$\mathrm{U}^{\mathrm{i}}_{2,\mathrm{n}} = \mathrm{V}^{\mathrm{i}}_{2,\mathrm{n}} + \varepsilon^{\mathrm{i}}_{2,\mathrm{n}} \text{ where } \mathrm{V}^{\mathrm{i}}_{2,\mathrm{n}} = \sum_{\mathrm{k}} \beta_{\mathrm{k}}\, \mathrm{X}^{\mathrm{i}}_{2,\mathrm{n},\mathrm{k}}$$

$$\mathrm{U}^{\mathrm{i}}_{3,\mathrm{n}} = \mathrm{V}^{\mathrm{i}}_{3,\mathrm{n}} + \varepsilon^{\mathrm{i}}_{3,\mathrm{n}} \text{ where } \mathrm{V}^{\mathrm{i}}_{3,\mathrm{n}} = \sum_{\mathrm{k}} \beta_{\mathrm{k}}\, \mathrm{X}^{\mathrm{i}}_{3,\mathrm{n},\mathrm{k}}\,. \qquad (4.2)$$

Note that the observed utility components for the current home are denoted as $\mathrm{V}^{\mathrm{i}}_{1}$ rather than $\mathrm{V}^{\mathrm{i}}_{1,\mathrm{n}}$ since the attributes are held constant across replications (n) for each respondent.

We estimated Eq. (4.2) as a base model using a Conditional Logit model (CNL) formulation where the error terms are assumed to follow a Gumbel distribution. In other words, unobserved components of utility are independently and identically distributed (i.i.d) across the set of alternatives ($J$) and observations.

According to Hess and Rose (2009), however, the assumptions for error terms can be violated due to circumstances related to the dataset generated by pivot designs. They argue that hypothetical alternatives are more likely to be correlated with each other than a reference alternative and a hypothetical alternative. This implies a potential violation of the i.i.d assumption across the alternatives. Such correlations between hypothetical alternatives can be addressed through use of a Nested logit (NL) model by imposing nesting structures in Eq. (4.2). One formulation assumes a current house is located in branch 1 and the two hypothetical houses are located in branch 2[30](Figure 4.2).

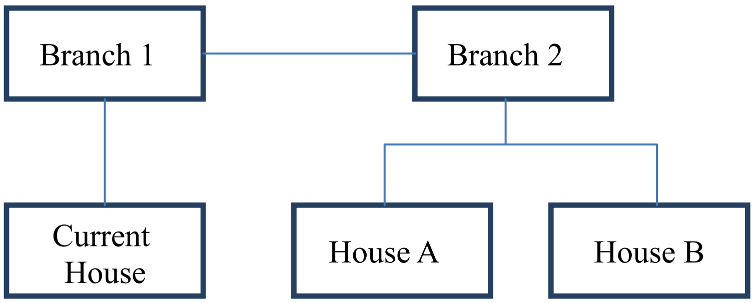



**Figure 4.2: Branch structures for nested logit model**

Another issue in relation to error terms pointed out by Hess and Rose (2009) is the possible violation of homoscedasticity across the alternatives. They have discussed the possible existence of heteroscedasticity across alternatives, which stems from the different levels variation in attributes between alternatives. This issue can be accommodated through an Error Component Logit (ECL) formulation of the Mixed Multinomial Logit (MMNL) approach which introduces error components associated with the alternative specific variance in Eq. (4.2). To take heteroscedasticity into consideration, the utility function can be re-expressed as Eq. (4.3).

$$U^{i}_{1,n} = V^{i}_{1} + \sigma_1 \varphi^{i}_{1,n} + \varepsilon^{i}_{1,n}$$

$$U^{i}_{2,n} = V^{i}_{2,n} + \sigma_2 \varphi^{i}_{2,n} + \varepsilon^{i}_{2,n}$$

[30] Alternatively, the correlated error terms for two hypothetical alternatives can be accommodated by arranging the error components in the same tree structure through the use of error component logit models.

$$U_{3,n}^{i} = V_{3,n}^{i} + \sigma_3 \varphi_{3,n}^{i} + \varepsilon_{3,n}^{i} \quad (4.3)$$

where $\sigma_j$ $(j = 1, 2, 3)$ is the standard deviation and parameter to be estimated associated with the variance for each alternative and $\varphi_{j,n}^{i}$ is the error component which has a standard normal distribution, $\varphi_{j,n}^{i} \sim N[0,1]$. As discussed by Walker (2001), one of the $\sigma_j$'s should be normalized to zero, which would have the smallest variance between them which can be identified from preliminary estimation.

In addition, as discussed in the previous section, this study employed two alternative design strategies, fractional factorial orthogonal versus efficient designs, to generate housing choice experimental designs. Since these two design strategies use different design approaches in constructing experimental designs, we test the hypothesis whether design differences would have an influence on the variance of hypothetical choice alternatives. This hypothesis can be examined through a modification of the ECL by specifying heteroscedasticity in the random error components. To control for heteroscedasticity across alternatives and the influence on error component variances captured by design differences for hypothetical alternatives simultaneously, the utility function can be generalized from Eq. (4.3) and re-specified as:

$$U_{1,n}^{i} = V_{1}^{i} + \varepsilon_{1,n}^{i}$$

$$U_{2,n}^{i} = V_{2,n}^{i} + \sigma_2 \exp\left(r_2 EF^{i}\right) \varphi_{2,n}^{i}$$

$$U_{3,n}^{i} = V_{3,n}^{i} + \sigma_3 \exp\left(r_3 EF^{i}\right) \varphi_{3,n}^{i} \quad (4.4)$$

where the error component heteroscedasticity is specified for $j = 2, 3$ and $\exp\left(r_j EF^{i}\right)$ is the heterogeneity in the variances of the error components for two hypothetical houses generated by $EF^i$, where $EF^i$ is a dummy variable for efficient designs and zero otherwise. Note that depending on the circumstances (i.e. if there is no observable difference between two error components and therefore they should not have a different error component parameter) $\sigma_j$ and $r_j EF^i$ can be constrained to the same value (Hess and Rose, 2009).

### 4.5 Estimation Results

Parameter estimates for the models developed in section 4.4 were estimated using the maximum or simulated maximum likelihood estimation procedures in the econometric software, NLOGIT 4. The results are summarized in table 4.8. CNL represents the base model which does not deal with potential concerns arising from the use of pivot-style data. NL is the nested logit model which allows for correlated error terms for two hypothetical alternatives by grouping them together in a same nesting structure. G-ECL model represents the extended ECL model which is generalized to allow for heteroscedasticity produced by different experimental design strategies in the variances.

Parameter estimates in CNL follow expected signs. The *current* variable is positive and statistically significant implying that all else being equal, respondents prefer their current house to hypothetical houses. The interaction terms, *low*price*, *med*price*, and *high*price* represent the marginal utility of income for each income level. The coefficients on these variables are negative and highly significant and the implied marginal utility of income decreases as income increases, which is consistent with the general assumption of decreasing marginal utility of income. While *low*size* is statistically insignificant, *mid*size* and *high*size* are positive and significant implying middle and high income households are sensitive to house size.

