Identifying the Economic Impacts of a Land-Use Policy: A Case Study of Okotoks, Alberta

by

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Abstract

Rapid economic and demographic growth is changing the nature of Alberta's urban and rural landscapes. This has had profound effects on land use, particularly in areas near to Edmonton and Calgary where there is great concern about urban sprawl into surrounding farmlands. In 2012, the Town of Okotoks shifted from a "finite growth" policy to a "continuous growth" policy, thus eliminating a key policy constraint on urban development. This new policy allows for accelerated conversion of open space and makes Okotoks a "natural experiment" of land-use policy change.

This thesis aims to examine the economic impacts of the land-use policy which governs development in Okotoks. Relying on data on single-family residential property transactions between 2010 and 2017 in Okotoks and surrounding area, the thesis explores people's willingness to pay for the pro-development policy, and also for different types of open space that are affected by the policy. A difference-in-difference method is incorporated into a hedonic price model. Spatial lag modeling using a spatial two-stage least squares (S2SLS) technique indicates that individuals value living near livestock pasture land and disvalue the pro-development policy. The average willingness to pay for avoiding the policy is estimated to be $CAD 33,754.

A separate analysis is undertaken to assess whether the policy reduces people's willingness to pay to live near developable open space. An endogenous switching regression allows us to estimate hedonic price models before and after the policy change. The results show that the pro-development policy reduces people's willingness to pay for developable open space such as forest, pasture and grassland within a 200-meter buffer of their properties.

These findings illustrate the ways that municipal land use policies affect residential property values, generating real trade-offs between the values of open space and development.

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Chapter 1. Introduction

1.1. Background

Parks, forests, grasslands and agricultural lands are different types of open space that provide a range of benefits, such as agricultural products, recreational services, aesthetic experiences, climate regulation, watershed protection, and wildlife habitat. They are valuable assets to their owners and to others who live nearby.

The Province of Alberta, one of the three Canadian prairie provinces, has diverse landscapes including glaciers, mountains, foothills, lakes, rivers, forests and open plains (Government of Alberta, 2016a). There are around 27 million hectares of forest in Alberta, accounting for 9% of forest cover nationwide (Statistics Canada, 2011). Forestry is a significant source of employment and recreation services. Moreover, forests are necessary to aboriginal people to support their livelihood and cultural activities (Government of Alberta, 2016b). The south and southeast areas of the province have large expanses of grasslands and parklands (See Appendix A), although 75% of the grasslands have been converted into tame forage or cultivated for annual crop production (Nature Conservancy of Canada, 2017). Bork (2016) indicates that grasslands can store 10% to 30% of the world's organic carbon, which improves soil stability. The value of carbon stored in native grasslands in Alberta exceeds $CAD 9 Billion (Rangeland Research Institute, 2016). Native grasslands also provide important habitat for plant and animal species, including amphibians, birds and mammals. It helps to preserve biodiversity. There are over 140 bee species found in Alberta, contributing to healthy grasslands (Bork, 2016). Meanwhile, Alberta has a large and vibrant agricultural industry. In 2016 the province had 40,638 farms, second only to Ontario among Canadian provinces. Since 1993, the nominal value of farmland in Alberta has been steadily increasing, as presented in Figure 1.1. Farm Credit Canada (2017) reports the average value of Canadian farmland increased 7.9% in 2016, while Albertan farmland increased 9.5%, the second-highest increase nationwide[1].

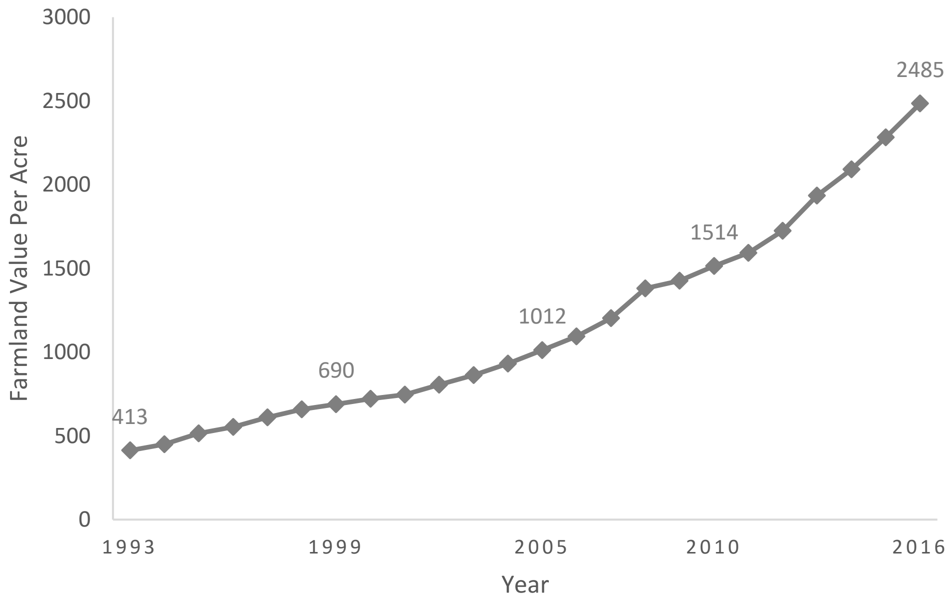


Figure 1.1. Nominal Farmland Value Per Acre in Alberta between 1993 and 2016

Data Source: (*Statistics Canada, 2016a*)

However, a trend of urban growth and sprawl in Alberta is resulting in the conversion of different types of open space to urban uses, such as industrial, commercial and residential (Government of Alberta, 2016c). One of the causes of urban encroachment is population growth. The growth rate of Alberta was always higher than the growth rate of Canada throughout the 1993 to 2015 period (Statistics Canada, 2016b). It was over double the growth rate for Canada from 2012 to 2014 (Government of Alberta, 2017a). Another cause of urban encroachment is economic growth

[1] The average value is estimated by using benchmark farm properties which are representative in each part of Canada (Farm Credit Canada, 2002).

(Bhatta, 2010). The gross domestic product (GDP) of Alberta was the third-highest among provinces and territories from 2012 to 2016 (Statistics Canada, 2017). In 2016, Alberta's GDP of $CAD 315 billion was distributed among a range of land intensive industries, including oil, gas and mining (17.0%), real estate (12%), construction (10.7%), and agriculture and forestry (1.6%) (Statistics Canada, 2017). Favourable economic conditions may raise income per capita, reduce the unemployment rate and stimulate housing demand, so land developers will be motivated to build more houses and more urban infrastructure. Figure 1.2 shows that the number of new housing units in Alberta increased annually by 71,828 units from 2002 to 2017, on average.

Figure 1.2. Annual Housing Starts in Alberta between 2002 and 2017[2]

Data Source: (*Government of Alberta, 2017b*)

[2] Housing starts are collected in urban centers with a population of 10,000 and over.

Since population and economic growth have significant pressures on open space, fragmentation and conversion of agricultural land are common in Alberta, especially in the Edmonton-Calgary corridor area which covers around 6% of the total area of Alberta. Qiu et al. (2015) indicate that there was a net increase of 625 km^2 of developed land within this area between 2000 and 2012, and most importantly, 72% of conversion was of the two highest land quality categories of agricultural land in Alberta. Specifically, 68,774 hectares of agricultural land, 6,574 hectares of forest and 5,200 hectares of grassland were converted to developed uses from 2000 to 2012. In addition, the largest city in Alberta, Calgary, grew from 242 km^2 to 754 km^2 between 1984 to 2013 (Stan and Sanchez-Azofeifa, 2017). Taking Rocky View County, Municipal District (M.D.) of Foothills No.31 and Calgary as an example, we compare land use in 2011 and 2016, using the 30-meter resolution land-use analysis provided by Agriculture and Agri-Food Canada. Cropland and pasture are classified as agricultural land (Wang, 2015)[3]. Open space including grassland, agricultural land and forest, and developed lands are expressed as percentages of total township area[4]. Similar spatial patterns in Figure 1.3 indicates that most townships experienced an decrease of open space and increase of development between 2011 and 2016. Particularly, the conversion of open space to developed uses was most common in townships near the City of Calgary.

[3] According to Agriculture and Agri-Food Canada (2016), grasslands are predominantly native grasses and vegetation, while pastures are periodically cultivated.
[4] In Alberta, townships are six-by-six mile square units of land formed by the intersection of townships (running east to west) and ranges (running south to north).

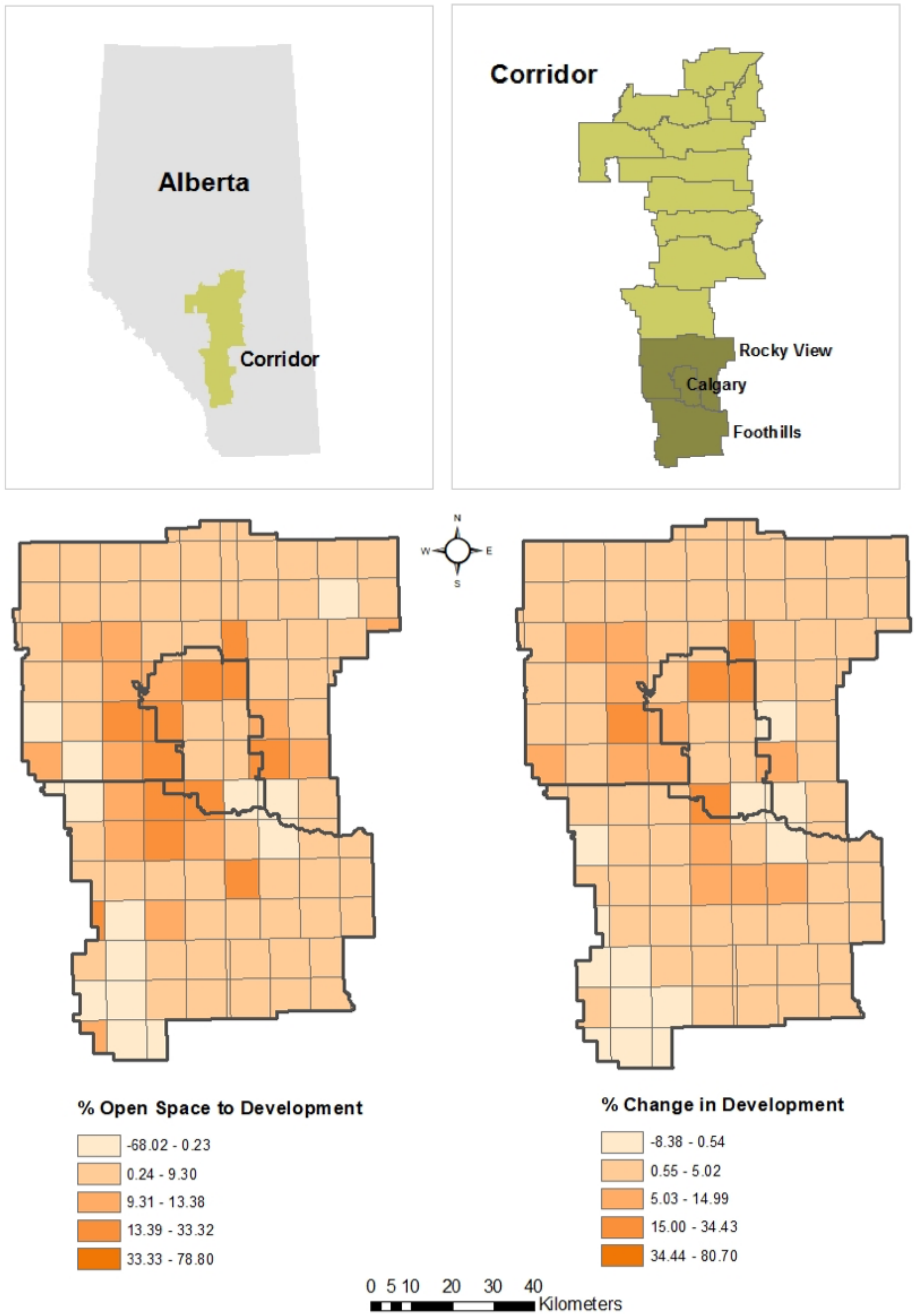


Figure 1.3. Changes of Open Space (left) and Developed Land (right) Surrounding Calgary: 2011-2016

Data Source: (*Agriculture and Agri-Food Canada, 2016*)

Considering the importance of open space, the Government of Alberta announced a new land use framework in 2008 (Government of Alberta, 2008). It mandated the development of regional plans for municipal land-use decisions and resource management, which help to resolve the specific land use and natural resource pressures in each of seven regions in the province. The land use framework is dedicated to balancing the goals of economic growth and environmental conservation. The Alberta Land Stewardship Act was announced in 2009, which encourages the use of conservation easements, conservation directives, conservation offsets and transfer of development credits to protect and conserve private agricultural land, natural scenic values and the environment (Government of Alberta, 2009).

Researchers have assessed the impacts of land-use regulations that preserve open space on land development decisions and land or property values. Lynch and Liu (2007) find that land preservation policies increased area of conserved lands and the probability of preservation in the US state of Maryland. Newburn and Ferris (2016) show that a low-density development policy in Baltimore, Maryland decreased the density of development in agricultural and watershed protection areas. In addition, Borchers and Duke (2012) find that agricultural and forestland easements in the US state of Delaware, generate a price premium on property values.

