**An Investigation of the Effects of Conversion Pressure and Fragmentation on Farmland Values in Alberta, Canada**

by

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

Master of Science

in

Agricultural and Resource Economics

Department of Resource Economics and Environmental Sociology

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## Abstract

The majority of the agricultural area in Alberta, Canada, is situated in the southern half of the province. This also coincides with the population distribution as most Albertans call this region home. Therefore, it is no surprise that there are multiple competing uses and demands for farmland. The purpose of this thesis is to use a hedonic model to study the factors that affect farmland values in Alberta. This study also incorporates measures for conversion pressure and fragmentation to see what impacts these factors have on farmland values. Understanding the factors that influence farmland values will assist policymakers concerned about land use, farmers, developers, lenders, real estate agents and conservationists.

Findings from this study suggest that Alberta farms are not unlike other North American farms found in the hedonic literature. For example, soil quality and irrigation have positive influences on farmland prices per acre, while the absence of a building or improvement has a negative influence. As for conversion pressure variables such as the distance to an urban centre or major highway, there is a negative relationship between distance and farmland values. Nearness to the largest urban centres in the province, Edmonton and Calgary, usually has a positive influence on farmland values. Similarly, the percentage change in population density of a county also has a positive influence on farmland values. Finally, the influence of fragmentation can be positive, but this interpretation depends both on the type of fragmentation measure used and the sample size. This last result highlights the complexity of the fragmentation issue, and suggests

there is no single measure that can capture all of the effects of fragmentation on farmland values. Combined, conversion pressure and fragmentation variables do appear to impact farmland values in Alberta, and should not be discounted by policymakers or land appraisers.

## Dedication

To my grandparents who provided me with many fond memories of farm life, and without whom there would have been no sparked interest in the farm landscape.

To my aunt, who was with us at the start of this thesis campaign, but did not see its completion.

## Acknowledgments

This research project was funded by Farm Credit Canada and the Alberta Land Institute. Other scholarship programs also assisted me during my master's program: Social Sciences and Humanities Research Council of Canada; Walter H. Johns Graduate Fellowship; Queen Elizabeth II Graduate Scholarships – Master's (received twice); Henry Kroeger Memorial Graduate Scholarship; and the Alberta Graduate Student Scholarship. I am grateful for this financial support and will look for ways to repay this generosity forward to future generations.

Thank you to my friends and family for going on this journey with me and for being patient with me. Special thanks to my family for their support throughout my post-secondary education. It would have been much more challenging and stressful without you and your love alongside me.

I would like to thank my arm's length examiner, Dr. Richard Vyn from the University of Guelph, for your insightful comments during the defence. I have tried to incorporate your comments in this revised thesis. Thank you Dr. Feng Qiu, my co-supervisor from the University of Alberta, for making time for me, and for explaining in detail different economic and econometric concepts and issues. Your positive attitude was much appreciated and uplifting. Finally, I benefited greatly from the support of my supervisor from the University of Alberta, Dr. Scott Jeffrey. You were with me every step of the way for the duration of the project, and provided so much feedback on all issues. All of your many hours spent reading my material, listening to my concerns, and answering emails was not unnoticed, and I do owe you many thanks! I do not know if there are words or actions that can repay all that you have given/done, but I will try by saying THANK YOU VERY MUCH!

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## List of Abbreviations and Acronyms

| | |
|---|---|
| AAF | Alberta Agriculture and Forestry |
| AAFC | Agriculture and Agri-Food Canada |
| AAFRD[a] | Alberta Agriculture, Food and Rural Development |
| AARD[a] | Alberta Agriculture and Rural Development |
| AIC | Akaike Information Criterion |
| ALR | Agricultural Land Reserve |
| ATDP | Agriculture Taxation Data Program |
| AVREP | Average net operating income per farm reporting |
| BIC | Bayesian Information Criterion |
| CAD | Canadian Dollar |
| CCS | Census consolidated subdivision |
| CPI | Alberta consumer price index |
| CSD | Census subdivision |
| ESRD | Alberta Environment and Sustainable Resource Development |
| ESRI | Environmental Systems Research Institute |
| FCC | Farm Credit Canada |
| GDP | Gross domestic product |
| HPF | Hedonic price function |
| LCLU | Land cover/land use |
| LSRS | Land Suitability Rating System |
| M.D. | Municipal District |
| n.d. | No date |
| NOAA | National Oceanic and Atmospheric Administration |
| OLS | Ordinary least squares |
| 2SLS | Two-stage least squares |

[a]These are the same ministries which have been reshuffled, dissolved and renamed throughout time (where AAFRD preceded AARD). This ministry was reinvented in 2015 to become AAF.

# Chapter 1: Introduction

## 1.1 Background

Despite having established Provincial Land Use Policies in 1996 that encourage municipalities to limit farmland fragmentation and conversion (Alberta Municipal Affairs 1996), these processes are still occurring in Alberta especially in more recent times. According to Haarsma (2014)[1] developed land increased by ~33.5% (from 303,026 ha to 404,461 ha) between 2000 and 2012, and of the converted developed land nearly 80% had previously been used for agricultural purposes. Qiu et al (2015) showed that fragmentation patterns vary, again over this same time period, with increased fragmentation occurring around the major Alberta cities of Edmonton and Calgary, and decreased fragmentation occurring in the more rural areas. Possible reasons for these changes relate to changing demographics, population growth, status of the farm economy, land values, and municipal policies (Alberta Agriculture, Food and Rural Development [AAFRD] 2002). The changing farm landscape has implications for both future food security, as well as for land management; that is, what if anything should be done about rural and urban residential sprawl. These changes to the farm landscape are an issue if farmland preservation is important to the population given its many amenities.

[1]Part of Haarsma's (2014) thesis has been published (see Haarsma and Qiu (2015)).

## 1.2 Economic Problem

Farm Credit Canada (FCC) has been reporting farmland values since at least 1985. Their data suggest that Alberta farmland values have increased each year between 1993 and 2013 (FCC 2014b). For farmers, where land is a major input, it is clear that land values can impact them throughout their lives. For example, the price of land determines to some extent who is able to participate in farming. Given the current price of land it is difficult to start farming without either inheriting land, buying it for a reasonable price from a family member, renting land or by having significant starting wealth. The value of farmland also affects an existing farmer's ability to expand his or her operation. The value of land may also impact farmers' abilities to acquire debt capital for use in their operations. Finally, farmers view land as a part of their retirement savings plan, so the value that it garners is very important.

There are a number of approaches to studying what influences farmland values. For example, one can consider the agricultural rents and the present value of expected future rents associated with development (Capozza and Helsley 1989). Alternatively, some research examines how transportation costs or the distance to a market centre influence the economic rents associated with agricultural land (Sinclair 1967). Finally, the attributes of the land may impact its value, such as its soil characteristics or the number of improvements (such as buildings) on the land.

As mentioned, farmland fragmentation and conversion are occurring in Alberta. In some valuation models the story of conversion has been incorporated as the cost of conversion (e.g., Capozza and Helsley 1989). On the other hand, studies on fragmentation have considered how fragmentation impacts production and profits (e.g., Latruffe and Piet 2013; Di Falco et al 2010). As might be expected, fragmentation can make production more expensive because one has to jump from plot to plot to conduct work, or hire more labour for the additional plots. If fragmentation and conversion are due to urban development, there is potential for nuisances to arise, such as in the form of increased traffic. Previous studies have suggested that fragmentation may have either an insignificant (Blarel et al 1992) or negative (Wan and Cheng 2001) effect on yields. However, it is less clear how fragmentation is impacting the actual value of farmland. Guiling et al (2007) find that the size of a farm parcel is inversely related to the price of land per acre. However, this is just one way of studying fragmentation, as fragmented parcels tend to be smaller. Alternatively or in addition, fragmentation measures exist and can be incorporated in farmland valuation models to see how fragmentation affects farmland values.

The most recent Alberta-based farmland valuation study was a 1982 Master's thesis by Dey (1982), who used data from 1940–1980 and 1961–1980. Given the changes in the economic and policy environment, as well as the increased degree of conversion of agricultural land, it is now timely to undertake an updated analysis of agricultural land values in Alberta. The results from this type of model are of value to several groups, including current farmers interested in selling or purchasing property, lenders who assist farmers in securing loans for business operations and expansion, nongovernmental organizations that are interested in purchasing land for conservation purposes, and policymakers who are interested in urban development or using land for conservation, tax revenues, or food security purposes.

## 1.3 Research Purpose and Objectives

The main purpose of this research is to estimate a farmland valuation model for Alberta. There are two main objectives of this study: (1) to determine which factors are most important in explaining Alberta farmland values; and (2) to further extend the use of the hedonic pricing model in the study of farmland markets by including measures for fragmentation and conversion pressure. Remote sensing data are incorporated to develop fragmentation measures.

## 1.4 Organization of the Study

Following this introductory chapter are four subsequent chapters. Chapter Two begins with a discussion of the hedonic pricing model, the model used throughout this thesis, including its origins and the theory to support it. That chapter also summarizes some of the fragmentation and conversion literature, as much as is relevant to the methods and farmland values.

Chapter Three contains information about the methodology. This chapter outlines the data that were used, and ends with a discussion of the model specification employed to generate the results found in the subsequent chapter.

Results are presented and discussed in Chapter Four. Several tables containing regression estimates are listed. Robustness checks are also included. The majority of this chapter focuses on the significance (or lack of significance) of the results and the interpretations of the coefficients.

Lastly, Chapter Five summarizes key take away messages (results) and provides a discussion of the policy implications of this work. Limitations of the methods/data are also covered, and suggestions for future research are noted.

# Chapter 2: Literature Review

The main objective of this chapter is to summarize some of the literature that has informed this study. As the hedonic pricing model was the method selected for this study, it is discussed first. The latter portion of this chapter makes note of studies related to fragmentation and conversion of agricultural land, as this is the single main contribution of this work to the literature.

## 2.1 Hedonic Pricing Models

This section covers the history of the hedonic method, followed by the theory behind the hedonic approach. The next piece in this section comprises some of the research that has used the hedonic pricing model to study the factors that affect farmland values. Some of the reasons behind variable selection are provided, as is a list of alternative approaches to hedonic modelling.

### 2.1.1 Hedonics – The Backstory

Microeconomic theory focuses on demand and supply schedules that work together to set a general market price. A perfectly competitive market is described as having a large number of buyers and sellers, perfect information and a homogeneous product among other things. However, Waugh (1929/1968) recognized that this last assumption held quality constant, and thus, ignored the prospect that quality itself may impact the price. In Waugh's (1929/1968, p. 30–31) words, "economic theories … [were] not comprehensive enough to explain certain important aspects of market values." Waugh (1929/1968) pointed out that previous theorists had at least thought about quality’s influence on price, but perhaps did not include it in their theories. For example, Carver (1919, p. 272) said ”The first law of the market is that things of the same kind and quality tend to have the same value at the same time and place. …If they are unlike, some of them being more desirable than others, of course some will have more power in exchange than the others.”

Waugh (1929/1968) went on to study three commodities, (cucumbers, asparagus, and tomatoes), and statistically analysed how some measurable qualities influenced the price. In this study he was able to determine which factors were most important, and outline the applications of his study (Waugh 1929/1968). Growers already had an understanding of how to achieve particular qualities and the trade-offs associated with favoring one quality over another (if they cannot coexist) (Waugh 1929/1968). However, what his study added was information about the price differences that would result if one particular trait was focused on compared to another (Waugh 1929/1968). This knowledge could affect the growers’ business practices (Waugh 1929/1968). In this respect, such a methodology was a very powerful tool for producers.

To Waugh’s (1929/1968) knowledge only two studies had looked specifically at the statistical relationship between prices and various qualities. Both of these were published during his study, one by Kuhrt (1926; 1927) and the other by Benner and Gabriel (1927).[2] Colwell and Dilmore (1999) found even earlier evidence of hedonic

[2]These original articles could not be obtained and verified.

regressions done by Haas (1922)[3] and Wallace (1926), both of whom studied farmland values. The number of studies looking at how factors affect prices continued to grow. In 1939 Court wrote about this method again, but this time he included the word "hedonic." The hedonic approach, however, was for a long time an empirical method with no rigorous basis in theory. This changed in the 1970s with papers by Rosen (1974)[4] and Freeman (1974).

### 2.1.2 Hedonics – The Theory

This section shows how Rosen (1974) developed a theory to describe hedonic models. The theory combines information about consumer and producer optimization problems and how these two groups interact in a market. Palmquist (1989) also noted that farmland was slightly different from the differentiated good that Rosen (1974) discussed. Therefore a short description of Palmquist's (1989) modified hedonic theory is mentioned here as well. For more information on the theory behind the hedonic price function (HPF) please refer to Rosen (1974), Freeman (2003), Day (2001), Palmquist (1991) and Taylor (2003).

#### *2.1.2.1 The Consumer's Maximization Problem*[5]

The HPF (2.1) for a good $Z$ relates the price paid in the market for the whole good to its vector of characteristics $z$ (Rosen 1974).

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[3]This original work could not be obtained and verified.
[4]Rosen (1974) is cited more often in the literature than Freeman (1974).
[5]This section summarizes Rosen's (1974) work. Therefore, the ideas contained within are not the writer's but are Rosen's.

$$P = P(z) = P(z_i, \dots, z_n) \tag{2.1}$$

(Rosen 1974)

where $P$ is the price of good $Z$ and $z_i$ is attribute $i$. From the consumer's point of view her/his goal is to maximize utility ($U$) subject to a budget constraint ($I$). If a numeraire good $x$ is set to unity and the consumer only buys one good, $Z$, then the optimization problem is as follows:

$$\begin{gathered} \text{maximize } U(x, z_\mathrm{i}, \dots, \mathrm{z_n}; \alpha) \\ \text{subject to } I = x + P(z_\mathrm{i}, \dots, \mathrm{z_n}) \end{gathered} \tag{2.2}$$

where $x$ is a numeraire good, $\boldsymbol{\alpha}$ are the consumer's characteristics/skills and $I$ is income (Rosen 1974). Forming a Lagrangian using (2.2) and then taking the first order conditions results in the following expression:

$$\frac{\frac{\partial U}{\partial z_i}}{\frac{\partial U}{\partial x}} = \frac{\partial P(z)}{\partial z_i} \forall i = 1, \dots, n \tag{2.3}$$

(Rosen 1974)

This Equation (2.3) has the nice property that it now underscores how the consumer utility problem relates to the implicit price of $z_i$ (i.e., the partial derivative of the HPF (2.1) with respect to $z_i$). Rosen (1974) used this to develop the concept of the bid curve. Along the bid curve a consumer is indifferent between willing to pay for attribute $z_i$ and having more of that attribute $z_i$. The slope of the bid curve works out to be the positive version of the marginal rate of substitution as shown on the left-hand side of Equation (2.3). As such the bid curve resembles an indifference curve, which has been rotated clockwise 90 degrees. Essentially, the HPF is the constraint for the bid curve. The HPF features the lowest price the consumer must pay in the market for $z_i$, whereas the bid curve is the maximum the consumer would be willing to pay for $z_i$, so at the point of tangency between the HPF and the bid curve the consumer will maximize utility (Day 2001). It is possible for each consumer to have her/his own bid curve depending on his/her utility, characteristics and income, so the HPF actually is an upper envelope for all of the optimizing bid curves (Day 2001).

#### *2.1.2.2 The Farmer as a Consumer*[6]

The understanding of hedonic pricing theory is a little more nuanced than what was described above, when it is applied to farmland. Rosen's (1974) theory used the example of a consumer trying to maximize utility. However, Palmquist (1989) noted that farmers who rent land are producers as well, so the more appropriate maximization problem is one which maximizes profit rather than utility. Land with a vector of characteristics $z$ is an input in the farmer's production function. The farmer's production function can be written implicitly as:

$$g(o, z, \alpha) = 0 \tag{2.4}$$

where $o$ is a vector of netputs (i.e., outputs and non-land inputs), $z$ maintains the definition as mentioned previously, and $\alpha$ are farmer-specific characteristics. The farmer's maximization problem is

$$\begin{gathered} \text{maximize } \pi^v = \textstyle\sum_{j=1}^{m} p_j o_j \\ \text{subject to } g(o, z, \alpha) = 0, \pi^v \geq 0 \end{gathered} \tag{2.5}$$

[6]The functions, ideas and logical framework for presenting the information in this subsection are from Palmquist (1989).

where $\pi^v$ are variable profits. Solving problem (2.5) will generate

$$o^* = o(p, z, \alpha) \quad (2.6)$$

which can be either a non-land input demand function or an output supply function (Palmquist 1989). If these are substituted into the profit function, a variable profit function is obtained (2.7):

$$\pi^{*v} = \sum_{j=1}^{m} p_j o_j(p, z, \alpha) = \pi^{*v}(p, z, \alpha) \quad (2.7)$$

(Palmquist 1989)

The farmer will be willing to bid for use of the land an amount, $\theta$, which is equal to the variable profits minus the desired level of profits and is shown in Equation (2.8).

$$\theta(z, p, \pi^{desired}, \alpha) = \pi^{*v}(p, z, \alpha) - \pi^{desired} \quad (2.8)$$

(Palmquist 1989)

This bid curve replaces the one discussed in the earlier section and the rest of the analysis proceeds as discussed in the previous paragraphs, including equating the marginal bid for a characteristic to the implicit rental price for a characteristic available in the market.

#### *2.1.2.3 Additional Points about the Hedonic Price Function*[7]

To fully understand the HPF, one needs to understand both the consumers' and the producers' objectives. While consumers submit bids with the objective of maximizing their utility, producers/suppliers will submit offers with the objective of

[7]Except where otherwise cited, this section summarizes Rosen's (1974) work.

maximizing their profit. The offer function displays the trade-off between the level of $z_i$ the supplier provides and the price the supplier is willing to accept to stay at a constant profit level. The producer problem accounts for a production function, costs of production and technology. The HPF is referred to as a joint (Rosen 1974) or double envelope (Freeman 2003) because it is an envelope for both the bid and offer curves. At the point of tangency between the bid or offer curve and the HPF, the optimal $z_i$ is chosen which maximizes utility or profit. Market transactions occur when each buyer is paired with a seller, and these interactions will reveal the underlying HPF or equilibrium price schedule.

There are several assumptions that must be made to allow for the HPF to be used. Miranowski and Hammes (1984) and Harrison and Rubinfeld (1978) outline these assumptions, some of which were also mentioned by Rosen (1974): buyers and sellers know of all the options (including characteristics) available to them in the market (a single market); the demand and supply for land are in equilibrium; and many properties with a variety of combinations of characteristics are available in the land market (this ensures the HPF is continuous, which facilitates the calculation of derivatives). Neither a producer nor a consumer can influence the equilibrium price (Rosen 1974); that is, they are both price-takers.

### 2.1.3 Hedonics – The Application to Farmland Valuation

The utility of the hedonic pricing model itself is evidenced by its wide application in studies of factors affecting things like crop prices (e.g., Wilson 1984), automobile prices (e.g., Goodman 1983), and housing prices. One advantage of the hedonic pricing model is that it can be used to tease out the effects of external factors. Examples in the housing price literature include studies of the effect on housing prices of factors such as a nearby landfill (Hite et al 2001), shale gas exploration (Gopalakrishnan and Klaiber 2014), air pollution (Nelson 1978; Harrison and Rubinfeld 1978) or agricultural amenities and disamenities (Ready and Abdalla 2005). Not surprisingly, the hedonic method has also been used to study what factors affect farmland values as well. There are many studies which look at this topic of which only a handful are listed here: Palmquist and Danielson (1989); Elad et al (1994); and Chicoine (1981).

Like many of the various farmland valuation models discussed in the next subsection (2.1.4), hedonic models can incorporate ideas from Von Thünen, Ricardo, and Capozza and Helsley. From Von Thünen economic rent declined with distance from the market, and this could be related to transportation costs because those costs would grow with distance from the market (Sinclair 1967). Ricardo (1817/1937) wrote about the economic theory of rent and used agricultural land to illustrate his points. In his theory, rent existed when land of different productive capabilities was brought into production (Ricardo 1817/1937). "Rent … [was] paid … for the use of the original and indestructible powers of the soil" (Ricardo 1817/1937, p. 33). At some point this idea materialized into a mathematical expression, often termed the capitalization formula or present value model, which related the price of land to the present value of expected future agricultural rents (Clark et al 1993a). Chryst (1965) observed that farmland values moved together with farm commodity prices in the early 1900s and thus, seemed to confirm the relationship between farm income and farmland price. However, Chryst (1965) also noticed that this was not the case in the 1950s and 1960s. He was not alone in this recognition that farmland prices and incomes lacked a correspondence in the 1950s and 1960s, as others like Reynolds and Timmons (1969) reported this as well. Chryst (1965) surmised that farmland price was related to supply and demand interactions for land, and recognized that farmland was often purchased for nonfarm purposes.

The literature was then advanced by those who tried to include nonfarm factors in farmland valuation models. Capozza and Helsley (1989) adapted an urban growth model to farmland valuation. They recognized that there was a gradient, so that at a near enough distance to an urban area farmland would sell for a price based on its agricultural rent, the costs of conversion and the present value of expected development rents (Capozza and Helsley 1989). At further distances from urban areas, only the agricultural rents would be relevant for predicting farmland values (Capozza and Helsley 1989). Whereas Capozza and Helsley (1989) focused on agricultural and urban areas, Blank (2008) suggested a model which expressed farmland values in terms of their current profit and the present value of the weighted sum of all expected future profits from all prospective land uses (not just urban).

In 1991, Falk recognized that the present value (capitalization) model was not adequately explaining farmland prices in Iowa over the 1921–1986 sample period. Falk and Lee (1998) found that the present value model still worked when evaluating long-run values, but it did not work as well in the short-run. Farmland valuation models today tend to include a number of factors that are related to the farm (productivity) as well as nonfarm aspects (e.g., urban influences). Palmquist (1989) categorized them in another way: unchangeable (those like soil type which cannot be controlled by the farmer) and changeable (those properties of the land that the farmer can manipulate to some degree such as irrigation). Blank (2008) categorized the factors influencing farmland values as productivity of agriculture, policies, amenities and urban influences, and that is how they will be discussed next using examples from the hedonics literature.

Traditional theory only considered the aspects of land related to agricultural productivity. Examples of these include a soil productivity index, soil erosion, temperature, and precipitation. Palmquist and Danielson (1989) reported that draining wet soils could improve land values, and higher soil quality contributed to higher land values. Huang et al (2006) also found a positive relationship between farmland value and soil productivity. Land values increased again with reductions in potential soil loss (Palmquist and Danielson 1989; Miranowski and Hammes 1984). Mendelsohn et al (1994) found temperature and precipitation effects depended on the month/season. These researchers used a Ricardian approach (Mendelsohn et al 1994), which closely resembled a hedonic approach. In general, the agricultural productivity variables responded in a way that was expected. Those that were likely to increase agricultural returns or productivity were also positively related to the farmland value.

Related to the idea that net farm income from the land has some impact on farmland values, government payments as a source of income may also have an impact. A Canadian study concluded that direct government agricultural subsidies, which fall under a number of programs, had a positive influence on farmland values (Weersink et al 1999). Another Canadian study by Clark et al (1993b) found some weak evidence that subsidies and income combined were capitalized into land values. Veeman et al (1993) simulated a one-time permanent removal of direct government subsidies on Canadian farmland prices and found this removal decreased the land prices by way of decreasing total farm cash receipts. None of these three papers used the hedonic approach.

Other policies, which are not tied directly to income, have also been studied. Chicoine (1981) found that industrial/commercial zoning raised land values relative to agricultural zoning, but residential zoning was not significant. In British Columbia, Canada, an Agricultural Land Reserve (ALR) program is in place which limits subdivision of agricultural parcels and limits non-agricultural uses of parcels if they are in a designated agricultural area (Cotteleer et al 2011). Cotteleer et al (2011) found only that distance to the ALR boundary had an effect on farmland values (with parcels more embedded within the ALR having higher land values), but a dummy variable indicating a parcel was located within the ALR was not significant. Another Canadian study looked at agricultural land zoning in Ontario, Canada, specifically vacant agricultural land, and found that the zoning did not reduce land values as a whole, but could have a negative impact on land values nearby to urban areas (Deaton and Vyn

2015). Lastly, Lynch et al (2007) looked at agricultural easements used to preserve farmland and found a negative effect of this program on farmland price if they used the hedonic approach and no effect or a negative effect if they used a propensity score matching approach.[8] Based on the information presented, policies will have different impacts on agricultural land values and these effects depend on other characteristics of the parcel such as its proximity to urban areas.

Also related to income streams and other potential uses are amenity effects. For example, in addition to food production, farmland provides habitat for wildlife. In the U.S., farmers are able to increase their income by allowing recreational users to access their properties (Henderson and Moore 2006). Henderson and Moore (2006) found that the coefficients for hunting lease rates, deer density, and recreation service income were positive and significant in predicting farmland values. Mixed results exist for the impact on farmland values of elk habitat (positive, negative or not significant), a fish productivity measure (positive or not significant), and the diversity of views from a parcel's centroid (positive or not significant) (Bastian et al 2002). However, the results are dependent on whether one considers a region or the entire state as well as the functional form used (Bastian et al 2002). Huang et al (2006) included a swine farm density variable, which was found to have a negative effect on farmland values. However, the authors noted that this result reflected an equilibrium outcome because it is possible for swine farms to have a positive and a negative effect (Huang et al 2006).

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[8]Propensity score matching is a nonparametric approach which matches preserved parcels to nonpreserved parcels that are otherwise similar in characteristics (Lynch et al 2007).

Finally, the last category of variables is the one that reflects urban influences. A number of papers have tried to include variables which signal such an influence. For example, Henderson and Moore (2006) included dummy variables which indicated if a county was considered a metropolitan area or if a county was next to a metropolitan area to try to capture the effects of urban sprawl on farmland demand. These variables were usually significant and had a positive impact on farmland values (Henderson and Moore 2006). Shi et al (1997) (who did not use a hedonic model) also included a measure that tried to reflect the demand for farmland, which summed three ratios that related the population of one of three metropolitan areas to the squared distance from the county to the metropolitan area. They found that this variable had a significant and positive effect on farmland values (Shi et al 1997). A number of other variables have been tried and they are discussed in more detail in Chapter Three.

### 2.1.4 Alternatives to Hedonic Models

The hedonic method is not the only type of method that has been employed to study farmland values. Others have tried simultaneous equations (e.g., Herdt and Cochrane 1966; Hardie et al 2001), recursive models (e.g., Reynolds and Timmons 1969), time series (e.g., Burt 1986; Falk and Lee 1998), urban growth models (e.g., Plantinga and Miller 2001; Hardie et al 2001), mixed models (e.g., Cavailhès and Wavresky 2003), and propensity score matching (e.g., Lynch et al 2007). Cotteleer et al (2011) also applied Bayesian Model Averaging and Markov Chain Monte Carlo Model Composition to the hedonic modelling approach. Inclusion of nonfarm factors as determinants of farmland values have become more prominent over time, while some of the methods have fallen out of favour including those that relate the land value to only the present value of expected future agricultural rents.[9] Pope et al (1979) also found that simultaneous equations were not as suitable as other model types at forecasting farmland prices. Furthermore, by recognizing the spatial dependencies that exist in the practice of real estate (i.e., realtors' consider a neighbourhood's past price history when setting a listing price, as do sellers who are deciding to renovate) (Can 1990), spatial econometrics are used more widely and have been combined with hedonic models (e.g., Patton and McErlean 2003; Huang et al 2006; and Cotteleer et al 2011). The hedonic approach was chosen for this study because it is able to encompass the theories that have come before it. It can include variables that relate to both agricultural returns and non-agricultural returns.