**Table 4.8: Estimation results for CNL, NL, and G-ECL model**

| Model | CNL model | | NL model | | G-ECL model | |
|---|---|---|---|---|---|---|
| | Coefficient | Std. Err. | Coefficient | Std. Err. | Coefficient | Std. Err. |
| current | 1.4364*** | 0.0465 | 1.7169*** | 0.1501 | 1.6979*** | 0.1430 |
| low*price | -0.0019*** | 0.0005 | -0.0021*** | 0.0006 | -0.0021*** | 0.0004 |
| mid*price | -0.0013*** | 0.0005 | -0.0016*** | 0.0006 | -0.0019*** | 0.0003 |
| high*price | -0.0013*** | 0.0004 | -0.0016*** | 0.0004 | -0.0012*** | 0.0003 |
| low*size | 0.0002 | 0.0001 | 0.0003 | 0.0002 | 0.0002 | 0.0001 |
| mid*size | 0.0004*** | 0.0001 | 0.0005*** | 0.0002 | 0.0005*** | 0.0001 |
| high*size | 0.0002* | 0.0001 | 0.0003* | 0.0002 | 0.0002** | 0.0001 |
| low*hage | -0.0342*** | 0.0051 | -0.0416*** | 0.0064 | -0.0375*** | 0.0045 |
| mid*hage | -0.0217*** | 0.0050 | -0.0258*** | 0.0063 | -0.0266*** | 0.0065 |
| high*hage | -0.0295*** | 0.0048 | -0.0331*** | 0.0060 | -0.0341*** | 0.0045 |
| low*distance | -0.0002 | 0.0006 | -0.0002 | 0.0006 | -0.0007 | 0.0006 |
| mid*distance | -0.00004 | 0.0006 | -0.00004 | 0.0006 | -0.0004 | 0.0005 |
| high*distance | -0.0022*** | 0.0006 | -0.0024*** | 0.0007 | -0.0021*** | 0.0006 |
| low*distancesq | 0.0004** | 0.0002 | 0.0005*** | 0.0002 | 0.0002 | 0.0002 |
| mid*distancesq | 0.0001 | 0.0002 | 0.0002 | 0.0003 | 0.0002 | 0.0002 |
| high*distancesq | 0.0004 | 0.0003 | 0.0004 | 0.0003 | 0.0005 | 0.0006 |
| wf*wq | 0.1826 | 0.1302 | 0.1565 | 0.1613 | 0.2431* | 0.1412 |
| low*wq | 0.3510*** | 0.0764 | 0.4482*** | 0.0996 | 0.3575*** | 0.0685 |
| mid*wq | 0.2265*** | 0.0718 | 0.2940*** | 0.0918 | 0.3074*** | 0.0713 |
| high*wq | 0.4832*** | 0.0865 | 0.5720*** | 0.1176 | 0.6353*** | 0.0870 |
| IV parameters | | | | | | |
| Branch1 | | | 1 | fixed | | |
| Branch2 | | | 1.403*** | 0.209 | | |
| Error Components | | | | | | |
| σ | | | | | 1.49*** | 0.136 |
| σ*EF | | | | | 0.021 | 0.13 |
| Log-likelihood | -2,285.35 | | -2,283.14 | | -2,043.72 | |
| $\rho^2$ | 0.26 | | 0.11 | | 0.34 | |

- Significant at the ***0.01 level; **0.05 level; *0.10 level.

The coefficients on the variables, *low*hage*, *mid*hage*, and *high*hage* are all negative implying that an increase in house age has a negative impact on choice. The variables, *low*distance*, *med*distance*, and *high*distance* signify the preference for the distance to the lake by the corresponding income groups. While the parameters of *low*distance*, *medium*distance* are not significant, *high*distance* is significant with negative signs indicating high income households place a premium on the distance to the lake. *Distancesq* is only significant for low income groups. The coefficient of *wf*wq* variable implies that, compared to non-waterfront households, waterfront home owners are sensitive to water quality in the lake to affect their choices. However, this variable is statistically insignificant in the CNL model.

Concerning the impact of water quality in Chestermere Lake on housing choices, a *wq* variable interacted with a dummy for each income group to identify the preference for water quality differentiated by each income range. The parameters of *low*wq, mid*wq,* and *high*wq* are all positive and significant. These three significant parameters suggest that increase in the level of water quality in the lake has a positive influence on housing choices.

In the NL model, Branch 1 represents a current house and the two hypothetical alternatives are assigned to Branch 2. Since Branch1 contains one alternative, we took a degenerate nest into account constraining the inclusive value (IV) parameter for Branch 1 to 1. The estimated coefficients on the most of the utility parameters are statistically significant and are not much different from those in the CNL model. However, the IV parameter for Branch 2 is greater than one, which is not consistent with global utility maximization discussed by Hensher et al. (2005). In such a case, one way to deal with this problem suggested by Hensher et al. (2005) is to rearrange alternatives in new tree structures. However, in our case, restructuring tree structures is not valid and thus a NL model would not be of further merit to consider.

In the G-ECL model, the standard deviation for the error components for the reference alternative (current house) was set to 0. The identification procedures for the normalization were based on the preliminary estimation, which exhibited the reference alternative having the smallest variance across the alternatives. In addition, we further constrained the standard deviations for the two hypothetical alternatives to be equal (i.e. only one σ to be estimated). The reasoning behind this decision relates to the fact that two hypothetical alternatives were both generic design alternatives and no difference in the error components between them were observed. The results for the G-ECL model indicate that compared to the CNL model, allowing for heteroscedasticity across alternatives significantly improves the log-likelihood values as well as McFadden R-squared value, $\rho^2$. Based on a likelihood ratio (LR) test, the G-ECL is preferred over the CNL. The statistically significant parameter for σ indicates that while the variance for the current house is fixed to $\frac{\pi^2}{6}$, the variance for the hypothetical alternatives is $\frac{\pi^2}{6}+1.49^2$, which suggests the presence of heteroscedasticity[31]. With respect to influences of different experimental design methods on the unobserved utility variance for hypothetical alternatives, the $\sigma$*EF* parameter is positive but not statistically significant. This implies that respondents with housing choice

[31] One might expect this result since respondents know more about their current house than hypothetical houses and thus there is less noise for the current house.

scenarios generated by efficient designs do not have a different unobserved utility variance for hypothetical alternatives from the other respondents. In other words, even though two experimental design strategies used different approaches in developing stated choice experiment tasks, they did not influence the unobserved parts of the utility function for the hypothetical choice alternatives.

In terms of the estimated parameters in the observed components of utility, the estimated coefficients on the most of the variables are slightly higher in absolute terms than those in CNL except for two variables, *high*price* and *high*distance*. Note that while the *low*distancesq* variable is no longer statistically significant in G-ECL model *wf*wq* variable appears to be statistically significant. This significant and positive sign of *wf*wq* variable implies that, compared to non-waterfront households, waterfront home owners are sensitive to water quality in the lake to affect their choices. In addition, we observe a relatively large increase in magnitudes on *current, mid*wq*, and *high*wq*. Changes on the estimated parameters of water quality-related variables either in the magnitude or in the level of significance between CNL and G-ECL models would have an influence on welfare measures regarding change in water quality associated with WMA.

### 4.6 Welfare Measures and Discussion

*Welfare measures*

We examine the welfare measures for a change in the level of water quality associated with the decrease in the level of water quality in Chestermere Lake. To measure the compensating variation associated with a change in the water quality level, we transfer each respondent's perception of the level of water quality to the level of the base or reference situation. For the hypothetical situation, we consider the degradation of water quality levels that could be expected as a result of no implementation of the WMA in the lake. In other words, environmental conditions regarding water quality levels in the lake would be worse than the reference situation.