The scholarly literature has relatively little coverage of the effects of land-use policies that approve development. Driven by growth pressure, governments undertake policy actions such as annexation and re-designation, to accommodate future growth. Consequently, the question how to evaluate such policy arises. The development policy may have long-term costs such as service provision and maintenance. City planners and land developers have to consider the trade-offs between the benefits and costs before a pro-development policy is implemented. The study by No Kim et al. (2016) in the Chestermere area of southern Alberta illustrates that individuals' willingness to pay (WTP) for a policy has impacts on tax revenue. It is acknowledged that property tax revenue is the primary source of income for many municipal governments. Therefore, to some extent, a pro-development policy may affect government spending in the future. In addition, people value agricultural open space (Ready and Abdalla, 2005), and forests (Raunikar and Buongiorno, 2006). A pro-development policy that threatens developable open space may change people's willingness to pay for those lands.

There are several challenges to accurately reveal the effects of a pro-development policy in the Alberta context. One challenge is to choose an appropriate study area. It is difficult to consider a large number of municipalities. The pace and drivers of development vary between municipalities, with little new development in some areas and rapid development in others. At the same time, land-use regulations vary considerably from one municipality to another. A second challenge is how to define the policy instrument. It is important to identify the groups affected by a policy (Lofgren and El-Said, 2001). The last challenge regards valuation of the policy and open space attributes of a property as non-market goods. Non-market goods can be valued using revealed or stated preference techniques. Although stated preference models can be more accurate in identifying the value of a specific attribute, they are complicated to apply because of the required advanced experimental design techniques and involved empirical challenges. What's more, under individuals' actual choices, revealed preference models are more valid. This thesis uses revealed preference models to reveal WTP for policy and open space.

1.2. Study Area

As mentioned in Section 1.1, many municipalities in Alberta are faced with development pressure. One such urban municipality in the Edmonton-Calgary corridor is the Town of Okotoks. In order to manage growth toward different objectives, the Okotoks Town Council has implemented distinctly different policies in recent years. Since the policy actions are correlated with conversion of open space, Okotoks becomes a good study area for Alberta to discuss economic impacts of municipal pro-development policies.

Figure 1.4 shows the position of Okotoks in the Edmonton-Calgary corridor, where it is surrounded by M.D. Foothills. It is located 18 km south of the City of Calgary.

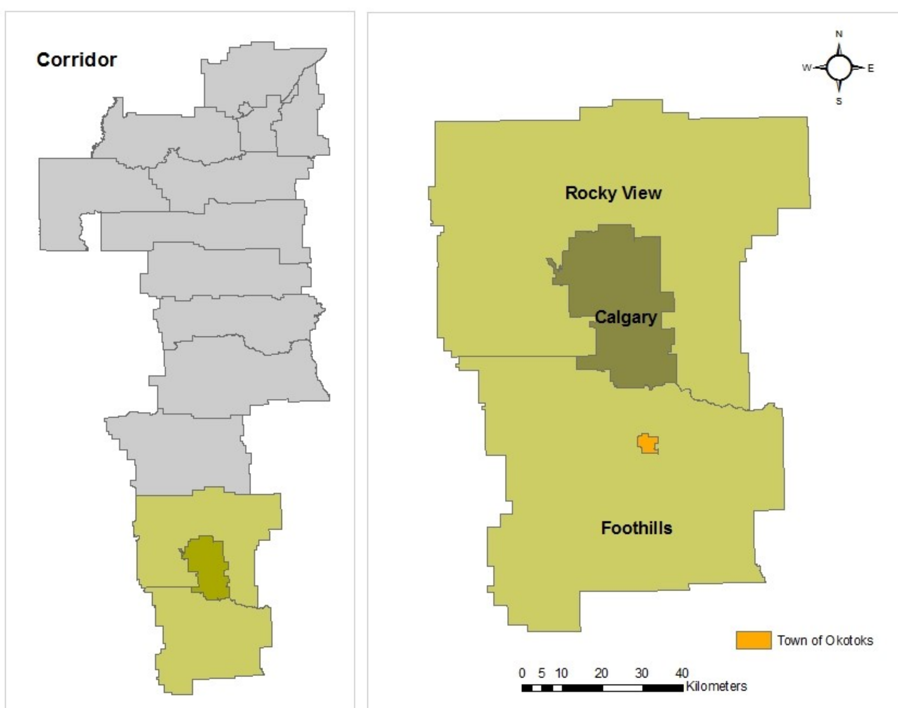


Figure 1.4. The Regional Context for the Town of Okotoks, Alberta

Growth in the population size of Okotoks was constrained by the limited water supply available from the Sheep River[5]. The Town had a population of 8,510 in 1996, as shown in Figure 1.4. In 1998, Okotoks issued a Municipal Development Plan (MDP) that was in favor of a "small town atmosphere" and a "sustainable Okotoks". The MDP indicated that growth would not occur beyond existing urban areas. The MDP enhanced the protection of the open space system in Okotoks, requiring a healthy urban forest, 95% preservation of environmentally significant lands, and 20% preservation of all land as public space and pathway systems (Town of Okotoks, 1998a). A land use bylaw following the announcement of the MDP also addressed the protection of recreational open space and the area around the Sheep River, under the divisions of restricted development district, environmental protection district and public service district within the Town (See Appendix B) (Town of Okotoks, 1998b). Meanwhile, the population of the town would be held to 25,000 to 30,000 residents so as not to exceed the carrying capacity of water available in Sheep River watershed (Town of Okotoks, 1998a). The Town Council referred to this as its finite growth policy. By 2011, the population had increased to 24,470. Okotoks was exposed not only to development pressures from the growth of the Calgary region, but also the establishment of country residential subdivisions near the town's boundaries. Figure 1.6 illustrates high density development in M.D. Foothills within close proximity to the town's boundaries. These pressures prompted the Okotoks Council to switch from the finite growth policy to a continuous growth policy in September 2012. This policy increased the target population to 60,000 over a 60-year plan. The Town of Okotoks (2014) predicts the town's population would increase to approximately 58,300 in 2076. The new policy allows for further urban development, at the minimum density of 8 housing units per gross developable acre (Town of Okotoks, 2014). Table 1.1 shows the predicted

[5] Source: http://www.mtroyal.ca/library/inc/cprs/pdfs/7-01-WEI-13%20Weigel,%20Nancy.pdf. Accessed on February 28, 2018.

demand for developable lands in the future. Total net lands required were forecast to be 543 hectares for a first 30-year plan and 399 hectares for a second 30-year plan (Town of Okotoks, 2014).

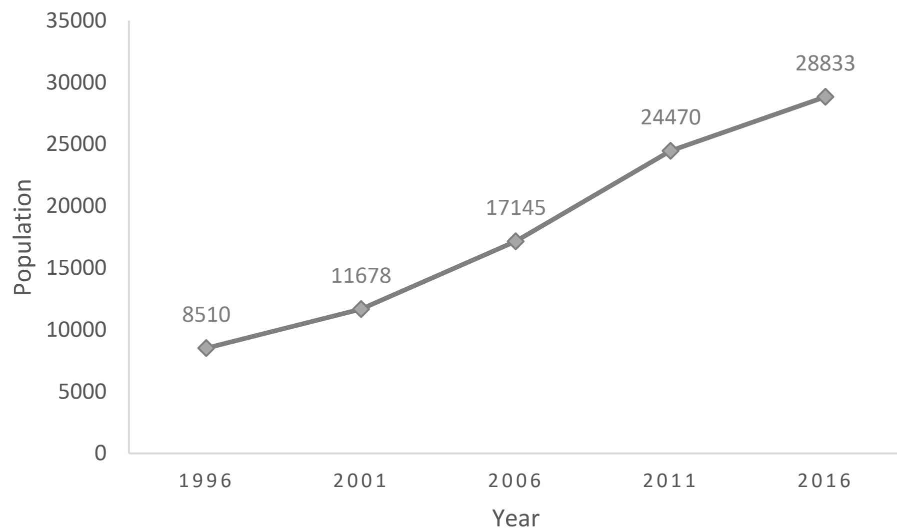


Figure 1.5. Population in Okotoks between 1996 and 2016

Data Source: (*Statistics Canada, 2016c*)

Table 1.1. Net Land Demand from 2013 to 2073 (Hectares)

	2013-2043	2043-2073	Total
Residential Demand	435	310	745
Commercial Demand	52	33	85
Industrial Demand	56	56	112
Total Net Land Required	543	399	942

Data Source: (*Town of Okotoks, 2014*)

After announcing the continuous growth policy, the Town initiated an annexation process with M.D. Foothills in September 2013 (Town of Okotoks, 2017a). Finally, in July 2017, the Government of Alberta approved this annexation. The annexation area is shown in Figure 1.6.

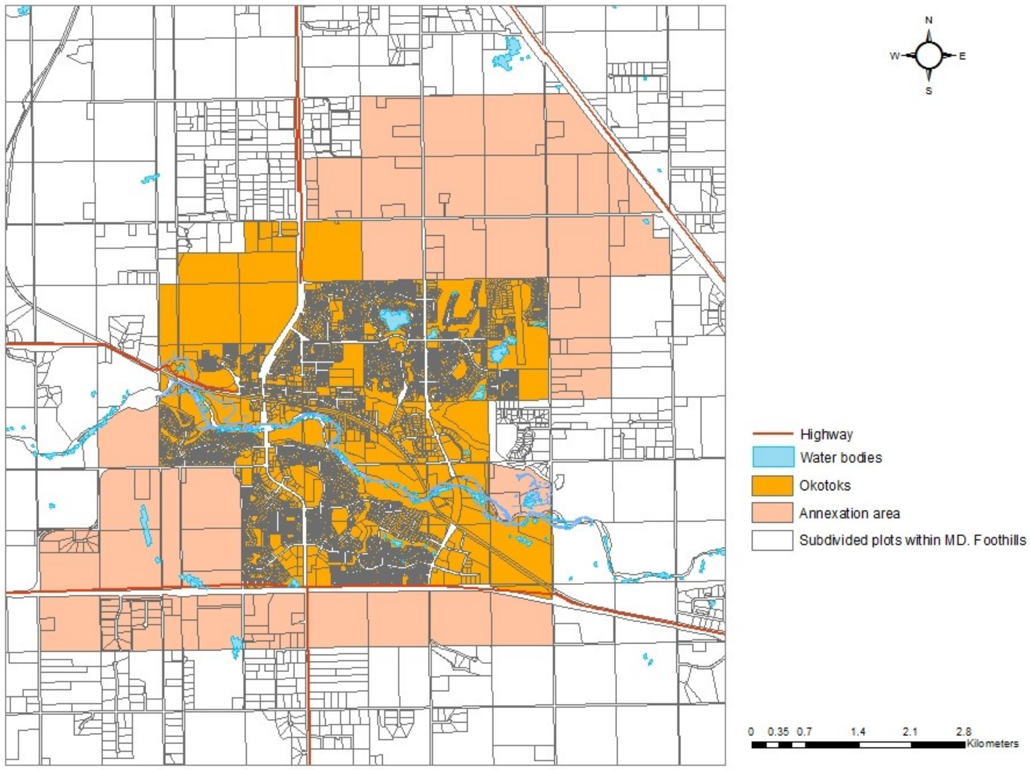


Figure 1.6. Annexation Area of Okotoks

Data Source: (*Town of Okotoks, 2017a*)

1.3. Objectives

This thesis aims to identify the economic impacts of a municipal land-use policy, specifically the growth policy of the Town of Okotoks in Alberta. Since this continuous growth policy approves development and urban growth, it threatens developable lands and allows for the acceleration of the conversion of those lands. Considering the importance of open space detailed in Section 1.1, we want to investigate:

i. The extent to which people value or disvalue this pro-development policy. More specially, what is the effect of this policy on property values in Okotoks?

ii. Whether and to what extent Okotoks residents value open space in their housing decisions;

iii. Whether and to what extent people's WTP for developable open space has changed due to the implementation of the continuous growth policy.

Based on single-family housing transaction data between 2010 and 2017, we incorporate the policy change, and the size of different types of open space such as pastures, croplands, grasslands and parks into a hedonic price model, then identify two effects of the new policy under two different empirical models.

1.4. Thesis Structure

This thesis has five chapters. Chapter 1 mainly introduces the background and objectives of the thesis. Chapter 2 illustrates the analytical framework, the hedonic price model, in detail. Chapter 3 and Chapter 4 present two separate empirical studies based on the hedonic price model discussed in Chapter 2, identifying two effects of the pro-development policy. Specifically, in Chapter 3, the study area is four townships surrounding the Town of Okotoks. We consider a difference-in-difference (DID) method in the hedonic price framework, incorporating the policy and sizes of open space into the model. Empirical estimations are performed by a spatial lag model under a spatial two-stage least squares regression. Through this chapter, we generate estimates of people's WTP for the continuous growth policy, which is also its effect on the property value. Meanwhile, WTPs for different types of open space are also calculated. Chapter 4 restricts the study area to the pre-2017 boundaries of the Town of Okotoks. The pro-development policy may influence homeowners' decisions of selling a house, hence characteristics of houses in the market are not random. An endogenous switching regression model is used to eliminate this self-selection bias problem. After considering homeowners' decision of selling a house due to the policy change, we estimate hedonic price models before and after the announcement of the new policy. The endogenous switching regression shows whether WTPs for different types of developable open space change because of the implementation of the new land-use policy. Moreover, it can also be used to calculate the effects of the new policy on the property value, which we compare to the results from Chapter 3. Chapter 5 concludes the thesis, illustrates policy implications, discusses limitations and puts forward suggestions for future research.

1.5. References

Agriculture and Agri-Food Canada. 2016. Annual Crop Inventory: Data Product Specifications. https://open.canada.ca/data/en/dataset/ba2645d5-4458-414d-b196-6303ac06c1c9. (Accessed on March 22, 2018).