## 2.2 Fragmentation and Conversion Literature

Although conversion and fragmentation can be closely related, they need not be the same thing. Looking to the literature on habitat fragmentation, Fahrig (2003) notes that one issue in the literature is a tendency to combine the effects of habitat fragmentation and habitat loss when in fact they can exist as two separate entities which may have different effects. Thus, like habitat loss or conversion and habitat fragmentation it is relevant to deal with fragmentation of farmland as a separate issue from farmland conversion because they could have different effects.

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[9]This is referring to the previously mentioned observation by Falk (1991).

This section provides an overview of the literature on conversion and fragmentation. It achieves this by discussing the effects and measures of conversion and fragmentation and by describing the degree of conversion and fragmentation in Alberta.

### 2.2.1 Conversion

Land cover/land use (LCLU) change is used in this paper to describe agricultural land conversion because agricultural vegetation is a type of land cover, while agricultural practices reflect a particular type of land use.  Land cover is defined as the biological and physical cover over the land, and examples include water, urban structures, vegetation and bare rock (Ellis 2013; National Oceanic and Atmospheric Administration [NOAA] 2015; Natural Resources Canada 2013). Satellite images can be used to study changes in land cover (NOAA 2015). On the other hand, land use refers to how humans make use of the landscape for purposes like development and conservation (NOAA 2015).

#### *2.2.1.1The Effects of Conversion*

The effects of conversion are numerous. They can be socioeconomic and environmental, and they can be felt at several levels (global, regional and local). The effects are so broad because of the basic nature of conversion. Conversion involves the substituting of one LCLU type for a different LCLU type (i.e., an addition and a deletion). Thus, even though the focus of this thesis is on agricultural land, it is difficult to speak of agricultural LCLU change without acknowledging the other LCLU changes that occur simultaneously when agricultural land increases or decreases. At a global level LCLU changes have impacts on the global carbon cycle, habitat loss, soil degradation, nutrient runoff, surface radiation balance, air quality and even infectious disease transmission (as summarized in a review by Foley et al 2005). DeFries et al (2004) highlight the trade-off between land uses required to meet society's needs and obtain societal advantages versus potentially harming ecosystems' long-term abilities of being able to continue to contribute to those needs.

The most obvious and prominent benefit of agriculture is the provision of food, although agriculture does provide other amenities. Concerns about food security often surface when the topic of agricultural land conversion is discussed. Studies have therefore often considered food security when quantifying agricultural land conversion. A study by Deng et al (2006) concluded that during their study period, despite losses of high quality land, enough land was brought into agricultural production so that food security was unaffected. However, others like Lichtenberg and Ding (2008) are still concerned about food security because of factors such as the loss of farmland capable of producing multiple crops per year.

Ready and Abdalla (2005) and others outline several amenities (e.g., groundwater recharge and habitat provision) and disamenities (e.g., nutrient runoff, noise and odours) associated with agricultural land. Thus, any addition or loss of agricultural land will affect the availability of these amenities/disamenities. Likewise, when agricultural land is created from clearing forests and breaking grasslands, there are costs in terms of lost ecosystem services provided by these types of LCLUs. Francis et al (2012) also highlight the need to take a balanced approach when deciding about converting agricultural land, one that compares the short-term benefits realized through conversion versus the long-term need for agricultural products.

Another concern about agricultural land conversion revolves around agricultural to urban land conversion. The concern is heightened in areas where a large amount of urban expansion occurs on agricultural land. In China, for example, Li et al (2013) reported that 80% of urban expansion occurred on agricultural land. Urbanization can influence farming activity through a number of mechanisms. For example, it may reduce the level of investment in farming if farmland conversion looks like it will occur in the future (the so called 'impermanence syndrome') (Lopez et al 1988). Lisansky (1986) commented on the farmers' loss of nearby agricultural services in areas where conversion was occurring. Similarly, Wu (2008) noted that information and equipment sharing between farmers would/may disappear as farms were converted. Furthermore, urbanization may encourage crop switching to crops of higher value like vegetables (Heimlich 1989), as Lopez et al (1988) found that only vegetable revenues increased around suburban areas. Crop switching may be a benefit or a "cost" associated with conversion depending on how costly it is to switch and whether revenues after switching will exceed the costs. Thus, the economic effects on the farmer could depend on the type of operation he/she runs and is capable of switching to and the degree of urban expansion around her/his farm.

#### *2.2.1.2 The Drivers of Conversion*

Complementary studies to those on LCLU change are those that try to identify and explain the drivers of farmland conversion. Notably, only a few of the studies are discussed here. Knowing these drivers can help to inform policy on farmland conversion. For example, Heilig (1997) assumes that future Chinese land use changes will be driven by industrialization and modernization, changes in consumer preferences, population growth, rural-to-urban migration, and economic and political institutional changes.

There is an underlying theory to support Heilig's and others' selection of drivers. For example, in formulating their theory on land values Capozza and Helsley (1989) discussed the timing of conversion. In their view, the optimal time of conversion was chosen to maximize the present value of an owner's agricultural land (Capozza and Helsley 1989). The present value of agricultural land was related to the rents from urban land after conversion, the costs of conversion, and the agricultural land rent before conversion (Capozza and Helsley 1989). Irwin and Bockstael's (2002) conceptual framework on the optimal time to develop a parcel likewise related to the models mentioned by Capozza and Helsley (1989) and Arnott and Lewis (1979). However, Irwin and Bockstael (2002) also included interaction effects or spillover effects because they felt the surrounding land uses would affect the net returns from developing a parcel. Table 2.1 summarizes the reasons for including drivers and provides example drivers for each category.

The reasons underlying the inclusion of particular drivers in a LCLU change model can assist with the interpretation of the signs on the coefficients/drivers used in empirical work. For example, when studying the change in farmland to developed land, Qiu et al (2015) found a negative relationship between the rate of farmland conversion and increased mean growing season temperature. Why this negative relationship was found could be explained in terms of opportunity costs (Qiu et al 2015). If the mean growing season temperature for a parcel made it a more productive parcel, this would have an impact on the agricultural returns of the parcel. Now knowing how to interpret the effects of drivers, the next two paragraphs summarize some of the results from conversion studies from selected papers.

Carrión-Flores and Irwin (2004) found that the probability of conversion to residential land increased because of a preference for high quality land, a preference for low-density and higher proportions of neighbouring residential and commercial lands (relative to industrial neighbours), and varied by local jurisdiction. Seto and Kaufmann (2003) found that agricultural land conversion to urban land was positively related to the ratio of agricultural land productivity to urban land productivity, completed investments in capital construction per capita, and off-farm wages, and was negatively related to agricultural labour productivity. Li et al (2013) studied the drivers of several types of land use change in China. They looked at how forestland, grassland and farmland remained in those uses or changed to other uses (farmland, forestland, grassland, water, urban land, and unused land) (Li et al 2013). From 2000 to 2005, increases in elevation, precipitation, urban and rural gross domestic product (GDP) per person and urban GDP per hectare decreased the probability that farmland would continue to exist as farmland, while temperature, slope, road density and public agricultural investment had the opposite effect, and rural GDP per hectare and land quality were not significant (Li et al 2013).

Two Alberta analyses using the same data set, but different methodologies, have also looked at the drivers of farmland conversion to developed land. The first study, by Haarsma (2014), used a geographically weighted regression and found a relationship between agricultural land conversion and several drivers, including population density, agricultural land values, household income, and distance to an elevator or a city. Further, Haarsma (2014) determined that these drivers could be positive, negative or insignificant depending on the location. The second study, by Qiu et al (2015), revealed the following drivers had an influence[10] on farmland conversion: the change in fragmentation of farmland (positive relationship); change in population density (positive); agricultural land values (positive); mean growing season temperature (negative); land suitability (negative); elevation (negative); and road density (positive). Many of the drivers in these Alberta analyses are similar to the ones listed earlier, with the exception of land values. Although they are not Alberta studies, Li et al (2013) and Lichtenberg and Ding (2009) also hint at the relationship between land values and LCLU change because they included proxies for land values (e.g., GDP) to see how they

[10]The direction of the influence is provided in parentheses.

affected land conversion. Given that this thesis is interested in what factors influence farmland values it is important to recognize that farmland values can also influence conversion. As the land value reflects the present value of land rents (e.g., urban premiums and agricultural rents), changes in the relative importance of these rent components can affect the selection between the various land use alternatives.  This issue is discussed again in Chapter Three.

Lambin et al (2001) took a different approach. Instead of conducting a single analysis to identify the causes of LCLU change, they brought together ideas from a variety of experts in the field of LCLU change (Lambin et al 2001). They suggested that globalization has a role to play in strengthening or diminishing the drivers of land use change (Lambin et al 2001). For example, a policy developed in China or Finland to conserve forest can lead to deforestation in countries like Russia, as demand for wood products still exists and merely shifts to a different source/location (Mayer et al 2005). Also, Brazilian rainforest and grassland may face pressure to convert to cropland from increased demand for feedstock for livestock in China, Brazil and India (Naylor et al 2005). Globalization can have a more positive impact on LCLU in local areas as consumers (importers) demand products that cannot be sourced from recently deforested areas (Lambin and Meyfroidt 2011). It is clear that there are many possible drivers of conversion, and they differ between studies based on what the researchers have elected to study.

### *2.2.1.3 Measuring Conversion*

The measures of conversion fall into two categories: those that note the change in LCLU over time, and those which act as a proxy for conversion. In the first case, the change in LCLU forms a dependent variable in studies that examine factors influencing LCLU changes. This can take a few different forms depending on the type of regression method being used. Irwin et al (2003) and Carrión-Flores and Irwin (2004), for example, used an indicator variable to denote the case where the LCLU changed from agriculture, (or forest or natural land) to residential land during a given time period. Li et al (2013) tried to predict categorical variables in a given time period (e.g., did farmland remain as farmland or change to forestland). Haarsma (2014) looked at the change in developed land over a time period and Haarsma (2014) and Qiu et al (2015) looked at the change from agricultural land to developed land over a time period. This method requires having a data set, often satellite data, and then identifying and/or quantifying LCLU at different times by location (e.g., parcel or township).

On the other hand, there are studies which use conversion as explanatory variables in their models. In this case, the conversion measure may resemble a driver of conversion. For example, Plantinga and Miller (2001) chose population change as a variable to proxy future development rents because it indicated the need for more urban space in the future, and as such the urban area overtakes the neighbouring rural area.[11] Cavailhès and Wavresky (2003) used the distance to a city because it in part

[11]Though, they did not refer to population change as a conversion measure.

reflected expectations about the timing of future conversion. Also, some of the measures for conversion do not signal conversion alone, but may also reflect transportation costs for the farmer (e.g., distance to a city/market). Regardless, the research question can assist in the selection of a conversion measure.

#### *2.2.1.4 Farmland Conversion in Alberta*

Researchers have quantified farmland conversion, and urban land use changes in Alberta. Some past studies used Census of Agriculture data and other non-satellite types of data to quantify changes in crop type (Rashford et al 2011) or agricultural land additions and deletions (e.g., AAFRD (2002) and five Alberta Agricultural Land Base Monitoring Reports spanning 1976–1995 (Bazian et al 1998)), while others have used satellite data (Haarsma 2014; Qiu et al 2015; Young et al 2006). Table 2.2 summarizes some of their findings. In general, urban land use tends to be increasing over time, and the quantity of agricultural land is decreasing. Hofmann (2001) reported that between 1971 and 1996 urban land in Alberta increased by 132%. This is important given that Haarsma (2014) and Qiu et al (2015) reported that about 80% of development expansion occurred on agricultural land.

Although in recent times it appears that farmland area is declining, this does not mean that it is declining in all time periods or in all locations. For example, from 1991 to 1995 Bazian et al (1998) actually reported a net gain in farmland in the White Area of

Alberta.[12] They attributed this increase to a change in public policy on land leases at the time, which made more farmland available on the market (Bazian et al 1998). In Haarsma's (2014) study, farmland was converted to other land uses (not just urban land uses), just as other LCLUs (e.g., forest and grassland) were converted to farmland. Bazian et al (1998) noted additions to farmland could occur because of public land sales, well abandonment, reclamation of extraction sites, and rural annexations. Conversely, losses could occur because of urban annexations, resource extraction, oil and gas activity, and subdivisions for residential, industrial and commercial purposes and public services and utilities (Bazian et al 1998). Some losses were more permanent than others (e.g., wellsites and resource extraction sites would eventually be reclaimed) (Bazian et al 1998).

As Deng et al (2006) noted it is important to consider both the quantity and quality of agricultural land use change to understand the implications for food security. In Canada, 7% of the land mass is suitable for agriculture, but only about 5% of the land is classified as being dependable agricultural land (Hofmann 2001).[13] In Alberta, Hofmann (2001) reported that 16% of the land is dependable agricultural land. Alberta researchers have studied the loss of quality agricultural land. Of the newly developed agricultural land about 90% (Qiu et al 2015) or 68.3% (Haarsma 2014) was of good

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[12]In Bazian et al's (1998) study the White Area includes agricultural land and settled land (but outside of incorporated urban boundaries), or one third of the province's acreage, and omits reserves (military and Aboriginal), parks (national and provincial) and the Green Area (i.e., an area covered in forest).

[13]Hofmann's data came from McCuaig and Manning (1982). Dependable, as defined by Hofmann (2001), refers to the Canada Land Inventory Classes 1–3. Classes 1–3 are the most suitable for crops (Hofmann 2001).

quality land depending on the area of interest. Qiu et al (2015) focused on the area around Edmonton and Calgary and the major highway connecting them (i.e., where the majority of Alberta's population resides). The findings from Haarsma (2014) related to the entire White Area of the province which included Qiu et al's (2015) study area, but also areas north, south, east and west considered to be private land.

### 2.2.2 Fragmentation

There are two general ways to think about farmland fragmentation. The first type of farmland fragmentation relates to LCLU. In this case, farmland is surrounded by other types of land cover (urban, trees, etc.) and thus other non-agricultural LCLU types intervene or come between patches of farmland to give the landscape a fragmented appearance. From the air the land may resemble a checkerboard of different LCLU types. The second type of farmland fragmentation relates to an individual farmer's land holdings, in that instead of having one contiguous parcel the farm is broken down into smaller parcels (fragments) which are distributed over an area. This type of fragmentation may occur due to inheritance, population pressure (as Blarel et al (1992) summarized the literature) or land restitution following regime changes (i.e., post-communism) (Dirimanova 2005). It is possible for the two types of farmland fragmentation to coexist, but it is also possible to have one type of fragmentation or the other. Although many of the impacts of fragmentation on agricultural production will be similar regardless of the process of fragmentation, the measures will look quite different.

#### *2.2.2.1 The Impacts of Fragmentation on Agriculture*

Just as there are costs and benefits of converting farmland, the same is true for fragmentation of farmland. Costs of fragmentation are often given as being an increase in the time it takes to travel to plots, management and supervision of plots, and the creation of additional boundaries which affect both fencing costs and the mechanization of farming (McCloskey 1975 as cited by McCloskey 1976;[14] Hung et al 2007; Blarel et al 1992; Sundqvist and Andersson 2006). The commonly cited benefits are risk reduction, often achieved through a decrease in the variance of total output (e.g., during a flood or drought some parcels will cope better than others), spreading harvesting times which alleviates the pressure on labour, and perhaps even increased biodiversity (as discussed in the review by Bentley 1987; Hung et al 2007; Buck 1964 and Johnson and Barlowe 1954 as cited by Blarel et al 1992[15]). Of course, if parcels are geographically distributed over a smaller or localized area, many of these benefits will be reduced or negligible.

A number of studies have looked at the impacts of fragmentation on agriculture. These studies often consider the production function or cost function, but few have looked at both the costs and benefits of the issue (Kawasaki 2010). Some of the findings are summarized in Table 2.3. For example, the "costs" of fragmentation tend to relate to decreases in crop yields. Wan and Cheng (2001, p. 186) stated that "land fragmentation affects the entire production process rather than a particular input or particular phase(s) of production." Wan and Cheng (2001) reported that land fragmentation was associated

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[14]The citation by McCloskey (1976) was not verified.
[15]The citations by Blarel et al (1992) were not verified.

with ineffective utilization of resources. When land is fragmented, land is removed from production for access routes and boundaries; more evaporation or seepage of inputs like water, pesticide and fertilizer occurs; and more fuel and labour are used for travelling to different plots (Wan and Cheng 2001). Although there are benefits related to the risk reduction, Kawasaki (2010) finds that the costs of fragmentation outweigh these benefits. As Kawasaki (2010) suggests, however, developed economies and less developed economies may view the magnitude of the benefits of fragmentation differently depending on the availability of insurance markets and other risk-spreading devices.

#### *2.2.2.2 Measuring Fragmentation*

In order to study the impacts of fragmentation, an objective means to measure this phenomenon is required. There are a number of metrics that can be used to measure fragmentation. These fragmentation measures can also be referred to as landscape (pattern) metrics, and have been used to study habitat fragmentation (see the review by Fahrig 2003) and changes in land cover (e.g., Young et al 2006). They have also been used along with production functions and/or cost functions (e.g., Nguyen et al 1996; Hung et al 2007; Tan et al 2008). These last examples have used measures that look at the fragmentation of land holdings, in which case the land cover could still be homogenous.

There is no single comprehensive fragmentation measure (Bentley 1987) as each has a particular function. For example, a fragmentation measure describing the number of plots per farm misses the distance between plots (Bentley 1987). Evidence of the abundance of fragmentation measures is shown in Table 2.4, which contains several of the possible fragmentation measures reported in the literature. Latruffe and Piet (2013) used a number of descriptors, not all of which are mentioned in Table 2.4, and grouped them into categories based on whether they described scattering of plots, distance from a plot to the farm, size of plots (Simpson index and Januszewski index), number of plots and shape of plots. Several of the measures in Table 2.4 are variations of one of several themes: (1) the number of plots per farm (more plots can indicate more fragmentation); (2) the size of the patch[16] (smaller patches could signal fragmentation); (3) the ratio of the perimeter to the area of a patch (a higher ratio could indicate more fragmentation); and (4) the land cover types surrounding a patch (if more nonfarm land cover patches surround a farm patch this suggests there is more fragmentation). Geoghegan et al (1997) and Cotteleer et al (2007; 2011) are two of the few studies identified that have included fragmentation measures in a hedonic pricing model. The latter research collaboration studied farmland values.

#### *2.2.2.3 Farmland Fragmentation in Alberta*

Alberta investigations have examined the LCLU type of fragmentation and the results are mixed. Haarsma (2014) and Qiu et al (2015) use similar data sets, but focus on different areas of the province. They find that fragmentation declined in aggregate from 2000 to 2012 in Alberta (Haarsma 2014; Qiu et al 2015). This finding is supported by Statistics Canada's (No date [n.d.-i]) data on the average Alberta farm size, which

[16]Patch refers to a contiguous agricultural LCLU area.

increased from 2001 to 2011. However, the decline in fragmentation is not a universal phenomenon as Qiu et al (2015) note that there are areas around the major urban centres of Edmonton and Calgary that are indeed experiencing farmland fragmentation. Thus, the patterning of farmland fragmentation is varied around the agricultural area of the province.

## 2.3 Chapter Summary

This chapter reviewed a lot of information from the basics on how a hedonic pricing model works, to the global and local LCLU changes that are occurring and their impacts. As conversion and fragmentation are major focal points of this thesis more about these phenomena including their benefits, costs, and measures were mentioned.

Although it is not the only method that can be used to study farmland values, the hedonic model used in property valuation can also be applied to farmland valuation as demonstrated by Palmquist (1989). There are a number of variables, supported by theory, which may be included in a hedonic pricing model and they fall into categories noted earlier: agricultural productivity, amenities, policies and urban effects (Blank 2008). Additionally, there is an abundance of literature on fragmentation and conversion. Previous Alberta studies recognize that these phenomena are features of the Alberta landscape, although less is known about the fragmentation of farmers' land holdings. It is entirely possible for fragmentation and conversion to enter into the hedonic model through several of the broader variable categories: agricultural productivity, urban effects and amenities. Chapter Three provides more information on how the hedonic model was employed and the variables chosen.

## 2.4 Tables for Chapter Two

**Table 2.1 Explanations for including particular drivers of conversion**

| Explanation for Inclusion as a Driver | Example Drivers[a] |
|---|---|
| Reflects the costs of conversion | • usually the physical aspects of the property fall under this category like slope<br>• administrative fees<br>• permits<br>• availability of public utilities |
| Urban rent | • distance/quality/availability of services<br>• spillover effects (e.g., surrounding land uses)<br>• congestion effects (e.g., population density)<br>• growth management policies (e.g., number of lots and land preserves) |
| Rent from undeveloped uses | • agricultural productivity that would be lost due to conversion |
| Other external policies or processes that may affect the probability of conversion[17] | • income per capita<br>• foreign direct investment<br>• public agricultural investment |

Sources: Irwin and Bockstael (2002), Irwin et al (2003), Carrión-Flores and Irwin (2004), Seto and Kaufmann (2003), Li et al (2013), Haarsma (2014) and Qiu et al (2015).[18]

[a]Drivers can be positive or negative.

[17]Items in this category can affect the three aforementioned categories.
[18]Although Irwin and Bockstael (2002), Irwin et al (2003), Carrión-Flores and Irwin (2004) and Seto and Kaufmann (2003) looked at urban land conversion, often the urban land had previously been agricultural land, so their papers are still relevant to this discussion.

**Table 2.2 Alberta urban and agricultural land cover/land use change studies**

| Study | Time Period | Location | Change in Agricultural Land (hectares) | Change in Urban Land (hectares) |
|---|---|---|---|---|
| AAFRD (2002) | 1997–1998 | Agricultural areas | Loss 10,655[a] | Not studied |
| Bazian et al (1998) | 1976–1995 | White Area[b] | Net loss of 102,305 | Not studied |
| Haarsma (2014) | 2000 and 2012 | White Area | Net loss 845,179 | Net gain of 101,436 |
| Qiu et al (2015) | 2000 and 2012 | Area between Edmonton and Calgary | Net loss of 178,508 | Net gain of 62,537 |
| Young et al (2006) | 1977 and 1987<br>1987 and 1998 | Beaver Hills and surroundings (east of Edmonton) | Not reported | Gain of 4,182<br>Gain of 20,621 |

Note: Edmonton and Calgary are the largest urban centres in Alberta. Edmonton is near the centre of Alberta and Calgary is about 300 km south.

[a]This study only looked at agricultural land converted to non-agricultural uses. It did not consider gains in agricultural land or agricultural land converted to other land uses.
[b]Alberta is divided into two areas, Green and White. The Green Area is mainly in the north and along the western border where the mountains are and is mostly forested (Government of Alberta 2012). The White Area is considered the settled area, where the majority of the population lives, and most of the land is privately owned (Government of Alberta 2012). The majority of agricultural activities occur in the White Area, although some grazing is allowed in the Green Area (Government of Alberta 2012).

**Table 2.3 Examples of fragmentation and agricultural productivity studies**

| Study | Location | Result |
|---|---|---|
| Blarel et al (1992) | Ghana and Rwanda | Fragmentation does not impact parcel yields. |
| Hung et al (2007) | Vietnam | Number of plots has a negative impact on crop yield. |
| Kawasaki (2010) | Japan | Costs of fragmentation are larger than the benefits. |
| Latruffe and Piet (2013) | France | Generalization: land fragmentation is related to higher production costs, lower revenue/profitability and lower crop yields. |
| Nguyen et al (1996) | China | Increasing crop outputs as plot size increases (with caveats). |
| Wan and Cheng (2001) | China | Increasing plot number leads to decreases in crop outputs. |

**Table 2.4 Fragmentation measures**

| Fragmentation Measure | Explanation | Examples of Studies who used this Measure[a] |
|---|---|---|
| Average Acres Sold | Summed acres per transaction divided by number of transactions | Mervish et al (2008) |
| Average Distance of Plots | Computes the average distance between farm plots and the farm homestead | Tan et al (2008) |
| Average Plot Size | Sum plot sizes per farm divided by the number of plots in the farm | Latruffe and Piet (2013); Nguyen et al (1996); |
| Contagion | Considers the conditional probability of a cell next to one or two cells of different land covers (i.e., are there several large patches or small patches)[b] | Hunsaker et al (1994); O'Neill et al (1988); |
| Contrasting Edge Proportion | Summed length of shared cell edge between two different land uses divided by this number and the summed length of shared cell edge between two of the same land use cells | Irwin and Bockstael (2007) |
| Contrasting Edge Ratio | Summed length of shared cell edge between two different land uses divided by summed length of shared cell edge between two of the same land use cells | Irwin and Bockstael (2007) |
| Cumulative Fragmentation Value | "Total number of parcels divided by [the number] of subdivisions approved" in a time period (AAFRD 2002, p. 18) | AAFRD (2002) |
| Edge Density | Summed perimeters divided by summed patch areas | Qiu et al (2015) |
| Edge to Interior Ratio | Summed ratios of perimeter to area for a single land cover type | Geoghegan et al (1997) |

*(Continued)*

Table 2.4 Continued

| **Fragmentation Measure** | **Explanation** | **Examples of Studies who used this Measure**[a] |
|---|---|---|
| Effective Mesh Size | Summed squared patch areas divided by total single land use area | Haarsma (2014); Qiu et al (2015); |
| Farm Size | Area of farm | Tan et al (2008) |
| Fragmentation Index | "Proportion of the perimeter bordering other farmland parcels multiplied by the size of the block of all farmland adjacent to the parcel" (Cotteleer et al 2011, p. 547) | Stobbe et al (2008); Cotteleer et al (2007; 2011); |
| Fragmentation Index using Land Sales | Sum all parcels sold under 80 acres and divide by all parcels sold (units are acres per acres) | Mervish et al (2008) |
| Loss and Fragmentation Index | Subjective measure developed based on municipal survey questions | AAFRD (2002) |
| Mean Dispersion | Calculates the proportion of different land use cells within a certain distance from a focal cell and divides the summed proportions by the number of cells in the same land use as the focal cell | Irwin and Bockstael (2007) |
| Mean Patch Size (or standard deviation) | Summed patch areas of a single land use divided by the number of patches of that land use | Carrión-Flores and Irwin (2004); Haarsma (2014); Irwin and Bockstael (2007); Qiu et al (2015); Young et al (2006); |
| Mean Perimeter to Area Ratio | Mean perimeter divided by mean area for a single land use<br>OR<br>Summed ratios of each patch's perimeter to area divided by the number of patches (calculated for a single land use) | Carrión-Flores and Irwin (2004); Haarsma(2014); Irwin and Bockstael (2007); Qiu et al (2015); |

*(Continued)*

Table 2.4 Continued

| **Fragmentation Measure** | **Explanation** | **Examples of Studies who used this Measure**[a] |
|---|---|---|
| Number of Land Sales | Count of land sales | Mervish et al (2008) |
| Number of Patches | Count of patches of a single land use | Carrión-Flores and Irwin (2004); Young et al (2006); |
| Number of Plots | Count of plots/parcels per farm or household | Blarel et al (1992); Hung et al (2007); Kawasaki (2010); Latruffe and Piet (2013); Wan and Cheng (2001); |
| Patch Density | Number of patches (of a single land use) divided by landscape area | Haarsma (2014); Irwin and Bockstael (2007); Qiu et al (2015); |
| Simpson Index | One minus the sum of the squared parcels' areas divided by the squared total farm size. (Higher values indicate more fragmentation). | Blarel et al (1992); Hung et al (2007); Latruffe and Piet (2013); Kawasaki (2010); Tan et al (2008); |
| Total Edge Metric | Summed perimeters for all patches of a single land use | Carrión-Flores and Irwin (2004) |

[a]This does not imply that these researchers were the first to use these measures.
[b]Hunsaker et al (1994) and O'Neill et al (1988) used different equations.