The step-by-step procedures to compute welfare measures are as follows. First, we calculate the utility levels for each household using the parameter estimates in table 4.8 and the corresponding attribute levels which represent the base situation. Second, the utility levels for each individual are recalculated by changing the water quality level; a 10% decrease in each respondent's perception level of water quality. Finally, the compensating variation (CV) is computed as dividing the difference of utility values between two situations by the marginal utility of income. An expression for CV in this case is:

$$\mathrm{CV_i} = \frac{1}{\lambda_i}\left[\mathrm{V_i^1} - \mathrm{V_i^0}\right] = \frac{1}{-\beta_{\mathrm{i*price}}}\left[\mathrm{V_i^1} - \mathrm{V_i^0}\right] \tag{4.5}$$

where i=low, middle, and high income households and superscript 1 and 0 denote the hypothetical and reference situations, respectively. Note that the difference of utility values in Eq. (4.5) is equal to $\left[\mathrm{V_i^1} - \mathrm{V_i^0}\right] = \left[\beta_{\mathrm{i*wq}} * (\mathrm{i} * \mathrm{wq}^1 - \mathrm{i} * \mathrm{wq}^0)\right]$ for CNL model and for G-ECL model it is equal to

$$\left[\mathrm{V_i^1} - \mathrm{V_i^0}\right] = \left[\beta_{\mathrm{i*wq}} * (\mathrm{i} * \mathrm{wq}^1 - \mathrm{i} * \mathrm{wq}^0) + \beta_{\mathrm{wf*wq}} * (\mathrm{wf} * \mathrm{wq}^1 - \mathrm{wf} * \mathrm{wq}^0)\right]$$

**Table 4.9: Welfare measures associated with 10% decrease in respondents'**

**water quality perception**

| Model | Income | Median values | Mean values |
|---|---|---|---|
| CNL | low income | -110,991 | -103,258 |
| | middle income | -93,142 | -98,384 |
| | high income | -227,756 | -216,806 |
| G-ECL | low income | -101,406 | -98,298 |
| | middle income | -90,619 | -101,922 |
| | high income | -324,017 | -334,266 |

-Values are in \$2007/household based on sample in the dataset.

Table 4.9 presents the median and mean welfare measures associated with hypothetical change in water quality level in the Chestermere Lake calculated by middle and high income groups from each model. The median welfare measures calculated from CNL model are about \$110,990 for low income households, \$93,140 for middle income households, and about \$227,760 for high income households while based on G-ECL model, they are about \$101,400, \$90,620, and \$324,020 for low, middle, and high income groups. The estimated mean welfare impacts using CNL model are about \$103,260 for low income households, \$98,380 for middle income households, and about \$216,800 for high income households. Based on G-ECL model, on the other hand, the resulting CVs are about \$98,300, about \$101,920, and \$334,270 for low, middle, and high income households, respectively. These figures illustrate the impact of the water management policy (WMA) on the stabilization of water quality and economic values of an increase in aquatic ecosystem services as a consequence of the WMA are substantial.

There is a relatively large difference in welfare measures for high income groups between two models. Based on mean values in table 4.9, the differences of the estimated welfare impacts for high income households between two models are about $117,460. This is due to the significant change in magnitude of *high*price* and *high*wq* as well as change in statistical significance of *wf*wq* in G-ECL model compared to those in CNL model. In addition, the differences of welfare measures between middle and high income groups are about $118,422 in CNL model and about $232,344 in G-ECL model indicating almost 2 times larger differences in G-ECL model. This illustrates the influence of allowing for different error structures between reference and hypothetical alternatives on change in the magnitude of parameters estimated and welfare measures when dealing with pivot-style data.

*Discussion*

The values in table 4.9 can be interpreted as the average increase in the property values due to the implementation of the WMA in Chestermere Lake. Using these estimates, we assess the aggregated impacts of the WMA by applying this across the total number of residences in Town of Chestermere. Based on these aggregated values, we compute the incremental property tax revenues to justify the Town's investment in the agreement. In other words, the local government's investment could be economically validated if the tax increments outweigh the costs. Since the tax is levied based on the appreciation of the home values, the Town has collected additional tax increments generated by the incremental increases in property values due to the WMA. The Town could use these tax-revenue increases to pay the WMA service fees. If the costs that the Town has paid to the WID for the WMA services could be offset by the tax benefits, it is reasonable to conclude that town-improvement investments are desirable to maintain the healthy aquatic ecosystem services which improve the human welfare.

**Table 4.10: Total aggregated value, tax increment and benefit-cost ratio**

| Model | Total aggregated value ($ millions)[1] | Tax rate (%) | Tax increments (Benefit) | WID fee paid 2006-2010 (Cost) | Benefit/ Cost |
|---|---|---|---|---|---|
| CNL | 585.8 | 0.461% | 2,700,161 | 1,848,978 | 1.39 |
| G-ECL | 749.1 | 0.461% | 3,453,375 | 1,848,978 | 1.77 |

[1]Total aggregated values are calculated using mean values in table 4.9 and are in year 2010 dollars. Tax rate is the average residential tax rates from year 2006 to 2010.

Table 4.10 presents total aggregated values evaluated in year 2010, total tax increments since the occurrence of the WMA, and tax benefit-cost ratio. In table 4.10, total aggregated values were calculated as follows.

$$\text{Total aggregated values} = (\sum_{\mathrm{i}} \text{mean values}_{\mathrm{i}} * \text{total number of dewellings}_{\mathrm{i}}) * \mathrm{NHPI}_{2010}$$

where $i$=low, middle, and high income households and $mean\ values_i$ is given in table 4.9. $NHPI_{2010}$ is New Housing Price Index in year 2010. We applied total number of private dwellings for middle and high income households based on National Household Survey Profile provided by Statistics Canada. In 2010, there were 4,635 private dwellings in total in Town of Chestermere. Of these dwellings, household total incomes which are under $80,000 (low income), between $80,000 and $149,999(middle income), and more than $150,000 (high income) correspond to 1,355, 1,745, and 1,535 dwellings, respectively. So, we used this number of dwellings for middle and high income households to calculate aggregated values.

WID fee is the sum of the annual fees that the Town of Chestermere has paid to the WID for the WMA-related services from year 2006 to 2010. The WID fees in each year are adjusted by applying the annual change in consumer price index (CPI) for the City of Calgary where base year is 2006 and base amount is $334,382.

The calculated total values that the WMA has generated are considerable, ranging from $586 to $749 million depending on the model specifications. The benefit-cost ratio indicates the additional tax revenues that the town has collected since the signing of the WMA more than offset the expenses that they have paid. This implies the town's payment based on increase in property tax serves sufficiently to cover the WID service fees. This becomes even more reliable if we consider the estimates from the G-ECL Model, which allows for more flexible error structures of the utility function than CNL model. Therefore, it seems that the Town has been making a profitable investment since they are more than recovering their investments.

## 4.7 Conclusions

This study attempted to explore the issue of model specifications that may arise through use of a pivot-style data in stated residential choice models. In addition, this paper also examined the influence of different experimental design approaches on the error component variances of hypothetical choice alternatives. The present paper sought to extend housing choice literature by applying advanced econometric approaches to allow for flexible error components of the utility function. We believe this study is the first attempt to control for heteroscedasticity across choice alternatives and examine the influence of design differences on the variance of hypothetical choice alternatives simultaneously in the context of a stated housing choice analysis.

Our study focuses on understanding households' preferences for water quality improvements in the Chestermere Lake associated with the implementation of 2005 Water Management Agreement (WMA). To identify households' preferences with respect to changes in water quality levels in the Lake, we administered a survey to a sample of residents in the Town of Chestermere and measured homeowners' *perceptions* about water quality using the water quality ladder. We employed a pivot-style experimental design to develop the choice experiments and applied two alternative design strategies to generate choice sets for respondents. The two designs employed are the fractional factorial orthogonal design and an efficient design. The choice alternatives presented to respondents consisted of three housing alternatives. In the choice tasks, respondents were asked to choose one of these alternatives and this process was repeated sixteen times. Using this approach, welfare measures associated with hypothetical deteriorations in water quality levels in the lake was estimated.

We estimated the base model which does not control potential concerns arising from the use of pivot-style data and the advanced models which are modified to allow for different structures in unobserved components of the utility function across choice alternatives. We then compare these two models to examine the influence of model specifications on parameters estimated and welfare measures. Our model results indicate that the advanced model outperforms the base model. The statistically significant parameter for error components indicates the presence of heteroscedasticity across choice alternatives. However, the statistically insignificant parameter that captures heterogeneity in the variances of the error components generated by different experimental design methods implies no influence of experimental design methods on the unobserved parts of the utility function for the hypothetical choice alternatives.