Bhatta, B. 2010. Causes and Consequences of Urban Growth and Sprawl. In *Analysis of Urban Growth and Sprawl from Remote Sensing Data.* Springer Science and Business Media, pp. 17-36.

Borchers, A.M., and J.M. Duke. 2012. Capitalization and Proximity to Agricultural and Natural Lands: Evidence from Delaware. *Journal of Environmental Management* 99:110-117.

Bork, E. 2016. An Overview of Current Research on Environmental Goods and Services in Alberta Grasslands.

https://rri.ualberta.ca/Portals/115/Documents/Presentations/Bork%20-%20Western%20Beef%20Development%20Center%20-%20Lanigan%20SK%20June%2021%202016.pdf?ver=2016-11-09-103031-627. (Accessed on April 6, 2018).

Farm Credit Canada. 2002. Farmland Values. http://publications.gc.ca/site/archivee-archived.html?url=http://publications.gc.ca/collections/collection_2017/fac-fcc/CC212-4-2002-2-eng.pdf. (Accessed on March 22, 2018).

Farm Credit Canada. 2017. 2016 FCC Farmland Values Report. https://www.fcc-fac.ca/content/dam/fcc/about-fcc/reports/farmland-values-report-2016.pdf. (Accessed on March 22, 2018).

Government of Alberta. 2008. Land Use Framework. https://www.edmonton.ca/city_government/documents/PDF/Alberta_Land_Use_Framework.pdf. (Accessed on February 28, 2018).

Government of Alberta. 2009. Alberta Land Stewardship Act. http://www.qp.alberta.ca/documents/Acts/A26P8.pdf. (Accessed on March 22, 2018).

Government of Alberta. 2016a. Location and Geography. http://www.albertacanada.com/business/overview/location-and-geography.aspx. (Accessed on February 28, 2018).

Government of Alberta. 2016b. Forest Health and Adaptation in Alberta: Annual Report. https://open.alberta.ca/publications/2560-760x. (Accessed on February 28, 2018).

Government of Alberta. 2016c. Fragmentation and Conversion of Agricultural Land in Alberta http://www1.agric.gov.ab.ca/$Department/deptdocs.nsf/all/luf15507/$FILE/fragmentation-conversion2016-01-18.pdf. (Accessed on February 28, 2018).

Government of Alberta. 2017a. Quarterly Population Report. http://www.finance.alberta.ca/aboutalberta/osi/demographics/Population-Estimates/Quarterly-2017-2018/2017-3rdQuarter.pdf. (Accessed on February 28, 2018).

Government of Alberta. 2017b. Housing Starts. http://economicdashboard.alberta.ca/HousingStarts. (Accessed on March 22, 2018).

Lofgren, H., and M. El-Said. 2001. Food Subsidies in Egypt: Reform Options, Distribution and Welfare. *Food Policy* 26:65-83.

Lynch, L., and X. Liu. 2007. Impact of Designated Preservation Areas on Rate of Preservation and Rate of Conversion: Preliminary Evidence. *American Journal of Agricultural Economics* 89:1205-1210.

Nature Conservancy of Canada. 2017. Prairie Grasslands Conservation Region. http://www.natureconservancy.ca/en/where-we-work/alberta/our-work/prairie-grasslands-conservation-region.html. (Accessed on March 22, 2018).

Newburn, D.A., and J.S. Ferris. 2016. The Effect of Downzoning for Managing Residential Development and Density. *Land Economics* 92:220-236.

No Kim, H., P.C. Boxall, and W.L. Adamowicz. 2016. The Demonstration and Capture of the Value of an Ecosystem Service: A Quasi-Experimental Hedonic Property Analysis. *American Journal of Agricultural Economics* 98:819-837.

Qiu, F., L. Laliberte, B. Swallow, and S. Jeffrey. 2015. Impacts of Fragmentation and Neighbor influences on Farmland Conversion: A Case Study of the Edmonton-Calgary Corridor, Canada. *Land Use Policy* 48:482-494.

Rangeland Research Institute. 2016. 2015-2016 Annual Report. https://rri.ualberta.ca/Portals/115/Documents/RRI-AnnualReport-2016.pdf?ver=2016-06-02-090131-697. (Accessed on April 6, 2018).

Raunikar, R., and J. Buongiorno. 2006. Willingness to Pay for Forest Amenities: The Case of Non-Industrial Owners in the South Central United States. *Ecological Economics* 56:132-143.

Ready, R.C., and C.W. Abdalla. 2005. The Amenity and Disamenity Impacts of Agriculture: Estimates from a Hedonic Pricing Model. *American Journal of Agricultural Economics* 87:314-326.

Stan, K.D., and A. Sanchez-Azofeifa. 2017. The Edmonton-Calgary Corridor: Simulating Future Land Cover Change under Potential Government Intervention. *Land Use Policy* 63:356-368.

Statistics Canada. 2011. Forest Land by Province and Territory. http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/envi34a-eng.htm. (Accessed on February 28, 2018).

Statistics Canada. 2016a. Value Per Acre of Farm Land and Building. http://www5.statcan.gc.ca/cansim/a26?lang=eng&id=20003. (Accessed on March 22, 2018).

Statistics Canada. 2016b. Population by Year, by Province and Territory. http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/demo02a-eng.htm. (Accessed on March 22, 2018).

Statistics Canada. 2016c. Census Profile. http://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/details/page.cfm?Lang=E&Geo1=POPC&Code1=0606&Geo2=PR&Code2=48&

Data=Count&SearchText=Okotoks&SearchType=Begins&SearchPR=01&B1=All&GeoLevel=PR&GeoCode=0606&TABID=1. (Accessed on March 22, 2018).

Statistics Canada. 2017. Gross Domestic Product, Expenditure-Based, by Province and Territory. http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/econ15-eng.htm. (Accessed on February 28, 2018).

Town of Okotoks. 1998a. Okotoks Municipal Development Plan. https://www.okotoks.ca/sites/default/files/pdfs/publications/MDP%20Consolidated%20June%202016.pdf. (Accessed on March 22, 2018).

Town of Okotoks. 1998b. Land Use Bylaw. https://www.okotoks.ca/sites/default/files/pdfs/publications/BY40-98%20Update%2020%20-%20July%202015.pdf. (Accessed on February 28, 2018).

Town of Okotoks. 2014. Town of Okotoks Growth Study and Financial Analysis. https://www.okotoks.ca/sites/default/files/pdfs/publications/Town%20of%20Okotoks%20Growth%20Study%20and%20Financial%20Assessment%202016.pdf. (Accessed on February 28, 2018).

Town of Okotoks. 2017a. Annexation. https://www.okotoks.ca/town-services/planning-development/planning/annexation. (Accessed on February 28, 2018).

Wang, H. 2015. Examination of Agricultural Land Conservation in the Alberta Capital Region, Canada. Master of Science, University of Alberta.

Chapter 2. Hedonic Price Model Approach

2.1. Introduction

There have been many studies of the value of non-market goods. Non-market goods include all environment amenities such as air, water or wildlife habitats, as well as some attributes of goods or attributes that lack actual markets (Atreya et al., 2013; Lansford and Jones, 1995; Leggett and Bockstael, 2000). The methods that have been developed to estimate those values are mainly based on stated preference and revealed preference (Bockstael and McConnell, 2007). Values estimated by stated preference methods tend to be more comprehensive than revealed preferences, capturing both use values and passive use values. However, sometimes stated preference models are complicated because of the required advanced experimental design techniques and empirical challenges involved (Bockstael and McConnell, 2007). Compared to the stated preference, a hedonic price model, one of the revealed preference models, is easier to estimate. The hedonic price model regards that a differentiated product is expressed as a bundle of characteristics. Since the price of a product depends on individuals' actual behavior on the market, the values of attributes revealed from this model are valid (Bockstael and McConnell, 2007).

Hedonic price modeling is a popular approach in real estate markets (Kim et al., 2003; Rosen, 1974; Sander et al., 2010; Yoo and Wagner, 2016). Because it decomposes the housing price into the values of structural characteristics, neighbourhood features, accessibility and environmental amenities, this approach can be used to estimate people's WTP for a change in a range of specific attributes. For example, Ottensmann et al. (2008) find that distance and time to the employment center negatively affect housing price in Indianapolis, in the US state of Indiana, which implies that individuals are willing to pay for better access to the employment center. Properties close to the airport may have lower prices due to the aircraft noise. Based on hedonic price model, Dekkers and Straaten (2009) explore a marginal benefit of reduction of aircraft noise around the Amsterdam region of the Netherlands. In addition, people are probably willing to pay for an improvement in air quality. While Kim et al. (2003) conclude that SO_2, one of the air pollutants, has a significant impact on housing price in Seoul, North Korea, Yusuf and Resosudarmo (2009) find that levels of different pollutants in Indonesia also negatively affect housing rental prices.

As mentioned in Chapter 1, different types of open space provide various functions such as food production, climate regulation, and scenic vistas, some of which are beyond the benefits that private landowners appropriate. Individuals may value living in close proximity to open space, and the hedonic price approach can be used to reveal that value (McConnell and Walls, 2005).

Physical relationship between each residential property and its surrounding open space can be investigated by defining distance to open space and size of that open space (Cho et al., 2011; Fernandez et al., 2018; Franco and Macdonald, 2017; Mahmoudi et al., 2013; Melichar and Kaprová, 2013; Schläpfer et al., 2015; Yoo and Wagner, 2016). Mahmoudi et al. (2013) examine whether residents in Adelaide, South Australia value national parks and reserves for garden or sport. They express environmental amenities as the distances to nearest park or reserve. Their results indicate that people value the proximity to golf courses, green space sporting facilities and coast. Schläpfer et al. (2015) find that possessing the view of major lake, and proximity of lake, wetland, undisturbed area, cultural site and nationally significant landscape will increase housing rental prices in urban, suburban and peri-urban areas of Switzerland. In addition, Sander et al.

(2010) define the landscape amenities as the percent of tree cover in each neighbourhood, and in different buffers around the neighbourhood. They conclude that an increase in tree cover within a 100-meter buffer around each neighbourhood increases average home sale price in Dakota and Ramsey Counties, Minnesota, US. Some studies combine the distance to nearest open space and the size of nearest open space in order to discuss their joint effects. While classifying open space into greenery area, urban forest, agricultural land and specially protected area, Melichar and Kaprová (2013) find that greenery area has the joint effects on housing prices in Prague, Czech Republic.

Whereas people value living in the vicinity of open space, different types of open space may have different values (Bowman et al., 2012; Farja, 2017; Geoghegan, 2002; Geoghegan et al., 2003; Irwin, 2002; Irwin and Bockstael, 2001; Kling et al., 2015; Netusil, 2013; Xiao et al., 2016). Some types of open space can be considered to be permanent. These areas have preservation or conservation easements, which help protect both market values and nonmarket amenity values. Ownership also matters. Individuals may react differently to public and private open space. Irwin and Bockstael (2001) distinguish open space into three categories: (1) private developable open space including cropland, pasture and forest; (2) private permanent open space with easements; and (3) public open space. They conclude that in four Maryland Counties, private permanent open space is valued most while public open space is valued least. Regarding ownerships, Netusil (2013) estimates the values of public and private open space such as wetland, streams and natural area, in Portland in the US state of Oregon. The study finds that privately owned wetland and stream are valued less than public ones. Similar with Netusil (2013), Kling et al. (2015) conclude that people value public open space including park, natural area and golf course, but do not value privately conserved land in Larimer County, Colorado.

Therefore, studies based on hedonic price model show that open space has external benefits. As land-use policies are closely associated with the maintenance of open space, values of different types of open space will help identify the effects of policies. The hedonic price method will be the basic conceptual model for Chapter 3 and Chapter 4.

2.2. Methodology

2.2.1. Theoretical Foundation for Hedonic Price Model

The key hypothesis of the hedonic price model is that goods are valued for their utility-bearing attributes or characteristics, so the observed price of a product is a combination of implicit prices of different attributes (Rosen, 1974).

The price of a good is determined by supply and demand, so the hedonic price model is discussed at the point that sellers and buyers are in a competitive equilibrium (Bockstael and McConnell, 2007). Assuming there are n measured characteristics z_i $(i = 1, 2, \dots, n)$, for a good z, (Rose 1974) denotes $z = (z_1, z_2, \dots, z_n)$, and the equilibrium price of the good is $P(z) = P(z_1, z_2, \dots, z_n)$, which is defined as the hedonic price function. The hedonic price function is mainly used to reveal information on buyers' preferences over z_i (Braden and Kolstad, 1991; Ready and Abdalla, 2005).

2.2.1.1. Consumer Optimization

Rosen (1974) supposes that a consumer buys one unit of the good z, and x units of a composite good[6]. The consumer's utility function can be expressed as:

$$U = U(x, z_1, z_2, \dots, z_n) \tag{1}$$

where the vector $(z_1, z_2, \dots, z_n)$ is attributes of the good z.

The consumer also has a budget constraint presented as below:

$$I = x + P(z_1, z_2, \dots, z_n) \tag{2}$$

where I is the consumer's income.

Subjected to Equation (2), the consumer chooses x and $(z_1, z_2, \dots, z_n)$ to maximize the utility in Equation (1). The first-order condition requires:

$$\left(\frac{\partial U}{\partial z_i} \Big/ \frac{\partial U}{\partial x}\right) = \frac{\partial P(z)}{\partial z_i} \tag{3}$$

where $i = 1, \dots, n$, and $\frac{\partial P(z)}{\partial z_i}$ is the implicit price of an attribute.