# Chapter 3: Study Location, Data and Methods

The purpose of this chapter is to describe where and how the study on farmland values was conducted. The first section of this chapter describes the study region (Alberta). Statistics Canada data are referenced throughout this section when referring to the number of farms, farm types, and tonnage of agricultural products. After covering the basics about agriculture in Alberta as a whole, a discussion follows about the smaller municipal units (known as counties) within Alberta. Statistics are included at the county level for measures such as income and farmland values to show how counties are similar and different.

The next section of this chapter covers the data used in this study. The sources and how the variables were derived are outlined. The section ends with the final hedonic model specification.

## 3.1 Study Location

### 3.1.1 The Basics

Alberta, a Canadian province, is the area of interest for this study. One way to describe Alberta is to look at the land cover. Agricultural land is primarily located in the southern half of this province, but pockets of agricultural land also occur in the northwest as well.  According to the 2011 Census of Agriculture, Alberta has over 50 million acres of farmland (Alberta Agriculture and Rural Development [AARD] 2013). This is smaller than the area of farmland reported in the 2001 Census of Agriculture

(Table 3.1). For reference, the entire province's area is more than 158 million acres (Statistics Canada 2012c). Also reported in Table 3.1 are numbers of farms and average farm size. From 2001 to 2011, farm numbers decreased while at the same time there was an increase in average farm size (Statistics Canada n.d.-i).

As farms changed over this time period, so too did the urban landscape. From 2001 to 2011 Alberta experienced population growth, increasing from 2,974,807 (including 2,405,160 urbanites) to 3,645,257 (including 3,030,402 urbanites) (Statistics Canada n.d.-b). Also, at this time the land area of Alberta's most populated city, Calgary, increased from 701.79 square kilometres to 825.29 square kilometres (Statistics Canada 2002c; Statistics Canada 2012a). For Edmonton, the province's second largest city in terms of population, land area stayed relatively consistent changing only slightly from 683.88 square kilometres to 684.37 square kilometres (Statistics Canada 2002d; Statistics Canada 2012b).[19] Although Edmonton's political boundaries have not changed recently, LCLU change in the area continues to occur; what was once open space is now becoming industrialized, commercialized or turned into homes.

A second way to describe Alberta is to consider its economy. In 2011, Alberta's GDP was $270 billion (in chained 2007 dollars) (Statistics Canada n.d.-o). Primary agricultural production and related supporting activities (e.g., fertilizer application

[19]Using ArcGIS (Environmental Systems Research Institute [ESRI] 2012) and 2001 and 2011 CSD cartographic maps (Statistics Canada 2002b; 2011b), the area calculated by the software increased from 721 to 848 $km^2$ for Calgary over this time period and stayed the same for Edmonton (~700 $km^2$). The CSD cartographic maps reflect the municipal (i.e., legislated) boundaries (Statistics Canada 2002a; 2011a).

service) contribute less than two percent to that GDP (Statistics Canada n.d.-n; AARD 2013).

Just like Alberta has a diversified economy, Alberta's agricultural sector is similarly diversified. Several types of agricultural farm types can be found in this region: horses, bees, sheep, dairy, poultry, crops, greenhouses, beef cattle, and swine. Plant production has a slight edge over animal production, accounting for approximately 54 percent of farms in 2011 (Statistics Canada n.d.-j). The most numerous types of farms are grains and oilseeds (as a group), followed closely by beef cattle farms (Statistics Canada n.d.-j). Hay farming is the third most commonly reported farm type by number (Statistics Canada n.d.-j).

The value of production mimics the farm numbers data. For example, in 2011 canola had a value of production of $2.8 billion (average dollar per tonne times the tonnes produced), followed by cattle and calves at $2.4 billion, wheat at $1.9 billion, barley for grain at $896 million, and tame hay at $595 million (AARD 2013). Comparatively, the top five crops by level of production in 2011 were wheat (all types, 8.8 million tonnes), tame hay (7.9 million tonnes), canola (5.3 million tonnes), barley (4.7 million tonnes), and all corn types (1.4 million tonnes) (Statistics Canada n.d.-c). Also, in terms of animal production at July 1, 2011 there were almost 5.5 million cattle, of which most were related to the beef industry (close to 5.3 million) while the remainder belonged to the dairy sector (Statistics Canada n.d.-g). In contrast, hog and sheep numbers were much lower at July 1, approximately 1.4 million head (Statistics Canada n.d.-h) and 203,000 respectively (Statistics Canada n.d.-f). Nearly 59 million birds were produced for the poultry meat industry and 605 million usable eggs were produced in 2011 (Statistics Canada n.d.-d; Statistics Canada n.d.-e).

The climate is also variable across the province with hotter temperatures typically occurring in the south. The majority (96%) of irrigated acres in the province are located in southern Alberta (AARD 2011). According to the 2011 Census of Agriculture approximately 7% of farms used irrigation (Statistics Canada n.d.-l; Statistics Canada n.d.-i). The majority of irrigation activity in Alberta is administered by a set of irrigation districts in the southern part of the province.

### 3.1.2 County Comparisons

There are also differences in the value of agricultural production across counties.[20] Information listed in Table 3.2 shows how counties (or census consolidated subdivisions [CCSs]) differed in 2011. The county with the lowest average net operating income per farm reporting (*NetIncFarm*) adjusted to 2015 Canadian Dollars (CAD) was Clearwater. This is not surprising when one considers the land cover map in Figure 3.1. Clearwater County is mostly covered in forest. Surprisingly, Northern Sunrise County, also mostly forest, had the highest *NetIncFarm* in 2011. After closer inspection of the data, it was noted that a cautionary warning regarding the value's accuracy was present, and the *NetIncFarm* was much higher in this year than in previous years of this county's

[20]For the purposes of this thesis the various types of municipalities, including counties, municipal districts, and specialized municipalities, are referred to as counties. Differences in naming reflect the municipalities' historical origins. Also, specialized municipalities are treated slightly different in legislation because a single government can be formed to govern both the rural and urban areas in the region (Alberta Municipal Affairs 2015).

history (Statistics Canada 2014). The next highest *NetIncFarm's* occurred in several of the counties in the south which have access to the irrigation districts including Vulcan, Taber and Forty Mile No. 8. For the entire province in 2011, the *NetIncFarm* was $61,205 (2015 CAD) (Statistics Canada 2014).

Not only do counties differ in terms of *NetIncFarm*, but they also differ in terms of the extent of development (Table 3.2). In this thesis the term "developed" or "development" refers to land that has been converted from vegetation to buildings or roads. The average amount of developed land per county (using Table 3.2 data) in 2011 was 3.42 percent (Agriculture and Agri-Food Canada [AAFC] 2012b; Statistics Canada 2006a).[21] Clear Hills County had the lowest proportion of developed land (0.07%), and Edmonton (67.16%) and Calgary (65.93%) had the highest. This is not surprising given that these two CCSs are primarily large cities. Strathcona County had the next highest percentage of developed land (12.38%). Strathcona County is a specialized municipality, and has a large urban centre contained within it, Sherwood Park. Although Sherwood Park is not called a city it still has one of the largest urban populations in Alberta.

Table 3.2 shows how variable farm numbers, farm income and urbanization are across the counties. Similarly, farmland values also vary across counties and across time

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[21]This is not a provincial statistic as some communities are not included in Table 3.2.

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as depicted in Figure 3.2 and Table 3.3.[22] In general, it appears that mean farmland values are increasing over time even after accounting for inflation. The data in this table and map represent all observations prior to outlier removal, and it is clear that some counties have particularly high land values over $10,000 per acre (2015 CAD). This may in part be due to the small parcel size of the sale, less than one acre in several cases.

The figures outline seventy-seven CCSs. Only those CCSs with farmland sales during the study period (2000–2011) are depicted in Figure 3.2, Table 3.2 and Table 3.3. This left out the following areas: the Municipality of Crowsnest Pass, Improvement Districts No. 9, 12 and 24, the Regional Municipality of Wood Buffalo, Kananaskis, and the Municipal District (M.D.) of Opportunity No. 17. These areas are located in either the northeast of the province or the western boundary which encompasses the Rocky Mountains.

As is clear in this section, agricultural activity is quite diverse in this province. Also, each county is unique in terms of its makeup, such as vegetation, climate, and degree of development. Farm incomes and farmland values likewise vary across the

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[22]As shown in Table 3.3 some counties (e.g., M.D. of Provost No. 52, County of St. Paul No. 19, Clearwater County, Lethbridge County, Strathcona County, Parkland County, Mountain View County and etc.), experienced dramatic changes (expressed in percentage terms) in the mean land value per acre. These changes are difficult to explain other than to say that the values in Table 3.3 are based on "raw" data prior to the removal of outliers. Closer examination of the data for these listed counties reveals that there are usually small parcels sold (including parcels of less than 1 acre) which are responsible for the high maximum prices per acre. In cases where there were few total sales (e.g., M.D. of Provost No. 52), this maximum value had a stronger influence on the mean. In some counties (e.g., Lethbridge County) there were several small parcel sales, which also influenced the mean value. Parcels originally located in cities (refer to Table 3.8) also tended to have higher values per acre. Possible explanations could be data error and/or the inclusion of non-agricultural sales (though these explanations were not confirmed with the data source provider).

province. The next section will show how some of the aforementioned statistics were used in an econometric model to determine what affects farmland values in Alberta.

## 3.2 Methodology

To determine how various factors affect agricultural land values in Alberta, first relevant factors must be selected, and second the model used to estimate these effects must be outlined. This section describes data sources, how variables were generated and reasons for including the variables in the study. Proxies for conversion and measures for fragmentation are just some of the factors included in the model. The section ends by showing how the factors are combined into the final hedonic model specification.

### 3.2.1 Data

Arm's length sales transaction data were provided by FCC (2014a). The original data set spanned the years 1998–2014 and contained 19,360 observations. Any county containing agricultural land was included in the study. That meant only a few counties were left out of the study including those along the mountains (to the west) and forested areas in the northeast. Data on farmland sales were collected by FCC if FCC played a role in financing the purchase or if FCC was aware of the sale (Bryan 2014c). Depending on who collected the data, sales inside an urban boundary may or may not have been recorded (Bryan 2014b). That said, not all relevant land sales were captured using this approach, and it is difficult to know the exact number of sales that were missed (Bryan 2014c).

After adjusting for inflation to 2002 dollars using the annual Alberta consumer price index (CPI) from Statistics Canada (n.d.-m), the value for each sale was divided by the parcel size to obtain the land value per acre (the dependent variable). For reasons of confidentiality only the county location rather than the exact parcel location was provided in the FCC data. As a result many of the explanatory variables were matched at a county level. FCC provided the year and month of sale, the farm type, the farm sale size in acres, and the value of improvements for each sales transaction. Typically the sales price of the land came from the vendor or purchaser (Gervais 2015). In some cases information was recorded regarding the breakdown of the sale between improvement(s) and land price based on the FCC researcher's own market knowledge (Gervais 2015).

As introduced in Chapter Two, theory and previous literature provide guidance as to what explanatory variables may have an influence on farmland values. Variables included in the model were chosen and defined based on available data. These are listed in Table 3.4. For example, the parcel size was included in the model. Previous literature (Clifton and Spurlock 1983; Palmquist and Danielson 1989) suggests parcel size has a negative influence on the per acre sales price. Xu et al (1993) hypothesized that this would be the case if there was a limited supply of buyers with the necessary capital to participate in the land sale transaction. Another variable, the presence of farm improvements (i.e., buildings)[23] was expected to have a positive effect (Elad et al 1994).

[23]FCC listed improvements as buildings, irrigation, etc. (Bryan 2014a).

Deflated prices were used to control for changes in prices over time. Researchers have tried deflating prices alone, or have used time trends or dummies for months or years in conjunction with nominal or deflated prices. Taylor (2003) suggests that using yearly dummies or deflating prices are both appropriate ways to deal with inflationary trends, but will not work well if supply and demand conditions change.

Farmland valuation models often incorporate agricultural returns of the land to reflect productivity. The expectation is that agricultural returns are positively related to land value. Attributes that reflect the agricultural productivity and that were hypothesized to a have a positive effect on farmland values included net operating income (operating revenues less expenses). Statistics Canada (2014) provides county level averages per reporting farm via their Agriculture Taxation Data Program (ATDP). Again, as with the farmland values, the Alberta CPI was used to deflate the values to 2002 dollars. Similarly, farm type was also used as a proxy for agricultural productivity. In this case a farm type dummy variable was included, with the crop farm type being omitted to avoid multicollinearity. Cavailhès and Wavresky (2003) used a similar approach.

A commonly included variable, soil quality, was also provided as a measure of income potential or agricultural productivity, and it too was assumed to have a positive effect on farmland value as found by Reiss and Kensil (1979)[24] (as cited by Chicoine (1981)). This was a county level measure that was static for this analysis and was

[24]This article could not be obtained and verified.

derived from a shapefile obtained from AAFC and AARD (2012). The measure of soil quality used in this study was the rating from the Land Suitability Rating System (LSRS). The LSRS is based on climate, landscape and soil factors (Agronomic Interpretations Working Group 1995). Many contributed to the development of this particular LSRS shapefile including, among others, David Spiess of Alberta Agriculture and Forestry (AAF) and Anthony Brierley of AAFC.[25] This LSRS shapefile combined data from multiple sources: the Agricultural Regions of Alberta Soil Inventory Database, the Soil Landscape of Canada database, the National Agro-climatic Information Service, and the National Soil Data Base. Using ArcGIS (Environmental Systems Research Institute [ESRI] 2012), the LSRS shapefile, and the 2006 CCS Statistics Canada (2006a) cartographic boundary map, the dominant land suitability rating for each county was isolated. The percent of Class two and three soils relative to all classes of soil types was then calculated using the summed areas of each, and this was the final variable that was included in the model. Alberta does not have Class one soils, the best soils for crops, but it does have Class two and three soils, which are still suitable for crops. Class nine is the lowest LSRS soil class and is unsuitable for crops.

Another variable related to agricultural productivity is whether or not irrigation is used. Bastian et al (2002) predicted that irrigation has a positive influence on land values. As suggested earlier, southern Alberta contains the majority of irrigation in the province, and the irrigation system is dominated by irrigation districts rather than

[25]The names of other people who played a role in generating this data set can be found here: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/sag15025/$file/lsrs_modifications_to_accommodate_additional_crops_final_2007.pdf?OpenElement (accessed August 7, 2015).

private irrigation licenses (AARD 2011). Therefore, an irrigation dummy variable was created and included in the model. If any portion of an irrigation district was located within a particular county (using the 2006 CCS boundaries (Statistics Canada 2006a) and the irrigation district shapefile (AARD n.d.)), that county was assigned a value of one for the dummy variable. Counties that did not contain an irrigation district were assigned a value of zero. Three counties (Special Area No. 2, Pincher Creek No. 9 and Foothills No. 31) bordered the irrigation district, so they were assigned values of one using this methodology, but arguably they could have been classified outside of the district because less than 300 acres of the irrigation districts overlapped each county (compared to at least 30,000 acres in the other counties in this situation).

A theoretical argument put forth by Capozza and Helsley (1989) suggests that returns to land can be separated into rents from agriculture and rents from future development. These future development rents cannot be readily quantified and so a proxy is used instead. This is referred to as conversion pressures in this thesis, and is quantified using multiple measures, including the distance to an urban centre, distance to a major highway, the percent change in population density and whether the farm is located in a county neighbouring Edmonton or Calgary, or Edmonton and Calgary themselves.

Elaborating on conversion pressures, Capozza and Helsley (1989) show how the farmland value is affected by distance, where at a sufficiently large distance from an urban centre only agricultural rent contributes to the value, as opposed to agricultural and development rent. It is expected that increased distance is negatively related to farmland value. It should be noted that distance can also reflect transportation costs related to both marketing goods and purchasing inputs (see Sinclair (1967) who discusses the Von Thünen theory). As Cavailhès and Wavresky (2003) point out, distance also indicates commute times for urban income earners, and thus, may reflect the likelihood of conversion.

Two distance measures were used in this paper to capture the effects just mentioned. ArcGIS (ESRI 2012, 2014 and 2015) software was used to compute these distance measures using the centroid of a county and measuring the distance in metres to the nearest point (centroid of an urban centre), or nearest line (Highway 2). The Highway 2 shapefile used was only a piece of the Highway 2 in existence. The piece that was used in the study was the connection between Edmonton and Calgary (the main "corridor" area), which is referred to as the Queen Elizabeth II Highway. This particular section of highway sees a higher traffic volume (Alberta Transportation 2014). There is also a portion of Highway 2 that runs south of Calgary all the way to the United States border, and a portion that runs north of Edmonton to Athabasca and then west to Peace River and Grande Prairie. Whether these omitted parts of highway have a similarly sized coefficient and significance could not be determined. Anecdotally, one broker also suggested looking at the difference between land values on the east and west side of Highway 2 because of differences in sale prices he had witnessed (Hansen 2015). Without the parcel's location, and because the highway cuts many counties in half, this type of test could not be completed. The importance of nearness to other highways was also not studied.

The distance from a county to the Queen Elizabeth II portion of Highway 2 (from hereon referred to as *Hwy2*) was one distance measure used in the study. The other distance measure used was the distance from the county to a population centre of at least 10,000 people (*UrbDist*). According to Alberta's *Municipal Government Act* (2000) a city must have a population above 9,999. Upon reaching this prerequisite population, an urban area may apply for city status, but not all of them choose to do this. Using the distance to the nearest city may therefore miss some of these larger centres. Furthermore, by taking into account population and time some of the distances to the nearest urban area may actually change over time. That is, one urban centre may be the first closest in 2000, but may be the second closest to a county in 2011 if another closer urban area reaches the prerequisite population by 2011. If such a change occurs, it is reflected in a smaller revised value for the *UrbDist* measure for the county, and associated with the sales transaction observation in that county. A number of shapefiles from Statistics Canada (2006a,b) and Alberta Environment and Sustainable Resource Development (ESRD 2013a,b) (urban service areas and Highway 2), and population data from Statistics Canada (2013) were used to complete this analysis.

Population data were also used to compute the five year change in population density (for this paper this was calculated for the span 1996–2000, 1997–2001, etc.). The CCS area was used to calculate the density. Statistics Canada completes censuses every five years (e.g., 1996, 2001, 2006, and 2011). In the interim years Statistics Canada estimates the population and links the populations to the 2006 census subdivision (CSD) boundaries. For this analysis, all years were used, and the CSDs were aggregated to the CCS level. The population density was expected to be positively related to the land value as found by Huang et al (2006).

The effects of fragmentation on land values have received less attention in the literature. As discussed in Chapter Two, there are a number of measures that can be used to represent fragmentation. Given the data available for this study, the LCLU fragmentation (as opposed to the fragmentation of land holdings due to social/political reasons) is the focus of this thesis. Three measures were selected for this analysis and they are listed in Table 3.5 along with the formulas used to calculate them. The first measure, *Small Parcel (≤ 80 acres) Sales Ratio (Sales80)*, was chosen based on Mervish et al (2008)[26] while the latter two, the *Mean Patch Size (MPSize)* and *Patch Density (PatchDenAc)*, were based on work by Irwin and Bockstael (2007). These measures were selected in part because of the availability of data, and because two recent papers on fragmentation in Alberta (Haarsma (2014) and Qiu et al (2015)) also used the *Mean Patch Size* and *Patch Density*. FCC data and StataCorp (2013) software were used to calculate the *Sales80*. StataCorp (2013) software was used to calculate the other fragmentation measures, in conjunction with ArcGIS (ESRI 2012 and 2015) and AAFC 56 metre

[26]The choice to use 80 acre sale parcels as a threshold for fragmentation was discussed in Mervish et al (2008) and is highlighted in Section 5.3. Also, feedback from conferences attended by the author in 2015 and 2016 suggested that 80 acres seemed reasonable because it represents half of a quarter section (or 160 acres), and smaller sized transactions may not be agricultural in nature.

resolution raster data and the CCS areas from the 2006 CCS Statistics Canada (2006a) map. The AAFC maps used were the 2009 AAFC Crop Type Map of the Prairies (AAFC 2010b), the 2010 AAFC Crop Type Map of the Prairies (AAFC 2011b), and the 2011 AAFC Crop Type Map of Canada (AAFC 2012b).

As indicated, the AAFC data are limited in terms of the number of years of available data. As a result, two alternative models were estimated, a large sample model covering the years 2000 to 2011 and a small sample model that included 2010 and/or 2011 only. The *Sales80* could be calculated for all years, so a large sample was run using that fragmentation measure. However, because AAFC data were used for the other two fragmentation measures (*Mean Patch Size* and *Patch Density*) and only a few years worth of data (2000, 2009, 2010, and 2011) were available a small sample model for those metrics was run for comparison purposes. As is explained in Subsection 3.2.3 the previous year's fragmentation values were used as a proxy for current fragmentation. That resulted in the analysis for the small sample model being limited to 2010 and 2011 only. The descriptive statistics for each of these sample sizes are listed in Table 3.6 and Table 3.7. The top and bottom one percent of outliers (determined by the dependent variable) were removed,[27] and then land sales which had not been assigned a farm type (i.e., data were missing) were removed. In general, the characteristics of the two samples are similar. The numbers of observations corresponding to various farm types represented in the sample do change with the years, with divergences being most

[27]More on this topic will be covered in Chapter Four.

noticeable for poultry, sheep, and greenhouses. These tended to have low representation in both sample sizes. The minimum and/or maximum also changed between the two samples more visibly for *PctPopDenChg* and *Sales80*.

### 3.2.2 Data Limitations and Adjustments

As highlighted above county level data were used in this analysis. However, county boundaries and definitions were not static during the study period. For example, Northern Sunrise County changed its name in 2002 (formerly called the M.D. of East Peace No. 131), and Lac La Biche County was reinvented from Lakeland County in 2007. In the case of the farmland values, which came with their own location coding, it was noted that the boundaries for Lac La Biche County and the M.D. of Bonnyville No. 87 differed between the FCC shapefile (FCC n.d.) and the Statistics Canada (2006a) boundary file. To deal with this inconsistency the border dividing these counties was dissolved and the two areas were treated as one county. This is reflected in Table 3.3 and parts of Table 3.2; that is, the values used in the farmland model are the same for the Lac La Biche and Bonnyville No. 87 counties. Other boundary differences between the FCC shapefile (FCC n.d.) and the CCS shapefile (Statistics Canada 2006a) occurred in the western regions (e.g., the County of Grande Prairie No. 1, the M.D. of Greenview No. 16, Yellowhead County, and the M.D. of Pincher Creek No. 9). Given the LCLU (Figure 3.1) in these regions these border differences were not thought to cause great perturbations in the data in terms of matching land values to the correct county.

The FCC data set also contained values for farmland transactions where the location is in a city; for example, Camrose, Leduc, Fort Saskatchewan and Red Deer. For the purposes of this analysis these locations were recoded to match the surrounding CCS. These changes are indicated in Table 3.8. Though not a city, Acadia No. 34 was also recoded to match its CCS because many of the other variables were calculated at the CCS level. Table 3.8 shows how few land sales exist in these communities, and how many fall into the outlier category.

The CCS contains information about the CSDs, such as small cities, towns, villages, summer villages, and the rural area of the county. Edmonton, Calgary and Drumheller have their own CCS, which is roughly equivalent in size and shape to their CSD (Statistics Canada 2006a,b). The CCS and CSD maps have slight differences, as the minimum *UrbDist* was expected to be zero for these two cities (i.e., Edmonton and Calgary), but was recorded as slightly larger than zero in Table 3.6. There were no land sales for Edmonton and Calgary in the small sample, so the minimum *UrbDist* was not zero (Table 3.7).

Another data issue concerns fragmentation. Specifically, some artifacts may have been introduced when calculating the fragmentation measures, *Mean Patch Size* and *Patch Density*. Because CCS boundaries were overlaid on the AAFC land cover data to generate these measures, some artificial patches were created by the boundaries themselves, as some agricultural land may actually be continuous across county boundaries.

Also, the AAFC land cover data are not entirely accurate at times. The overall accuracies of the maps for 2009, 2010 and 2011 were 80%, 88.34%, and 88% respectively (AAFC 2010a; AAFC 2011a; AAFC 2012a). It is entirely possible that data were misclassified or unclassified (e.g., no data or cloud cover prevented classification) (AAFC 2009a). Each of the 2009–2011 maps were developed using images from their respective growing seasons (AAFC n.d.). Though not used to generate fragmentation measures, the 2000 AAFC metadata suggested that a single growing season was not sufficient for the acquisition of cloud free imagery (AAFC 2009a). The presence of clouds makes it difficult to classify LCLU (AAFC 2009a). Roads to the south of the Town of Bonnyville are an example of the type of inaccuracies that were possible. The roads in this area were incomplete (missing), and this varied across 2009–2011. This was unusual given the assumption that roads would remain static or increase in amount over time rather than decrease (as was seen in 2010 in this area). Given this observation about the roads, agricultural patches may have been misclassified as well, thus impacting the fragmentation measures. However, there is no way of recognizing and rectifying this issue using the data available for this study.

One further point about the AAFC data was that both the 2010 and 2009 versions were 56 metre resolution, but the 2011 version was 30 metre. This was rectified by resampling the 2011 version (using ArcGIS (ESRI 2012 and 2015)) to the coarser resolution. One advantage of completing this step was that the 2011 version could be snapped to the previous 2010 version, so cells aligned prior to resampling. It is uncertain whether the 2010 version's cells (created by AAFC) aligned with the 2009 version's cells. This could create a problem for the reliability of using past 2009 AAFC data as a proxy for current 2010 AAFC data if they did not match up.

The last data issue of concern was the net operating income. The ATDP reports on incorporated farms with gross operating revenues of $25,000 or more and with 50% or more of their sales from agriculture, and reports on unincorporated and communal farms with gross operating revenues of $10,000 or more (Statistics Canada n.d.-a). The data received from Statistics Canada came with signals about whether the data could be used, used with caution, or not used at all. The coefficient of variation was calculated for the components of net operating income (total operating revenues and total operating expenses) and depending on the outcomes of these two components the data were labelled based on some thresholds (Statistics Canada 2014). For example, if at least one component had a coefficient of variation equal to or greater than 35%, the net operating income was not published (Statistics Canada 2014). The average net operating income per farm reporting (*AVREP*) (renamed to *NetIncFarm* in this thesis) was used for this analysis. When Statistics Canada did not publish the *AVREP* because it was unreliable, the value was coded as missing. This was the reality for Big Lakes County (in 2008 and 2011), Drumheller (2008, 2011), Parkland County (2009, 2010), Yellowhead County (2010), M.D of Bighorn No. 8 (2011), and M.D. of Spirit River No. 133 (2011). StataCorp (2013) automatically dropped these observations from the regression when data were missing. There were a few instances where the estimated total net income for the county was not provided (the dividend in the equation used to generate *AVREP*), but the variable of use, *AVREP* was still okay to use with caution. This was true of Northern Sunrise County in 2011 (note the large value in Table 3.2) and Special Area No. 4 in 2010. Another handful of values were used despite being labelled “use with caution.” Also, Statistics Canada provided the *AVREP* rounded to the nearest dollar. The CPI adjusted values were calculated using the rounded values, so errors were introduced due to rounding.