The impacts of the water management policy on the stabilization of water quality in the lake are substantial. The additional tax benefits generated since the implementation of the WMA are sufficient enough to cover the costs associated with the WMA service. In comparison of welfare measures between base and advanced models, relatively large differences between the models are observed due to the significant change in magnitude and level of statistical significance of some parameters. This highlights the influence of model specifications on both parameters estimated and welfare measures. Thus, it is suggested that care is required when framing empirical models using data generated by pivot style designs.

## References


Adamowicz, W., J. Louviere, and J. Swait. 1998. "Introduction to Attribute-based Stated Choice Methods", Final Report to Resource Valuation Branch, Damage Assessment Center, NOAA, US Department of Commerce. January. 44 pp

Alberta Lake Management Society's Lakewatch Program. 2010. *2010 Chestermere Lake Report,* completed with support from Government of Alberta

Braden, J. B., L. O. Taylor, D. Won, N. Mays, A. Cangelosi, and A. A. Patunru. 2008. "Economic Benefits of Remediating the Buffalo River, New York Area of Concern", *Journal of Great Lakes Research* 34:631-648

Carson, R. T. and J. J. Louviere. 2011. "A Common Nomenclature for Stated Preference Elicitation Approaches", *Environmental and Resource Economics* 49(4): 539–559

Chattopadhyay, S., J. B. Braden, and A. Patunru. 2005. "Benefits of Hazardous Waste Cleanup: New Evidence from Survey- and Market-Based Property Value Approaches", *Contemporary Economic Policy* 23(3):357-375

Domínguez-Torreiro, M. 2014. "Alternative experimental design paradigms in choice experiments and their effects on consumer demand estimates for beef from endangered local cattle breeds: an empirical test", *Food Quality and Preference* 35:15-23

Earnhart, D. 2001. "Combining Revealed and Stated Preference Methods to Value Environmental Amenities at Residential Locations", *Land Economics* 77(1): 12-29

Earnhart, D. 2002. "Combining Revealed and Stated Data to Examine Housing Decisions Using Discrete Choice Analysis", *Journal of Urban Economics* 51: 143-169

Environment, Government of Alberta: www.environment.alberta.ca

Hensher, D. A., J. M. Rose, and W. H. Greene. 2005. *Applied Choice Analysis: A Primer*. Cambridge University Press: Cambridge

Hess, S. and J. M. Rose. 2009. "Should reference alternatives in pivot design SC surveys be treated differently?", *Environmental and Resource Economics* 42(3): 297-317

Louviere, J., D. Hensher, and J. Swait. 2000. *Stated Choice Methods: Analysis and Application*. Cambridge University Press: Cambridge

Mitchell, R. and E. Prepas. 1990. *Atlas of Alberta Lakes*. University of Alberta Press. Available at: http://alberta-lakes.sunsite.ualberta.ca/

Mitchell, R.C. and R. T. Carson. 1986. "The Use of Contingent Valuation Data for Benefit Cost Analysis in Water Pollution Control", Report to U.S. Environmental Protection Agency, Resources for the Future (September)

Patunru, A. A., J. B. Braden, and S. Chattopadhyay. 2007. "Who cares about environmental stigmas and does it matter? Latent segmentation evidence on property values", *American Journal of Agricultural Economics* 89 (3): 712-726

Phaneuf, D., L. Taylor, and J. Braden. "Combining RP and SP data to estimate preferences for residential amenities: a GMM approach", *Land Economics*, forthcoming

Rose, J. M., M C. J. Bliemer, D. A. Hensher, and A. T. Collins. 2008. "Designing efficient stated choice experiments in the presence of reference alternatives", *Transportation Research Part B* 42:395-406

Russell, C. S., W. J. Vaughan, C. D. Clark, D. J. Rodriguez, and A. H. Darling. 2001. ""Investigating Water Quality: Measuring Benefits, Costs, and Risks", Inter-American Development Bank

Statistics Canada: www.statcan.gc.ca

Walker, J. 2001. "Extended discrete choice models: Integrated framework, flexible error structures, and latent variables. Ph. D. thesis, MIT, Cambridge, MA

White, J. S. and P. Biol. 2001. The water quality of Chestermere Lake: *A state of the knowledge report*. *Aqua*lity Environmental Consulting Ltd

# CHAPTER 5: CONCLUSIONS

This thesis presents three studies which examine the economic impact of increases in the level of an ecosystem service (property values) resulting from change in water management policy. This thesis focuses on an artificial lake, Chestermere Lake, which has probably yielded positive externalities to town residents and any visitors around it since the implementation of Water Management Agreement (WMA) signed in September 2005 between the Town and the irrigation organization managing the lake. All three studies utilize different methodological approaches to demonstrate the economic value of the improvement in aquatic conditions generated by WMA on property values and also examines how the Town has captured some of this value in its tax policy.

The first study utilizes revealed preference methods and applies a combination of hedonic property methods and quasi-experimental methods. The second study applies a discrete house choice method based on the random utility model. This second study proposes an alternative method to validate more precise welfare impacts with respect to changes in the qualities of environmental attributes using an explicit approach to deal with choice set formation. The third study utilizes stated preference methods to overcome the deficiency of use of the revealed preference data which are used in the two previous studies. The third study focuses on understanding the households' preferences in connection with changes in water quality.

The first study examines differential effect of the WMA on the property sales prices between two different property groups, waterfront and non-waterfront houses using two quasi-experimental hedonic property approaches. Quasi-experimental hedonic property approaches have been recently employed to investigate the impact of environmental policy or exogenous events but none of the previous studies have assessed the effect of water management scheme on residential property values in a quasi-experimental framework. Following the quasi-experimental literature we exploit the WMA as an endogenously implemented policy (e.g. an experimental treatment). The first quasi-experimental approach we employed in the first study is a difference-in-difference (DID) analysis. In DID analysis, we used a group fixed effects strategy to control for unobserved differences that might affect house prices between groups defined by spatial dependencies (Heintzelman 2010; Zabel and Guignet 2012; Muehlenbachs et al. 2012). However, Bertrand et al. (2004) point out the problems such as potential endogeneity of the policy effect that might be inherent in DID frameworks. To address these problems and thus to obtain improved estimates of the impact of the WMA, we also employed a second quasi-experimental method, a difference-in-difference-in-difference (DIDID) approach which is a more robust analysis than DID analysis. In DIDID analysis, the triple difference estimator was used by involving both geographically distinct sales observations and a control group within the treatment group.

We find evidence that WMA had a substantial and positive impact on property values for waterfront homeowners who benefit from them. The impacts are estimated to be a 5.5% and a 3.4% increase in property values for waterfront houses based on DID and DIDID analysis, respectively. Based on a statistical test, however, the impacts of WMA estimated between two analyses are verified to be equivalent. This illustrates the significance of water management in generating increased economic values of an ecosystem service. Using property values increased as a result of WMA, we also assessed the additional property tax revenues arising from these values. As a result, the total benefits arising from the implementation of the WMA can be used to some extent to offset the annual costs paid by local government to irrigation agency to manage water conditions in the lake.

The welfare impacts derived from the quasi-experimental hedonic property analysis in the first study would be valid only for marginal change in attributes (Grafton et al., 2004). To validate non-marginal changes in attributes as well as identifying more precise welfare measures the second study applies different methodology that develops a discrete residential choice model based on RUM. A few studies have used discrete choice models to examine residential choice in the context of environmental amenities (Palmquist and Israngkura, 1999; Banzhaf and Smith, 2007; Bayer et al., 2009; Klaiber and Phaneuf, 2010; Tra, 2010). The second study extends these studies by examining the issue of the choice set formation, which has become crucial in estimating accurate model parameters and thus generating accurate welfare measures. While the choice set issue has been addressed in other choice literatures such as transportation mode choice and recreational site choice, it is not well-researched in the housing choice literature. To address the issue regarding the choice set formation the second study develops the discrete house choice model which approximates home buyers' consideration set in their housing purchase behavior. In essence, the second study explores several formulations of endogenous choice sets in which the decision maker's selection of a choice set is based on certain attributes and the final selection is made from this reduced choice set.