Equation (3) presents that marginal rates of substitution of an attribute and the composite good equals to the implicit price of that attribute, when optimization is satisfied. The implicit price reflects demand and supply interactions in the market and is denoted as a "first stage" hedonic analysis (Bockstael and McConnell, 2007).

In order to relate the implicit price to a consumer's WTP for an attribute, Rosen (1974) put forward a concept of bid function $\theta(z_1, z_2, \dots, z_n; U, I)$, which implies the maximum expenditure a

[6] The price of a composite good is assumed as 1.

consumer is willing to pay for values of $(z_1, z_2, \ldots, z_n)$ at a given utility and income. $\frac{\partial\theta(z_1,z_2,\ldots,z_n;U,I)}{\partial z_i}$ denotes the inverse demand function for z_i. When utility is maximized, the hedonic price function and the bid function are at the point of tangency. Considering that the bid functions vary from one consumer to another as they have different characteristics and incomes, Bateman et al. (2001) point out that the hedonic price function is an upper envelope for optimal bid curves.

$\frac{\partial\theta(z_1,z_2,\ldots,z_n;U,I)}{\partial z_i}$, a consumer's WTP for attribute z_i, is the most accurate welfare measure in this theory (Bockstael and McConnell, 2007). Because households' characteristics such as income and family size are not available in our dataset, we only focus on the "first stage" estimation, which is used as an approximate estimation of the WTP for this specific attribute.

2.2.2. Hedonic Price Model in Real Estate Market

For a single family property, there is a bundle of attributes capitalized into the price, such as structural characteristics, locational attributes, neighbourhood profiles, and environmental amenities (Bin et al., 2009; Boxall et al., 2005). According to the hedonic price function $P(z)$ discussed in Section 2.2.1, the housing prices can thus be specified as:

$$P(z) = P(\boldsymbol{S}, \boldsymbol{L}, \boldsymbol{N}, \boldsymbol{E}) \tag{4a}$$

$$P_i = \beta_0 + \boldsymbol{\beta'_1 S_i} + \boldsymbol{\beta'_2 L_i} + \boldsymbol{\beta'_3 N_i} + \boldsymbol{\beta'_4 E_i} + \varepsilon_i \tag{4b}$$

where Equation (4a) presents the vector of attributes of a house; Equation (4b) is the empirical model with linear specification[7]; subscripts i represents a property; P_i is a housing price; $\boldsymbol{S_i}$ is a vector of structural characteristics, including living area, numbers of bedrooms, numbers of

[7] There are other model specifications commonly used in the literature such as double log and semi-log functional forms.

bathrooms, and size of plot; $\boldsymbol{L_i}$ is a vector of locational attributes, such as distance to employment centers; $\boldsymbol{N_i}$ is a vector of neighbourhood characteristics, including median household income, and levels of education; $\boldsymbol{E_i}$ is a vector of environmental amenities, represented by the amount of different types of open space within a certain buffer[8]; $\boldsymbol{\beta'_1}$, $\boldsymbol{\beta'_2}$, $\boldsymbol{\beta'_3}$, and $\boldsymbol{\beta'_4}$ are vectors of parameters of all attributes; and ε_i is a random error term.

Through the estimation of Equation (4b), we can get the implicit price for an additional unit of a characteristic, thus revealing the approximate WTP for such characteristic.

2.3. Conclusions

Based on survey designs, stated preference methods directly ask participants how much they are willing to pay for a good or service. Differently, revealed preference methods rely on consumers' previous payment behavior (Bockstael and McConnell, 2007; Bowman et al., 2012). The hedonic price model, as one of the revealed preference methods, has been a popular method for valuating non-marketed goods.

Since the land-use policy we are discussing in this thesis, the continuous growth policy, has impacts on the maintenance of open space, understanding the value of open space will help us evaluate this policy. Studies that use hedonic price techniques to reveal values of different types of open space are discussed in Section 2.1. Section 2.2 mainly reviews the theory behind this hedonic price approach. A housing price is decomposed into values of a bundle of attributes

[8] Definitions of environmental amenities will be discussed in detail in Chapter 3.

associated with the house. Under the maximization of a consumer's utility, the implicit price of an attribute can be approximately used as people's WTP for this specific attribute.

As the main conceptual framework for the coming Chapters 3 and 4, the hedonic price model will help identify the effects of the continuous growth policy on property values, and on people's WTPs for different types of open space.

2.4. References

Atreya, A., S. Ferreira, and W. Kriesel. 2013. Forgetting the Flood? An Analysis of the Flood Risk Discount over Time. *Land Economics* 89:577-596.

Bateman, I., B. Day, I. Lake, and A. Lovett. 2001. The Effect of Road Traffic on Residential Property Values: A Literature Review and Hedonic Pricing Study: Scottish Executive.

Bin, O., C.E. Landry, and G.F. Meyer. 2009. Riparian Buffers and Hedonic Prices: A Quasi-Experimental Analysis of Residential Property Values in the Neuse River Basin. *American Journal of Agricultural Economics* 91:1067-1079.

Bockstael, N.E., and K.E. McConnell. 2007. Environmental and Resource Valuation with Revealed Preferences: A Theoretical Guide to Empirical Models: Springer Science and Business Media.

Bowman, T., J.C. Tyndall, J. Thompson, J. Kliebenstein, and J.P. Colletti. 2012. Multiple Approaches to Valuation of Conservation Design and Low-Impact Development Features in Residential Subdivisions. *Journal of Environmental Management* 104:101-113.

Boxall, P.C., W.H. Chan, and M.L. McMillan. 2005. The Impact of Oil and Natural Gas Facilities on Rural Residential Property Values: A Spatial Hedonic Analysis. *Resource and Energy Economics* 27:248-269.

Braden, J.B., and C.D. Kolstad. 1991. Measuring the Demand for Environmental Quality: Elsevier Science Pub. Co.

Cho, S.-H., S.G. Kim, and R.K. Roberts. 2011. Values of Environmental Landscape Amenities during the 2000-2006 Real Estate Boom and Subsequent 2008 Recession. *Journal of Environmental Planning and Management* 54:71-91.

Dekkers, J.E.C., and J.W.v.d. Straaten. 2009. Monetary Valuation of Aircraft Noise: A Hedonic Analysis around Amsterdam Airport. *Ecological Economics* 68:2850-2858.

Farja, Y. 2017. Price and Distributional Effects of Privately Provided Open Space in Urban Areas. *Landscape research* 42:543-557.

Fernandez, L., B. Cutter, R. Sharma, and T. Scott. 2018. Land Preservation Policy Effect or Neighborhood Dynamics: A Repeat Sales Hedonic Matching Approach. *Journal of Environmental Economics and Management*.

Franco, S.F., and J.L. Macdonald. 2017. Measurement and Valuation of Urban Greenness: Remote Sensing and Hedonic Applications to Lisbon, Portugal. *Regional Science and Urban Economics*.

Geoghegan, J. 2002. The Value of Open Space in Residential Land Use. *Land Use Policy* 19:91-98.

Geoghegan, J., L. Lynch, and S. Bucholtz. 2003. Capitalization of Open Spaces into Housing Values. *Agricultural and Resource Economics Review* 32:33-45.

Irwin, E.G. 2002. The Effects of Open Space on Residential Property Values. *Land Economics* 78:465-480.

Irwin, E.G., and N.E. Bockstael. 2001. The Problem of Indentifying Land Use Spillovers: Measuring the Effects of Open Space in Residential Property Values. *American Journal of Agricultural Economics* 83:698-704.

Kim, C.W., T.T. Phipps, and L. Anselin. 2003. Measuring the Benefits of Air Quality Improvement: A Spatial Hedonic Approach. *Journal of Environmental Economics and Management* 45:24-39.

Kling, R.W., T.S. Findley, E. Gahramanov, and D.M. Theobald. 2015. Hedonic Valuation of Land Protection Methods: Implications for Cluster Development. *Journal of Economics and Finance* 39:782-806.

Lansford, N.H., and L.L. Jones. 1995. Recreational and Aesthetic Value of Water Using Hedonic Price Analysis. *Journal of Agricultural and Resource Economics* 20:341-355.

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

Mahmoudi, P., D. Hatton MacDonald, N.D. Crossman, D.M. Summers, and J. Van der Hoek. 2013. Space Matters: The Importance of Amenity in Planning Metropolitan Growth. *Australian Journal of Agricultural and Resource Economics* 57:38-59.

McConnell, V., and M. Walls. 2005. The Value of Open Space: Evidence from Studies of Nonmarket Benefits: Resources for the Future Washington, DC.

Melichar, J., and K. Kaprová. 2013. Revealing Preferences of Prague's Homebuyers toward Greenery Amenities: The Empirical Evidence of Distance-Size Effect. *Landscape and Urban Planning* 109:56-66.

Netusil, N.R. 2013. Urban Environmental Amenities and Property Values: Does Ownership Matter? *Land Use Policy* 31:371-377.

Ottensmann, J.R., S. Payton, and J. Man. 2008. Urban Location and Housing Prices within a Hedonic Model. *The Journal of Regional Analysis and Policy* 38:19-35.

Ready, R.C., and C.W. Abdalla. 2005. The Amenity and Disamenity Impacts of Agriculture: Estimates from a Hedonic Pricing Model. *American Journal of Agricultural Economics* 87:314-326.

Rosen, S. 1974. Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition. *Journal of Political Economy* 82:34-35.

Sander, H., S. Polasky, and R.G. Haight. 2010. The Value of Urban Tree Cover: A Hedonic Property Price Model in Ramsey and Dakota Counties, Minnesota, USA. *Ecological Economics* 69:1646-1656.

Schläpfer, F., F. Waltert, L. Segura, and F. Kienast. 2015. Valuation of Landscape Amenities: A Hedonic Pricing Analysis of Housing Rents in Urban, Suburban and Periurban Switzerland. *Landscape and Urban Planning* 141:24-40.

Xiao, Y., Z. Li, and C. Webster. 2016. Estimating the Mediating Effect of Privately-Supplied Green Space on the Relationship between Urban Public Green Space and Property Value: Evidence from Shanghai, China. *Land Use Policy* 54:439-447.

Yoo, S., and J.E. Wagner. 2016. A Review of the Hedonic Literatures in Environmental Amenities from Open Space: A Traditional Econometric vs. Spatial Econometric Model. *International Journal of Urban Sciences* 20:141-166.

Yusuf, A.A., and B.P. Resosudarmo. 2009. Does Clean Air Matter in Developing Countries' Megacities? A Hedonic Price Analysis of the Jakarta Housing Market, Indonesia. *Ecological Economics* 68:1398-1407.

Chapter 3. Does a Municipal Development Policy Affect Property Values? A Spatial Quasi-Experimental Hedonic Model Approach

3.1. Introduction

Conversion of open space into developed uses will not only reduce amenities provided by the land, but also bring nuisance effects, such as traffic and noise due to construction. Those outcomes can have negative impacts on residential property values (Boennec and Salladarré, 2017; Bolitzer and Netusil, 2000). Therefore, while buying a house, individuals tend to consider both current land uses and land-use designation policies. In other words, both current land uses and land-use regulations may influence housing prices.

A few previous studies have attempted to capture effects of policies on property values by incorporating the difference-in-difference (DID) technique, a quasi-experimental method, into a hedonic price model. Bin et al. (2009) use this approach to investigate the effects of a riparian buffer area rule on property values in the state of North Carolina, US. They find no effects and thus no WTP for the buffer area policy. Heintzelman (2010) estimates whether housing prices are affected by the Community Protection Act in the U.S. state of Massachusetts. They use the DID approach to target towns which are influenced after the implementation of the policy. Results indicate that it has no impacts on property values in the short run. No Kim et al. (2016) focus on waterfront properties that may be affected after the announcement of a water management agreement for the Chestermere Lake in Alberta. They conclude that this agreement results in an increase in house prices in the adjacent urban area.

It is very common in a real estate market that nearby dwelling prices are spatially dependent, in view of the influences of common culture, policies, facilities, and recreational amenities. Spatial effects may exist and lead to inefficiency and bias problems in hedonic price models (Anselin and Bera, 1998; Asabere, 2014; Geoghegan et al., 2003; Irwin, 2002; Irwin and Bockstael, 2001). Whereas considering neighbourhood and time fixed effects in hedonic price models can reduce spatial correlation (Abbott and Klaiber, 2011; No Kim et al., 2016; Schläpfer et al., 2015), it causes a same relationship within a neighbourhood but sharp artificial geographic breaks among neighbourhoods (Bockstael, 1996; Gnagey and Grijalva, 2018). A solution for this problem is modeling the correlation directly in spatial models (Anselin and Bera, 1998). For example, Geoghegan et al. (2003) use a spatial error model (SEM) to estimate the values of permanent open space in three Counties in the US state of Maryland. They illustrate that spatial autocorrelation in erro terms will result in inefficient coefficients. Regarding that other homebuyers' decision will influence a homebuyer's decision, Anselin and Lozano-Gracia (2008) adopt a spatial lag model (SLM) to reduce the spatial autocorrelation. Münch et al. (2016) justify that property values are dependent because of observed characteristics such as nearby environmental amenities, and unobserved characteristics, thereby they include spatial lags of dependent and independent variables into the hedonic price model.