### 3.2.3 Model Specification

A pooled cross-sectional model was used in this analysis. A panel data model could not be considered because without exact parcel locations it was impossible to follow individual parcel sales across time. In line with the hedonic method discussed in Chapter Two, attributes of farmland were included as right-hand side variables to investigate what effect (if any) they had on farmland values. The final model specification is shown in Equation (3.1). All variables were logged if they were strictly positive for all observations. This included the dependent variable (farmland value). Dummy variables and the variables interacted with the dummy variables were not logged. A complete description/definition of the variables is provided in Table 3.4 and Table 3.5. The model specification is as follows:

$$
\begin{aligned}
Y_{i/kt} = \beta_0 + \beta_1 NoBuild_{it} & \\
& + \beta_2 CheapBuild_{it} + \beta_3 Size_{it} + \beta_4 Irrig_{kt} + \beta_5 SoilQlty_{kt} \\
& + \beta_6 NetIncFarm_{kt} + \beta_7 PopDenChg_{kt} + \beta_8 Hwy2_{kt} \\
& + \beta_9 UrbDist_{kt} + \beta_{10} Edm - Neighbours_{kt} \\
& + \beta_{11} Cal - Neighbours_{kt} + \sum \beta_i FarmType_{it} \\
& + \beta_{12} Frag_{kt} + \beta_{13} Frag * Edm - Neighbours_{kt} \\
& + \beta_{14} Frag * Cal - Neighbours_{kt} + \varepsilon_{i/kt}
\end{aligned} \tag{3.1}
$$

where $i$ refers to the individual parcel, $k$ refers to county, $t$ is the year, and *Frag* refers to a fragmentation measure.

As indicated in Table 3.3, in some cases land values could be over $100,000 per acre. To deal with potential outliers, the top and bottom one percent of observations were removed, similar to Deaton and Vyn (2015). Prior to removal of outliers the minimum dependent variable was $14/acre and the maximum value was $8,523,696/acre (2002 CAD) for the large sample size. After the removal of outliers the values ranged from $123/acre to $122,924/acre (2002 CAD) for the large sample. These and other descriptive statistics following outlier removal are shown in Table 3.6 and Table 3.7 for the large and small samples respectively.

In this study the province of Alberta was treated as a single market. Palmquist (1991) stated that coefficients will be biased if a single market is assumed when in reality it does not exist. Alternatively, coefficients are imprecise if the market is assumed to be segmented when it is not (Palmquist 1991). Freeman (2003) lists two conditions required for segmentation. First, the supply and/or demand structures must not be the same across segments (Freeman 2003). Secondly, participants cannot participate in other segments because there is a barrier (e.g., geographical or informational) (Freeman 2003). Taylor (2003) stated that statistical tests and the researcher's judgment can help determine if market segments are appropriate. One possible approach is to perform F-tests to see if coefficients are equal across segments (Taylor 2003; Palmquist 1991). However, if there is misspecification then results for these tests can be misleading (Taylor 2003; Palmquist 1991). Regarding farmland valuation studies there are those like Elad et al (1994) and Patton and McErlean (2003) who break their locations into submarkets. Others like Huang et al (2006) and Palmquist and Danielson (1989) treat the entire state (equivalent to a province) as one market.

Although it is unlikely that an individual farmer will purchase land for example around both Edmonton and Calgary (because it is not economical to transfer the equipment and inputs necessary to successfully run the operation), it is common to purchase land in neighbouring counties. Therefore, there is the possibility of what Geoghegan et al (1997, p. 261)[28] terms "sliding boundaries" existing for the local farmland market faced by each farmer. Based on this discussion Alberta was treated as a single market for this analysis, although there are arguments in favour of treating the northwest portion as a separate region based on the land cover shown in Figure 3.1.

The models in this thesis were estimated using ordinary least squares (OLS), with the exception of cases noted below. The need for more involved procedures was motivated by potential complexity in the relationships between land values and fragmentation and/or conversion. For example, some studies on conversion (e.g., some

[28]Geoghegan et al (1997) presents an argument in favour of a spatial expansion model.

of the studies reviewed in 2.2.1.2) use land values as a right-hand side variable. Fragmentation of land use as it relates to conversion could similarly be driven by land values. Land values themselves consist of rents from undeveloped uses and urban uses. If rents from undeveloped uses are likely to remain stagnant because they are largely dictated by the naturally endowed elements of the physical environment,[29] there could be some reason to suspect that increases in land values would be related more to increases in urban rents than undeveloped use rents, and this could drive fragmentation via conversion. Alternatively, it is possible that there is an omitted unobserved effect, which affects both the fragmentation rate and the land value. A study by Kjelland et al (2007) considered the changes in the non-agricultural value component of land values and the change in the area or number of properties in a certain size category, and found a positive correlation (not causation) between smaller sized property classes and the non-agricultural value.

Given that there was the potential for endogeneity between the fragmentation values and farmland values, which can lead to biased estimates, appropriate techniques had to be employed. In this case, instruments for fragmentation were included, and then tests were done to see if the variables were exogenous. The previous year's fragmentation measure was used as an instrument for current fragmentation as other measures (e.g., neighbouring fragmentation values), though useful, could not be employed given the nature of the data set. Two-stage least squares (2SLS) estimation

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[29]Two counter examples to this statement would be changes in non-urban rent due to climate change or policy changes that allow for payment for ecosystem services.

was used when instruments were included in the model and this is illustrated in Equations (3.2) and (3.3):

*First-stage regressions* (3.2)

$$\begin{aligned} Frag_{kt} = \beta_0 + \beta_1 PastFrag_{kt} + \beta_2 PastFrag * Edm - Neighbours_{kt} \\ + \beta_3 PastFrag * Cal - Neighbours_{kt} \\ + \sum_k \beta_{kt} EXOGENOUS_{kt} + \mu_1 \end{aligned}$$

$$\begin{aligned} Frag * Edm - Neighbours_{kt} \\ = \beta_0 + \beta_1 PastFrag_{kt} \\ + \beta_2 PastFrag * Edm - Neighbours_{kt} \\ + \beta_3 PastFrag * Cal - Neighbours_{kt} \\ + \sum_k \beta_{kt} EXOGENOUS_{kt} + \mu_2 \end{aligned}$$

$$\begin{aligned} Frag * Cal - Neighbours_{kt} \\ = \beta_0 + \beta_1 PastFrag_{kt} \\ + \beta_2 PastFrag * Edm - Neighbours_{kt} \\ + \beta_3 PastFrag * Cal - Neighbours_{kt} \\ + \sum_k \beta_{kt} EXOGENOUS_{kt} + \mu_3 \end{aligned}$$

*Second-stage regression* (3.3)

$$Y_{i/kt} = \beta_0 + \beta_1 \hat{\mu}_1 + \beta_2 \hat{\mu}_2 + \beta_3 \hat{\mu}_3 + \sum_{i/k} \beta_{i/kt} EXOGENOUS_{i/kt} + \varepsilon_{i/kt}$$

where *i* is individual parcel, *k* is county, *t* is year, *PastFrag* is the previous year's fragmentation and EXOGENOUS represents all of the remaining independent variables found in Equation (3.1). In some cases only $\mu_1$ was estimated in Chapter Four. A discussion about tests done for heteroscedasticity and exogeneity of the variables is provided in Chapter Four. Robustness checks are also discussed in that chapter.

### 3.2.4 More on the Functional Form

Although theory has been used to assist in the selection of the explanatory variables (e.g., inclusion of an irrigation measure), the literature continually admits that theory does not provide any information on the choice of the functional form (e.g., Cropper et al 1988; Taylor 2003; Palmquist 1991; Halvorsen and Pollakowski 1981; and Goodman 1978).The exception may be that theory can speak to the reasonableness of using a linear versus a nonlinear form. A linear functional form implies that the marginal implicit price of a farmland attribute is constant. This would be the case if farmland attributes could be easily separated and repackaged,[30] but in reality this may not be the case at least for some attributes. For example, owning a half section of farmland may not be equivalent to owning two quarter sections. It is less clear from theory how to choose amongst the various nonlinear functional forms.

Several studies have investigated how to go about selecting the best functional form for a HPF. Cropper et al (1988) noted that many used the goodness-of-fit criterion to select the form. Some of the earlier studies investigating this issue of how to select a functional form for a hedonic pricing model included Milon et al (1984), Halvorsen and Pollakowski (1981), Cassel and Mendelsohn (1985), Goodman (1978) and Cropper et al (1988). In all of these cases a Box-Cox transformation was used in conjunction with a hedonic pricing model. The advantage of the Box-Cox transformation is that various alternative functional forms are nested within it and tests can be performed to see which form is most appropriate. Using simulations of housing sales data Cropper et al

[30]Rosen (1974) talked about arbitrage related to untying and repackaging products.

(1988) ran a number of comparisons of the means of the errors, where the error was "the difference between the derivative of the HPF and the household's true marginal bid" (Cropper et al 1988, p. 671). From there they determined that the linear Box-Cox transformation and quadratic Box-Cox transformation performed the best when all variables were known, and the simple linear or linear Box-Cox transformation worked well when some variables were unobserved by the researcher, or proxies were used for some variables (Cropper et al 1988). If a Box-Cox transformation turns out to be the appropriate model, the cons are that it is more difficult to interpret the coefficients and separate the effects of any one characteristic on the price (Milon et al 1984) because the implicit price of one characteristic relies on the amounts of all characteristics including itself and on the value of the property (Cassel and Mendelsohn 1985).

## 3.3 Chapter Summary

This chapter introduced the model specification used to study the factors that affect farmland values across Alberta. After reading this chapter one should have a better understanding about agriculture in Alberta, how the variables were obtained and generated, some issues with the data and estimation, and the expected signs on the estimated coefficients.

## 3.4 Tables and Figures for Chapter Three

**Table 3.1 Farm statistics for Alberta in 2001 and 2011**

| | 2001 | 2011 |
|---|---|---|
| Number of farms reporting | 53,652 | 43,234 |
| Area of all farms (acres) | 52,058,898 | 50,498,834 |
| Average farm size (acres) | 970 | 1,168 |

Source: Statistics Canada (n.d.-i)

**Table 3.2 Basic county statistics for 2011 (all observations)**

| County Name[a] | Number of Farms[b] | Average Farm Size (acres)[b] | Contains Irrigation District[c] | Net Income per Farm (2015 CAD)[d] | Percent Developed[e] |
|---|---|---|---|---|---|
| Clearwater County | 1,096 | 652 | No | 1,509 | 0.29 |
| Woodlands County | 294 | 701 | No | 4,674 | 0.32 |
| Lac Ste. Anne County | 936 | 637 | No | 4,795 | 1.09 |
| M.D.[f] of Lesser Slave River No. 124 | 160 | 781 | No | 14,986 | N/A[g] |
| Yellowhead County | 695 | 692 | No | 15,337 | 0.34 |
| County of Grande Prairie No. 1 | 1,206 | 867 | No | 19,655 | 1.33 |
| Brazeau County | 487 | 595 | No | 21,176 | 0.97 |
| Special Area No. 2 | 473 | 4,581 | Yes | 22,581 | 0.44 |
| Parkland County | 782 | 514 | No | 26,425 | 5.26 |
| M.D. of Pincher Creek No. 9 | 448 | 1,786 | Yes | 27,094 | 0.56 |
| M.D. of Bonnyville No. 87 | 739 | 1,006 | No | 27,919 | N/A |
| Lac La Biche County | 239 | 1,162 | No | 27,919 | N/A |
| Calgary | 55 | 565 | No | 29,054 | 65.93 |
| M.D. of Foothills No. 31 | 1,224 | 729 | Yes | 29,650 | 2.50 |
| Saddle Hills County | 463 | 1,319 | No | 30,965 | 0.18 |
| Leduc County | 1,255 | 450 | No | 31,594 | 3.47 |
| County of Barrhead No. 11 | 667 | 697 | No | 32,584 | 0.84 |
| M.D. of Greenview No. 16 | 639 | 1,150 | No | 34,942 | 0.13 |
| Clear Hills County | 443 | 1,321 | No | 35,869 | 0.07 |
| Mackenzie County | 626 | 879 | No | 38,486 | N/A |
| Athabasca County | 697 | 860 | No | 38,812 | 0.56 |

*(Continued)*

Table 3.2 Continued

| County Name[a] | Number of Farms[b] | Average Farm Size (acres)[b] | Contains Irrigation District[c] | Net Income per Farm (2015 CAD)[d] | Percent Developed[e] |
|---|---|---|---|---|---|
| Thorhild County | 462 | 782 | No | 40,492 | 0.53 |
| County of St. Paul No. 19 | 788 | 1,016 | No | 40,666 | 1.43 |
| Cypress County | 827 | 2,824 | Yes | 43,667 | 0.67 |
| County of Stettler No. 6 | 705 | 1,401 | No | 49,367 | 0.62 |
| Red Deer County | 1,531 | 636 | No | 51,725 | 2.85 |
| Edmonton | 73 | 178 | No | 53,002 | 67.16 |
| Lacombe County | 1,045 | 639 | No | 54,518 | 1.82 |
| Mountain View County | 1,636 | 571 | No | 54,528 | 1.77 |
| County of Paintearth No. 18 | 420 | 1,840 | No | 54,931 | 0.99 |
| County of Vermilion River | 1,029 | 1,325 | No | 57,238 | 1.26 |
| Camrose County | 999 | 821 | No | 58,236 | 1.31 |
| M.D. of Provost No. 52 | 425 | 2,083 | No | 59,404 | 0.60 |
| County of Two Hills No. 21 | 554 | 1,170 | No | 59,663 | 0.82 |
| Westlock County | 777 | 782 | No | 60,452 | 0.70 |
| Ponoka County | 1,106 | 582 | No | 60,650 | 1.27 |
| M.D. of Willow Creek No. 26 | 772 | 1,459 | Yes | 62,719 | 0.89 |
| Lethbridge County | 933 | 751 | Yes | 64,063 | 3.66 |
| County of Wetaskiwin No. 10 | 956 | 640 | No | 66,361 | 1.42 |
| Rocky View County | 1,271 | 761 | Yes | 67,555 | 3.43 |
| County of Northern Lights | 446 | 1,379 | No | 68,777 | 0.10 |
| Smoky Lake County | 454 | 1,096 | No | 72,806 | 0.57 |
| County of Newell | 717 | 2,034 | Yes | 77,124 | 0.79 |
| Beaver County | 677 | 1,041 | No | 77,343 | 0.83 |
| Cardston County | 497 | 1,696 | Yes | 78,878 | 0.64 |
| Wheatland County | 782 | 1,434 | Yes | 80,120 | 0.86 |
| Strathcona County | 658 | 335 | No | 80,853 | 12.38 |
| Sturgeon County | 823 | 568 | No | 84,255 | 4.81 |
| Special Area No. 4 | 279 | 3,668 | No | 85,321 | 0.32 |
| M.D. of Wainwright No. 61 | 501 | 1,728 | No | 87,425 | 0.79 |
| M.D. of Peace No. 135 | 166 | 1,248 | No | 88,770 | 1.92 |
| County of Minburn No. 27 | 604 | 1,188 | No | 89,984 | 1.01 |
| Special Area No. 3 | 464 | 3,484 | No | 95,319 | 0.36 |

*(Continued)*

Table 3.2 Continued

| **County Name**[a] | **Number of Farms**[b] | **Average Farm Size (acres)**[b] | **Contains Irrigation District**[c] | **Net Income per Farm (2015 CAD)**[d] | **Percent Developed**[e] |
|---|---|---|---|---|---|
| Lamont County | 753 | 759 | No | 96,474 | 0.92 |
| Starland County | 300 | 1,929 | No | 97,748 | 0.49 |
| County of Warner No. 5 | 488 | 2,279 | Yes | 113,807 | 0.74 |
| Birch Hills County | 295 | 1,899 | No | 118,506 | 0.24 |
| Kneehill County | 686 | 1,213 | No | 118,722 | 0.80 |
| M.D. of Smoky River No. 130 | 310 | 1,895 | No | 119,614 | 0.49 |
| Flagstaff County | 650 | 1,430 | No | 120,055 | 0.88 |
| County of Forty Mile No. 8 | 524 | 3,250 | Yes | 128,894 | 0.34 |
| M.D. of Taber | 652 | 1,582 | Yes | 138,045 | 0.83 |
| Vulcan County | 603 | 2,246 | Yes | 143,561 | 0.42 |
| Northern Sunrise County | 181 | 1,585 | No | 327,653 | N/A |
| M.D. of Fairview No. 136 | 225 | 1,352 | No | N/A | 0.57 |
| M.D. of Spirit River No. 133 | 69 | 1,191 | No | N/A | 0.80 |
| Big Lakes County | 375 | 1,154 | No | N/A | 0.21 |
| Ranchland No. 66 | 78 | 5,971 | No | N/A | 0.15 |
| M.D. of Bighorn No. 8 | 44 | 4,628 | No | N/A | 0.92 |
| Drumheller | N/A | N/A | No | N/A | 10.76 |

[a]County name or census consolidated subdivision name (e.g., Drumheller)
[b]Statistics Canada (n.d.-k)
[c]AARD (n.d.)
[d]This column lists the average net operating income per farm reporting from Statistics Canada (2014) adjusted to 2015 Canadian Dollars (CAD).
[e]Computed from AAFC (2012b) and Statistics Canada (2006a) data
[f]M.D. = Municipal District
[g]N/A data were not provided due to confidentiality restrictions, or data were missing/lacking.

**Table 3.3 Land value per acre statistics by county for 2001 and 2011 (all observations; 2015 Canadian Dollars)[a]**

| County Name[b] | 2001 | | | 2011 | | | % Change in Mean[e] |
|---|---|---|---|---|---|---|---|
| | MIN[c] | MAX[d] | MEAN | MIN[c] | MAX[d] | MEAN | |
| Clear Hills County | 45 | 691 | 330 | 74 | 661 | 413 | 25.0 |
| Mackenzie County | 259 | 553 | 393 | 147 | 3,191 | 435 | 10.8 |
| Special Area No. 3 | 144 | 623 | 364 | 149 | 1,481 | 452 | 24.3 |
| Special Area No. 4 | 279 | 790 | 549 | 186 | 890 | 504 | -8.3 |
| Special Area No. 2 | 159 | 688 | 344 | 218 | 1,072 | 507 | 47.1 |
| County of Northern Lights | 65 | 405 | 232 | 159 | 798 | 539 | 132.5 |
| M.D.[f] of Spirit River No. 133 | 559 | 891 | 665 | 640 | 640 | 640 | -3.7 |
| Big Lakes County | 261 | 837 | 515 | 332 | 1,304 | 644 | 25.0 |
| M.D. of Provost No. 52 | 774 | 160,771 | 80,773 | 234 | 964 | 655 | -99.2 |
| M.D. of Greenview No. 16 | 21 | 4,839 | 734 | 213 | 1,234 | 665 | -9.5 |
| Saddle Hills County | 65 | 691 | 372 | 366 | 1,184 | 668 | 79.7 |
| County of Paintearth No. 18 | 380 | 777 | 531 | 490 | 991 | 729 | 37.4 |
| Northern Sunrise County | 186 | 493 | 349 | 332 | 1,505 | 748 | 114.6 |
| M.D. of Wainwright No. 61 | 518 | 744 | 621 | 563 | 1,344 | 868 | 39.8 |
| M.D. of Peace No. 135 | 393 | 475 | 435 | 698 | 1,596 | 1,006 | 131.0 |
| M.D. of Fairview No. 136 | 344 | 665 | 465 | 920 | 1,606 | 1,070 | 130.0 |
| Woodlands County | 129 | 991 | 614 | 864 | 1,289 | 1,096 | 78.5 |
| M.D. of Smoky River No. 130 | 60 | 778 | 475 | 452 | 1,850 | 1,134 | 138.8 |
| County of Grande Prairie No. 1 | 36 | 3,191 | 788 | 636 | 2,818 | 1,160 | 47.3 |
| Birch Hills County | 43 | 605 | 484 | 823 | 1,463 | 1,164 | 140.7 |
| County of St. Paul No. 19 | 47 | 387,135 | 13,445 | 103 | 8,499 | 1,213 | -91.0 |
| Athabasca County | 208 | 1,267 | 490 | 665 | 2,127 | 1,229 | 150.5 |
| Starland County | 584 | 830 | 748 | 612 | 3,010 | 1,292 | 72.8 |

*(Continued)*

Table 3.3 Continued

| County Name[b] | 2001 MIN[c] | 2001 MAX[d] | 2001 MEAN | 2011 MIN[c] | 2011 MAX[d] | 2011 MEAN | % Change in Mean[e] |
|---|---|---|---|---|---|---|---|
| County of Two Hills No. 21 | 210 | 1,181 | 540 | 624 | 2,773 | 1,429 | 164.9 |
| County of Minburn No. 27 | 477 | 1,444 | 806 | 1,130 | 2,107 | 1,529 | 89.8 |
| Vulcan County | 381 | 16,609 | 3,704 | 884 | 2,228 | 1,542 | -58.4 |
| Lac Ste. Anne County | 388 | 3,177 | 905 | 870 | 5,027 | 1,581 | 74.6 |
| Thorhild County | 311 | 1,440 | 818 | 931 | 2,148 | 1,674 | 104.6 |
| M.D. of Lesser Slave River No. 124 | N/A[g] | N/A | N/A | 334 | 5,850 | 1,891 | N/A |
| Beaver County | 467 | 1,604 | 881 | 250 | 8,586 | 1,927 | 118.8 |
| County of Wetaskiwin No. 10 | 91 | 2,765 | 1,113 | 111 | 5,070 | 1,937 | 74.1 |
| County of Warner No. 5 | 187 | 6,936 | 1,360 | 291 | 5,454 | 1,977 | 45.3 |
| Brazeau County | 579 | 17,851 | 2,408 | 1,396 | 3,720 | 2,011 | -16.5 |
| Clearwater County | 950 | 345,657 | 14,318 | 655 | 4,575 | 2,040 | -85.8 |
| Camrose County | 557 | 26,961 | 3,221 | 821 | 3,947 | 2,107 | -34.6 |
| Lamont County | 467 | 1,363 | 869 | 1,167 | 3,231 | 2,113 | 143.1 |
| Yellowhead County | 574 | 8,133 | 1,991 | 958 | 9,307 | 2,151 | 8.1 |
| Flagstaff County | 692 | 1,272 | 1,021 | 851 | 5,936 | 2,210 | 116.5 |
| County of Forty Mile No. 8 | 415 | 3,284 | 1,645 | 450 | 4,984 | 2,250 | 36.8 |
| Cardston County | 278 | 23,434 | 3,093 | 923 | 4,785 | 2,524 | -18.4 |
| M.D. of Willow Creek No. 26 | 346 | 8,400 | 1,973 | 964 | 18,182 | 2,894 | 46.7 |
| Smoky Lake County | 151 | 2,765 | 608 | 1,013 | 16,116 | 3,633 | 497.6 |
| M.D. of Taber | 104 | 7,090 | 2,303 | 999 | 10,749 | 3,682 | 59.8 |
| Ranchland No. 66 | 1,510 | 1,510 | 1,510 | 3,762 | 3,762 | 3,762 | 149.1 |
| Ponoka County | 562 | 27,988 | 2,964 | 133 | 24,130 | 3,944 | 33.1 |
| County of Barrhead No. 11 | 491 | 15,210 | 1,583 | 883 | 50,523 | 4,298 | 171.5 |

*(Continued)*

Table 3.3 Continued

| County Name[b] | 2001 MIN[c] | 2001 MAX[d] | 2001 MEAN | 2011 MIN[c] | 2011 MAX[d] | 2011 MEAN | % Change in Mean[e] |
|---|---|---|---|---|---|---|---|
| Westlock County | 294 | 2,012 | 941 | 1,127 | 34,534 | 4,656 | 394.6 |
| County of Stettler No. 6 | 478 | 2,111 | 1,029 | 574 | 36,105 | 4,791 | 365.6 |
| Lacombe County | 1,219 | 3,279 | 2,107 | 1,794 | 39,887 | 5,366 | 154.7 |
| Leduc County | 1,080 | 3,599 | 1,912 | 1,413 | 42,546 | 5,621 | 193.9 |
| County of Newell | 833 | 2,765 | 1,460 | 766 | 21,273 | 6,105 | 318.2 |
| County of Vermilion River | 415 | 1,244 | 725 | 111 | 132,955 | 6,156 | 749.6 |
| Red Deer County | 386 | 4,327 | 1,802 | 798 | 51,348 | 6,357 | 252.7 |
| Wheatland County | 344 | 13,874 | 2,046 | 1,335 | 28,036 | 7,077 | 245.9 |
| M.D. of Foothills No. 31 | 1,486 | 30,385 | 6,641 | 2,460 | 30,930 | 7,848 | 18.2 |
| Kneehill County | 1,206 | 2,765 | 1,737 | 1,711 | 71,329 | 9,024 | 419.4 |
| M.D. of Pincher Creek No. 9 | 484 | 19,253 | 3,751 | 1,924 | 81,685 | 14,700 | 291.9 |
| Rocky View County | 1,590 | 172,828 | 24,613 | 2,506 | 79,179 | 19,066 | -22.5 |
| Cypress County | 236 | 58,070 | 9,031 | 702 | 89,232 | 28,189 | 212.1 |
| Sturgeon County | 659 | 96,784 | 5,754 | 2,303 | 478,640 | 34,793 | 504.7 |
| Parkland County | 475 | 13,826 | 2,524 | 1,943 | 123,860 | 38,514 | 1,426.1 |
| Strathcona County | 1,859 | 6,842 | 3,234 | 4,645 | 94,308 | 39,194 | 1,111.9 |
| Lethbridge County | 550 | 12,248 | 3,783 | 301 | 862,476 | 45,206 | 1,094.9 |
| Drumheller | N/A | N/A | N/A | 382,147 | 382,147 | 382,147 | N/A |
| Mountain View County | 1,499 | 22,601 | 4,298 | 386 | 11,396,182 | 445,392 | 10,262.4 |
| Edmonton | 2,869 | 7,777 | 4,604 | N/A | N/A | N/A | N/A |
| M.D. of Bighorn No. 8 | 2,420 | 5,527 | 4,377 | N/A | N/A | N/A | N/A |
| M.D. of Bonnyville No. 87 | 58 | 3,524 | 595 | N/A | N/A | N/A | N/A |
| Lac La Biche County | 58 | 3,524 | 595 | N/A | N/A | N/A | N/A |
| Calgary | N/A | N/A | N/A | N/A | N/A | N/A | N/A |

*(Continued)*

Table 3.3 Continued

[a]Source: Farm Credit Canada (2014a)
[b]County name or census consolidated subdivision name (e.g., Drumheller)
[c]Minimum land value per acre
[d]Maximum land value per acre
[e]Percentage increase or decrease in the mean value from 2001 to 2011
[f]M.D. = Municipal District
[g]N/A signals no land sales were reported by the data provider in this year

Table 3.4 Explanation of model variables (excluding fragmentation measures)[a]

| | Name | Description | Expected Sign | Source | Years Available |
|---|---|---|---|---|---|
| **Dependent Variable** | Y | Farmland value per acre (2002 CAD) | | FCC (2014a) | All years |
| **Explanatory Variables** | Size | Size (acres) of individual parcel sold | - | FCC (2014a) | All years |
| | GoodBuild | Improvement(s) present on parcel whose combined value is at least $5,000 (2002 CAD) (omitted dummy) | + | FCC (2014a) | All years |
| | NoBuild | No improvement(s) present on parcel (dummy) | - | FCC (2014a) | All years |
| | CheapBuild | Improvement(s) present on parcel, but whose combined value is less than $5,000 (2002 CAD) (dummy) | - | FCC (2014a) | All years |
| | PctPopDenChg | A five year county percent change in population density | + | Statistics Canada (2006a,b; 2013) | All years |
| | NetIncFarm | Average net operating income per farm reporting (at the county level) (2002 CAD) | + | Statistics Canada (2014) | All years |
| | Irrig | County contains an irrigation district (dummy) | + | AARD (n.d.) and Statistics Canada (2006a) | All years[b] (same value) |

*(Continued)*

Table 3.4 Continued

| Explanatory Variables | Name | Description | Expected Sign | Source | Years Available |
|---|---|---|---|---|---|
| | Hwy2 | Distance (metres) from the centroid of a county to the Queen Elizabeth II Highway (a major highway in Alberta) | - | Calculated in ArcGIS using ESRD (2013a) and Statistics Canada (2006a) data | All years[b] (same distance) |
| | UrbDist | Distance (metres) from the centroid of a county to the centroid of the nearest population centre >9,999 people | - | Calculated in ArcGIS using ESRD (2013b) and Statistics Canada (2006a,b; 2013) | All years[c] (same distance, except when population changes) |
| | Edm-Neighbours | Identifies those counties immediately adjacent to Edmonton, as well as Edmonton (dummy) | + | Statistics Canada (2006a) | All years[b] (same value) |
| | Cal- Neighbours | Identifies those counties immediately adjacent to Calgary, as well as Calgary (dummy) | + | Statistics Canada (2006a) | All years[b] (same value) |

*(Continued)*

Table 3.4 Continued

| Explanatory Variables | Name | Description | Expected Sign | Source | Years Available |
|---|---|---|---|---|---|
| | SoilQlty | Percentage of soil acres with a dominant land classification of 2 or 3 (highest quality) relative to all classes of soils in a county. | + | Calculated in ArcGIS using AAFC and AARD (2012) and Statistics Canada (2006a) data | All years[b] (same value) |
| | **Farm Type** | 50% or more of farm income comes from the dominant farm type (dummy) | | FCC (2014a) | All years |
| | Crop | Agricultural crops (e.g., wheat) (omitted dummy) | | | |
| | Beef | Beef cattle operation | | | |
| | Dairy | Dairy cattle or goat operation | | | |
| | Mixed | Mixed operation | | | |
| | Hog | Hog operation | | | |
| | Poultry | Poultry operation | | | |
| | Sheep | Sheep operation | | | |
| | Greenhs | Greenhouse operation | | | |
| | SpecEnter | Specialty Enterprise (e.g., horses, furs, and bees) | | | |

*(Continued)*

Table 3.4 Continued

[a]Acronyms: AAFC = Agriculture and Agri-Food Canada; AARD = Alberta Agriculture and Rural Development; CAD = Canadian Dollar; ESRD = Alberta Environment and Sustainable Resource Development; FCC = Farm Credit Canada; n.d. = no date;

[b]The reported value stayed the same for all years.