Following Banzhaf and Smith (2007), we use two main criteria, 1) geographic similarity and 2) temporal dimensions to define the individual's choice set from the universal choice alternatives. However, our approach to construct sets of choice alternatives is different from the previous studies in the sense that 1) we allow for the number of choice alternatives to vary among each household depending on their purchase date and the stock of properties for sale and 2) we relax the assumption that home purchasers equally consider all alternatives in their choice set. In other words, while some alternatives in the predetermined choice set are available to the decision maker, the degree of their consideration could differ based on particular attributes of those alternatives. To allow for varying degrees of availability of properties, we assume that home buyers could take into consideration house prices and the requirement of renovation for their final purchase decision. An implicit availability/perception model developed by Cascetta and Papola (2001) is used to modify the equal consideration of choice alternatives.

We estimate various choice models defined by different temporal windows. We compare these models and determine the preferred model based on statistical tests discussed by Ben-Akiva and Lerman (1985). Using one sample of choice sets chosen as a preferred model we estimated models with/without the choice set formation and compare welfare measures to examine the impact of choice set considerations on welfare measures. The results suggest that similar to the findings in the first study WMA had a substantial and positive impact on housing choices for waterfront properties. The choice set formation models indicate that homebuyers were less likely to consider properties with high prices as well as the older houses that are more likely to be renovated. For the comparison between models with/without accounting for choice set formation, log-likelihood tests support in favor of choice set formation models. There is considerable difference in welfare impacts between standard model and choice set formation model, which implies for better welfare measures the process of choice set formation should be also considered in the context of a discrete housing choice model.

The second study, however, is not without limitations. The first limitation is that Cascetta and Papola (CP)'s approach to modify choice set formation is not an explicit method but an approximation to measure the probability of each alternative in the choice set to be considered by decision makers. The second limitation is associated with the evaluation of the welfare measures which uses approximation of the marginal utility of money because of lack of individual household's income data.

In an attempt to further understand the implications of using the various approaches to estimating economic impacts, we compare the marginal implicit prices (MIP) for several attributes that are common among models developed the $1^{st}$ and $2^{nd}$ chapters. For the *area* attribute, the marginal implicit price was calculated to be $96.8 for a unit change in the 1$^{st}$ hedonic study while it is estimated to be $45.5 in the 2$^{nd}$ discrete choice study. The MIP for a unit change in the *distance* variable appears to be similar between two studies; -$38.8 and -$31.3 based on 1$^{st}$ and 2$^{nd}$ analysis, respectively. It is unclear why there would be differences or similarities between the MIPs in the two modelling approaches, but at least the signs of the directions are consistent.

The third study applies Attribute-Based Stated Choice Methods (ABSCM), one of the stated preference methods, to understand households' preferences in water quality improvements. The two previous studies utilize market transaction data but these data can be limited regarding variation in water quality associated with the lake as well as the individual specific characteristics of property buyers. To overcome the deficiency of information regarding the change in water quality in the lake we develop choice experiments and administer a survey to a sample of town residents. In developing choice experiments, we employ a pivot-style experimental design to derive the attribute levels of the alternatives in the choice tasks. A few studies have pursued this design approach in the context of housing choices (Chattopadhyay et al. 2005; Braden et al. 2008), but none of them tested for issues that may arise through use of a pivot-style design as to potential systematic differences in unobserved parts of utility function between alternatives stressed by Hess and Rose (2009).

This third study extends the stated housing choice literature by applying advanced econometric approaches which are generalized to allow for flexible error components across choice alternatives. Given the use of pivot-style experimental designs, we applied two alternative design strategies, 1) fractional factorial orthogonal design and 2) efficient design to generate choice sets for respondents. This third study is the first attempt to examine the influence of experimental design methods on the error component variances simultaneously.

To measure homeowners' *perceptions* about the water quality we use water quality ladder proposed by Mitchell and Carson (1986). In the choice tasks, we presented respondents with three housing alternatives; their current homes and two hypothetical houses. Each property provided was represented by a combination of one or more different levels of housing-related attributes and water quality levels. Respondents were asked to choose one of these alternatives and this process was repeated sixteen times based on various changes in housing characteristics and counterfactual scenarios involving changes in water quality. Using this approach, we estimate homeowners' willingness to pay (WTP) for hypothetical changes in water quality levels.

We compare the advanced models which are modified to allow for different structures in unobserved components of the utility function across choice alternatives with the base model. In terms of model performance, the advanced model outperforms the base model. While the parameter for error components appears to be statistically significant the parameter that captures heterogeneity in the variances of the error components generated by different experimental design methods is statistically insignificant. Based on these results, we found heteroscedasticity across choice alternatives but did not find evidence that design differences influenced the unobserved parts of the utility function.

When comparing mean MIP estimated between different income households in the 3rd study for the attributes such as *size* and *hage* to those calculated in the 1st and/or 2nd study, they appear in general to be 2 to 5 times greater than those obtained in the 1st and/or 2nd analysis which employed revealed preference (RP) methods. These differences in marginal value estimates between the two different methods may stem from two facts. First, the variable definitions used are different between the RP models in the first two studies and the stated preference (SP) approach used in the 3rd study. The *size* variable used in the 3rd study is more extensively defined than *area* variable defined in the 2nd and 3rd study since it allows the number of bed and bathrooms to change as living sizes change. Second, the survey respondents may reveal greater willingness to pay for the changes in attributes in the hypothetical housing choices using SP approaches to determine economic values (Braden et al. 2008). Thus, the direct comparison of MIP for the common attributes among the three studies may not be valid.

The impacts of the water management policy on the stabilization of water quality in the lake are considerable. We found that increases in water quality levels in the lake has a positive influence on housing choices. In benefit-cost analysis, the additional tax benefits are sufficiently enough to offset the WMA service fees. There are relatively large differences in welfare measures between base and advanced models. This is due to the significant change in magnitude of water quality-related variables between the two models. A comparison of models across different model specifications shows that model parameters and welfare measures are sensitive to how to specify the model structures suggesting the need of precautions when dealing with the data generated by pivot-style designs.

Finally, while this thesis focuses on a small local area in Alberta, the findings from all three studies may be of interest to policy makers associated with water management and could provide valuable guidance to design future strategies to secure healthy aquatic ecosystems in similar residential environments.

## References


Banzhaf, H. S. and V. K. Smith. 2007. "Meta-analysis in model implementation: choice sets and the valuation of air quality improvements", *Journal of Applied Econometrics* 22:1013-1031

Bayer, P. J., N. Keohane, and C. Timmins. 2009. "Migration and hedonic valuation: the case of air quality", *Journal of Environmental Economics and Management* 58:1-14

Ben-Akiva, M. and S. R. Lerman. 1985. *Discrete Choice Analysis: Theory and Application to Travel Demand*. MIT Press: Cambridge, MA.

Bertrand, M., E. Duflo, and S. Mullainathan. 2004. "How much should we trust differences-in-differences estimates?" *Quarterly Journal of Economics* 119 (February): 249-275.

Braden, J. B., L. O. Taylor, D. Won, N. Mays, A. Cangelosi, and A. A. Patunru. 2008. "Economic Benefits of Remediating the Buffalo River, New York Area of Concern", *Journal of Great Lakes Research* 34:631-648

Cascetta, E. and A. Papola. 2001. “Random utility models with implicit availability/perception of choice alternatives for the simulation of travel demand”, *Transportation Research Part C* 9(4): 249–263

Chattopadhyay, S., J. B. Braden, and A. Patunru. 2005. “Benefits of Hazardous Waste Cleanup: New Evidence from Survey- and Market-Based Property Value Approaches”, *Contemporary Economic Policy* 23(3):357-375

Grafton, Q., W.L. Adamowicz, D. Dupont, H. Nelson, R. Hill, and S. Renzetti. 2004. *The Economics of the Environment and Natural Resources*. Basil Blackwell Publishers

Heintzelman, M. D. 2010. “The Value of Land Use Patterns and Preservation Policies.” *The B.E. Journal of Economic Analysis & Policy*: Vol. 10: Iss. 1 (Topics), Article 39.