However, to our knowledge, few if any prior studies on policies have incorporated a quasi-experimental method into a spatial hedonic framework. Ignoring spatial interactions and spillovers can result in biased WTP estimation thus misleading policy recommendations. Based on residential property values from 2010 to 2017 around the Town of Okotoks, Alberta, we use DID in a spatial hedonic pricing model to capture the effects of the continuous growth policy on housing prices, in other words, to reveal people's WTP for such a policy. The estimation utilizes the spatial two-stage least squares regression technique that further allows for heteroscedasticity and autocorrelation consistent (HAC) standard errors. Direct impacts as well as spillover impacts are estimated.

This chapter has several contributions to the field of valuation under a hedonic price model. Firstly, as we mentioned above, a quasi-experimental method and a spatial hedonic price model are combined. Without the spatial modeling, coefficients may be biased and inefficient. Without the quasi-experimental design, the findings of policy effects may be misleading. Secondly, we decompose the marginal effects into direct and indirect components, which enables us to measure the spillovers of each attribute on nearby property values directly. The decomposition has only been discussed in a few studies (Mitra and Saphores, 2016; Singh et al., 2018). Ignoring the indirect impacts would result in an incorrect (often underestimated) WTP estimates.

The reminder of this chapter is as follows. In Section 3.2, the DID method and two different spatial models are presented. At the beginning of Section 3.3, we present descriptive statistics for all data, explain the choice of an appropriate functional form and perform diagnostic tests to choose between the spatial lag and spatial error models. Next, estimation results without and with the DID variable are discussed. Section 3.4 estimates people's WTP for open space and most importantly, the WTP for this continuous growth policy. Section 3.5 concludes this paper.

3.2. Methodology

3.2.1. Difference-in-Difference Method

Because of the presence of measurement error, omitted explanatory variables and sample selection from a non-randomized population, estimations may be biased. In order to control for unobserved factors, we can use an experimental or quasi-experimental approach (Greenstone and Gayer, 2009). However, it is difficult to perform a randomization in a real estate market. Usually researchers attempt to use different quasi-experiments to figure out a counterfactual, then identify the causal impact of a change.

DID is one of the quasi-experimental approaches (Atreya et al., 2013). It includes one assignment, two groups and at least two periods. Treatment and control groups have a common trend before the assignment, which is also called the first period. Then in the second period, only participants will receive the treatment. The effect of treatment on outcomes is expressed as:

$$ATE = \{E[y_{11}] - E[y_{10}]\} - \{E[y_{01}] - E[y_{00}]\} \tag{1}$$

where ATE is the average treatment effect; $E[y_{11}] - E[y_{10}]$ is the difference of outcomes for the treatment group; $E[y_{01}] - E[y_{00}]$ is the difference of outcomes for the control group.

3.2.2. Spatial Effects and Spatial Econometric Models

An ordinary linear regression model assumes that all observations are not correlated with each other. The error terms are homoscedastic and independent. Specifically, if observations are independent, explanatory variables of observation i have no influence on the dependent variables of observation j. However, spatial econometrics is performed when observations are spatially dependent with each other (LeSage and Pace, 2009). The spatial dependence is very common in a real estate market. For example, a well-maintained landscape around a house can potentially add values to other nearby properties because of the amenities.

3.2.2.1. Spatial Lag Model (SLM)

The spatial lag model presents only the endogenous interaction effects among dependent variables. The model with interaction effects is shown in Equations (2) and (3).

$$Y = \rho WY + \alpha\iota + X\beta + \varepsilon \tag{2}$$

$$Y = (I_n - \rho W)^{-1}\alpha\iota + (I_n - \rho W)^{-1}X\beta + (I_n - \rho W)^{-1}\varepsilon \tag{3}$$

where Y is an $(n \times 1)$ vector of observations; X is an $(n \times k)$ matrix of explanatory variables; $\alpha\iota$ is an $(n \times 1)$ vector of constant terms; W is an $(n \times n)$ spatial weights matrix; ε is an $(n \times 1)$ vector of error terms; ρ is a spatial autoregressive coefficient; β is a coefficient vector; and WY denotes the endogenous interaction effects (LeSage and Pace, 2009).

3.2.2.2. Spatial Error Model (SEM)

The spatial error model allows interaction effects among disturbance terms. Each observation is spatially dependent on unobservable neighbouring characteristics. The model is expressed in Equation (4), (5) and (6):

$$Y = \alpha\iota + X\beta + u \tag{4}$$

$$u = \lambda Wu + \varepsilon \tag{5}$$

$$\varepsilon \sim N(0, \sigma^2 I_n) \tag{6}$$

where u is an $(n \times 1)$ vectors of error terms; λ is a spatial autocorrelation coefficient; ε is a white noise vector and Wu is the interaction effects among the disturbances (LeSage and Pace, 2009).

3.2.2.3. Spatial Weights Matrix

The spatial weights matrix W is very important in spatial models. It illustrates spatial relations between n observations. Specifically, w_{ij} reflects the spatial influence of observation j on observation i. We consider two spatial weight matrices in this paper (Anselin, 2002).

(1) k-Nearest Neighbour Weights

According to the distances from observation i to other observations, we can figure out k closest observations to i, which are denoted as $N_k(i) = \{j(1), \dots, j(k)\}$. Those observations have spatial correlations with observation i. The spatial weight matrix is presented as:

$$w_{ij} = \begin{cases} 1, & j \in N_k(i) \\ 0, & otherwise \end{cases}$$

(2) Radial Distance Weights

It is also called distance band weights. d is a bandwidth. If the spatial distance from observation i to j is not more than the bandwidth, there is a spatial influence. This spatial weight matrix is shown as below:

$$w_{ij} = \begin{cases} 1, & 0 \le d_{ij} \le d \\ 0, & d_{ij} > d \end{cases}$$

After defining the spatial weight matrix, researchers usually normalize W, which means the elements of each row sum to one.

3.2.2.4. Marginal Effects

Under an OLS estimation, the marginal effect of an independent variable r on the dependent variable can be specified as $\frac{\partial y_i}{\partial x_{ir}} = \beta_r$, for observation i. The assumption of independence of observations implies there is no indirect impacts on another observation j, so $\frac{\partial y_j}{\partial x_{ir}} = 0$.

However, the interpretation becomes complicated if the model contains spatial lags of the dependent variable (LeSage and Pace, 2009). We take SLM model in Equation (3) as an example.

$$V(W) = (I_n - \rho W)^{-1} = I_n + \rho W + \rho^2 W^2 + \rho^3 W^3 + \cdots \tag{7}$$

$$Y = V(W)(X\beta + \alpha\iota + \varepsilon) \tag{8}$$

where $V(W) = \begin{pmatrix} V_{11} & \cdots & V_{1n} \\ \vdots & \ddots & \vdots \\ V_{n1} & \cdots & V_{nn} \end{pmatrix}$.

Now for each variable r, we have $\frac{\partial y_i}{\partial x_{ir}} = V_{ii}\beta_r$, and $\frac{\partial y_j}{\partial x_{ir}} = V_{ji}\beta_r$. A change in an independent variable for an i^{th} observation may influence the dependent variables of all other observations. Therefore, there are three different measures of impact on the dependent variable.

(1) The average direct impacts: average changes in i^{th} observation arising from changes of x_{ir};

(2) The average indirect impacts: average changes over all other observations arising from changes of x_{ir}. It is also called spatial spillover effects;

(3) The average total impacts: average changes over all n observations arising from changes of x_{ir}.

3.2.3. Estimation of Spatial Models

If spatial dependence is present in the dependent variable itself, an OLS estimator will be biased. If it is in the unobserved residuals, an OLS estimator will still be unbiased but inefficient (Anselin and Bera, 1998). In this case, the inference drawn from the model estimation and statistic tests becomes inaccurate. This section discusses how a spatial two-stage least squares regression can be used to generate efficient and consistent estimates.

The spatial model is still assumed to follow a general process as:

$$Y = \rho WY + \alpha\iota + X\beta + u \tag{9}$$

$$Y = Z\gamma + u \tag{10}$$

where W is an $(n \times n)$ spatial weights matrix; $Z = (WY, \iota, X)$; and $\gamma' = (\rho, \beta', \alpha')$.

The spatial model in Equation (9) suggests there is endogeneity because of the spatially lagged dependent variable WY. The dependent variable Y is correlated with the disturbances so that OLS estimations would be biased. Endogeneity can be eliminated by a spatial two-stage least squares (S2SLS) approach (Anselin and Lozano-Gracia, 2008; Kelejian and Prucha, 2007). In particular, the S2SLS estimation defines $H = (X, WX, W^2X^2)$ as a non-stochastic matrix of instruments for WY. The predicted value of WY is expressed as $H(H'H)^{-1}H'WY$. Denoting $\hat{Z} = (H(H'H)^{-1}H'WY, \iota, X)$, the S2SLS estimates for γ are presented as below:

$$\hat{\gamma}_{s2sls} = (\hat{Z}'\hat{Z})^{-1}\hat{Z}'Y \tag{11}$$

Moreover, the spatial error autocorrelation is an unspecified form (Anselin and Lozano-Gracia, 2008). Disturbances may be heteroskedastic or correlated with each other. It assumes the error terms are generated as follows:

$$u = R\varepsilon \tag{12}$$

where ε is a white noise vector; and R is an $(n \times n)$ non-stochastic matrix whose elements are unknown (Kelejian and Prucha, 2007).

Regarding the characteristics of the error term, Kelejian and Prucha (2007) develop the heteroskedastic and autocorrelation robust approach and incorporate it into the S2SLS estimates. This estimation method ensures efficiency and asymptotical consistency of coefficients.

3.3. Data and Results

3.3.1. Data Description

Our study aims to reveal people's WTP for the continuous growth policy. We assume that the policy affects the value for single family houses in the town jurisdiction, and in the wider community of people who visit and use services in Okotoks. In order to capture spatial dependence among the price of dwellings, and meanwhile guarantee an adequate sample of rural residential properties, we define the study area to include the 4 townships around Okotoks and 2 km buffers around these townships. The total study area is around 576 km^2. It is shown as in Figure 3.1.

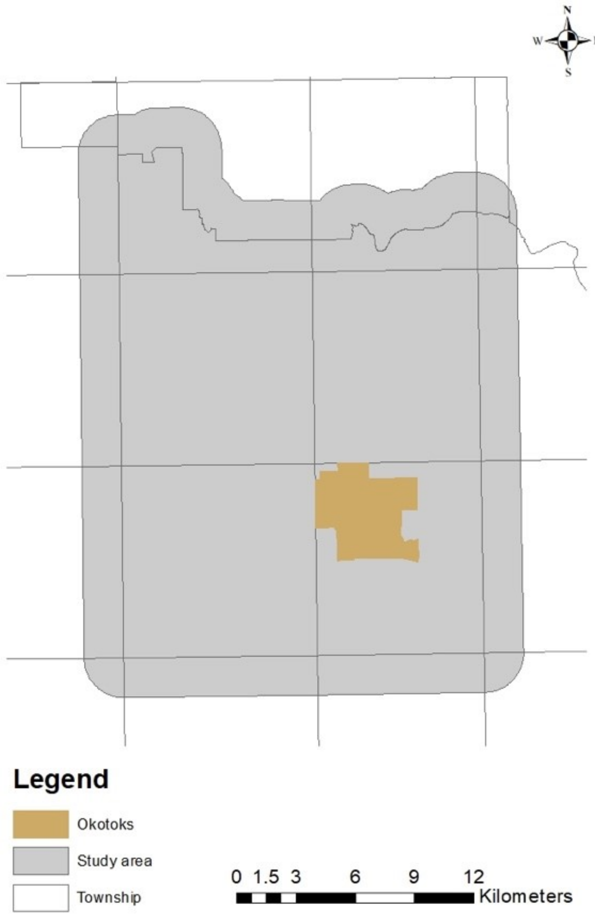


Figure 3.1. Map of the Study Area

Arms-length transaction data for single-family residential properties is provided by the Brookfield Real Property Solutions (RPS), which is a leading provider of residential real estate valuation in Canada owned by Brookfield Asset Management[9]. Its housing transaction data covers lots of urban and rural area across the nation[10]. Although we have access to data from previous years, we choose 2010 as our starting year. The 2008 global financial crisis affected the real estate markets across

[9] See the description of Brookfield RPS on its website: https://www.rpsrealsolutions.com.

[10] Taking the City of Calgary as an example, Brookfield RPS covers about 50% of all Calgary Real Estate Board (CREB) recorded sales (17,797) in 2016 (See the number of residential property transactions on CREB: http://www.creb.com/Housing_Statistics/Daily_Housing_Summary/).

Canada. Figure 3.2 presents housing price changes in Canada, showing the dramatic drop from 2008 to 2009. What's more, the oil and gas sector has a major contribution to the economy of Alberta. It accounted for 36.1% of provincial GDP in 1985[11], and still represented 17% of provincial GDP in 2016 (Government of Alberta, 2017c). Having the third largest petroleum reserves in the world, Alberta produced 81% of Canada's crude oil in 2016 (Government of Alberta, 2017c). There was an oil price crash between 2008 and 2009. The sharp decreasing price of oil shown in Figure 3.3 influenced the economy and thus the real estate market.