[c]The reported value stayed the same for all years except in rare instances when a nearer urban area surpassed the population threshold.

**Table 3.5 Fragmentation measures**

| Fragmentation Measure (Short Name) | Formula | Explanation | Fragmentation increases when this coefficient is… |
|---|---|---|---|
| Small Parcel (≤ 80 acres) Sales Ratio (Sales80)[a] | $\frac{\sum s_{kt}^{80}}{\sum s_{kt}}$ | Total area (acres) of sales less than or equal to 80 acres divided by total area (acres) of all sales in county *k* in year *t*. | + |
| Mean Patch Size (MPSize)[b] | $\frac{\sum_i a_{ik}}{n_k}$ | The sum of agricultural patch areas *i* in a county *k* divided by the total number (*n*) of agricultural patches in a county in a given year. | - |
| Patch Density (PatchDenAc)[b] | $\frac{n_k}{A_k}$ | The total number (*n*) of agricultural patches in county *k* divided by the total county area *A* in a given year. | + |

[a]Mervish et al (2008) used less than 80 acres only.
[b]Adapted from Irwin and Bockstael (2007)

**Table 3.6 Descriptive statistics for variables, trimmed large sample hedonic model (2000–2011)[a,b]**

| | Name (units where applicable) | Number of Observations[c] | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|---|---|
| **Dependent Variable** | Y (2002 CAD/acre)[d] | | 3,105 | 9,621 | 123 | 122,924 |
| **Explanatory Variables** | | | | | | |
| | Size (acres) | | 269 | 549 | 0.1 | 20,017 |
| | Hwy2 (metres) | | 172,758 | 155,468 | 1,737 | 633,932 |
| | UrbDist (metres) | | 75,203 | 73,261 | >0 | 393,783 |
| | NetIncFarm (2002 CAD) | 14,802 | 31,075 | 21,807 | -57,364 | 245,066 |
| | PctPopDenChg (%) | | 4.6 | 5.9 | -14.9 | 28.2 |
| | SoilQlty (%) | | 59.4 | 25.9 | 0 | 92.9 |
| **Fragmentation Variable** | Sales80 | | 0.04 | 0.08 | 0.00 | 1.00 |
| **Dummy Variables** | | **Number of Observations[c]** | **Count if =1** | **Proportion if =1** | | |
| | GoodBuild | | 5,531 | 0.3713 | | |
| | NoBuild | | 9,050 | 0.6076 | | |
| | CheapBuild | | 314 | 0.0211 | | |
| | Irrig | | 3,442 | 0.2311 | | |
| | Edm-Neighbours | | 1,084 | 0.0728 | | |
| | Cal-Neighbours | | 637 | 0.0428 | | |
| | Crop | | 8,333 | 0.5594 | | |
| | Beef | | 2,815 | 0.1890 | | |

*(Continued)*

Table 3.6 Continued

| Dummy Variables | | Number of Observations[c] | Count if =1 | Proportion if =1 |
| --- | --- | --- | --- | --- |
| | Mixed | | 3,366 | 0.2260 |
| | Dairy | | 127 | 0.0085 |
| | Hog | | 61 | 0.0041 |
| | Poultry | | 57 | 0.0038 |
| | Sheep | | 7 | 0.0005 |
| | Greenhs | | 24 | 0.0016 |
| | SpecEnter | | 105 | 0.0070 |

[a]The top and bottom one percent of dependent variable outliers were removed.

[b]Variable names are defined in Table 3.4 and Table 3.5

[c]The number of observations is 14,895 unless otherwise stated.

[d]CAD = Canadian Dollar

Table 3.7 Descriptive statistics for variables, trimmed small sample hedonic model (2010–2011)[a,b]

| | Name (units where applicable) | Number of Observations[c] | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|---|---|
| **Dependent Variable** | Y (2002 CAD/acre)[d] | | 3,864 | 10,468 | 127 | 102,483 |
| **Explanatory Variables** | | | | | | |
| | Size (acres) | | 263 | 621 | 0.1 | 20,017 |
| | Hwy2 (metres) | | 204,829 | 190,695 | 1,737 | 633,932 |
| | UrbDist (metres) | | 95,293 | 108,992 | 930 | 393,783 |
| | NetIncFarm (2002 CAD) | 1,908 | 39,886 | 28,759 | -57,364 | 245,066 |
| | PctPopDenChg (%) | | 4.6 | 3.0 | -3.9 | 11.0 |
| | SoilQlty (%) | | 56.6 | 26.9 | 0.3 | 92.9 |
| **Fragmentation Variables** | | | | | | |
| | Sales80 | | 0.04 | 0.06 | 0.00 | 0.43 |
| | MPSize ($metres^2$) | 1,680 | 9,927,986 | 9,319,754 | 189,719 | 1.16E+08 |
| | PatchDenAc ($acres^{-1}$) | 1,680 | 0.00061 | 0.00054 | 0.00003 | 0.00300 |
| **Dummy Variables** | | **Number of Observations[c]** | **Count if =1** | **Proportion if =1** | | |
| | GoodBuild | | 734 | 0.3764 | | |
| | NoBuild | | 1,178 | 0.6041 | | |
| | CheapBuild | | 38 | 0.0195 | | |
| | Irrig | | 445 | 0.2282 | | |
| | Edm-Neighbours | | 103 | 0.0528 | | |

*(Continued)*

Table 3.7 Continued

| **Dummy Variables** | | **Number of Observations**[c] | **Count if =1** | **Proportion if =1** |
|---|---|---|---|---|
| | Cal-Neighbours | | 92 | 0.0472 |
| | Crop | | 1,170 | 0.6000 |
| | Beef | | 313 | 0.1605 |
| | Mixed | | 402 | 0.2062 |
| | Dairy | | 22 | 0.0113 |
| | Hog | | 8 | 0.0041 |
| | Poultry | | 12 | 0.0062 |
| | Sheep | | 2 | 0.0010 |
| | Greenhs | | 6 | 0.0031 |
| | SpecEnter | | 15 | 0.0077 |

[a]The top and bottom one percent of dependent variable outliers were removed.
[b]Variable names are defined in Table 3.4 and Table 3.5
[c]The number of observations is 1,950 unless otherwise stated.
[d]CAD = Canadian Dollar

**Table 3.8 Observations in the Farm Credit Canada (FCC) data set reassigned to nearby census consolidated subdivisions (CCSs)[a]**

| Farm Credit Canada Name | Assigned to CCS | Number of sales before outliers removed | Number of sales after outliers removed[b] |
|---|---|---|---|
| Acadia No. 34 | Special Area No. 3 | 43 | 39 |
| Airdrie | Rocky View County | 5 | 1 |
| Camrose | Camrose County | 5 | 2 |
| Fort Saskatchewan | Strathcona County | 1 | 1 |
| Leduc | Leduc County | 1 | 1 |
| Lethbridge | Lethbridge County | 19 | 13 |
| Lloydminster (Alberta part) | County of Vermilion River | 4 | 1 |
| Medicine Hat | Cypress County | 10 | 8 |
| Red Deer | Red Deer County | 6 | 1 |
| Spruce Grove | Parkland County | 4 | 2 |
| St. Albert | Sturgeon County | 3 | 0 |
| Wetaskiwin | County of Wetaskiwin No. 10 | 4 | 0 |

[a]Recoding occurred to allow for matching of variables calculated at the CCS level to the farmland values in the FCC data set. Refer to Subsection 3.2.2.
[b]The top and bottom one percent of dependent variable outliers were removed.

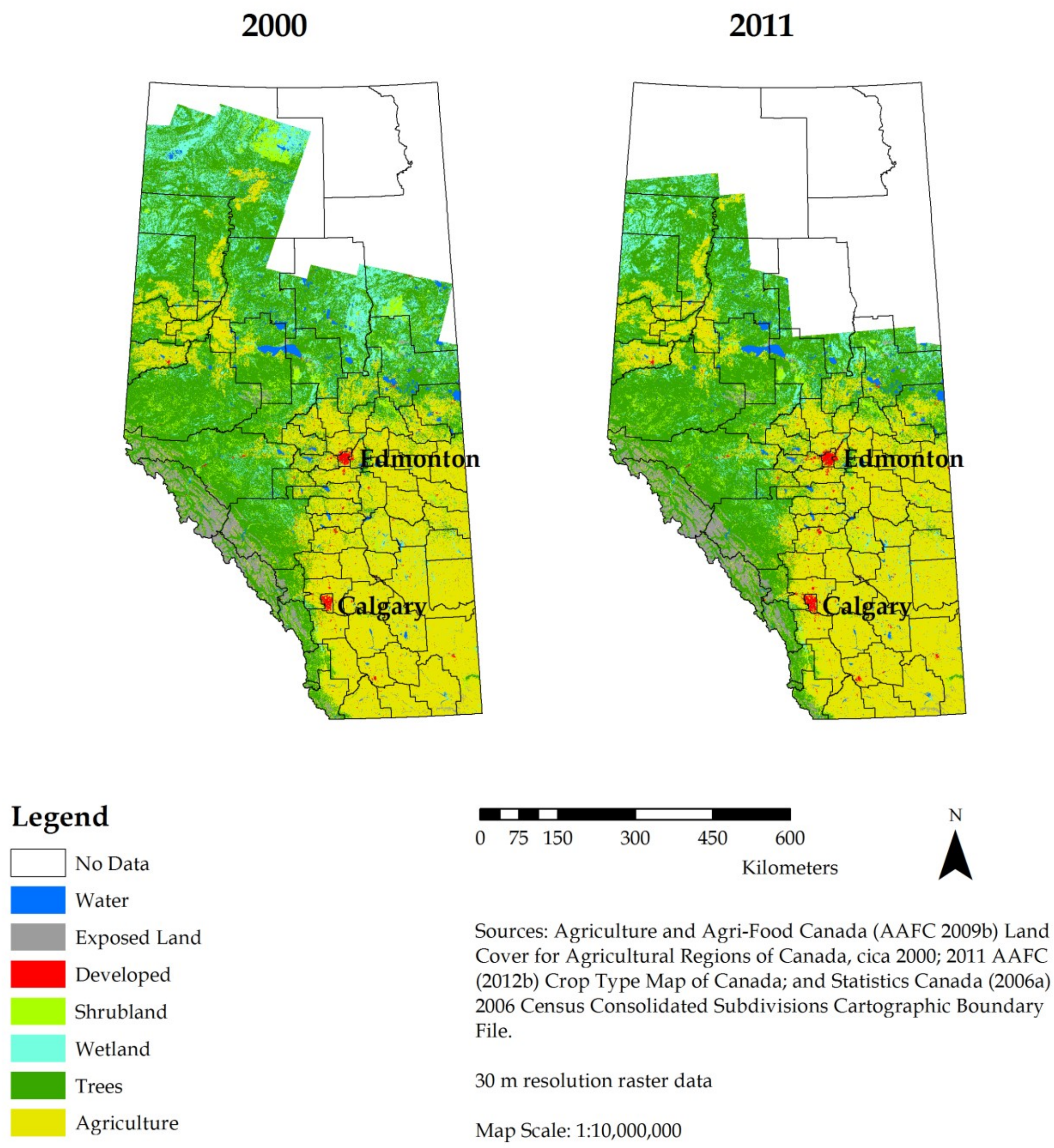


**Figure 3.1 Alberta Land Cover, 2000 and 2011**

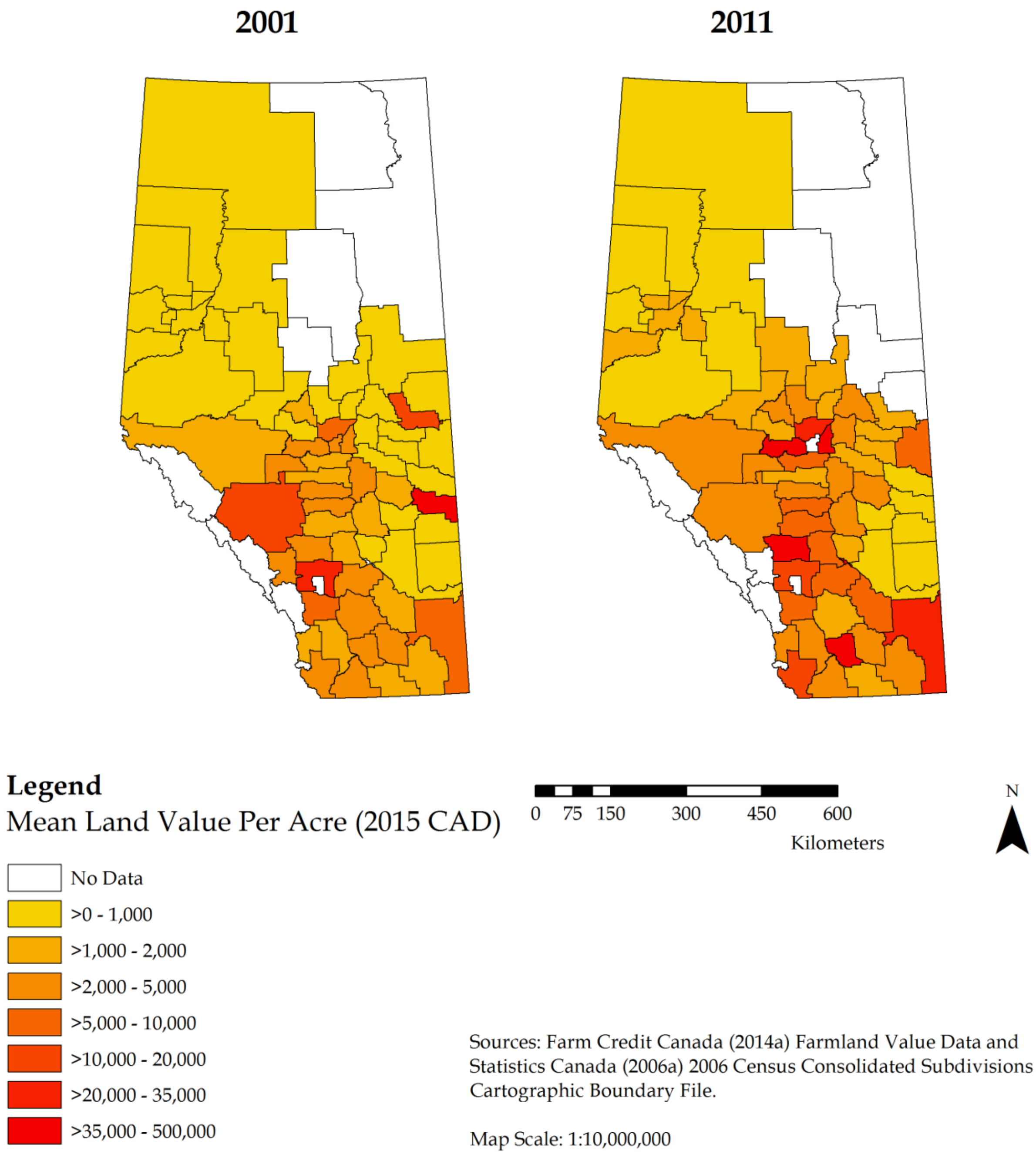


**Figure 3.2 Average Land Value per Acre Sold by County, 2001 and 2011 (all observations; 2015 CAD)**

# Chapter 4: Results and Discussion

## 4.1 Introduction

The main focus of this chapter is to provide a presentation and discussion of study results. Functional forms are discussed in the Diagnostics Section, along with the issues of heteroscedasticity, endogenous fragmentation regressors, and instrument validity. Next, the results are discussed. There are several results reported that cover different time periods, and use different fragmentation measures or, in some cases, no fragmentation measures. Key interpretations are highlighted. The fourth section of this chapter covers other areas of concern, such as how the choice to remove certain outliers, or how the inclusion or exclusion of certain explanatory variables, influenced the results. A chapter summary follows near the end. Related supplementary materials are also included in the appendices.

## 4.2 Diagnostics

Researchers have used the log-log functional form in hedonic farmland valuation models (e.g., Patton and McErlean 2003; Deaton and Vyn 2010), although it is not the only functional form chosen for this type of analysis.[31] The aforementioned researchers used Box-Cox transformations to support their choice of the log-log functional form. Box-Cox transformations in this thesis (not shown) did not support the use of traditional functional forms. However, the ability to use transformations was limited because few of the variables were strictly positive (i.e., only parcel size, and distances to

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[31]For example, Palmquist and Danielson (1989) used the semi-log functional form.

Highway 2 and a large urban area). Another potential issue with the Box-Cox transformation was presented by Blaylock et al (1980). They discussed how in the presence of heteroscedasticity the Box-Cox transformed parameters may be biased, and hypothesis tests may be misleading (Blaylock et al 1980). Zarembka (1974) reported that the bias of the transformed parameter of the dependent variable will be such that it leads to constant error variance. Table 4.1 later shows that heteroscedasticity is an issue for the regressions in the current study.

Similar to the analysis using the Box-Cox transformations, the PE test (as explained in Verbeek 2012) did not help to determine whether the ln-ln or linear model was more appropriate (not shown). Rather, the PE test results suggested that neither the ln-ln nor the linear model were appropriate most of the time.

Instead, goodness-of-fit measures were used to compare the various functional forms: linear, linear-ln, linear-inverse, ln-linear, ln-ln and ln-inverse. These results are presented in Appendix A (Table A.1). Table A.1 contains results for multiple test models, which involved removal of different types of outliers. Outliers were alternatively defined as follows:

- sales under 5 acres in size
- sales under 5 acres in size followed by the removal of any sales $10,000 per acre (2002 CAD)[32] and larger

[32]All dollar values in this chapter were converted from their nominal value to 2002 CAD using the Alberta CPI for the relevant year.

- the top and bottom 1% of sales per acre; and,
- sales under 40 acres in size.

There were also problems with the goodness-of-fit measures approach because measures such as R-squared (Greene 2003) and Akaike Information Criterion (AIC) (Burnham and Anderson 2002) could not be used to compare models using different transformations of the dependent variable. However, Wooldridge (2006) demonstrated a method to obtain an R-squared value from a logged dependent variable that could then be compared to the R-squared values from regressions that used a linear dependent variable. Using all variables except for the fragmentation variables, usually the ln-ln model or the linear-inverse specifications had the best fit.

It was decided to use the ln-ln model for the remainder of the thesis. As well, results in Table A.2 show how even when the linear-inverse has a more positive R-squared value, the ln-ln form more often has significant explanatory variables. Table A.2 also demonstrates that unexpected signs sometimes occurred for coefficients on explanatory variables when the dependent variable was linear (versus being logged). In this case, the *NoBuild* was positive, whereas when the dependent variable was logged this variable was negative. Unexpected signs also occurred in two other outlier models (not shown) when the dependent variable was linear.

Fragmentation measures were next incorporated into the regressions. Given previous concerns about endogeneity (see Chapter Three), instruments were included. The instrument selected was the previous year's fragmentation measure. The instrument was also interacted with the Edmonton and Calgary (and their neighbours) dummies, given the different patterns of fragmentation around these cities compared to the rest of the province as found by Qiu et al (2015). For clarity, when the text refers to three instruments the reference is to the use of the previous year's fragmentation and the previous year's fragmentation interacted with the above dummies in the models.

Table 4.1 illustrates the various tests for homoscedasticity that were performed using a single instrument for fragmentation. The null hypothesis of homoscedasticity was rejected in all cases. Based on these tests robust standard errors were computed for the remainder of the thesis.

For the results to be compelling, the instruments themselves must be studied more closely. A valid instrument must satisfy two conditions:  it must be uncorrelated with the disturbance term and it must be correlated with the endogenous explanatory variable. Of these, only the second condition can be empirically tested. StataCorp (2013) was used to compute the effective F-statistic, which is the same as the robust F-statistic for the instrument in the first-stage regression in the just-identified single instrumental variable case (Pflueger and Wang 2014; Montiel Olea and Pflueger 2013). Given the presence of heteroscedasticity, the effective F-statistic had to be compared to modified critical values (see Montiel Olea and Pflueger 2013). Table 4.2 reports that all of the effective F-statistics exceed the critical value. Therefore, the null hypothesis of weak instruments was rejected. The null hypothesis was rejected for other sample years (i.e., 2010–2011 and 2010) using the fragmentation measures reported in Table 4.2, with the exception of the *LnPatchDenAc* in the 2010–2011 model (Table B.2). This case had an effective F-statistic of 9.132, which was smaller than the critical value of 12.039 when tau was 30% and the significance level alpha was 5%. The other thing to note was that this particular test was only relevant for single instrumental variables. In the three instrumental variable models, these instruments could not be tested to see if they were weak instruments.

The next set of tests that were performed considered whether the fragmentation measures were exogenous. Results varied depending on the years contained in the sample (Table 4.3). StataCorp (2013) was used to perform a robust regression-based test (which was confirmed manually). This test, which relies on estimating robust standard errors, is appropriate when heteroscedasticity is present (Cameron and Trivedi 2010). In cases where the null hypothesis of exogeneity was rejected, models were estimated using 2SLS; otherwise OLS estimation was used because it is more efficient. The 2011 sample (Table 4.3) was a bit unusual compared to the 2010–2011 (some) or 2010 (Table B.2) models in that the null hypothesis of exogenous fragmentation variables could not be rejected.

## 4.3 Results

In this section, results are presented for a large sample (years 2000–2011) and a small sample (year 2011) when the top and bottom 1% of land values per acre are removed as outliers. Appendix B reports results based on other small sample models, estimated using other years (2010–2011 and 2010 alone). Any land values per acre matched with explanatory variables that have missing values were also automatically dropped by StataCorp (2013). Unspecified farm types were manually dropped. There were 80 of these for the entire data set (years 1999–2011) after removing the aforementioned outliers. Each table presents a model run without the fragmentation measures (called *No Fragmentation*), and then corresponding models with the various fragmentation measures, which are named based on the specific measure included; the *Ln Mean Patch Size* model includes the *LnMPSize* measure of fragmentation, the *Ln Patch Density* model includes the *LnPatchDenAc*, and the *Small Parcel (≤ 80 acres) Sales Ratio* model includes the *Sales80* measure.

Based on the test results presented in Table 4.3 concerning the exogenous/endogenous nature of the fragmentation measures, models were estimated using the appropriate technique (2SLS or OLS), as discussed above. The results for these models are reported in Table 4.4 and Table 4.5.

### 4.3.1 Large Sample Model Results

Considering Table 4.4 first, the coefficients on the explanatory variables were quite similar regardless of whether or not fragmentation was included in the model, and most were statistically significant. Exceptions included the *LnUrbDist* and *Edm-Neighbours* variables, as the coefficient estimates for these variables differed between the two models. However, the estimates were not significant in the fragmentation model. Other variables which were not significant in either model included the *Poultry* and *Sheep* dummies.

The data contain variables indicating if no improvements were present on the property (*NoBuild*) or if improvements valued under $5,000 (*CheapBuild*) were present. *CheapBuild* had a larger negative effect on land price per acre compared with either there being no improvements (*NoBuild)* or the presence of improvements worth $5,000 or more (*GoodBuild*). In comparison, Elad et al (1994) found that a building rated as good contributed to a higher land value than either a building rated as poor or the absence of any buildings. However, in their case the absence of any buildings had a more negative impact than a building rated as poor (Elad et al 1994). One possible explanation for the Table 4.4 result is the presence of demolition or renovation costs to deal with improvements worth less than $5,000.

The negative coefficient on parcel size (i.e., *LnSize*) is consistent with results reported by many previous studies, including Xu et al (1993), Elad et al (1994) and Palmquist and Danielson (1989). One possible explanation for this result is that there is a thinner market for larger parcels because there are fewer buyers with the necessary capital (Xu et al 1993). Palmquist and Danielson (1989) hypothesized that the inverse relationship could be a result of subdivision costs (legal and political).

As expected, variables related to agricultural productivity (i.e., *Irrig*, *SoilQlty* and *NetIncFarm*) were all positive and significant. Xu et al (1993) used a gross income per acre variable and also found this to be positive and significant for most of the regions examined in their study. The positive relationship between higher soil quality and farmland prices was also supported by work done by Huang et al (2006), Xu et al (1993) and Palmquist and Danielson (1989). Xu et al (1993) and Bastian et al (2002) similarly found a positive relationship between the proportion of acres irrigated or a productivity rating related to irrigation.

The effects of farm type were interpreted relative to the crop farm dummy, which was omitted. Beef cattle and hog farms tended to lower land values per acre compared to crop farms, while mixed, dairy,[33] greenhouses, and specialty enterprises tended to raise farmland values per acre more than crop farms. Perhaps the beef cattle and hog farms' depressed values are related to the soil quality, which could be correlated (though not tested); while the other farm types (dairy farms etc.) tend to reflect the production of higher valued commodities. Also, recall that the *SoilQlty* and *NetIncFarm* variables were county level, but the farm types were parcel level, so these parcel level farm type dummies could be picking up some of the differences.

#### 4.3.1.1 Results Related to Conversion Pressure

There are a number of variables which were incorporated into the land value models because of their potential relationship with the influence of conversion pressure. These variables included *PctPopDenChg*, *LnHwy2*, *LnUrbDist*, *Edm-Neighbours* and *Cal-Neighbours*. In the different models these variables were mostly all significant and had the expected signs. The five year percentage change in population density had a positive effect. Palmquist and Danielson (1989) and Huang et al (2006) found that

[33]Dairy and poultry are supply managed farm types whose returns are typically higher and less variable.

population density was positively related to farmland price per acre, while population change was not significant for Palmquist and Danielson (1989).