Hess, S. and J. M. Rose. 2009. “Should reference alternatives in pivot design SC surveys be treated differently?”, *Environmental and Resource Economics* 42(3): 297-317

Klaiber, H. A. and D. J. Phaneuf. 2010. “Valuing open space in a residential sorting model of the Twin Cities”, *Journal of Environmental Economics and Management* 60:57-77

Mitchell, R.C. and R. T. Carson. 1986. “The Use of Contingent Valuation Data for Benefit Cost Analysis in Water Pollution Control”, Report to U.S. Environmental Protection Agency, Resources for the Future (September)

Muehlenbachs, L., E. Spiller, and C. Timmins. 2012. "Shale Gas Development and Property Values: Differences across Drinking Water Sources." Working Paper 18390, National Bureau of Economic Research.

Muller, N. Z. 2009. "Using hedonic property models to value public water bodies: An analysis of specification issues." *Water Resources Research* 45: W01402, doi:10.1029/2008WR007281.

Palmquist, R. B. and A. Israngkura .1999. "Valuing Air Quality with Hedonic and Discrete Choice Models", *American Journal of Agricultural Economics* 81(5):1128-1133

Tra, C. I. 2010. "A discrete choice equilibrium approach to valuing large environmental changes", *Journal of Public Economics* 94: 183-196

Zabel, J. E. and D. Guignet. 2012. "A hedonic analysis of the impact of LUST sites on house prices." *Resource and Energy Economics* 34:549-564

# Appendix B: Chestermere Survey

## A Survey of Homeowners: Environmental Quality and Housing Choice

A research team at University of Alberta is currently working on a project about water management and quality in Alberta. We are especially interested in studying Albertans' choice of residential housing around Chestermere Lake. In particular our research project focuses on understanding the relationship between water quality and choices about where to live.

Water is one of the most important natural resources we have. Not only does it provide us with drinking water, but water is also a vital element to maintain healthy aquatic ecosystems which provide us with many other beneficial services. For example, lakes provide scenery within communities and they can also be used for recreational activities such as fishing, swimming, and boating. Chestermere Lake provides these types of benefits. Our project aims to develop estimates of the value of the services provided by this water body to residents who live near it. As a homeowner living close to this lake, your responses to the questions in this survey will provide information that can help water managers improve the management of this water body and continue to supply these beneficial services in the future.

This survey has four components. First we collect information about your current home. Next we ask you about some of the circumstances regarding the purchase of your current home. The third part asks you to imagine that you were making a choice between possible alternative housing options – we ask you to choose between "your current home" and hypothetical new or "modified homes" in which some of characteristics of the home are different from your current house. These questions help us understand the role of environmental factors in house purchase decisions. The final part of the survey will ask you to provide some information about your household, including a question about moving to new locations conditional on your working status.

For each question, please provide the answer that best represents your opinion, belief, or situation.

We will hold your answers in the strictest confidence. Moreover, no individual responses to this survey will be released – only aggregate information.

Once you visit our research website, you will be provided with the information and asked to click "yes" or "no" to continue with the survey. Clicking "yes" indicates that you have given your full informed consent to participation in this study.

If you have any questions about the survey or the project, please contact Dr Peter Boxall, Department of Resource Economics & Environmental Sociology, at the University of Alberta by email: peter.boxall@ualberta.ca or by telephone: 780-492-5694.

Thank you very much for helping us with our research project.

**Part A. Questions about your current residence**

1. What is the postal code of your current residence? ( )
2. About when did you purchase your current home?
   Month ( ) Year ( )
3. Approximately how old is your house? ( ) year(s)
4. How many bedrooms does your house contain? ( ) bedrooms
5. How many bathrooms does your house contain? ( ) bathrooms
6. Approximately how large is your lot? ( ) square feet or ( ) square meters
7. Approximately what is the size of living space in your house?
   ( ) square feet or ( ) square meters
8. Is your house a single-family house? ○ Yes ○ No
9. Is your house attached to another house? ○ Yes ○ No
10. Does your house have air conditioning? ○ Yes ○ No
11. Does your house have a deck or balcony? ○ Yes ○ No
12. Does your house contain any fireplaces? ○ Yes ○ No
    If **yes**, how many fireplaces? ( ) fireplace(s)
13. Does your house have a garage? ○ Yes ○ No
    If **yes**, how many cars can fit in your garage? ( ) car(s)
14. Is your house a waterfront house? ○ Yes ○ No
15. Approximately how far is your house from Chestermere Lake? ( ) meters
16. Approximately what was the sale price of your house **when you purchased it**? $ ( )
    If you don't want to reveal the sale price of your current house, would you consider selecting the price range below that includes the sale price of your current home **when you purchased it**? *Please check **one.***

| | |
|---|---|
| ○ Less than $ 100,000 | ○ $100,000 - $ 199,999 |
| ○ $ 200,000 - $ 299,999 | ○ $300,000 - $ 399,999 |
| ○ $ 400,000 - $ 499,999 | ○ $500,000 - $ 599,999 |
| ○ $ 600,000 - $ 699,999 | ○ $700,000 - $ 799,999 |
| ○ $ 800,000 - $ 899,999 | ○ $ 900,000 - $ 999,999 |
| ○ $ 1,000,000 - $ 1,499,999 | ○ $ 1,500,000 - $ 1,999,999 |
| ○ $ 2,000,000 - $ 2,499,999 | ○ $ 2,500,000 - $ 2,999,999 |
| ○ $ 3,000,000- $ 3,499,999 | ○ $ 3,500,000 - $ 3,999,999 |
| ○ $ 4,000,000- $ 4,499,999 | ○ $ 4,500,000 - $ 4,999,999 |
| ○ More than $ 5,000,000 | |

**Part B. Questions about the purchase of your current home**

17. Before buying your current house, where did you move from?
    ( ) City, ( ) Province
18. Approximately how far away was your previous house from your current house? *Please check **one**.*
    - ○ Less than 2km
    - ○ 2km-4.9km
    - ○ 5km-9.9km
    - ○ 10km -19.9km
    - ○ 20km-49.9km
    - ○ 50km-99.9km
    - ○ Greater than 100km
19. At the time you moved to your current house, were you employed?
    ○ Yes ○ No
    **If yes**, where was your workplace located?
    ( ) City, ( ) Province
20. Approximately how long did you search for houses before purchasing your current house?
    ( ) month(s)
21. Approximately how many different houses did you visit before purchasing your current house? ( ) houses
22. How important was each of the factors listed below in your house purchase decision?
    *Please choose **one** number for each factor.*

| **Factor** | **Not at all important** | **Somewhat important** | **Very important** |
|---|---|---|---|
| House price | 1 | 2 | 3 |
| Lot size | 1 | 2 | 3 |
| House size | 1 | 2 | 3 |
| Garage size | 1 | 2 | 3 |
| House age | 1 | 2 | 3 |
| Waterfront or not | 1 | 2 | 3 |
| Nature, recreation, and boating in the lake | 1 | 2 | 3 |
| Distance to the lake | 1 | 2 | 3 |
| Water quality of the lake | 1 | 2 | 3 |

23. What types of houses did you take into consideration when you searched houses?
    - ○ Waterfront houses only
    - ○ Non-waterfront house only
    - ○ Both waterfront and non-waterfront houses

24. At the time you bought your current home, how strongly did you agree or disagree with the following descriptions of Chestermere Lake?