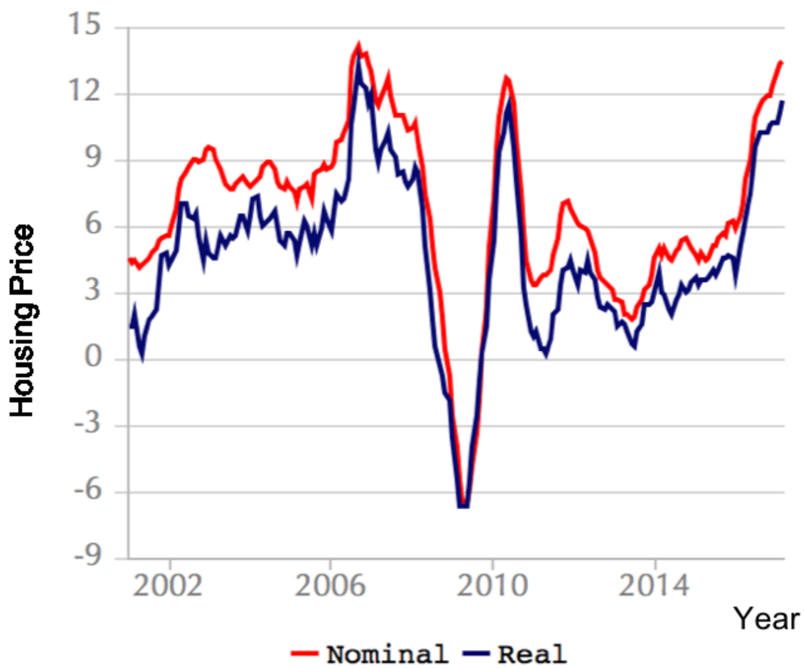


Figure 3.2. Housing Price Change in Canada

Source: (*Global Property Guide*[12])

[11] Source: https://en.wikipedia.org/wiki/Economy_of_Alberta. Accessed on March 22, 2018.
[12] Source: https://www.globalpropertyguide.com/real-estate-house-prices/C#canada). Accessed on February 28, 2018.

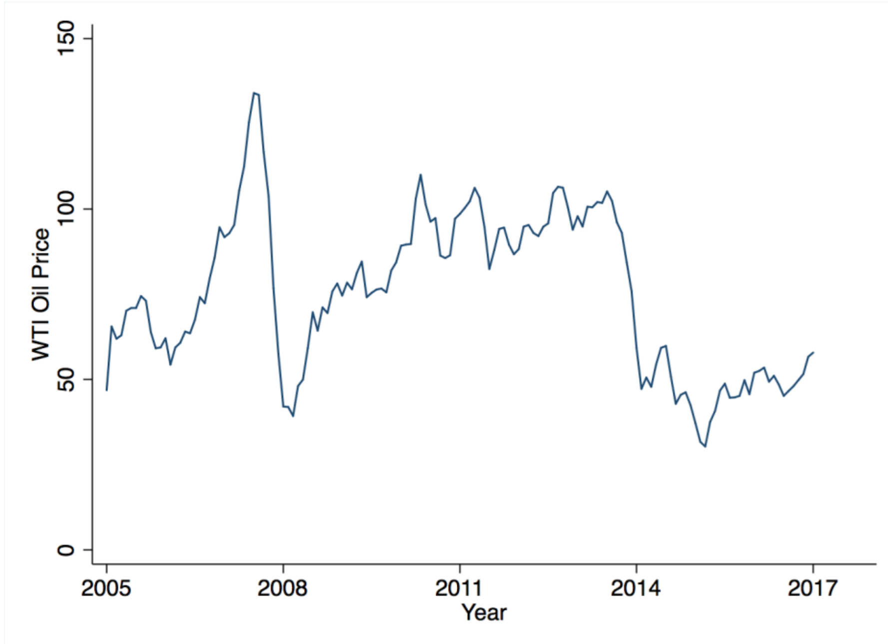


Figure 3.3. The West Texas Intermediate (WTI) Price of Oil ($US/bbl) between 2005 and 2017

Data Source: (*Government of Alberta, 2018*)

After dropping observations with missing values, updating longitude and latitude information which is not matched with address, and choosing the most recent sale prices for properties having more than one transactions during the period, we finally arrive at a sample of 1,426 observations from 2010 to 2017. Using the Alberta Consumer Price Index (CPI), sales prices are adjusted to constant 2016 Canadian dollars. Figure 3.4 displays the spatial distribution of real property values in our study area. Houses close to Calgary, or located in rural areas generally have higher prices than those in the town overall.

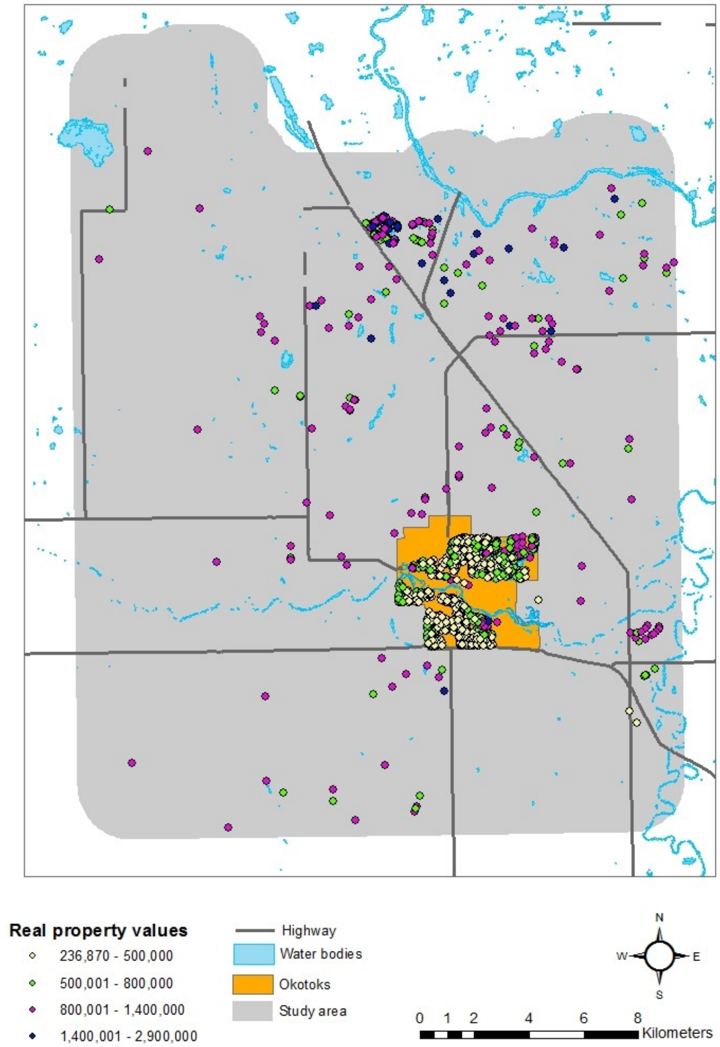


Figure 3.4. Map of Spatial Distribution of Housing Sales Price in the Study Area

Data Source: (*Brookfield Real Property Solutions*)

Regarding the hedonic price model, we need data on housing characteristics in order to estimate individuals' WTP for those characteristics. These include variables on structural, locational, and neighbourhood characteristics and environmental amenities. Table 3.1 summarizes all those variables that we use in this study.

Structural variables are mainly obtained from the original dataset. The original data from the Brookfield RPS includes nominal sales prices and some structural information for each property, such as the square feet of living area and lot size, number of bathrooms, bedrooms and garages, and the year that it was sold.

Locational variables are generated by ArcGIS. The City of Calgary is 18 kilometers north of the Town of Okotoks. Calgary is the third-largest city in Canada and the largest in Alberta. Private companies are involved in energy, agriculture, transportations and financial services. Consequently, distance to the downtown of Calgary represents the distance to a major employment center[13] (Geoghegan et al., 2003). Since our sample is about a town and its surrounding rural area, the number of hospitals is limited. It is more reasonable to calculate the distance from the property to the nearest hospital or medical clinic. Moreover, we consider proximity to the nearest water features. Since water features provide scenic views and recreational opportunities, researchers believe that people are willing to pay more for a house closer to water bodies (Bin et al., 2009; Leggett and Bockstael, 2000).

School quality is also an important element for homebuyers. The study area belongs to the Foothills School Division No.38. Each observation is located in a specific school block. In this division, the blocks only differ in the available elementary schools. Based on average school quality scores available through the Fraser Institute[14], we find scores ranged from 5.70 to 7.16 out of a maximum

[13] Distance to Calgary and distance to the nearest hospital were generated under the road network data from CanMap Content Suite.
[14] The school quality scores were obtained through the Fraser Institute website: http://alberta.compareschoolrankings.org/elementary/SchoolsByRankLocationName.aspx. Accessed on February 28, 2018.

score of 10.00. Therefore, an elementary school with a score higher than average (6.43) is defined as high quality.

Housing prices are always influenced by their neighbourhoods. Our neighbourhood data is based on 2011 census tracts from Statistics Canada at the "Dissemination Area" (DA) level. Most researchers measure population density by using the area of all types of land in a neighbourhood (Ihlanfeldt and Taylor, 2004; Stoms et al., 2009). Considering that people only live on developed lands, density based on developed lands can better reflect the effect of housing density. Meanwhile, we adjust the median household income to 2016 dollars by the Alberta CPI. We capture abnormally low and abnormally high income through two binary variables[15]. The education level in each DA also matters. Researchers postulate that the more people with college education, the higher housing prices in a neighbourhood (Borchers and Duke, 2012; Geoghegan et al., 2003). In terms of highest education, percentage with high school certificates and percentage with postsecondary certificates are included in our analysis. We also assume that the employment rate in a neighbourhood affects housing prices. Employment rate captures economic conditions in the area (Cho et al., 2008).

Open spaces have potential influences on dwelling prices. Based on the 30-meter resolution land-use and land-cover raster image in 2016 from Agriculture and Agri-Food Canada, we obtain different categories of open space in the study area. According to prior studies of the effects of open spaces on housing prices, we distinguished all open spaces into five categories: parks, forests, pastures, croplands, and grasslands. Following City of Calgary (2002), we assume residents can

[15] We use interquartile range (IQR), which is the income value of the third quantile minus the income value of the first quantile. We set low income equal to 1 if income is less than the value of the first quantile minus 3 times IQR, and high income equal to 1 if income is greater than the value of the third quantile plus 3 times IQR (Brown and Wetherill, 1990).

easily get access to open space opportunities if such open spaces are within 450 meters or a five-minute walk from their home. In terms of sizes of open space, we try 100-meter, 200-meter, 300-meter and 400-meter rings within the 450 meter radius under separate S2SLS regressions in order to evaluate the buffer within which people value open spaces (Geoghegan et al., 1997; Irwin, 2002; Irwin and Bockstael, 2001; Yoo et al., 2017). Finally, we choose a 200-meter buffer surrounding each property as the threshold, and define acres of different types of open space within each 200-meter buffer as open space variables[16].

We also include a variable reflecting season. There are two concerns. Property transactions in summer may be more than in other seasons due to the Canadian school schedule. What's more, people always experience a long and severe winter in Canada. Spending time outdoors in summer becomes more comfortable and valuable, so they may be more likely to look for a house in summer. Hence, we add a dummy variable for season to this study. In order to capture the time fixed effects, dummies for each year were also included.

Table 3.1 provides summary data for the variables included in the model. It is worth noting that the mean house price in this area ($CAD 600,205) was 9.5% higher than the mean home price in Calgary in 2016 ($CAD 548,095) (Calgary Real Estate Board, 2018).

Table 3.1. Descriptive Statistics for Variables Included in the Okotoks Hedonic Price Model

Variables	Definition	Min	Mean	Max	Std.Dev.

[16] Coefficients of open spaces within 100-meter and 200-meter buffers are significant, while those within 300-meter and 400-meter buffers are not, so the 200 meter is the threshold that people may value open spaces.

Sales price	House transaction price (2016$ CAD)	236,870	600,205	2,900,000	300,078
Structural variables					
Living area	Square feet of living space	703	1,964	6,588	651
Lot size	Square feet of lands owned by a household	376	25,327	431,244	60,766
Condition	1 if the condition of the house is "excellent" or "good", 0 otherwise	0	0.8331	1	0.3730
Basement	1 if the basement is "finished", 0 otherwise	0	0.6227	1	0.4849
Bathroom	Number of bathrooms	0	2.7970	6	0.7228
Bedroom	Number of bedrooms	1	2.8100	6	0.7339
Garage	Number of garages	0	2.0370	5	0.7384
Age	Age of the house	0	10.9000	108	11.8465
Locational variables					
Calgary	Distance to the downtown of Calgary (meters)	23,156	37,928	48,850	4,447
Hospital	Distance to nearest hospital or clinic (meters)	210	3,066	15,656	2,923
Water[17]	Euclidean distance to nearest water feature (meters)	135	591	3,710	494
School quality	1 if the quality index of elementary school in public school neighbourhood is greater than 6.43, 0 otherwise	0	0.5428	1	0.4983
Neighbourhood variables					
Density	Population/acres of developed lands in each DA	0.3843	9.5741	18.3768	4.8443

[17] According to Agriculture and Agri-Food Canada (2016), water is defined as types of water bodies, such as lakes, reservoirs, rivers, streams.