Both the distance to Highway 2 and the distance to the nearest urban area with a population over 9,999 had a negative influence on farmland values per acre (although the latter was not significant in one regression). Thus, those parcels located in counties that are more closely situated to populated urban areas or Highway 2 tended to have higher farmland values per acre on average than those parcels located in counties further away from those entities. Several other researchers found a similar relationship for distances to a freeway exchange (Chicoine 1981) or for distance to urban areas (Elad et al 1994; Patton and McErlean 2003; Huang et al 2006; Chicoine 1981). The effect of distance to highways or urban centres is believed to be related to decreasing distance to input and product markets (Elad et al 1994) (transportation costs (Sinclair 1967)), but also the speculative value (Patton and McErlean 2003); that is, development pressure. Bastian et al (2002) did find the opposite relationship, but attributed this to a preference for fewer nuisances and more recreational/scenic amenities at larger distances from town sites.

Finally, the effect of being located in and around the counties of the major population centres in Alberta, Edmonton and Calgary, was positive and significant for the *No Fragmentation* model. One explanation for this result is that there is development pressure in these highly populated areas. In the fragmentation model only the *Cal-Neighbours* variable was positive and significant. Chicoine (1981) included a dummy variable if the parcel was located next to a town, which was also found to have a positive impact.

#### *4.3.1.2 Fragmentation Results*

As noted in Chapter Three *Sales80* was the only fragmentation measure that could be included in the large sample model due to lack of data availability in the case of the other measures. When *Sales80* was included in the model it had a large positive coefficient relative to other linear explanatory variables included in the model. Thus, if the proportion of total farmland sold in parcels of no more than 80 acres is a valid measure of fragmentation, then there is support from the current analysis for the idea that increased fragmentation has a positive influence on farmland value per acre, ceteris paribus.

Table B.1 provides additional results using the three instruments for fragmentation rather than one. The *Sales80*, *Edm-Neighbours* and *Cal-Neighbours* coefficients in Table B.1 were greater in magnitude than the ones reported in Table 4.4. Also, *Edm-Neighbours* was significant in one regression in Table B.1. In order to interpret the effects of the coefficients one must take into account the interaction terms. For counties outside of the Edmonton and Calgary regions fragmentation had a positive influence on farmland values per acre. However, this impact was attenuated around both Edmonton and Calgary especially when fragmentation rates were higher. The effect of being located in or near Edmonton and Calgary also had a negative impact on farmland values overall, but this effect diminished as fragmentation diminished. This means that in the absence of fragmentation, being in proximity to Edmonton and Calgary could have a positive influence on the farmland value per acre. It is unclear why this might be the case. Further discussion about other results for other coefficients is provided in Appendix B.

#### *4.3.1.3 Implicit Prices*

Table 4.4 also reports implicit price calculations. Depending on the variable, the implicit price may be negative or positive. For variables whose estimated coefficients were statistically significant, the implicit prices were typically quite similar across the two models (though there were exceptions, e.g., *Cal-Neighbours*). Factors that had a large positive influence on the dollar per acre included the fragmentation variable, *Greenhs*, *Cal-Neighbours*, and *Irrig*. Those that had a large negative influence included *NoBuild*, *CheapBuild*, *Beef* and *Hog*.

### 4.3.2 Small Sample Model Results

Table 4.5 reports the results using data from 2011 only, for the following models: *No Fragmentation, Small Parcel (≤ 80 acres) Sales Ratio*, *Ln Mean Patch Size*, and *Ln Patch Density*. In general, signs were consistent for all significant variables across all models although the magnitude of the coefficients differed across models. Significance levels were generally similar across all models, but some differences did arise. For example, *NetIncFarm* was not significant in any of the models except *Ln Patch Density*, but *Cal-Neighbours* was not significant only for the *Ln Patch Density* model. *PctPopDenChg* was only significant for two models.

As for interpretation of the coefficients for the small sample models, explanatory variables *NoBuild* (negative), *CheapBuild* (negative), *LnSize* (negative), *Irrig* (positive), *SoilQlty* (positive) demonstrated the same relationship with the dependent variable as was discussed earlier for the large sample model. The magnitude of the coefficients did vary, however, between the large and small samples for some of the models.

The farm types were consolidated for the small sample models because there were very few observations in any given year for many of the farm types other than *Beef*, *Crop*, and *Mixed*, and this was more apparent in the small sample case. Any farm type involving livestock was included under *Animal*; any farm type involving plant material was included under *Plant* (omitted); and the *Mixed* farm type was preserved from the large sample. In the large sample the effect of the *Mixed* farm type variable was positive and significant relative to *Crop*, but in the small samples *Mixed* was no longer significant. In the small samples, *Animal* was negative and significant, which suggested that the effects of *Beef* and *Hog* were dominating relative to the effects of *SpecEnter* and *Dairy*. The latter two variables had generated positive and significant coefficients in the large sample models.

#### *4.3.2.1 Results Related to Conversion Pressure*

The direction of effects (positive or negative) for the conversion proxy variables did not differ to any great extent between sample sizes (with one exception for *Edm-Neighbours*). However, in the small sample models some of these variables were not statistically significant, and the magnitudes for the coefficient estimates differed.

*PctPopDenChg* still had a positive relationship with farmland values, but was significant in only two models. *LnHwy2* and *LnUrbDist* were negatively associated with the dependent variable, and *Edm-Neighbours* and *Cal-Neighbours* were positively associated. The *LnUrbDist* and *Edm-Neighbours* variables were significant in the small sample *Small Parcel (≤ 80 acres) Sales Ratio* model compared to the large sample (Table 4.4).

#### *4.3.2.2 Fragmentation Results*

The small sample models allowed for a comparison of different fragmentation measures. Similar to the results for the large sample model, in the small sample model the *Sales80* variable had a positive and significant coefficient. However, the magnitude of the coefficient was greater for the small sample. This again suggested that an increase in fragmentation in the county leads to higher farmland values per acre. The coefficient for *LnMPSize* was negative and significant. This can signify that as the mean agricultural patch size increases in a county, the fragmentation of farmland declines, contributing to a decreased farmland value per acre. The coefficient for *LnPatchDenAc* was positive and significant, suggesting that as the number of agricultural patches in a county increases, farmland fragmentation increases and the farmland value increases. Given this small sample size, the interpretation of the coefficients on the fragmentation measures is consistent for all models. Fragmentation tends to lead to higher farmland values per acre. This study considered the fragmentation level at a particular point in time. Though not investigated, it is also possible that the change in fragmentation level across time could have an effect.

Table B.2 (in Appendix B) reports results for other sample years (i.e., 2010–2011 and 2010 only) that are not reported in Table 4.5. If compared to Table 4.5, results in Table B.2 were similar for *Sales80* in both samples, while only the 2010–2011 sample years had a similar interpretation across the two tables for *LnMPSize* and *LnPatchDenAc*. Specifically, for the 2010 sample *LnMPSize* and *LnPatchDenAc* had a sign opposite to what was reported for other samples. It is difficult to know how to deal with this contrary result. More discussion about the Table B.2 results is provided in Appendix B.

Table B.1 has information on the three instruments case using slightly different sample years (2010–2011), compared to Table 4.5. As mentioned earlier, the weak instrument test could not be performed, but given that the single instrument was valid it is likely that the additional instruments were similarly valid, as they were interacted with the major city dummies. This therefore established an association between the instrument and the endogenous variable. Comparing the small sample in Table B.1 to Table 4.5, the coefficient on *Sales80* was of a similar sign (positive), magnitude and significance. However, in Table B.1 the *Edm-Neighbours* coefficient was not significant. The *Cal-Neighbours* was positive and significant on its own in both tables, but when the interaction with fragmentation was taken into account in Table B.1 it suggested that highly fragmented areas around Calgary had a negative influence of farmland values. This interpretation is mostly consistent with the interpretation for the larger sample also presented in Table B.1.

Several of the results suggested that an increase in fragmentation, as it was measured here, leads to higher farmland values per acre. One possible explanation for this is that fragmentation could be another signal of development pressure if roads and services encroach onto farmland and break it into fragments. In this situation, similar to Capozza and Helsley's (1989) idea, agricultural land could be selling for more than its value of agricultural land rent.

This result is not consistent across all previous studies, however. Stobbe et al (2008) studied the impacts of fragmentation as well, and found that lower levels of fragmentation were associated with higher land values, which is the opposite of the result in the current analysis. However, their data covered the Agricultural Land Reserve (ALR) in British Columbia. They did not include an interaction variable between fragmentation and the ALR, though they did indicate whether or not a parcel was in the ALR. It may be the case that the relationship for parcels outside of the ALR would be different, but the net effect over the entire study area (including inside and outside the ALR) was a negative relationship between fragmentation and farmland values per hectare. It is conceivable that land restricted to only agricultural uses would show more of a negative relationship between farmland values and fragmentation (as reported by Stobbe et al 2008) because of the link between farm size and economies of scale. Additionally, Stobbe et al's (2008) study area was classified as urban fringe, whereas in this thesis urban and rural areas of Alberta were studied together and this may also help to explain the different result.

It should also be noted that the fragmentation measures reported here could at least partly reflect fragmentation resulting from natural habitat encroachment onto farmland rather than be caused by development. Haarsma's (2014) thesis reported that both types of conversion (agricultural to natural habitat or developed land) occurred in Alberta during the time period studied in his research.

## 4.4 Robustness Checks and Sensitivity Analysis

A number of checks were run to gauge the sensitivity of results to changes in explanatory variables and outliers. These are discussed in the following subsections.

### 4.4.1 Removal of the Net Operating Income Variable

It can be argued that *NetIncFarm* (average net operating income per farm reporting) is not an appropriate explanatory variable for a hedonic model because it is not an attribute of the parcel. Although having the farm income associated with an individual parcel could reflect other attributes of the parcel related to agricultural productivity that perhaps were not adequately captured by the farm type, *SoilQlty* or *Irrig* variables, in this study only the county level farm income was available. In this case the farm income was included to reflect the health of the agricultural economy of the neighbourhood. Income measures have also been included in hedonic models to reflect the neighbourhood's attributes (Taylor 2003). To investigate the effect of removing *NetIncFarm*, the large samples were rerun without this variable. The results are reported in Table 4.6. The sample sizes differed because observations that had missing data were dropped from the regression if that variable was included in the regression. The differences in sample size were a result of using or not using the *NetIncFarm* and *PastSales80* variables.

It was expected that the effect of variables related to agricultural productivity (i.e., *SoilQlty*, *Irrig* or the farm types) would change if the *NetIncFarm* variable was removed. In general, signs and significance of coefficient estimates for these variables were not affected by the removal of the *NetIncFarm* variable; that is, they remained consistent when compared to Table 4.4 estimates. The magnitude of the coefficients did change between Table 4.4 and Table 4.6. For example, the coefficient for *Irrig* did increase, while the coefficient for *SoilQlty* decreased slightly. From these results, inclusion of *NetIncFarm* did not appear to have an adverse outcome on the results.

### 4.4.2 Outlier Removal Comparison

From the literature there was no universal rule for defining and selecting the outliers to be removed prior to performing the regression analysis for the land valuation models. Deaton and Vyn (2015) removed the top and bottom 1% of sale prices.[34] The land value data provider, FCC, also provided some suggestions about possible outlier definitions. Table 4.7 reports various large sample regressions using the *Sales80* variable after alternatively removing the following outliers: the top and bottom 1% of sales per acre (as applied in other tables); any sales under 5 acres in size; any sales under 40 acres in size; and a combination of removing any sales under 5 acres in size followed by the removal of any sales $10,000 per acre and larger. Checks were

[34]In a second step, they excluded properties under 5 acres (Deaton and Vyn 2015).

completed for weak instruments, heteroscedasticity and endogeneity. Each of the following null hypotheses was rejected: instruments are weak; constant variance; and exogenous fragmentation variables. As a result 2SLS estimation was used and robust standard errors were computed. Sample sizes differed because removing different types of outliers removed different amounts of observations.

The estimates were not the same across the models, but were relatively consistent in terms of signs and significance. Exceptions included *LnUrbDist* which was negative and significant for two regressions. This result was not unexpected, but it was problematic to explain why it was significant for only two models. One possible explanation was that *LnUrbDist* and *Sales80* are correlated. Pearson's correlation[35] between *LnUrbDist* and *Sales80* for all tables in this document suggested that a correlation of <-0.4 tended to be related with a lack of significance of the *LnUrbDist*, but there were exceptions to this generalization in Table B.1 and Table C.1. The *Edm-Neighbours* variable was negative and significant for the same two regressions just mentioned. Again, this result was a bit different than expected because it was expected that *Edm-Neighbours* would have a positive impact as that was found in other models in the absence of the fragmentation variable. No conclusions could be drawn by analysing the point biserial correlations between *Edm-Neighbours* and *Sales80* for the various tables.

The farm type signs and significance varied amongst the models in Table 4.7. The mixed farm type was only significant for two of the models and was positive in one and

[35]This discussion ignores normality and outlier concerns.

negative in the other. Again it is unclear why this would be the case. The hog farm type was significant for two regressions, and the *Greenhs* variable was only significant for one regression. This latter result can possibly be explained by how outliers were removed. For example, removing sales less than 40 acres left three greenhouses, whereas 24 remained in the regression when the top and bottom 1% of outliers were removed. Ignoring these exceptions, the same conclusions could be reached about the effects of various factors on the dependent variable as were discussed in Section 4.3.

## 4.5 Chapter Summary

There are several implications that can be drawn from the results presented in this chapter. For the most part, signs and significance for explanatory variables were consistent with expectations. Variables that considered additional value added or not added by the presence or absence of an improvement(s) had the expected signs. The parcel size had a negative relationship with farmland value per acre. The soil quality of a county, whether an irrigation district was present in a county, and average net operating income per farm reporting (county level) were usually positively related to the dependent variable although the latter was not always significant. The signs on farm types tended to vary with the farm type, but cropping farms may have a more positive relationship with the dependent variable relative to other farm types aside from specialty farms (including dairy and greenhouses).

As for the focus of this thesis (i.e., conversion and fragmentation), the conversion pressure variables, such as the change in population density in a county over a five year period and the distance to the highway connecting the major urban centres of Edmonton and Calgary, had the expected signs, positive and negative respectively. The distance from the centroid of a county to the nearest large urban area was always negative, but not always significant. Why this result occurred is not clear. Usually, a farm sale near or in Calgary had a higher land value per acre, but the results around Edmonton were less conclusive. Differences in land development, amalgamation approaches, and municipal politics could be a potential contributor to this difference between the Edmonton and Calgary regions.

Lastly, fragmentation effects were a bit varied depending on the fragmentation measure considered and the time period. There is some evidence that higher fragmentation leads to higher land values per acre, at least in more rural counties, but there were some contrary results in a few years. This could be related to the data sources/type/quality, the level of aggregation, and the underlying change in fragmentation over time. Additionally, this could merely highlight the degree of complexity of this issue. Relying on the effects of a single fragmentation measure could be misleading. Some of these discrepancies and unexplained parts will be better explained after the limitations of the study are discussed in the next chapter. Suggestions for further research (also provided in the next chapter) will highlight potential areas of improvement for the present study.

## 4.6 Tables for Chapter Four

**Table 4.1 Tests for homoscedasticity: Reported p-values (Ho: constant variance)[a,b]**

| | **Model** | | | | | |
|---|---|---|---|---|---|---|
| | **Large Sample (Year=2000–2011)** | | **Small Sample (Year=2011)** | | | |
| **Tests for Homoscedasticity** | *No Fragmentation* | *Small Parcel (≤ 80 acres) Sales Ratio* | *No Fragmentation* | *Small Parcel (≤ 80 acres) Sales Ratio* | *Ln Mean Patch Size* | *Ln Patch Density* |
| Breusch-Pagan/ Cook-Weisberg | 0.0000 | | 0.0000 | | | |
| White's test | 0.0000 | | 0.0000 | | | |
| Pagan-Hall general | | 0.0000 | | 0.0000 | 0.0000 | 0.0000 |
| Pagan-Hall with assumed normality | | 0.0000 | | 0.0000 | 0.0000 | 0.0000 |
| White/Koenker nR2 | | 0.0000 | | 0.0000 | 0.0000 | 0.0000 |
| Breusch-Pagan/ Godfrey/Cook-Weisberg | | 0.0000 | | 0.0000 | 0.0000 | 0.0000 |

[a]Top and bottom 1% outliers (based on the dependent variable) were removed
[b]Single instrumental variable used

**Table 4.2 Test for a weak instrument: F-Statistics (Ho: instrument is weak)[a,b,c]**

| **Sample Year(s)** | **Fragmentation Variable** | **Effective F-Statistic** |
|---|---|---|
| 2000–2011 | Sales80 | 357.185 |
| 2011 | Sales80 | 340.452 |
| 2011 | LnMPSize | 280.824 |
| 2011 | LnPatchDenAc | 238.599 |

[a]Top and bottom 1% outliers (based on the dependent variable) were removed
[b]Critical value is 37.418 (when the significance level alpha = 5% and when tau = 5% of the worst-case benchmark)
[c]Single instrumental variable used

**Table 4.3 Tests for exogenous fragmentation measures: F-Statistics and p-values (Ho: exogenous fragmentation variables)[a,b]**

| Sample Year(s) | Fragmentation Variable | Test Results: F-Statistic | Test Results: p-value |
|---|---|---|---|
| 2000–2011 | Sales80 | F(1, 14759)=49.19 | 0.0000 |
| 2011 | Sales80 | F(1, 1018)=1.12 | 0.2905 |
| 2011 | LnMPSize | F(1, 811)=0.29 | 0.5891 |
| 2011 | LnPatchDenAc | F(1, 811)=1.44 | 0.2297 |

[a]Top and bottom 1% outliers (based on the dependent variable) were removed
[b]Single instrumental variable used

**Table 4.4 Parameter estimates and implicit prices for large sample (2000–2011) hedonic models of Alberta farmland prices (robust standard errors in parentheses)[a,b]**

| Dependent variable: Ln of farmland price per acre 2002 CAD[c] | Model: *No Fragmentation* — *Coefficient Estimates* | *Implicit Prices[d]* | Model: *Small Parcel (≤ 80 acres) Sales Ratio* — *Coefficient Estimates* | *Implicit Prices[e]* |
|---|---|---|---|---|
| **Estimation[f]** | OLS | | 2SLS | |
| R-squared | 0.7187 | | 0.7184 | |
| F-statistic | 1,332 | | 1,299 | |
| Sample Size | 14,802 | | 14,781 | |
| **Explanatory variable[g]** | | | | |
| GoodBuild | Omitted | | Omitted | |
| NoBuild | -0.1531*** | -439.41 | -0.1583*** | -453.00 |
| | (0.0108) | | (0.0109) | |
| CheapBuild | -0.2510*** | -686.90 | -0.2466*** | -676.45 |
| | (0.0334) | | (0.0332) | |
| LnSize | -0.5162*** | -5.94 | -0.5064*** | -5.83 |
| | (0.0071) | | (0.0073) | |
| Irrig | 0.5747*** | 2403.60 | 0.5895*** | 2485.60 |
| | (0.0188) | | (0.0184) | |
| SoilQlty | 0.0029*** | 8.90 | 0.0025*** | 7.85 |
| | (0.0003) | | (0.0002) | |
| NetIncFarm | 3.40E-06*** | 0.01 | 3.66E-06*** | 0.01 |
| | (3.03E-07) | | (3.03E-07) | |

*(Continued)*

Table 4.4 Continued

| Dependent variable: Ln of farmland price per acre 2002 CAD[c] | Model | | | |
|---|---|---|---|---|
| | *No Fragmentation* | | *Small Parcel (≤ 80 acres) Sales Ratio* | |
| | *Coefficient Estimates* | *Implicit Prices*[d] | *Coefficient Estimates* | *Implicit Prices*[e] |
| **Explanatory variable**[g] | | | | |
| PctPopDenChg | 0.0226*** | 69.88 | 0.0250*** | 77.46 |
| | (0.0012) | | (0.0013) | |
| LnHwy2 | -0.1833*** | -3.28[h] | -0.1823*** | -3.27[h] |
| | (0.0059) | | (0.0056) | |
| LnUrbDist | -0.0430*** | -1.77[h] | -0.0059 | -0.24[h] |
| | (0.0100) | | (0.0091) | |
| Edm-Neighbours | 0.3928*** | 1489.10 | -0.0209 | -64.14 |
| | (0.0268) | | (0.0562) | |
| Cal-Neighbours | 0.4212*** | 1621.19 | 0.3241*** | 1184.54 |
| | (0.0389) | | (0.0400) | |
| Crop | Omitted | | Omitted | |
| Beef | -0.1919*** | -540.48 | -0.1920*** | -540.64 |
| | (0.0125) | | (0.0124) | |
| Mixed | 0.0656*** | 209.93 | 0.0451*** | 142.91 |
| | (0.0152) | | (0.0155) | |
| Dairy | 0.1901*** | 647.86 | 0.1809*** | 613.83 |
| | (0.0465) | | (0.0467) | |
| Hog | -0.1992*** | -559.02 | -0.2169*** | -603.54 |
| | (0.0668) | | (0.0701) | |
| Poultry | -0.0166 | -50.90 | -0.0657 | -196.81 |
| | (0.0835) | | (0.0895) | |
| Sheep | -0.0035 | -10.95 | -0.0151 | -46.31 |
| | (0.2086) | | (0.2193) | |
| Greenhs | 0.5821*** | 2444.22 | 0.6446*** | 2801.49 |
| | (0.1725) | | (0.1785) | |
| SpecEnter | 0.2552*** | 899.86 | 0.1801** | 610.71 |
| | (0.0785) | | (0.0807) | |
| Sales80 | | | 2.5081*** | 7762.43 |
| | | | (0.2903) | |
| Constant | 11.6892*** | | 11.1701*** | |
| | (0.1046) | | (0.1069) | |

*(Continued)*

Table 4.4 Continued

[a]***, ** and * represent statistical significance at the 1 percent level, 5 percent level, and 10 percent level, respectively

[b]Top and bottom 1% outliers (based on the dependent variable) were removed

[c]CAD = Canadian Dollar

[d]Implicit prices are calculated at the mean values, which are as follows: $Y_{mean}$=3,095; $Size_{mean}$=269; $Hwy2_{mean}$=172,817 and $UrbDist_{mean}$=75,220. A modified version of the procedure from Halvorsen and Palmquist (1980) is used to calculate the implicit prices (i.e., Y*{EXP($b_i$)-1}) of the dummy variables as was employed by Bin et al (2006). The implicit price for the double log is $\frac{\delta P}{\delta z_i} = b_i \frac{P}{z_i}$ and the implicit price for the semi-log is $\frac{\delta P}{\delta z_i} = b_i P$.

[e]Implicit prices are calculated at the mean values, which are as follows: $Y_{mean}$=3,095; $Size_{mean}$=269; $Hwy2_{mean}$=172,709; and $UrbDist_{mean}$=75,163.

[f]OLS refers to ordinary least squares, while 2SLS refers to two-stage least squares estimation.

[g]Variable names are defined in Table 3.4 and Table 3.5

[h]These values reflect the implicit price per kilometre rather than per metre.

**Table 4.5 Parameter estimates for small sample (2011) hedonic models of Alberta farmland prices (robust standard errors in parentheses)[a,b,c]**

| | Model | | | |
|---|---|---|---|---|
| **Dependent variable: Ln of farmland price per acre 2002 CAD[d]** | *No Fragmentation* | *Small Parcel (≤ 80 acres) Sales Ratio* | *Ln Mean Patch Size* | *Ln Patch Density* |
| R-squared | 0.7598 | 0.7669 | 0.7233 | 0.7311 |
| F-statistic | 191 | 194 | 115 | 121 |
| Sample size | 1,034 | 1,034 | 862 | 862 |
| **Explanatory variable[e]** | | | | |
| GoodBuild | Omitted | Omitted | Omitted | Omitted |
| NoBuild | -0.1970*** | -0.1995*** | -0.1331*** | -0.1366*** |
| | (0.0419) | (0.0411) | (0.0427) | (0.0423) |
| CheapBuild | -0.2623* | -0.2451* | -0.3031** | -0.3059** |
| | (0.1378) | (0.1323) | (0.1267) | (0.1278) |
| LnSize | -0.5209*** | -0.5022*** | -0.5207*** | -0.5105*** |
| | (0.0287) | (0.0296) | (0.0319) | (0.0318) |
| Irrig | 0.7790*** | 0.7630*** | 0.7191*** | 0.7785*** |
| | (0.0679) | (0.0665) | (0.0860) | (0.0744) |
| SoilQlty | 0.0074*** | 0.0080*** | 0.0041*** | 0.0021* |
| | (0.0011) | (0.0010) | (0.0012) | (0.0011) |
| NetIncFarm | 8.04E-07 | 8.45E-07 | 1.96E-06 | 3.80E-06*** |
| | (7.40E-07) | 7.28E-07 | (1.29E-06) | (1.14E-06) |
| PctPopDenChg | 0.0111 | 0.0059 | 0.0160* | 0.0159* |
| | (0.0090) | (0.0087) | (0.0089) | (0.0086) |
| LnHwy2 | -0.1381*** | -0.1400*** | -0.1482*** | -0.1304*** |
| | (0.0217) | (0.0216) | (0.0218) | (0.0218) |
| LnUrbDist | -0.1654*** | -0.1378*** | -0.0912*** | -0.0980*** |
| | (0.0258) | (0.0253) | (0.0268) | (0.0253) |
| Edm-Neighbours | 0.7768*** | 0.5130*** | 0.7338*** | 0.6547*** |
| | (0.1231) | (0.1385) | (0.1172) | (0.1150) |
| Cal-Neighbours | 0.1908* | 0.2437** | 0.2250* | 0.1052 |
| | (0.1132) | (0.1113) | (0.1180) | (0.1195) |
| Plant | Omitted | Omitted | Omitted | Omitted |
| Animal | -0.2406*** | -0.2437*** | -0.2989*** | -0.2978*** |
| | (0.0514) | (0.0501) | (0.0516) | (0.0514) |
| Mixed | -0.0266 | -0.0218 | 0.0423 | 0.0450 |
| | (0.0542) | (0.0541) | (0.0715) | (0.0713) |

*(Continued)*

Table 4.5 Continued

| **Explanatory variable[e]** | **Model** | | | |
|---|---|---|---|---|
| | *No Fragmentation* | *Small Parcel (≤ 80 acres) Sales Ratio* | *Ln Mean Patch Size* | *Ln Patch Density* |
| Sales80 | | 3.0844*** (0.5802) | | |
| LnMPSize | | | -0.0658* (0.0355) | |
| LnPatchDenAc | | | | 0.2427*** (0.0469) |
| Constant | 12.6329*** (0.3342) | 12.1637*** (0.3359) | 13.1085*** (0.5801) | 13.7581*** (0.4124) |

[a]***, ** and * represent statistical significance at the 1 percent level, 5 percent level, and 10 percent level, respectively
[b]Top and bottom 1% outliers (based on the dependent variable) were removed
[c]Estimated with ordinary least squares
[d]CAD = Canadian Dollar
[e]Variable names are defined in Table 3.4 and Table 3.5