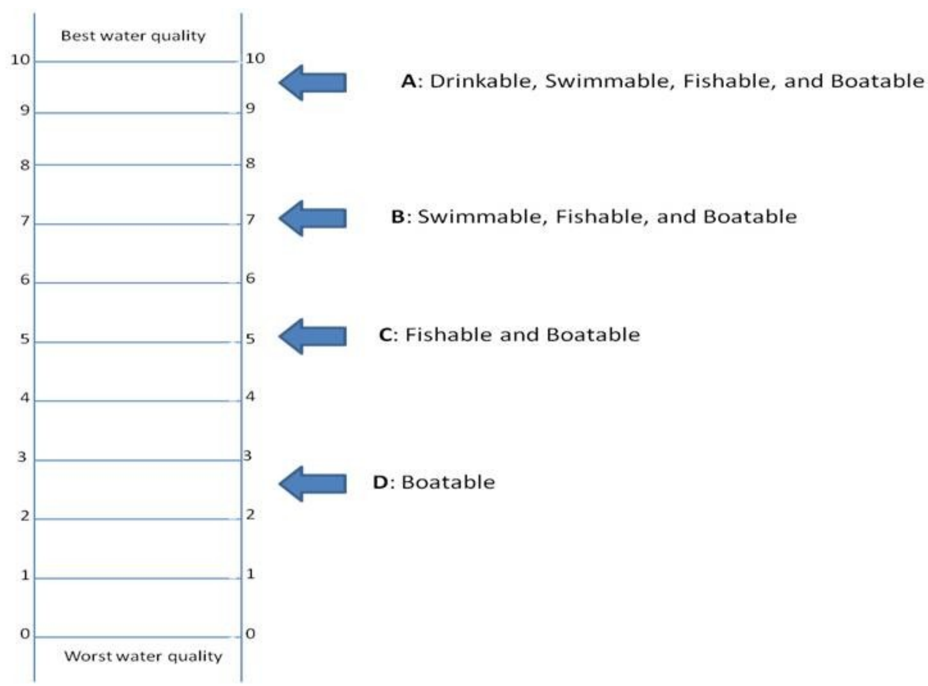
*Please choose **one** number for each statement.*

| **The lake** | **Strongly disagree** | **Somewhat disagree** | **Somewhat agree** | **Strongly agree** | **No opinion** |
|---|---|---|---|---|---|
| Was attractive | 1 | 2 | 3 | 4 | 5 |
| Was an important local amenity to me and my family | 1 | 2 | 3 | 4 | 5 |
| Would improve the quality of the life of my family and me | 1 | 2 | 3 | 4 | 5 |
| Would be a good place for recreation | 1 | 2 | 3 | 4 | 5 |
| Was a major factor in my home purchase decision | 1 | 2 | 3 | 4 | 5 |

**Part C. Choosing a house**

In this section we would like you to imagine that you are currently looking to move and you are searching for houses available on the market. The scenarios below will ask you to choose between your current home and different homes in which one or more housing features are changed. Please do not worry about moving costs, legal fees and other costs of the decision other than the price of the new and existing properties.

One of the features of the existing and new properties we will ask you to consider is the quality of the water in the water bodies close to the place you currently reside. This is a difficult issue to describe, but we have chosen to describe this using a *Water Quality Ladder.* This approach links water quality to assessments of the ability to use the water for drinking, swimming, fishing and boating using "rungs" which range from 10 to 0. This ladder is shown below:




Using the ladder

- **Level A** on the water quality ladder lies above 9.5 points on the scale of 0 to 10 and indicates that water quality is good enough for recreational activities such as swimming, fishing, and boating and that it is safe to drink without any treatment by municipal authorities.
- **Level B** on the water quality ladder lies between 7 and 9.5 points and indicates that water quality is acceptable for recreational activities such as swimming, fishing, and boating but it is not good enough for drinking without any water treatment.

- **Level C** on the water quality ladder is between 5 and 7 points indicating that water quality is only acceptable for fishing and boating. Although some kinds of fish can live in lower quality water (e.g. carp), game fish like trout, pike or perch could survive in water rated at this level.
- **Level D** on the water quality ladder lies between 2.5 and 5 points. This level indicates that water quality is only acceptable for boating. Water quality in this level would not be harmful to you if you fell into water for a short time while boating.

25. When you purchased your current residence, how would you best describe the condition of Chestermere Lake using this water quality ladder?

    *Please check **one circle** in the table below.*

| Points | 0 | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Points | 5.5 | 6.0 | 6.5 | 7.0 | 7.5 | 8.0 | 8.5 | 9.0 | 9.5 | 10 | |
| | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | |

26. Currently how would you best describe the condition of Chestermere Lake using this water quality ladder?

    *Please check **one circle** in the table below.*

| Points | 0 | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Points | 5.5 | 6.0 | 6.5 | 7.0 | 7.5 | 8.0 | 8.5 | 9.0 | 9.5 | 10 | |
| | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | |

In this section you will be presented with sixteen choices. For each choice, **you will be asked to choose between 3 houses: "your current house" and two "hypothetical houses" (labeled as House A and House B)** which, compared to your current house, vary in terms of the housing characteristics presented in the table below.

<u>Please assume that "your current house" and the "hypothetical houses" are identical except for these characteristics.</u>

| **Characteristics** | **Compared to your current house** |
|---|---|
| **House size:**<br>The amount of living space in your house usually measured in square feet | ☞House size is 30% larger<br>☞House size is 15% larger<br>☞No change<br>☞House size is 15% smaller<br>☞House size is 30% smaller |
| **House age:**<br>How old a house is, usually measured in years | ☞House is newer than your current house<br>☞No change<br>☞House is 10 years older<br>☞House is 20 years older |
| **Distance from the lake for waterfront house:**<br>How far the house is from the lake, usually measured in meters | ☞No change<br>☞House is 100 meters farther away from the lake<br>☞House is 250 meters farther away from the lake<br>☞House is more than 500 meters farther away |
| **Distance from the lake for non-waterfront house:**<br>How far the house is from the lake, usually measured in meters | ☞House is 100 meters closer to the lake (or being waterfront if your home is closer than 100 meters)<br>☞No change<br>☞House is 100 meters farther away from the lake<br>☞House is more than 250 meters farther away |
| **Water quality in the lake:**<br>The level of water quality in the lake | ☞Water quality is 20% better<br>☞Water quality is 10% better<br>☞No change<br>☞Water quality is 10% worse<br>☞Water quality is 20% worse |
| **House price:**<br>The dollar amount that the different house costs relative to the price you paid for your current house | ☞House price is 30% more<br>☞House price is 15% more<br>☞No change<br>☞House price is 15% less<br>☞House price is 30% less |

## You will now be asked to make a choice sixteen times.

**Choose only <u>one</u> house in each choice scenario.**
**Assume that three alternatives including your current house are the only options available. Please treat each of the choices <u>separately</u>. The housing features within each choice scenario should not be compared with features in other choice scenarios, and the choice you make in one scenario should not impact the choice you make in another.**

Scenario 1

| Characteristics | Your current house | House A | House B |
|---|---|---|---|
| **House size** | | 30% smaller | 30% larger |
| **House age** | | Newer | Newer |
| **Distance from lake** | | No change | More than 500 meters farther |
| **Water quality** | | 20% better | 20% worse |
| **House price** | | No change | 30% less |
| **Which house would you prefer to choose?** | | | |

Scenario 2

| Characteristics | Your current house | House A | House B |
|---|---|---|---|
| **House size** | | 15% larger | 30% larger |
| **House age** | | Newer | 20 years older |
| **Distance from lake** | | No change | No change |
| **Water quality** | | 10% worse | No change |
| **House price** | | 15% less | 30% more |
| **Which house would you prefer to choose?** | | | |

Scenario 3

| Characteristics | Your current house | House A | House B |
|---|---|---|---|
| **House size** | | No change | 30% smaller |
| **House age** | | Newer | No change |
| **Distance from lake** | | 100 meters farther | No change |
| **Water quality** | | 10% worse | 20% worse |
| **House price** | | 15% less | 30% less |
| **Which house would you prefer to choose?** | | | |