% of high school certificate	Percentage of people aged 15 years old or over with high school certificate or equivalent in each DA	18.2900	28.1600	62.0000	5.5800
% of postsecondary education	Percentage of people aged 15 years old or over with postsecondary certificate in each DA	24	57.4800	65.2500	6.1100
Employment rate	Employment rate of people aged 15 years old or over in each DA	52.8000	72.3000	86.9000	5.5300
Low median household income	1 if the median household income is less than 79,979.56 in each DA, 0 otherwise (2016 $CAD)	0	0.0750	1	0.2635
High median household income	1 if the median household income is greater than 149,030.73 in each DA, 0 otherwise (2016 $CAD)	0	0.0470	1	0.2117
Open space variables					
Forest	Acres of forests within a 200-meter buffer	0	0.3211	10.2724	0.9603
Pasture	Acres of pastures within a 200-meter buffer	0	0.0507	4.5322	0.2924
Cropland	Acres of croplands within a 200-meter buffer	0	0.9166	22.1362	2.6009
Grassland	Acres of grasslands within a 200-meter buffer	0	2.5083	23.6633	4.5041
Park	Acres of parks within a 200-meter buffer	0	3.5061	18.3504	3.5149
Season	1 if the house is sold between April and September, 0 otherwise	0	0.5947	1	0.4911
N	1426				

3.3.2. Model Specification

It is important to choose an appropriate functional form for the estimation. In order to determine which functional form provides the best fit, we run OLS estimations based on four different functional forms in Appendix C. Comparing R^2 and adjusted R^2, as well as following prior studies, we choose the double log functional form to have the best fit, according to Appendix C (Atreya et al., 2013; Tyrvainen, 2000). The hedonic pricing model is defined as:

$$\ln(P_{it}) = \beta_0 + \boldsymbol{\beta}_1' \ln \boldsymbol{X}_{it} + \boldsymbol{\beta}_2' \boldsymbol{D}_{it} + \theta_t + \varepsilon_{it} \tag{13}$$

Where P_{it} is the property sales price; $\boldsymbol{X}_{it}$ is a vector of non-zero variables and $\boldsymbol{D}_{it}$ is a vector of variables with zero values; and θ_t denotes time fixed effects.

3.3.3. Diagnostic Tests

Since all observations are spatially distributed, they may be correlated with each other. Following the literature, we use the Moran's I test on the residuals of an OLS estimation, to check whether spatial dependence is present or not (Anselin, 2001; Paterson and Boyle, 2002).

We take an empirical approach to define the spatial weight matrix. We consider both radial distance and nearest neighbour criteria and select on the basis of goodness-of-fit. Following this, the spatial weight matrix is defined by the 2 nearest neighbours. Moran's I test in Table 3.2 identifies that spatial autocorrelation does indeed exist. Moreover, the Lagrange Multiplier (LM) test is used to choose between SLM and SEM (Mei et al., 2017). Table 3.3 suggests that the SLM model is better because its LM statistic is much larger than for the SEM model.

Table 3.2. Moran's I Test for Spatial Dependence

Moran's I statistic	Standard deviate	*P* value
0.2221	9.5469	2.2e-16

Table 3.3. Lagrange Multiplier Tests for Choosing between SLM and SEM

	Statistic	*P* value
LM spatial lag	98.371	2.2e-16
LM spatial error	81.873	2.2e-16
Robust LM spatial lag	25.258	1.781e-07
Robust LM spatial error	10.759	0.001038

3.3.4. Results without DID Variable

We begin by estimating the spatial lag model using a S2SLS with HAC estimators without accounting for the policy treatment in Table 3.4. In order to correctly interpret the effects of explanatory variables on the dependent variable, results are based on Section 3.2.2.4. Table 3.4 suggests that the spatial autoregressive coefficient is significantly less than 0.2.

Average impacts of forest are significantly positive. For a property, one more acre of forest within a 200-meter buffer raises its price by 0.89%, and it also increases prices of other properties that are in our study area by 0.16%. Increasing an acre of pasture for a dwelling, all dwelling prices would go up by 3.10% on average. However, the amount of park within the 200-meter buffer has no effects on housing prices. Compared to parks, open space such as pasture and forest not only provide wild views, but also can provide wildlife habitats and promote biodiversity. Since urban residents get limited accesses to those natural settings, they may be more valuable than parks.

In terms of structural characteristics, an increase of 1% square feet of living area for a property raises all property values. The larger the lot size of a property, the higher its price and other dwelling prices. For condition and basement dummies, a property with an “excellent” or “good” condition, as well as a finished basement increase all property prices. Significantly negative direct, indirect and total impacts of age imply that as a house gets older, its own price and other property prices decline. All impacts of bathroom and bedroom are significantly negative, which suggest that holding the area of residence constant, increasing numbers of bathrooms or bedrooms would reduce areas for each room. In this case, housing prices decrease.

If a property is located further away from the downtown of Calgary, its own price and all other property prices would be reduced. People want to live close to the city of Calgary due to the convenience of access to work in the city. This partly explains the intense development of rural residential properties between Okotoks and Calgary. Distances to hospital have significantly positive influences on housing prices. That a house close to a hospital or a medical clinic has a lower price may indicate a concern about traffic volumes in those areas. Meanwhile, people value water. In close proximity to water bodies, a property has a higher price, which also raises other dwelling prices. This is because of the recreational and aesthetic values of water (Lansford and Jones, 1995).

Except for density, other neighbourhood attributes are not significant. Higher population density in a neighbourhood decreases its housing prices as well as other housing values in other neighbourhoods. Since population density can measure congestion, its effects are negative (Geoghegan et al., 2003).

Positive impacts of season mean that if a house is sold between April and September, its price would increase, so would other housing prices.

Except for the S2SLS regression, an OLS and a maximum likelihood estimation for the spatial lag model are also presented in Appendix D and Appendix E, respectively. Estimators of OLS are biased, while the maximum likelihood estimation indicates that the results of S2SLS are robust.

Table 3.4. Estimation Results of a S2SLS without Accounting for the Policy Treatment

Variables	Direct Impact	Indirect Impact	Total Impact
Forest	0.0089**	0.0016*	0.0105**
	(2.3932)	(1.7544)	(2.3076)
Pasture	0.0265**	0.0045*	0.0310**
	(1.9487)	(1.8316)	(1.9682)
Cropland	-0.0020	-3e-04	-0.0023
	(-1.3385)	(-1.3389)	(-1.3545)
Grassland	-0.0013	-2e-04	-0.0016
	(-0.818)	(-0.8051)	(-0.821)
Park	4e-04	1e-04	5e-04
	(0.499)	(0.4504)	(0.4941)
Log (living area)	0.6858***	0.1179***	0.8037***
	(12.752)	(4.7437)	(17.1698)
Log (lot size)	0.0765***	0.0137***	0.0901***
	(8.4717)	(2.8128)	(6.6547)
Condition (1/0)	0.0430***	0.0078***	0.0508***

	(3.2264)	(2.0394)	(3.0284)
Basement (1/0)	0.1031***	0.0179***	0.1210***
	(14.7357)	(3.8474)	(13.4504)
Bathroom	-0.0386***	-0.0067***	-0.0454***
	(-8.2533)	(-3.5555)	(-7.9587)
Bedroom	-0.0835***	-0.0145***	-0.0980***
	(-10.9803)	(-3.8634)	(-10.7764)
Garage	0.0421***	0.0078***	0.0499***
	(2.7841)	(1.827)	(2.6123)
Age	-0.002***	-3e-04***	-0.0023***
	(-3.1078)	(-3.5829)	(-3.3169)
Log (Calgary)	-0.2998***	-0.0508***	-0.3506***
	(-5.2818)	(-4.4217)	(-5.8231)
Log (hospital)	0.0216***	0.0037***	0.0253***
	(3.936)	(2.8155)	(3.9343)
Log (water)	-0.0224**	-0.0035**	-0.026**
	(-2.0617)	(-2.4579)	(-2.1499)
School quality (1/0)	-0.0093	-0.0017	-0.0109
	(-0.6979)	(-0.6813)	(-0.6993)
Log (density)	-0.0283**	-0.0045***	-0.0327**
	(-2.2781)	(-2.9796)	(-2.4069)
% of high school certificate	7e-04	1e-04	8e-04
	(0.7755)	(0.7275)	(0.7732)
% of postsecondary education	0.0000	0.0000	0.0000
	(-0.0336)	(0.0405)	(-0.0224)
Employment rate	0.0013	2e-04	0.0015
	(1.1475)	(1.0895)	(1.151)
Low median household income (1/0)	0.0073	9e-04	0.0083
	(0.3608)	(0.2586)	(0.3472)
High median household income (1/0)	-0.0290	-0.0060	-0.0350
	(-1.0044)	(-0.9471)	(-1.0011)

Season	0.0162*	0.0030	0.0192*
	(1.8105)	(1.4397)	(1.7618)
	0.1535		
ρ	0.15348***		

Note: ***, **, and * denotes significance level at 10%, 5% and 1%;
z-values are in parentheses.

3.3.5. Results with DID Variable

In order to figure out effects of the policy change in the Town of Okotoks, we add a policy treatment, and choose appropriate treatment as well as control groups.

As mentioned in Chapter 1, Okotoks implements a finite growth policy in 1998 to protect the natural open space system while keeping the population between 25,000-30,000 within the town's boundaries. But in September 2012, the Okotoks town council relaxed the policy to one of continuous growth to allow more development within and beyond existing boundaries. We assume that the more recent policy change will intensify the exploitation of developable open space. As discussed before, we try different buffers within walkable distances, and only can conclude that people value forest and pasture within a 200-meter buffer.

Since people value proximity to these kinds of developable lands, and the policy change opens up the possibility that these lands will be developed in the near future, the treatment group includes all properties having developable lands within a 200-meter ring of the property, while the control group contains those without developable lands in that ring. In other words, we assume that such policy does not influence properties in the control group. The two groups are subject to the same contemporaneous influences such as macroeconomic changes in the housing market. Meanwhile, we define developable lands to include forest, pasture, cropland and grassland. Therefore, the DID method captures the average effect of the policy on those properties with developable lands in a 200-meter buffer. We set the developable open space variable equal 1 when there are developable lands in a 200-meter radius.

We need to determine a cut-off date for the effect of the treatment. The new policy was announced in September 2012, so the variable of the policy implementation equals to 1 if a property is sold after September 2012[18]. Table 3.5 summarizes housing transactions under treatment and control groups.

Table 3.5. The Distribution of Property Transactions in Treatment and Control Groups before and after September 2012

	Pre-treatment	Post-treatment	Total
Treatment group ($developable = 1$)	217	965	1,182
Control group ($developable = 0$)	71	173	244
Total	288	1,138	1,426

The model without the DID variable in Equation (13) changes to:

$$\ln(P_{it}) = \beta_0 + \boldsymbol{\beta}_1' \ln \boldsymbol{X}_{it} + \boldsymbol{\beta}_2' \boldsymbol{D}_{it} + \beta_3 developable_{it} + \beta_4 policy\ implementation_{it} + \beta_{DID} DID_{it} + \theta_t + \varepsilon_{it} \quad (14)$$

where variable DID_{it} is the interaction of $developable_{it}$ and $policy\ implementation_{it}$.

[18] We tried different dates close to September 2012 and found that these results were robust.

According to Equation (1), the coefficient $\hat{\beta}_{DID}$ indicates the true casual effects of the policy change on properties with developable lands around. This DID estimator is presented as the following expression:

$$\hat{\beta}_{DID} = \left(\ln\bar{P}_{treatment,policy\ implementation=1} - \ln\bar{P}_{treatment,policy\ implementation=0}\right) - \left(\ln\bar{P}_{control,policy\ implementation=1} - \ln\bar{P}_{control,policy\ implementation=0}\right) \tag{15}$$

where the bar implies the mean value of a property (Bin et al., 2009; No Kim et al., 2016).

Results are still based on the spatial lag model, which considers endogenous interactions among observations. Usually the DID method assumes that an observation's outcome is only affected by its own treatment, and there is no spillover treatment effects, which is called the Stable Unit Treatment Value Assumption (SUTVA) (Rubin, 1978). However, when spatial interactions occur, the treatment can propagate through the network so that some observations would also be affected (Arduini et al., 2016; Manski, 2013). Now ATE becomes the aggregation of the Average Direct Treatment Effect (ADTE) and the Average Indirect Treatment Effect (AITE). ADTE denotes the direct effects without spatial feedback as well as feedback loop treatment effects on its own outcome by individual i's treatments, and AITE is the indirect effects of i's treatment on other observations (Arduini et al., 2016).

The spatial lag model is estimated by using the S2SLS method. Table 3.6 implies that acres of forest, pasture and cropland have effects on property values. One more acre of cropland within the 200-meter buffer decreases all property prices by 0.30%. Although croplands can provide scenic views and wildlife habitats, there are also disamenities such as noise, dust and odors coming from the application of pesticides or fertilizers. Regarding the developable open space dummy, if a property has developable lands within its 200-meter buffer, its own price increased and other property prices were influenced as well. The policy implementation variable actually captures a raw time effect for all properties (Bin et al., 2009). This time dummy increases all property values in our study area. With respect to the DID variable, the new policy discounts property prices by 4.77% in the treatment group. It also has negative spatial spillovers on other properties. Regarding estimations of other variables, their signs and significance are consistent with what we find in Table 3.4.