**Table 4.6 Sensitivity analysis for *NetIncFarm*: Parameter estimates for large sample (2000–2011) hedonic models of Alberta farmland prices (robust standard errors in parentheses)[a,b]**

| | Model | | |
|---|---|---|---|
| **Dependent variable: Ln of farmland price per acre 2002 CAD[c]** | *No Fragmentation* | *No Fragmentation and No Income* | *Small Parcel (≤ 80 acres) Sales Ratio and No Income* |
| **Estimation[d]** | OLS | OLS | 2SLS |
| R-squared | 0.7187 | 0.7121 | 0.7122 |
| F-statistic | 1,332 | 1,360 | 1,326 |
| Sample size | 14,802 | 14,895 | 14,872 |
| **Explanatory variable[e]** | | | |
| GoodBuild | Omitted | Omitted | Omitted |
| NoBuild | -0.1531*** | -0.1504*** | -0.1559*** |
| | (0.0108) | (0.0109) | (0.0110) |
| CheapBuild | -0.2510*** | -0.2542*** | -0.2525*** |
| | (0.0334) | (0.0339) | (0.0335) |
| LnSize | -0.5162*** | -0.5131*** | -0.5039*** |
| | (0.0071) | (0.0071) | (0.0074) |
| Irrig | 0.5747*** | 0.6557*** | 0.6776*** |
| | (0.0188) | (0.0163) | (0.0161) |
| SoilQlty | 0.0029*** | 0.0024*** | 0.0022*** |
| | (0.0003) | (0.0003) | (0.0003) |
| NetIncFarm | 3.40E-06*** | | |
| | (3.03E-07) | | |
| PctPopDenChg | 0.0226*** | 0.0222*** | 0.0244*** |
| | (0.0012) | (0.0013) | (0.0013) |
| LnHwy2 | -0.1833*** | -0.1870*** | -0.1852*** |
| | (0.0059) | (0.0060) | (0.0057) |
| LnUrbDist | -0.0430*** | -0.0451*** | -0.0105 |
| | (0.0100) | (0.0100) | (0.0092) |
| Edm-Neighbours | 0.3928*** | 0.3850*** | -0.0109 |
| | (0.0268) | (0.0267) | (0.0555) |
| Cal-Neighbours | 0.4212*** | 0.3110*** | 0.2109*** |
| | (0.0389) | (0.0383) | (0.0395) |

*(Continued)*

Table 4.6 Continued

| Explanatory variable[e] | Model: No Fragmentation | No Fragmentation and No Income | Small Parcel ($\leq$ 80 acres) Sales Ratio and No Income |
|---|---|---|---|
| Crop | Omitted | Omitted | Omitted |
| Beef | -0.1919*** | -0.2149*** | -0.2181*** |
| | (0.0125) | (0.0124) | (0.0123) |
| Mixed | 0.0656*** | 0.0616*** | 0.0404*** |
| | (0.0152) | (0.0153) | (0.0156) |
| Dairy | 0.1901*** | 0.1973*** | 0.1900*** |
| | (0.0465) | (0.0463) | (0.0466) |
| Hog | -0.1992*** | -0.1916*** | -0.2090*** |
| | (0.0668) | (0.0665) | (0.0696) |
| Poultry | -0.0166 | -0.0166 | -0.0654 |
| | (0.0835) | (0.0819) | (0.0878) |
| Sheep | -0.0035 | -0.0154 | -0.0272 |
| | (0.2086) | (0.2072) | (0.2178) |
| Greenhs | 0.5821*** | 0.5513*** | 0.6070*** |
| | (0.1725) | (0.1664) | (0.1714) |
| SpecEnter | 0.2552*** | 0.2546*** | 0.1853** |
| | (0.0785) | (0.0770) | (0.0789) |
| Sales80 | | | 2.4113*** |
| | | | (0.2897) |
| Constant | 11.6892*** | 11.8656*** | 11.3757*** |
| | (0.1046) | (0.1047) | (0.1074) |

[a]***, ** and * represent statistical significance at the 1 percent level, 5 percent level, and 10 percent level, respectively
[b]Top and bottom 1% outliers (based on the dependent variable) were removed
[c]CAD = Canadian Dollar
[d]OLS refers to ordinary least squares, while 2SLS refers to two-stage least squares estimation.
[e]Variable names are defined in Table 3.4 and Table 3.5

**Table 4.7 Sensitivity analysis for outliers: Parameter estimates for large sample (2000–2011) hedonic models of Alberta farmland prices (robust standard errors in parentheses)[a,b]**

| | Outliers Removed | | | |
|---|---|---|---|---|
| **Dependent variable: Ln of farmland price per acre 2002 CAD[c]** | *Top and bottom 1% of sales values per acre* | *Sales < 5 acres* | *Sales < 5 acres and any additional sales ≥ $10,000 per acre* | *Sales < 40 acres* |
| R-squared | 0.7184 | 0.6450 | 0.5943 | 0.5761 |
| F-statistic | 1,299 | 947 | 926 | 760 |
| Sample Size | 14,781 | 14,473 | 14,039 | 13,690 |
| Minimum Parcel Size (acres) | 0.1 | 5 | 5 | 40 |
| Maximum dependent variable | 122,924 | 155,402 | 9,997 | 47,710 |
| **Explanatory variable[d]** | | | | |
| GoodBuild | Omitted | Omitted | Omitted | Omitted |
| NoBuild | -0.1583*** | -0.1504*** | -0.1545*** | -0.1224*** |
| | (0.0109) | (0.0108) | (0.0103) | (0.0107) |
| CheapBuild | -0.2466*** | -0.2740*** | -0.2739*** | -0.2420*** |
| | (0.0332) | (0.0349) | (0.0341) | (0.0349) |
| LnSize | -0.5064*** | -0.4271*** | -0.3381*** | -0.2579*** |
| | (0.0073) | (0.0088) | (0.0084) | (0.0101) |
| Irrig | 0.5895*** | 0.5750*** | 0.5427*** | 0.5307*** |
| | (0.0184) | (0.0190) | (0.0186) | (0.0197) |
| SoilQlty | 0.0025*** | 0.0026*** | 0.0027*** | 0.0029*** |
| | (0.0002) | (0.0003) | (0.0002) | (0.0003) |
| NetIncFarm | 3.66E-06*** | 3.52E-06*** | 3.22E-06*** | 3.26E-06*** |
| | (3.03E-07) | (3.02E-07) | (2.84E-07) | (2.99E-07) |
| PctPopDenChg | 0.0250*** | 0.0257*** | 0.0245*** | 0.0268*** |
| | (0.0013) | (0.0013) | (0.0012) | (0.0013) |
| LnHwy2 | -0.1823*** | -0.1852*** | -0.1801*** | -0.1883*** |
| | (0.0056) | (0.0064) | (0.0066) | (0.0073) |
| LnUrbDist | -0.0059 | -0.0173 | -0.0293** | -0.0287** |
| | (0.0091) | (0.0111) | (0.0121) | (0.0129) |
| Edm-Neighbours | -0.0209<br>(0.0562) | -0.1178<br>(0.0721) | -0.2536***<br>(0.0712) | -0.1604*<br>(0.0890) |

*(Continued)*

Table 4.7 Continued

| Explanatory variable[d] | Outliers Removed: *Top and bottom 1% of sales values per acre* | *Sales < 5 acres* | *Sales < 5 acres and any additional sales ≥ $10,000 per acre* | *Sales < 40 acres* |
|---|---|---|---|---|
| Cal-Neighbours | 0.3241*** | 0.3339*** | 0.1485*** | 0.3632*** |
| | (0.0400) | (0.0421) | (0.0389) | (0.0433) |
| Crop | Omitted | Omitted | Omitted | Omitted |
| Beef | -0.1920*** | -0.2418*** | -0.2470*** | -0.2695*** |
| | (0.0124) | (0.0129) | (0.0126) | (0.0129) |
| Mixed | 0.0451*** | 0.0163 | -0.0132 | -0.0630*** |
| | (0.0155) | (0.0158) | (0.0146) | (0.0158) |
| Dairy | 0.1809*** | 0.1636*** | 0.1940*** | 0.1756*** |
| | (0.0467) | (0.0448) | (0.0421) | (0.0422) |
| Hog | -0.2169*** | -0.1714** | -0.0916 | -0.1168 |
| | (0.0701) | (0.0690) | (0.0670) | (0.0760) |
| Poultry | -0.0657 | -0.0189 | 0.0256 | 0.0514 |
| | (0.0895) | (0.0882) | (0.0927) | (0.0923) |
| Sheep | -0.0151 | 0.0169 | -0.1345 | 0.0417 |
| | (0.2193) | (0.2598) | (0.1795) | (0.1070) |
| Greenhs | 0.6446*** | 0.3849 | 0.1196 | 0.0623 |
| | (0.1785) | (0.2708) | (0.2190) | (0.1291) |
| SpecEnter | 0.1801** | 0.2092*** | 0.2173*** | 0.2069** |
| | (0.0807) | (0.0798) | (0.0807) | (0.0902) |
| Sales80 | 2.5081*** | 3.1111*** | 3.2905*** | 3.7886*** |
| | (0.2903) | (0.3953) | (0.3871) | (0.5391) |
| Constant | 11.1701*** | 10.8809*** | 10.4867*** | 10.1066*** |
| | (0.1069) | (0.1239) | (0.1174) | (0.1269) |

[a]***, ** and * represent statistical significance at the 1 percent level, 5 percent level, and 10 percent level, respectively

[b]Two-stage least squares estimation was used throughout.

[c]CAD = Canadian Dollar

[d]Variable names are defined in Table 3.4 and Table 3.5

# Chapter 5: Conclusions, Policy Implications, Limitations and Future Research

The main objective of this work was to study the effects of various factors on farmland values in Alberta, Canada. A secondary objective was to specifically consider the effects of fragmentation and conversion on farmland values in this region. A hedonic farmland model was employed to achieve this task using data from FCC and other sources. A number of variables were included such as the parcel size, the soil quality for the county, whether irrigation was used in the area, the distances to a major highway and larger urban areas, the percentage change in the population density in the area, and the farm type. Alternative sample sizes were used in different models because of differences in the years of data available for the fragmentation measures. Fragmentation measures included the ratio of area of small parcels sold relative to area for all parcels sold, the mean agricultural patch size and the agricultural patch density.

This chapter focuses on summarizing what was covered in the previous chapters, in particular the results chapter. The key results from the hedonic model are highlighted again. The chapter comes full circle when it reintroduces the implications of the study first mentioned in Chapter One.  Limitations of the study which qualify the results are discussed next. To end, this chapter proposes directions for future research to extend the understanding of the effects of conversion and fragmentation on farmland values in Alberta.

## 5.1 Summary of Key Findings

Chapter Four and the appendices reported that for many of the variables used in this thesis including those related to conversion the results conformed to those used in farmland hedonic models in the literature. The results for newly introduced fragmentation variables varied and it was difficult to draw some conclusions, but in at least one instance increased fragmentation appeared to lead to higher farmland values per acre.

For many of the included variables the results were consistent regardless of the sample size, or inclusion/exclusion of some variables or observations. The size of the parcel for sale was consistently negatively related to the farmland value and significant. When a parcel included improvements valued under $5,000 on it, the building variable was also negative and usually significant relative to improvements worth more than that amount. Vacant land (i.e., the absence of improvements) usually had a negative effect on farmland values, but it was a smaller effect than that of low-value improvements.

Variables which were related to agricultural productivity also had the expected signs and were significant most of the time. If a farm was located in a county with an irrigation district, the dummy variable representing this characteristic positively impacted farmland values as did higher percentages of quality soils in the county. The dummy variables representing the various farm types were more variable, but crop farms or specialty farms tended to have a more positive influence on the farmland value than beef cattle farms. The last variable which was classified under this category, average net operating income per farm reporting, was usually positive, but was not always significant.

The measures signalling conversion pressure included the percentage change in population density, the distance to Highway 2, the distance to the nearest large urban centre, and dummy variables for the largest cities in the province, Edmonton and Calgary, and their contiguous county neighbours. The first measure, population density, was consistently positive and usually significant. The distance measures were negative, but not always significant. These measures can arguably signal the degree of transportation costs for the agricultural producer as well as the development potential. Lastly, the dummy variables for Edmonton, Calgary and their neighbours were usually significant and positive (e.g., Table 4.5).

The results dealing with fragmentation were not as consistent as the previous variables just discussed. Of those, however, the fragmentation measure using the ratio of land sales sized 80 acres and under relative to all land sales was always positive and significant. This particular measure used increased proportion of area sold in small parcels as a signal of more fragmentation, and this had a positive influence on farmland values. Other fragmentation measures (i.e., the *Mean Patch Size* and the *Patch Density*), which could only be computed for smaller sample sizes because of data availability, were sometimes (but not always) consistent with this relationship (e.g., Table B.2).

## 5.2 Conclusions and Policy Implications for Alberta

Given the results it is evident that the factors which affect farmland values are related to the characteristics which reflect its agricultural productivity (e.g., soil quality, farm type, irrigation and net operating income), and also factors like parcel size and presence of higher valued improvements. These results are similar to what is reported in the literature suggesting that the factors which affect American and other Canadian farm values also impact Alberta farm values. This consistency in results also provides assurances about the methodology used. Additional factors like fragmentation and conversion pressures also tend to have an impact on farmland values. These conclusions have implications for policy and stakeholders who have an interest in farmland.

Consistent with previous studies, the conclusion from the current study is that it is often no longer the case that farmland prices reflect only their value from agricultural production, although this may still hold in specific rural locations. What this means is that appraisals that only consider the value of agricultural production may underestimate the farmland's value (Henderson and Moore 2006). This has implications for any individual or business that makes use of an appraisal approach. For example, those in the real estate business may find these results useful, compare them to their knowledge of the industry, and perhaps may incorporate some of these findings into their own assessments when helping a seller to set a listing price for their property and also when helping a buyer to negotiate an offer. The final sale price can have implications for farm expansion and retirement income generated from the sale of land. Factors which influence the appraised value will also influence the loan amount for which a farmer is eligible. In Alberta, farmland tax assessment in 2015 was based on the agricultural use value valuation standard (*Matters Relating to Assessment and Taxation Regulation* 2004), but policymakers may be interested in the information contained in this thesis if they choose to move to farmland assessment focused on a market value based standard. Changes in property assessment can lead to changes in the taxes paid by the property owner, ultimately influencing the farmer's net earnings.

Furthermore, if farmland is valued at more than its agricultural land use, this will have ramifications for conservationists and policymakers who may now face higher fees to conserve agricultural land, but also provide them with more credibility or justification for preservation if the land is worth more than its agricultural productive value. Agricultural best management practices which have an environmental benefit may also be impacted. If there is an expectation that the land value would be higher than its agricultural value, there might be an incentive to sell the land, and thus, there could be less incentive to put in efforts that improve the land for agriculture and the environment. Factors which raise land values could lead to a decrease in the supply of affordable farmland, especially if land is priced beyond a farmer's approved credit amount.

This is one of very few studies which has incorporated fragmentation as an explanatory variable in a farmland valuation model. By using multiple fragmentation measures whose impacts do vary by type and sample size, this paper highlights the complexity of the issue of farmland fragmentation. In Chapter Two it was evident that there are several types of fragmentation measures, and no measure can capture all of the effects of fragmentation. Latruffe and Piet (2013) share a similar view regarding the use of multiple measures of fragmentation to study farm performance. Therefore, relying on a single measure is unlikely to be comprehensive enough to explain how fragmentation affects farmland values. This conclusion has implications for policymakers as it will require that they take a multidimensional approach to study farmland values and LCLU change.

## 5.3 Limitations and Assumptions

This section discusses some of the limitations arising from the nature of the data. The confidential restrictions and the consequences arising from that are described first. Other limitations of the farmland value data are discussed next, followed by a discussion of the drawbacks and inconsistencies posed by the spatial data used and the income data.

Chapter Three mentioned that there were confidentiality restrictions on what characteristics were provided with the farmland sales data. This had many consequences; parcel characteristics like soil quality, distance and fragmentation had to be computed for the county level and then matched based on which county the sale was located in. Thus, using county averages may not have reflected the unique characteristics of or surrounding the parcel of interest. Conversely, these characteristics did portray the conditions under which the agricultural economy functions in each county. Additionally, to create the fragmentation measures *Mean Patch Size* and *Patch Density,* the county boundaries broke otherwise contiguous parcels into patches creating artificial fragmentation.

As real estate practices often consider comparable neighbouring properties when setting the price, spatial considerations are also likely a factor (Can 1990). Spatial dependence is becoming more common to test for and control for in hedonic valuation models. Due to the nature of the land value data used in this thesis however, spatial econometrics which would have controlled for spatial dependence could not be performed without a more specific parcel location (i.e., legal land description). Thus, there was no way to test for the effects of neighbouring land values.

Also, without the parcel's specific location it was impossible to determine if repeat sales were included in the data set or not. Deaton and Vyn (2015) omitted all repeat sales in one of their restrictions in case there was an unobserved factor (that would bias the results) that led to the higher turnover rate of those properties. In their study, the same general conclusions could be drawn with and without the repeat sales included in the estimation (Deaton and Vyn 2015). Though this lends support for this not being a limitation of the data, it does rely on the assumption that the farmland market which Deaton and Vyn (2015) studied was similar to the Alberta farmland market.

Additionally, there was no way to determine whether a single buyer bought multiple properties perhaps for farm expansion. In the theory presented in Chapter Two the first order conditions were premised on one buyer purchasing one piece of property. The model can be altered when multiple homogeneous properties are purchased (Rosen 1974). However, in the case of farmland expansion and as Palmquist (1986) pointed out a farmer may buy multiple pieces of land that are heterogeneous, but are valuable because they are nearby to each other. Palmquist (1986) did not provide any additional information on this potential issue. In the case of farmland expansion, the decision to purchase additional farmland very likely depends on the location of previous holdings, and a lack of data on the parcel's location would constitute an omitted variable in the model and therefore could result in bias. From the given data set it was impossible to know the extent of this potential issue.

Similarly, the farmland value data set was also missing information on the characteristics of the buyers. Nothing in the data set suggested whether the land was bought for farming purposes versus (future) development purposes (except maybe high sale prices). Cavailhès and Wavresky (2003) argued that the characteristics of buyers and sellers could impact land prices. Chicoine (1981) included the type of buyer and seller (whether they were an individual or corporation etc.) in their hedonic price model. Elad et al (1994) included the reason for purchasing the tract (i.e., agricultural, industrial/commercial, residential/recreational or other uses (omitted)). However, Taylor (2003) argued that characteristics of the buyer and seller should not be included in the hedonic regression. Many other farmland hedonic models did not include these types of variables. Based on this discussion it was difficult to determine if missing information on the buyers or sellers was important.

Furthermore, regarding the data used in this thesis, the data set may have missed (excluded) land purchases for non-agricultural purposes, and/or other sales that occurred without FCC's involvement or knowledge (Bryan 2014c). If agricultural land was purchased for non-agricultural purposes and these sales were not included in this data set, this could have implications for the fragmentation and conversion results.

Up until now the limitations have been the result of missing data accompanying the farmland sales data set. In addition, the land cover data used to calculate the fragmentation measures *Mean Patch Size* and *Patch Density* had their own set of limitations. First, the way that the fragmentation measures were calculated grouped all surrounding LCLUs as one category (i.e., not agriculture). This precluded attempts to draw conclusions about the effects of the various types of fragmentation on farmland values, such as natural habitat encroachment/presence (e.g., wetlands and forests) versus farmland fragmentation due to development. Second, given the AAFC data had a resolution of 56 metres by 56 metres the fragmentation measures could have missed smaller types of fragmentation including fragmentation caused by some small country residential lots. Third, it was possible that data were unclassified or misclassified (AAFC 2009a). Given the nature of the AAFC data, the fragmentation measures calculated using those data may have been slightly erroneous or misleading.

The one fragmentation measure which did not use the AAFC data was based on another paper by Mervish et al (2008) in which they looked at the ratio of area of small parcels sold to area for all parcels sold. The choice to use less than 80 acres in the current study was based on the Mervish et al's (2008) opinion about when a divestment of beef cattle would occur because the landscape was becoming too fragmented. First, it would appear that this measure was based on the assumption that the number of small sales in an area was correlated to the actual number of small parcels in an area. Second, it was possible that different farm types would respond differently to whichever threshold was set. For example, a greenhouse surrounded by sales of parcels under 10 acres may not have had much effect on the greenhouse's land value because greenhouses generally do not require much space. This also highlighted the idea that the future land use of those smaller parcels may be equally important, but this measure could not capture this effect.

There were also unique issues associated with the income data from Statistics Canada. Some farms actually changed counties in 2011 based on the techniques used to link farms to counties (Ng 2014). It is impossible to pick out which farms' income data were shifted to another county, and to what degree this impacted the average income measures. The income data were also associated with the 2011 Census boundaries (Ng 2014) rather than the 2006 CCS boundaries used for the majority of the analyses. Without access to the individual income data points, no method could be employed to readjust the data to the 2006 boundaries. However, a visual inspection of the 2011 and

2006 boundaries did not reveal easily identifiable changes except that Calgary's boundaries expanded slightly in the later year.

Finally, there were issues that apply more generally to the generated data set rather than the individual pieces of data discussed above. Miranowski and Hammes (1984) point out (and these issues would also hold for this thesis) that their sample was not random, which could lead to biased results. Also, nonmarket benefits or societal benefits were not included in the implicit prices that could be calculated from the data (Miranowski and Hammes 1984). Freeman (2003) also warned about using the hedonic model under conditions that are changing rapidly. Notably, the large sample (2000–2011) did span a recession (from 2008–2009). The latter issue was addressed using the small samples to some degree (except for using some 2009 instrumental variables). The first issue was not addressed.

## 5.4 Future Research

There are several areas where further study is warranted. The most obvious approach would be in line with current research using spatial econometrics to control for spatial error dependence, spatial lag dependence and/or spatial autocorrelation between neighbours for other independent variables. This approach would require the acquisition of parcel level land value data. Several more fragmentation measures could be tried as suggested in Chapter Two, and they could be calculated within the vicinity of the parcel. The use of this approach assumes that data would be available for each neighbouring parcel, which may not be the case if the data come from real estate sales.

As suggested in Chapter Two not all fragmentation is related to fragmented LCLU. In some studies (mentioned in Chapter Two) researchers looked at the effects of fragmented land holdings on farm performance. This type of fragmentation is also present in Alberta in part because of the small market for land. That is, farmers looking to expand their farms may purchase a parcel at some distance from their homestead because of its amenities or price, and because they do not know when if ever contiguous neighbouring parcels will become available. Conducting an Alberta study that looks at farmland values and specific locations of individual holdings could be completed using survey data. This type of study would allow for a comparison of the two types of fragmentation: fragmented land holdings (which affects travel time/labour management) and fragmented LCLU (which may affect efficiency of agricultural land use and reflect development pressure).

Further study could look at the differences between counties (like policy differences with regards to subdividing parcels) if more data (and thus degrees of freedom) were available. If the data allowed for it, panel analysis would also be useful because it would hold many characteristics of the parcel consistent over time while the conversion and fragmentation variables changed.

Additionally, in Alberta there is a large amount of oil and gas activity. Having data on specific well locations and their status (operational, abandoned or reclaimed), as well as pipeline easements, at the time of the land sale could also have a role to play in determining farmland values. The expected sign of such activity is difficult to predict because surface access lease agreements can mean more income for the farmer, but such activities can also mean more nuisances and fragmentation around the site of oil/gas activity, and also potential soil, water and/or air contamination. Likewise transmission lines and wind turbines may also have an impact on farmland values. Also, the Alberta Government suggests that the degree of available water tied to the land would have an influence on the land value (AAF 2013).

Aside from using more data, simulations could be developed to see how different fragmentation rates influence the farmland value over time. This may be relevant to city planners who are interested in planning future development and expansion, who may also have concerns about how their plans influence farmland fragmentation, conversion and their effects. Policymakers could look at the effects of each type of fragmentation measure, as they may vary, or the changes in the fragmentation measures over time. Lastly, as this studied looked at how fragmentation influenced farmland values, then discovering the particular mechanism by which fragmentation impacts farming could be the purpose of a future study. Similar to the work by Kawasaki (2010), a study on the benefits and costs of fragmentation could be conducted to create a more complete picture of how fragmentation influences farming in Alberta.

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# Appendices

## Appendix A: Choice of Functional Form using Different Outliers (years 2000–2011)

**Table A.1 Comparison of different functional forms using goodness-of-fit measures[a,b]**

Outliers removed: Parcels under 5 acres
N=14,492; Maximum Y=$155,402/acre;[c] Minimum parcel size: 5 acres;

| *Transformation on variables* | | | | | | |
|---|---|---|---|---|---|---|
| *Y* | *X* | *R-squared* | *R-squared (lnY)* | *AIC[d]* | *BIC[d]* | *Choice of functional form* |
| Linear | Linear | 0.2022 | | 285,593 | 285,744 | |
| Linear | Ln[e] | 0.3009 | | 283,679 | 283,830 | |
| Linear | Inverse[e] | 0.4188 | | 281,003 | 281,155 | Ln-ln |
| Ln | Linear | 0.1966 | 0.5442 | 30,025 | 30,177 | |
| Ln | Ln | 0.4497 | 0.6508 | 26,164 | 26,316 | |
| Ln | Inverse | 0.3845 | 0.5967 | 28,254 | 28,405 | |

Outliers removed: Parcels under 5 acres then sales $10,000/acre and larger
N=14,055; Maximum Y=$9,997/acre; Minimum parcel size: 5 acres;

| *Transformation on variables* | | | | | | |
|---|---|---|---|---|---|---|
| *Y* | *X* | *R-squared* | *R-squared (lnY)* | *AIC* | *BIC* | *Choice of functional form* |
| Linear | Linear | 0.3721 | | 236,577 | 236,728 | |
| Linear | Ln | 0.4842 | | 233,814 | 233,965 | |
| Linear | Inverse | 0.5236 | | 232,697 | 232,848 | Linear-inverse |
| Ln | Linear | 0.3561 | 0.5391 | 24,844 | 24,995 | |
| Ln | Ln | 0.4665 | 0.6032 | 22,741 | 22,892 | |
| Ln | Inverse | 0.3383 | 0.5110 | 25,675 | 25,826 | |

*(Continued)*

Table A.1 Continued

Outliers removed: Top and bottom 1% of $/acre sales
N=14,802; Maximum Y=$122,924/acre; Minimum parcel size: 0.1 acres;

| *Transformation on variables* | | | | | | |
|---|---|---|---|---|---|---|
| *Y* | *X* | *R-squared* | *R-squared (lnY)* | *AIC* | *BIC* | *Choice of functional form* |
| Linear | Linear | 0.1968 | | 310,296 | 310,448 | Ln-ln |
| Linear | Ln | 0.4460 | | 304,797 | 304,950 | |
| Linear | Inverse | 0.3854 | | 306,333 | 306,485 | |
| Ln | Linear | 0.1883 | 0.5249 | 34,805 | 34,957 | |
| Ln | Ln | 0.5277 | 0.7187 | 27,049 | 27,201 | |
| Ln | Inverse | 0.0160 | 0.5121 | 35,198 | 35,350 | |

Outliers removed: Parcels under 40 acres
N=13,707; Maximum Y=$47,710/acre; Minimum parcel size: 40 acres;

| *Transformation on variables* | | | | | | |
|---|---|---|---|---|---|---|
| *Y* | *X* | *R-squared* | *R-squared (lnY)* | *AIC* | *BIC* | *Choice of functional form* |
| Linear | Linear | 0.2713 | | 246,929 | 247,080 | Linear-inverse[f] |
| Linear | Ln | 0.2868 | | 246,635 | 246,785 | |
| Linear | Inverse | 0.2900 | | 246,574 | 246,724 | |
| Ln | Linear | 0.2632 | 0.5676 | 23,667 | 23,817 | |
| Ln | Ln | 0.2716 | 0.5822 | 23,195 | 23,346 | |
| Ln | Inverse | 0.2564 | 0.5258 | 24,933 | 25,083 | |

[a]All explanatory variables used were the same in each model run: *NoBuild*, *CheapBuild*, *Size*, *Irrig*, *SoilQlty*, *NetIncFarm*, *PctPopDenChg*, *Hwy2*, *UrbDist*, *Edm-Neighbours*, *Cal-Neighbours*, *Beef*, *Mixed*, *Dairy*, *Hog*, *Poultry*, *Sheep*, *Greenhs*, and *SpecEnter*. *Crop* and *GoodBuild* were omitted. The variable names including the dependent variable are defined in Table 3.4.
[b]Non-robust standard errors were used.
[c]Dollar values are expressed in 2002 Canadian Dollars.
[d]The Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) are only comparable when the dependent variable is the same.
[e]The only explanatory variables that were strictly positive and could be ln or inverse transformed were *Hwy2*, *UrbDist* and *Size*.