Scenario 4

| Characteristics | Your current house | House A | House B |
|---|---|---|---|
| **House size** | | No change | No change |
| **House age** | | Newer | No change |
| **Distance from lake** | | 250 meters farther | 250 meters farther |
| **Water quality** | | No change | 10 % worse |
| **House price** | | 30% more | 30% less |
| **Which house would you prefer to choose?** | | | |

**Scenario 5**

| Characteristics | Your current house | House A | House B |
|---|---|---|---|
| **House size** | | No change | 15% smaller |
| **House age** | | 20 years older | Newer |
| **Distance from lake** | | 100 meters farther | More than 500 meters farther |
| **Water quality** | | No change | 10% better |
| **House price** | | 15% less | 15% more |
| **Which house would you prefer to choose?** | | | |

**Scenario 6**

| Characteristics | Your current house | House A | House B |
|---|---|---|---|
| **House size** | | 30% smaller | 30% smaller |
| **House age** | | No change | Newer |
| **Distance from lake** | | No change | No change |
| **Water quality** | | 10% better | 10% better |
| **House price** | | 15% less | 15% more |
| **Which house would you prefer to choose?** | | | |

**Scenario 7**

| Characteristics | Your current house | House A | House B |
|---|---|---|---|
| **House size** | | 30% larger | No change |
| **House age** | | 10 years older | Newer |
| **Distance from lake** | | 100 meters farther | More than 500 meters farther |
| **Water quality** | | 10% better | 20% worse |
| **House price** | | 30% less | 30% more |
| **Which house would you prefer to choose?** | | | |

**Scenario 8**

| Characteristics | Your current house | House A | House B |
|---|---|---|---|
| **House size** | | No change | 15% larger |
| **House age** | | 20 years older | Newer |
| **Distance from lake** | | 250 meters farther | 100 meters farther |
| **Water quality** | | 10% better | 10% better |
| **House price** | | 30% less | 15% more |
| **Which house would you prefer to choose?** | | | |

**Scenario 9**

| Characteristics | Your current house | House A | House B |
|---|---|---|---|
| **House size** | | No change | 15% larger |
| **House age** | | 20 years older | 10 years older |
| **Distance from lake** | | 250 meters farther | More than 500 meters farther |
| **Water quality** | | No change | 20% worse |
| **House price** | | 30% less | 30% less |
| **Which house would you prefer to choose?** | | | |

**Scenario 10**

| Characteristics | Your current house | House A | House B |
|---|---|---|---|
| **House size** | | 30% smaller | 15% larger |
| **House age** | | No change | Newer |
| **Distance from lake** | | No change | 100 meters farther |
| **Water quality** | | 10% better | 20% better |
| **House price** | | 30% less | No change |
| **Which house would you prefer to choose?** | | | |

**Scenario 11**

| Characteristics | Your current house | House A | House B |
|---|---|---|---|
| **House size** | | 15% smaller | 30% larger |
| **House age** | | No change | Newer |
| **Distance from lake** | | More than 500 meters farther | 100 meters farther |
| **Water quality** | | 10% better | 20% worse |
| **House price** | | 15% more | 30% more |
| **Which house would you prefer to choose?** | | | |

**Scenario 12**

| Characteristics | Your current house | House A | House B |
|---|---|---|---|
| **House size** | | No change | No change |
| **House age** | | Newer | 10 years older |
| **Distance from lake** | | More than 500 meters farther | 250 meters farther |
| **Water quality** | | 10 % worse | 10% better |
| **House price** | | 30% more | No change |
| **Which house would you prefer to choose?** | | | |

Scenario 13

| Characteristics | Your current house | House A | House B |
|---|---|---|---|
| **House size** | | 15% larger | 30% smaller |
| **House age** | | No change | No change |
| **Distance from lake** | | 100 meters farther | No change |
| **Water quality** | | No change | 10% better |
| **House price** | | 15% less | 15% more |
| **Which house would you prefer to choose?** | | | |

Scenario 14

| Characteristics | Your current house | House A | House B |
|---|---|---|---|
| **House size** | | 30% larger | 30% larger |
| **House age** | | 20 years older | Newer |
| **Distance from lake** | | No change | More than 500 meters farther |
| **Water quality** | | 10% better | 20% worse |
| **House price** | | 30% less | 15% less |
| **Which house would you prefer to choose?** | | | |

Scenario 15

| Characteristics | Your current house | House A | House B |
|---|---|---|---|
| **House size** | | 30% larger | No change |
| **House age** | | 20 years older | No change |
| **Distance from lake** | | 100 meters farther | 250 meters farther |
| **Water quality** | | 10% worse | 10% better |
| **House price** | | 15% less | 30% more |
| **Which house would you prefer to choose?** | | | |

Scenario 16

| Characteristics | Your current house | House A | House B |
|---|---|---|---|
| **House size** | | 30% larger | No change |
| **House age** | | 20 years older | 10 years older |
| **Distance from lake** | | 250 meters farther | 250 meters farther |
| **Water quality** | | 20% better | No change |
| **House price** | | 30% more | 15% less |
| **Which house would you prefer to choose?** | | | |

**Part D. Household Information**

We would now like to ask you a few final questions. Please be assured that the information you provide will be kept confidential and is completely anonymous. We will only use this information to compare groups of people. Your identity will not be linked to your responses in any way.

27. How old are you? ( ) years old
28. How many individuals including yourself currently live in your household? ( ) individual(s)
29. Do you have any dependent children ages 3-17 who currently live in your house?

   ○ Yes ○ No

   If **yes**, how many children do you have?

   *Please select **one** response from the options below.*

   ○ One
   ○ Two
   ○ Three
   ○ Four
   ○ Five or more

30. What is the highest level of education you have completed?

   *Please select **one** response from the options below.*

   ○ Grade school or some high school
   ○ High school diploma
   ○ Post-secondary technical school
   ○ Some college or university
   ○ College degree or diploma
   ○ University undergraduate degree
   ○ University graduate degree (Masters or PhD)

31. What is your current employment status?

   *Please select **one** response from the options below.*

   ○ Working full-time
   ○ Working part-time
   ○ Retired
   ○ Unemployed

32. What category best represents your total annual household income (including all family members) before taxes **at the time you purchased your home**?

    *Please select* ***one*** *from the options below.*

    - ○ Less than $50,000
    - ○ $50,000 - $99,999
    - ○ $100,000 - $199,999
    - ○ $200,000 - $299,999
    - ○ $300,000 - $399,999
    - ○ $400,000 - $499,999
    - ○ $500,000 - $599,999
    - ○ Greater than $600,000

33. A question about moving to new locations:

Suppose your employer asked you to consider relocating to a different city. Imagine that the new location is very similar to your current residential location. For example, all of the attributes below would be the same:

- House quality and value
- School quality
- Crime rate
- Types of new neighbors (ages, number of children, etc.)
- Environment quality (water quality, air quality, scenery)
- Traffic congestion and commuting times
- The climate / weather
- The other houses, services and shops in the neighborhood
- Working hours

Your employer would cover all moving costs (including legal fees, moving company fees, real estate agent fees, etc.). The differences between your current neighborhood and the new neighborhood are:

- The new neighborhood is about 500 kilometres from your current residence
- You do not know your neighbors in the new neighborhood

If your employer asked you to consider relocating, please indicate for each change in income listed below, whether you would accept or not accept the change in income in exchange for moving by placing a checkmark in one box in each row.

| **Change in Income** | Definitely not accept | Probably not accept | Probably accept | Definitely accept |
|---|---|---|---|---|
| $20,000 lower annual household income (before taxes) | | | | |
| $10,000 lower annual household income (before taxes) | | | | |
| No change in annual household income (before taxes) | | | | |
| $10,000 higher annual household income (before taxes) | | | | |
| $20,000 higher annual household income (before taxes) | | | | |

34. What are the main factors that you would consider in deciding whether to accept the offer to move or not?

______________________________________________________________

## Thank you very much for participating in this study!!