Table A.1 Continued

[f]Although the R-squared is higher for the linear-inverse the ln-ln had significant explanatory variables more often when considering the explanatory variables.

**Table A.2 Further analysis showing how the ln-ln functional form has significant explanatory variables more often than the linear versions (N=13,707)[a,b,c,d]**

| | Functional Form | | | | | |
|---|---|---|---|---|---|---|
| Variable | *Linear* | *Linear-ln* | *Linear-inverse* | *Ln-linear* | *Ln-ln* | *Ln-inverse* |
| GoodBuild | Omitted | Omitted | Omitted | Omitted | Omitted | Omitted |
| NoBuild | 84.2024** | 38.2598 | -6.6483 | -0.0689*** | -0.1200*** | -0.1486*** |
| | (36.7726) | (36.5837) | (36.1398) | (0.0107) | (0.0106) | (0.0111) |
| CheapBuild | -162.0023 | -199.9264* | -205.4722* | -0.2387*** | -0.2585*** | -0.2470*** |
| | (116.6938) | (115.4741) | (115.1726) | (0.0339) | (0.0333) | (0.0355) |
| Size | -0.1088*** | | | -0.0002*** | | |
| | (0.0256) | | | (7.44E-06) | | |
| LnSize | | -330.3690*** | | | -0.2914*** | |
| | | (25.8174) | | | (0.0075) | |
| InverseSize | | | 107240.33*** | | | 70.0277*** |
| | | | (5345.0349) | | | (1.6470) |
| Irrig | 355.0222*** | 517.3377*** | 558.7139*** | 0.3415*** | 0.5351*** | 0.5623*** |
| | (57.9445) | (55.7031) | (54.7373) | (0.0168) | (0.0161) | (0.0169) |
| SoilQlty | 1.1299 | -0.0136 | 3.9471*** | 0.0018*** | 0.0033*** | 0.0074*** |
| | (0.8587) | (0.8077) | (0.7453) | (0.0002) | (0.0002) | (0.0002) |
| NetIncFarm | 0.0053*** | 0.0059*** | 0.0057*** | 2.49E-06*** | 3.02E-06*** | 2.80E-06*** |
| | (0.0009) | (0.0009) | (0.0009) | (2.70E-07) | (2.65E-07) | (2.82E-07) |
| PctPopDenChg | 51.4680*** | 29.4380*** | 35.0913*** | 0.0401*** | 0.0238*** | 0.0363*** |
| | (3.6162) | (3.8058) | (3.7421) | (0.0011) | (0.0011) | (0.0012) |
| Hwy2 | -0.0016*** | | | -1.93E-06*** | | |
| | (0.0002) | | | (4.75E-08) | | |
| LnHwy2 | | -249.4037*** | | | -0.1966*** | |
| | | (17.9351) | | | (0.0052) | |

*(Continued)*

Table A.2 Continued

| Variable | Linear | Linear-ln | Linear-inverse | Ln-linear | Ln-ln | Ln-inverse |
|---|---|---|---|---|---|---|
| | | | Functional Form | | | |
| InverseHwy2 | | | 2101044.5*** | | | 1028.092*** |
| | | | (178889.83) | | | (55.1240) |
| UrbDist | -0.0004 | | | -7.34E-07*** | | |
| | (0.0003) | | | (1.01E-07) | | |
| LnUrbDist | | -47.3078** | | | -0.0613*** | |
| | | (20.6097) | | | (0.0059) | |
| InverseUrbDist | | | 0.0871** | | | 0.0001*** |
| | | | (0.0380) | | | (1.17E-05) |
| Edm-Neighbours | 1523.6348*** | 1477.0236*** | 1519.5427*** | 0.4304*** | 0.4394*** | 0.4934*** |
| | (74.7987) | (74.0502) | (75.3841) | (0.0217) | (0.0214) | (0.0232) |
| Cal-Neighbours | 3861.8205*** | 3693.1104*** | 3930.5298*** | 0.4925*** | 0.4029*** | 0.6202*** |
| | (115.9727) | (115.4816) | (113.8523) | (0.0337) | (0.0333) | (0.0351) |
| Crop | Omitted | Omitted | Omitted | Omitted | Omitted | Omitted |
| Beef | -339.3721*** | -273.7278*** | -271.1375*** | -0.3410*** | -0.2690*** | -0.2737*** |
| | (43.9988) | (43.2468) | (42.8814) | (0.0128) | (0.0125) | (0.0132) |
| Mixed | 179.0767*** | 118.0139** | 16.3872 | 0.0044 | -0.0360** | -0.0886*** |
| | (48.7999) | (48.8688) | (49.3280) | (0.0142) | (0.0141) | (0.0152) |
| Dairy | 106.4477 | -9.2378 | 122.1542 | 0.2216*** | 0.1811*** | 0.3251*** |
| | (185.6164) | (183.9144) | (183.1671) | (0.0539) | (0.0531) | (0.0564) |
| Hog | -27.4338 | -210.7963 | -208.8963 | 0.0254 | -0.1038 | -0.0352 |
| | (283.8993) | (281.0459) | (280.3847) | (0.0825) | (0.0811) | (0.0864) |
| Poultry | 221.8328 | 111.7562 | 22.4232 | 0.1606* | 0.1107 | 0.0944 |
| | (296.1853) | (293.1287) | (292.7579) | (0.0860) | (0.0846) | (0.0902) |
| Sheep | 32.3582 | -122.8910 | 19.4831 | 0.1409 | 0.0822 | 0.2283 |
| | (987.8412) | (977.3400) | (975.0889) | (0.2869) | (0.2820) | (0.3005) |

*(Continued)*

Table A.2 Continued

| Variable | Functional Form<br>*Linear* | *Linear-ln* | *Linear-inverse* | *Ln-linear* | *Ln-ln* | *Ln-inverse* |
|---|---|---|---|---|---|---|
| Greenhs[e] | -179.7769 | -386.4726 | -338.5315 | 0.2117 | 0.0327 | 0.1334 |
| | (1140.5779) | (1128.5316) | (1125.8904) | (0.3313) | (0.3257) | (0.3469) |
| SpecEnter | 1631.0006*** | 1495.2953*** | 1250.9302*** | 0.3816*** | 0.2978*** | 0.1841** |
| | (243.6526) | (241.2894) | (241.4617) | (0.0708) | (0.0696) | (0.0744) |
| Constant | 901.5132*** | 5832.4914*** | -258.4508*** | 6.8237*** | 10.7992*** | 5.5781*** |
| | (86.7944) | (282.5193) | (66.7580) | (0.0252) | (0.0815) | (0.0206) |

[a]***, ** and * represent statistical significance at the 1 percent level, 5 percent level, and 10 percent level, respectively

[b]Outliers removed: parcels under 40 acres

[c]Non-robust standard errors in parentheses

[d]Variable names including the dependent variable are defined in Table 3.4

[e]Only three greenhouses remain in the sample.

## Appendix B: Additional Regressions using Different Sample Sizes

The first table referenced in this section reports some of the changes observed when three instruments were used instead of a single instrument. The fragmentation variables are discussed in the relevant subsections in Chapter Four.

When considering the large sample, there were not too many differences between Table B.1 and Table 4.4. In Table B.1 the building dummies and parcel size remained negative and significant. The characteristics reflecting the returns to agriculture were usually both positive and significant (i.e., *Irrig*, *SoilQlty*, and *NetIncFarm*). The conversion pressure variables tended to increase farmland values per acre as in Table 4.4. The main difference other than those discussed in Subsection 4.3.1.2 was *LnUrbDist,* which was negative and significant in Table B.1 unlike in the *Small Parcel (≤ 80 acres) Sales Ratio* model in Table 4.4. This effect was an expected result. A county in close proximity to a large urban area was expected to drive up the farmland values per acre relative to those counties located further away from large urban areas.

Comparing the different samples sizes within Table B.1 most coefficients had a similar interpretation. Exceptions included the *NetIncFarm*, the *Edm-Neighbours* and *Sales80xEdm-Neighbours*, and the *Mixed* farm type variables which were all not significant for the smaller sample. The *NetIncFarm* and *Mixed* variables were usually not significant in the even smaller sample (year 2011) shown in Table 4.5.

**Table B.1 Further analysis using three instruments: Parameter estimates for large sample (years 2000–2011) and small sample (years 2010–2011) hedonic models of Alberta farmland prices (robust standard errors in parentheses)[a,b,c,d]**

| | **Model** | |
|---|---|---|
| **Dependent variable: Ln of farmland price per acre 2002 CAD[e]** | *Large Sample* | *Small Sample* |
| **Years** | 2000–2011 | 2010–2011 |
| R-squared | 0.7157 | 0.7538 |
| F-statistic | 1,256 | 271 |
| Sample Size | 14,781 | 1,906 |
| **Explanatory variable** | | |
| GoodBuild | Omitted | Omitted |
| NoBuild | -0.1536*** | -0.1946*** |
| | (0.0109) | (0.0293) |
| CheapBuild | -0.2333*** | -0.2344** |
| | (0.0333) | (0.1038) |
| LnSize | -0.4989*** | -0.5284*** |
| | (0.0073) | (0.0207) |
| Irrig | 0.5481*** | 0.6408*** |
| | (0.0183) | (0.0520) |
| SoilQlty | 0.0018*** | 0.0059*** |
| | (0.0002) | (0.0007) |
| NetIncFarm | 4.11E-06*** | 9.75E-07 |
| | (3.06E-07) | (6.52E-07) |
| PctPopDenChg | 0.0222*** | 0.0161** |
| | (0.0012) | (0.0064) |
| LnHwy2 | -0.1564*** | -0.1302*** |
| | (0.0059) | (0.0161) |
| LnUrbDist | -0.0322*** | -0.1103*** |
| | (0.0075) | (0.0186) |
| Edm-Neighbours | 0.5125*** | 0.5289 |
| | (0.1074) | (0.4768) |
| Cal-Neighbours | 0.5837*** | 0.6153*** |
| | (0.0479) | (0.1883) |
| Crop/Plant | Omitted | Omitted |
| Animal | | -0.1882*** |
| | | (0.0359) |

*(Continued)*

Table B.1 Continued

| | Model | |
|---|---|---|
| **Explanatory variable** | *Large Sample* | *Small Sample* |
| Beef | -0.2020*** | |
| | (0.0127) | |
| Mixed | 0.0317** | -0.0218 |
| | (0.0156) | (0.0432) |
| Dairy | 0.1527*** | |
| | (0.0462) | |
| Hog | -0.2385*** | |
| | (0.0720) | |
| Poultry | -0.0626 | |
| | (0.0849) | |
| Sheep | -0.0211 | |
| | (0.2309) | |
| Greenhs | 0.6543*** | |
| | (0.1782) | |
| SpecEnter | 0.2010** | |
| | (0.0791) | |
| Sales80 | 5.7829*** | 3.4583*** |
| | (0.4033) | (0.8250) |
| Sales80xEdm-Neighbours | -5.2265*** | -2.2685 |
| | (0.6227) | (2.5172) |
| Sales80xCal-Neighbours | -4.5247*** | -4.3136* |
| | (0.4682) | (2.3212) |
| Constant | 11.0905*** | 11.9674*** |
| | (0.0953) | (0.2438) |

[a]***, ** and * represent statistical significance at the 1 percent level, 5 percent level, and 10 percent level, respectively
[b]Top and bottom 1% outliers (based on the dependent variable) were removed
[c]Estimated using two-stage least squares
[d]Variable names are defined in Table 3.4, Table 3.5 and Section 4.2
[e]CAD = Canadian Dollar

For completeness, other sample sizes are mentioned in Table B.2. A test to see if the fragmentation measure was exogenous was performed for all models. In contrast to Table 4.5, the null hypothesis of an exogenous measure was rejected for some of the models in Table B.2. Two-stage least squares was estimated in those instances. It is unclear why this test was rejected dependent on the sample year.

In the 2010–2011 sample, the instrument for the *Ln Patch Density* model was likely a weak instrument. This was different than for other samples or other fragmentation models. Using a weak instrument probably impacted the tests for an exogenous fragmentation variable, and is cause for concern with regards to both the estimated coefficients and the standard errors. However, for most of the coefficients the signs, magnitudes and significance for this model were similar to other models using the same sample years.

Comparing across all models and all sample years (i.e., considering Table 4.5 and Table B.2 together), the building dummies (*NoBuild* and *CheapBuild*) continued to have a negative influence on farmland values relative to a good building on the property, though *CheapBuild* was not always significant. The parcel size had an inverse relationship with the dependent variable in all models. Most of the variables related to agricultural returns (i.e., *Irrig*, *SoilQlty* and *NetIncFarm*) were positive and significant most of the time; the exception was the *NetIncFarm* in 2010 for two of the regressions and 2011 for three regressions. The *Animal* farm types relative to *Plant* farm types were always negative and significant in both tables, whereas the *Mixed* farm type showed no effect.

Regarding the proxy variables for conversion pressure, *PctPopDenChg* was consistently positive and significant in Table B.2 unlike results in Table 4.5. Distance to

Highway 2 was always negative and significant regardless of the sample year, and this was mostly true for the *LnUrbDist* as well (with 2 exceptions in Table B.2). *Edm-Neighbours* was often positive and significant, but sometimes insignificant in Table B.2 versus Table 4.5 where it was always positive and significant. The opposite occurred for *Cal-Neighbours;* Table B.2 showed a positive and significant relationship all the time, whereas Table 4.5 had one case where *Cal-Neighbours* was not significant. The fragmentation variables were discussed in Chapter Four Subsection 4.3.2.2.

**Table B.2 Further analysis showing the other small samples (years 2010–2011 and 2010 only): Parameter estimates for hedonic models of Alberta farmland prices (robust standard errors in parentheses)[a,b,c]**

| | Model | | | | | |
|---|---|---|---|---|---|---|
| **Dependent variable: Ln of farmland price per acre 2002 CAD[d]** | *Small Parcel (≤ 80 acres) Sales Ratio* | *Ln Mean Patch Size* | *Ln Patch Density* | *Small Parcel (≤ 80 acres) Sales Ratio* | *Ln Mean Patch Size* | *Ln Patch Density* |
| **Year(s)** | 2010–2011 | 2010–2011 | 2010–2011 | 2010 | 2010 | 2010 |
| Weak instrument test (effective F-statistic)[e] | 52.347 | 57.879 | 9.132 | 44.056 | 385.931 | 204.915 |
| Weak instrument issue? | No | No | Yes | No | No | No |
| Endogeneity test (p-value) | 0.0045 | 0.1146 | 0.6491 | 0.0002 | 0.0000 | 0.0000 |
| Estimation[f] | 2SLS | OLS | OLS | 2SLS | 2SLS | 2SLS |
| R-squared | 0.7510 | 0.7430 | 0.7469 | 0.7570 | 0.7506 | 0.7484 |
| F-statistic | 309 | 238 | 244 | 137 | 116 | 116 |
| Sample size | 1,906 | 1,650 | 1,650 | 872 | 761 | 761 |
| **Explanatory variable** | | | | | | |
| GoodBuild | Omitted | Omitted | Omitted | Omitted | Omitted | Omitted |
| NoBuild | -0.1973*** | -0.1452*** | -0.1454*** | -0.1467*** | -0.1551*** | -0.1652*** |
| | (0.0295) | (0.0307) | (0.0305) | (0.0420) | (0.0467) | (0.0470) |
| CheapBuild | -0.2382** | -0.2651** | -0.2679** | -0.2383 | -0.2174 | -0.2172 |
| | (0.1025) | (0.1060) | (0.1048) | (0.1478) | (0.1651) | (0.1693) |
| LnSize | -0.5302*** | -0.5444*** | -0.5421*** | -0.5496*** | -0.5611*** | -0.5626*** |
| | (0.0212) | (0.0213) | (0.0211) | (0.0268) | (0.0289) | (0.0290) |

*(Continued)*

Table B.2 Continued

| Explanatory variable | Model: *Small Parcel (≤ 80 acres) Sales Ratio* | *Ln Mean Patch Size* | *Ln Patch Density* | *Small Parcel (≤ 80 acres) Sales Ratio* | *Ln Mean Patch Size* | *Ln Patch Density* |
|---|---|---|---|---|---|---|
| **Year(s)** | 2010–2011 | 2010–2011 | 2010–2011 | 2010 | 2010 | 2010 |
| Irrig | 0.6421*** | 0.6272*** | 0.6094*** | 0.4250*** | 0.4788*** | 0.5097*** |
| | (0.0511) | (0.0531) | (0.0516) | (0.0829) | (0.0908) | (0.0943) |
| SoilQlty | 0.0059*** | 0.0046*** | 0.0039*** | 0.0023** | 0.0032*** | 0.0033*** |
| | (0.0007) | (0.0008) | (0.0008) | (0.0010) | (0.0012) | (0.0011) |
| NetIncFarm | 1.16E-06* | 2.43E-06*** | 2.30E-06*** | 2.37E-06* | 1.17E-06 | 1.72E-06 |
| | (6.06E-07) | (7.50E-07) | (7.20E-07) | (1.28E-06) | (1.51E-06) | (1.43E-06) |
| PctPopDenChg | 0.0151** | 0.0186*** | 0.0237*** | 0.0226** | 0.0309*** | 0.0285*** |
| | (0.0064) | (0.0065) | (0.0066) | (0.0097) | (0.0106) | (0.0109) |
| LnHwy2 | -0.1357*** | -0.1425*** | -0.1333*** | -0.1361*** | -0.1410*** | -0.1495*** |
| | (0.0153) | (0.0153) | (0.0155) | (0.0214) | (0.0224) | (0.0238) |
| LnUrbDist | -0.1067*** | -0.0814*** | -0.0754*** | -0.0576** | -0.0171 | -0.0248 |
| | (0.0185) | (0.0187) | (0.0183) | (0.0259) | (0.0301) | (0.0296) |
| Edm-Neighbours | 0.1511 | 0.6075*** | 0.5763*** | -0.5148 | 0.2848** | 0.2884** |
| | (0.1939) | (0.0877) | (0.0863) | (0.3335) | (0.1380) | (0.1383) |
| Cal-Neighbours | 0.2959*** | 0.4283*** | 0.3758*** | 0.4206** | 0.7760*** | 0.8006*** |
| | (0.0896) | (0.0903) | (0.0904) | (0.1912) | (0.1607) | (0.1632) |
| Plant | Omitted | Omitted | Omitted | Omitted | Omitted | Omitted |
| Animal | -0.1874*** | -0.2469*** | -0.2581*** | -0.1363*** | -0.1388** | -0.1409** |
| | (0.0358) | (0.0371) | (0.0370) | (0.0516) | (0.0566) | (0.0567) |
| Mixed | -0.0315 | 0.0525 | 0.0505 | 0.0586 | 0.0899 | 0.0800 |
| | (0.0437) | (0.0499) | (0.0495) | (0.0670) | (0.0718) | (0.0727) |

*(Continued)*

Table B.2 Continued

| Explanatory variable | Model | | | | | |
|---|---|---|---|---|---|---|
| | *Small Parcel (≤ 80 acres) Sales Ratio* | *Ln Mean Patch Size* | *Ln Patch Density* | *Small Parcel (≤ 80 acres) Sales Ratio* | *Ln Mean Patch Size* | *Ln Patch Density* |
| **Year(s)** | 2010–2011 | 2010–2011 | 2010–2011 | 2010 | 2010 | 2010 |
| Sales80 | 3.2231*** | | | 3.5594*** | | |
| | (0.9851) | | | (1.0966) | | |
| LnMPSize | | -0.0532*** | | | 0.1615*** | |
| | | (0.0154) | | | (0.0486) | |
| LnPatchDenAc | | | 0.1109*** | | | -0.1808*** |
| | | | (0.0188) | | | (0.0639) |
| Constant | 12.0089*** | 12.8147*** | 12.7009*** | 11.7164*** | 8.8361*** | 10.1476*** |
| | (0.2468) | (0.2979) | (0.2385) | (0.3133) | (0.8784) | (0.6066) |

[a]***, ** and * represent statistical significance at the 1 percent level, 5 percent level, and 10 percent level, respectively

[b]Top and bottom 1% outliers (based on the dependent variable) were removed

[c]Variable names are defined in Table 3.4 and Table 3.5

[d]CAD = Canadian Dollar

[e]The critical value is 37.418 (when the significance level alpha = 5% and when tau = 5% of the worst-case benchmark). The null hypothesis is the instrument is weak.

[f]OLS refers to ordinary least squares, while 2SLS refers to two-stage least squares estimation. The choice between OLS and 2SLS was determined by the endogeneity test (Ho: exogenous fragmentation variable).

## Appendix C: Irrigation

As covered in Chapter Three, the *Irrig* dummy variable was assigned a value of one for those counties whose boundaries overlap with the boundaries of at least one irrigation district. Three counties (i.e., Foothills No. 31, Pincher Creek No. 9 and Special Area No. 2) borders overlapped, but fewer than 300 acres of each of these counties overlapped an irrigation district. To investigate whether this dummy value assignment was cause for concern, two additional regressions were performed and compared to those from Table 4.4. *AdjIrrig* is the modified *Irrig* dummy variable where those three aforementioned counties are reassigned a value of zero instead of one. Table 4.4 is reproduced along with two more regressions in Table C.1.

Many of the results are unaffected by the irrigation dummy reassignment. Signs and significance did not change much from regression to regression. However, two variables' significance changed slightly: *SpecEnter* and *LnUrbDist*. Also, there were a few changes regarding the coefficients on the irrigation dummy variables. The original *Irrig* is greater in magnitude than the revised *AdjIrrig*, but otherwise the interpretation is the same. The coefficients for *SoilQlty* and *NetIncFarm* also changed in magnitude slightly. This is not unexpected given that all three of these variables are suspected of reflecting agricultural returns.

Given these results there is limited concern with using the original *Irrig* variable for the majority of the analysis. Also, *Irrig* may represent the higher number of private irrigation licenses in the southern part of the province relative to other areas of the province as shown on the private irrigation map by AARD (2011).

**Table C.1 Further analysis for *AdjIrrig*: Parameter estimates for large sample (2000–2011) hedonic models of Alberta farmland prices (robust standard errors in parentheses)[a,b]**

| | Model | | | |
|---|---|---|---|---|
| **Dependent variable: Ln of farmland price per acre 2002 CAD[c]** | *No Fragmentation* | *No Fragmentation and AdjIrrig* | *Small Parcel (≤ 80 acres) Sales Ratio* | *Small Parcel (≤ 80 acres) Sales Ratio and AdjIrrig* |
| **Estimation[d]** | OLS | OLS | 2SLS | 2SLS |
| R-squared | 0.7187 | 0.7061 | 0.7184 | 0.7066 |
| F-statistic | 1,332 | 1,181 | 1,299 | 1,158 |
| Sample Size | 14,802 | 14,802 | 14,781 | 14,781 |
| **Explanatory variable[e]** | | | | |
| GoodBuild | Omitted | Omitted | Omitted | Omitted |
| NoBuild | -0.1531*** | -0.1522*** | -0.1583*** | -0.1567*** |
| | (0.0108) | (0.0110) | (0.0109) | (0.0111) |
| CheapBuild | -0.2510*** | -0.2443*** | -0.2466*** | -0.2405*** |
| | (0.0334) | (0.0324) | (0.0332) | (0.0323) |
| LnSize | -0.5162*** | -0.5171*** | -0.5064*** | -0.5084*** |
| | (0.0071) | (0.0072) | (0.0073) | (0.0075) |
| Irrig | 0.5747*** | | 0.5895*** | |
| | (0.0188) | | (0.0184) | |
| AdjIrrig | | 0.3982*** | | 0.4068*** |
| | | (0.0194) | | (0.0189) |
| SoilQlty | 0.0029*** | 0.0018*** | 0.0025*** | 0.0014*** |
| | (0.0003) | (0.0003) | (0.0002) | (0.0002) |
| NetIncFarm | 3.40E-06*** | 4.77E-06*** | 3.66E-06*** | 5.03E-06*** |
| | (3.03E-07) | (3.28E-07) | (3.03E-07) | (3.29E-07) |

*(Continued)*

Table C.1 Continued

| **Explanatory variable**[e] | **Model** *No Fragmentation* | *No Fragmentation and AdjIrrig* | *Small Parcel (≤ 80 acres) Sales Ratio* | *Small Parcel (≤ 80 acres) Sales Ratio and AdjIrrig* |
|---|---|---|---|---|
| PctPopDenChg | 0.0226*** | 0.0218*** | 0.0250*** | 0.0238*** |
| | (0.0012) | (0.0012) | (0.0013) | (0.0013) |
| LnHwy2 | -0.1833*** | -0.1751*** | -0.1823*** | -0.1729*** |
| | (0.0059) | (0.0059) | (0.0056) | (0.0058) |
| LnUrbDist | -0.0430*** | -0.0478*** | -0.0059 | -0.0172* |
| | (0.0100) | (0.0101) | (0.0091) | (0.0094) |
| Edm-Neighbours | 0.3928*** | 0.3953*** | -0.0209 | 0.0209 |
| | (0.0268) | (0.0267) | (0.0562) | (0.0585) |
| Cal-Neighbours | 0.4212*** | 0.7567*** | 0.3241*** | 0.6751*** |
| | (0.0389) | (0.0402) | (0.0400) | (0.0403) |
| Crop | Omitted | Omitted | Omitted | Omitted |
| Beef | -0.1919*** | -0.1659*** | -0.1920*** | -0.1651*** |
| | (0.0125) | (0.0129) | (0.0124) | (0.0128) |
| Mixed | 0.0656*** | 0.0727*** | 0.0451*** | 0.0548*** |
| | (0.0152) | (0.0158) | (0.0155) | (0.0160) |
| Dairy | 0.1901*** | 0.1947*** | 0.1809*** | 0.1867*** |
| | (0.0465) | (0.0463) | (0.0467) | (0.0463) |
| Hog | -0.1992*** | -0.1934*** | -0.2169*** | -0.2099*** |
| | (0.0668) | (0.0664) | (0.0701) | (0.0691) |
| Poultry | -0.0166 | -0.0051 | -0.0657 | -0.0502 |
| | (0.0835) | (0.0884) | (0.0895) | (0.0934) |
| Sheep | -0.0035 | -0.0154 | -0.0151 | -0.0251 |
| | (0.2086) | (0.2069) | (0.2193) | (0.2157) |

*(Continued)*

Table C.1 Continued

| | Model | | | |
|---|---|---|---|---|
| **Explanatory variable[e]** | *No Fragmentation* | *No Fragmentation and AdjIrrig* | *Small Parcel (≤ 80 acres) Sales Ratio* | *Small Parcel (≤ 80 acres) Sales Ratio and AdjIrrig* |
| Greenhs | 0.5821*** | 0.6351*** | 0.6446*** | 0.6886*** |
| | (0.1725) | (0.1772) | (0.1785) | (0.1821) |
| SpecEnter | 0.2552*** | 0.2866*** | 0.1801** | 0.2179*** |
| | (0.0785) | (0.0778) | (0.0807) | (0.0811) |
| Sales80 | | | 2.5081*** | 2.2739*** |
| | | | (0.2903) | (0.3025) |
| Constant | 11.6892*** | 11.7111*** | 11.1701*** | 11.2643*** |
| | (0.1046) | (0.1064) | (0.1069) | (0.1075) |

[a]***, ** and * represent statistical significance at the 1 percent level, 5 percent level, and 10 percent level, respectively
[b]Top and bottom 1% outliers (based on the dependent variable) were removed
[c]CAD = Canadian Dollar
[d]OLS refers to ordinary least squares, while 2SLS refers to two-stage least squares estimation.
[e]Variable names are defined in Table 3.4 and Table 3.5. *AdjIrrig* stands for the adjustments made to exclude some counties (i.e., Foothills No. 31, Pincher Creek No. 9 and Special Area No. 2) from the original *Irrig* variable.