Table 3.6. Estimation Results of a S2SLS Accounting for the Policy Treatment

Variables	Direct Impact	Indirect Impact	Total Impact
Developable open space (1/0)	0.0505***	0.0080***	0.0585***
	(3.6678)	(3.173)	(3.7921)
Policy implementation time (1/0)	0.0886***	0.014***	0.1026***
	(4.7499)	(3.8326)	(5.0258)
DID (causal effect of the policy) (1/0)	-0.0477**	-0.0072**	-0.0549**
	(-2.4898)	(-2.835)	(-2.6027)
Forest	0.0083**	0.0014**	0.0097**
	(2.3273)	(1.7922)	(2.2676)
Pasture	0.0285**	0.0045**	0.033**
	(2.1761)	(2.0288)	(2.2028)
Cropland	-0.0026**	-4e-04**	-0.003**
	(-2.0066)	(-2.3135)	(-2.0795)
Grassland	-0.0017	-3e-04	-0.0020
	(-1.0084)	(-0.9435)	(-1.0046)
Park	1e-04	0.0000	1e-04

	(0.1514)	(0.0985)	(0.1445)
Log (living area)	0.6903***	0.1104***	0.8007***
	(13.1357)	(4.8216)	(17.4112)
Log (lot size)	0.0759***	0.0126***	0.0885***
	(8.3015)	(2.8825)	(6.7449)
Condition (1/0)	0.0389***	0.0066***	0.0455***
	(2.9305)	(1.993)	(2.7968)
Basement (1/0)	0.1045***	0.0169***	0.1214***
	(13.9615)	(3.9901)	(13.4365)
Bathroom	-0.0376***	-0.0061***	-0.0437***
	(-8.4946)	(-3.4542)	(-7.9095)
Bedroom	-0.0833***	-0.0135***	-0.0968***
	(-10.6425)	(-3.8502)	(-10.3431)
Garage	0.0406***	0.0070***	0.0475***
	(2.6721)	(1.8213)	(2.5345)
Age	-0.0021***	-3e-04***	-0.0024***
	(-3.441)	(-3.7027)	(-3.6554)
Log (Calgary)	-0.3109***	-0.0492***	-0.3601***
	(-5.6451)	(-4.5374)	(-6.2081)
Log (hospital)	0.0223***	0.0036***	0.0259***
	(4.0151)	(2.8441)	(3.9908)
Log (water)	-0.0235**	-0.0035**	-0.027**
	(-2.1283)	(-2.5999)	(-2.2233)
School quality (1/0)	-0.0126	-0.0021	-0.0146
	(-0.9089)	(-0.8615)	(-0.9079)
Log (density)	-0.0289**	-0.0043***	-0.0332**
	(-2.3087)	(-3.0851)	(-2.4376)
% of high school certificate	5e-04	1e-04	6e-04
	(0.5896)	(0.5512)	(0.5868)
% of postsecondary education	-4e-04	-1e-04	-5e-04
	(-0.3155)	(-0.2626)	(-0.3091)

Employment rate	0.0015	2e-04	0.0017
	(1.3331)	(1.3445)	(1.3496)
Low median household income (1/0)	0.0049	4e-04	0.0053
	(0.2452)	(0.1318)	(0.2304)
High median household income (1/0)	-0.0219	-0.0042	-0.0262
	(-0.8064)	(-0.8154)	(-0.8126)
Season	0.0184**	0.0032	0.0215**
	(1.9995)	(1.5644)	(1.9446)
ρ	0.1482***		

Note: ***, **, and * denotes significance level at 10%, 5% and 1%;
z-values are in parentheses.

3.4. Welfare Measurement

Transaction data only reveals the hedonic price function, but it is not a bid function for individuals. If we want to get inverse demand curves and the exact WTP for the policy, we need to know who are living in the houses as well as their characteristics (Bockstael and McConnell, 2007). As illustrated in Chapter 2, we use the implicit price, which is also the marginal effect, to approximately capture residents' WTP for the policy as well as for open space. In terms of the OLS approach, the marginal effect of one more acre of open space on property values is shown as below:

$$MWTP_{o.o} = \frac{\partial P}{\partial x_r} P = \hat{\beta}_r P \tag{16}$$

where $\hat{\beta}_r$ is the estimate of variable r, P is the housing price, and $MWTP_{o.o}$ denotes a marginal WTP of an open space variable under an OLS regression.

Marginal effect of a dummy is different from Equation (16). The average percentage change in P for a discrete change in x_r from 0 to 1, should be shown as:

$$p_r = 100\left(\exp\left(\hat{\beta}_r\right) - 1\right) \tag{17}$$

where p_r is the average percentage change of P with respect to the change of x_r (Halvorsen and Palmquist, 1980).

Then the marginal WTP of the dummy ($MWTP_{o.d}$) can be calculated as:

$$MWTP_{o.d} = \frac{p_r}{100} * \mathrm{P} \tag{18}$$

Since the spatial lag model includes a spatially-lagged dependent variable, the calculation of marginal effects is slightly different from that in OLS estimation. We know from Equations (7) and (8) that the partial derivative of the dependent variable with respect to the explanatory variable is no longer the coefficient $\hat{\beta}_r$, but $(I_n - \hat{\rho}W)^{-1} * \hat{\beta}_r$. The spatial multiplier $(I_n - \hat{\rho}W)^{-1}$ can be simplified as $(1 - \hat{\rho})^{-1}$ (Anselin and Lozano-Gracia, 2008; Atreya et al., 2013). Now marginal WTPs are presented as follows:

$$MWTP_{s.o} = (\frac{1}{1-\hat{\rho}})\hat{\beta}_r P \tag{19}$$

$$MWTP_{s.d} = \left(\exp\left(\frac{1}{1-\hat{\rho}} * \hat{\beta}_r\right) - 1\right) * P \tag{20}$$

where $\hat{\rho}$ is the estimate of the spatial autoregressive coefficient, $MWTP_{s.o}$ is the marginal willingness to pay for open space variables and $MWTP_{s.d}$ is the marginal willingness to pay for characteristics captured by dummy variables.

Table 3.7 summarizes all coefficients of the S2SLS regression, and also of OLS and the spatial lag model under the maximum likelihood estimation. Among all three regressions, one of types of open space, pasture, has significant positive effects on housing prices, so we calculate the WTPs for one more acre of pasture within a 200-meter buffer of a property based on the sample mean of sales prices ($CAD 600,205), according to Equation (19). Moreover, the coefficient of DID in each regression is significant, so the WTP for the policy is calculated based on the average sales prices ($CAD 635,943) in the treatment group, under Equation (20). Although many estimated coefficients look similar, the marginal effects are still quite different. Results are shown in Table 3.8. The S2SLS not only filters out spatial spillover effects, but also allows for a weaker assumption on the nature of the disturbance terms, so the WTPs are more accurate. Taking results of the S2SLS as an example, on average, individual households are willing to pay $CAD 19,589 for one more acre of pasture within a 200-meter radius of their house. Most importantly, the marginal effect of the treatment is negative, which implies that the implementation of the new policy decreases prices of properties with developable lands in a 200-meter radius. The property value decreases by 5.2793%. In other words, individual residents are willing to pay $CAD 33,574 to prevent the change in policy. Therefore, people would like to pay for pasture, but would seek compensation for a change from a finite growth policy to a continuous growth policy.

Residents discount property prices due to the policy, meanwhile positive spillover effects strengthen individuals' WTP for stopping the change in policy. The continuous growth policy aims to increase the population capacity of the town. More people implies more dwellings, more industries and more infrastructure. Hence residents who have access to nearby developable lands want to pay for keeping the original finite growth policy.

Table 3.7. Parameters under Different Estimation Methods

		SLM	
Variables	OLS	ML	S2SLS
Developable open space (1/0)	0.0594***	0.0472**	0.0495***
	(0.0201)	(0.0191)	(0.014)
Policy implementation time (1/0)	0.0842**	0.0876***	0.0869***
	(0.0345)	(0.0327)	(0.0192)
DID (causal effect of the policy) (1/0)	-0.0464**	-0.0461**	-0.0462**
	(0.0226)	(0.0215)	(0.0198)
Forest	0.0126***	0.0074	0.0084**
	(0.0048)	(0.0046)	(0.0036)
Pasture	0.0267*	0.0280**	0.0278**
	(0.0138)	(0.0131)	(0.0136)
Cropland	-0.0033*	-0.0023	-0.0025**
	(0.0017)	(0.0016)	(0.0013)
Grassland	-3e-04	-0.0020	-0.0017
	(0.0018)	(0.0017)	(0.0016)
Park	-3e-04	2e-04	1e-04
	(0.0013)	(0.0012)	(9e-04)
Log (living area)	0.7408***	0.6680***	0.6814***
	(0.0202)	(0.0203)	(0.0559)
Log (lot size)	0.0790***	0.0750***	0.0757***
	(0.0064)	(0.0061)	(0.0091)
Condition (1/0)	0.0401***	0.0388***	0.0391***
	(0.0113)	(0.0107)	(0.0132)
Basement (1/0)	0.1057***	0.1028***	0.1033***
	(0.0084)	(0.0079)	(0.0077)
Bathroom	-0.0422***	-0.0363***	-0.0374***
	(0.0075)	(0.0071)	(0.0045)
Bedroom	-0.0907***	-0.0808***	-0.0826***

	(0.0062)	(0.0059)	(0.0079)
Garage	0.0461***	0.0397***	0.0409***
	(0.0061)	(0.0058)	(0.0151)
Age	-0.0023***	-0.0020***	-0.0020***
	(5e-04)	(4e-04)	(6e-04)
Log (Calgary)	-0.3634***	-0.2939***	-0.3067***
	(0.0466)	(0.0448)	(0.0547)
Log (hospital)	0.0328***	0.0198***	0.0222***
	(0.0073)	(0.007)	(0.0056)
Log (water)	-0.0274***	-0.0214***	-0.0225**
	(0.0057)	(0.0054)	(0.0115)
School quality (1/0)	-0.0078	-0.0127	-0.0118
	(0.0095)	(0.009)	(0.0136)
Log (density)	-0.0374***	-0.0257***	-0.0279**
	(0.008)	(0.0077)	(0.0129)
% of high school certificate	7e-04	5e-04	5e-04
	(0.0011)	(0.001)	(9e-04)
% of postsecondary education	-5e-04	-4e-04	-5e-04
	(0.0013)	(0.0012)	(0.0013)
Employment rate	0.0022**	0.0013	0.0015
	(0.0011)	(0.001)	(0.0011)
Low median household income (1/0)	0.0032	0.0042	0.0040
	(0.0232)	(0.022)	(0.0208)
High median household income (1/0)	-0.0133	-0.0259	-0.0236
	(0.0239)	(0.0227)	(0.0282)
Season	0.0197	0.0186	0.0188**
	(0.0078)	(0.0074)	(0.0095)
Constant	10.7898***	8.3297***	8.7824***
	(0.5581)	(0.5846)	(0.8394)
ρ	-	0.1816***	0.1482***
Fixed effects	Y	Y	Y

Note: ***, **, and * denotes significance level at 10%, 5% and 1%;

Standard errors are in parentheses.

Table 3.8. WTP for Pasture and the Land-Use Policy under Different Estimation Methods

		SLM	
	OLS	ML	S2SLS
Pasture ($CAD/Acre)	16,025	20,535	19,589
Treatment effect (%)	-4.4534	-5.4772	-5.2793
Treatment effect ($CAD)	-28,834	-34,832	-33,574

3.5. Conclusions

The study uses the Alberta Town of Okotoks as a natural experiment to identify causal effects of urban development policy on property values. The DID method is performed under a hedonic price framework. After diagnostic tests, we perform a spatial lag model under a S2SLS estimation, so that direct impacts and spillover impacts are both revealed. Models without the DID variable implies that people value pasture. For a property, acres of pasture around it have significantly positive effects on its own price, and also have significantly positive effects on other property values. With respect to models with the DID variable, the new policy has negative effects on property prices in the treatment group. It also has negative externalities on other properties. WTPs for one more acre of pasture and the policy are calculated using the spatial multiplier. People value pasture and disvalue the policy. In our study area, the WTP for one more acre of pasture is $CAD 19,589. Meanwhile, the average home buyer is willing to pay $CAD 33,574 to avoid the change to the continuous growth policy.

This study contributes to literatures regarding the WTP for land-use policies. Instead of preservation policies, we focus on the relaxation of such restrictive policies. What's more, DID and spatial effects are combined. We find that spatial lag model is most appropriate to capture spatial dependence in our study. The results are based on a S2SLS regression with HAC estimators. Compared to the OLS estimation, estimators of S2SLS are asymptotically consistent and more efficient. Further studies need to choose more appropriate treatment and control groups, to improve the empirical outcomes. Moreover, apart from the effects on housing prices, we can also discuss the impacts of such policy on WTP for open space, under a quasi-experiment framework.

3.6. References

Abbott, J.K., and H.A. Klaiber. 2011. An Embarrassment of Riches: Confronting Omitted Variable Bias and Multi-Scale Capitalization in Hedonic Price Models. *The Review of Economics and Statistics* 93:1331-1342.

Agriculture and Agri-Food Canada. 2016. Annual Crop Inventory: Data Product Specifications. https://open.canada.ca/data/en/dataset/ba2645d5-4458-414d-b196-6303ac06c1c9. (Accessed on March 22, 2018).

Anselin, L. 2001. Spatial Econometrics. In *A Companion to Theoretical Econometrics.*

Anselin, L. 2002. Spatial Weights. http://www.dpi.inpe.br/gilberto/tutorials/software/geoda/tutorials/w8_weights.pdf. (Accessed on February 28, 2018).

Anselin, L., and A.K. Bera. 1998. Spatial Dependence in Linear Regression Models with an Introduction to Spatial Econometrics. *Statistics Textbooks and Monographs* 155:237-290.

Anselin, L., and N. Lozano-Gracia. 2008. Errors in Variables and Spatial Effects in Hedonic House Price Models of Ambient Air Quality. *Empirical Economics* 34:34.

Arduini, T., E. Patacchini, and E. Rainone. 2016. Identification and Estimation of Network Models with Heterogeneous Externalities. https://pdfs.semanticscholar.org/3d61/1d1c0b7c1a496e53bc822880fda37b2fbd76.pdf. (Accessed on March 22, 2018).

Asabere, P.K. 2014. The Value of Homes in Cluster Development Residential Districts: The Relative Significance of the Permanent Open Spaces Associated with Clusters. *The Journal of Real Estate Finance and Economics* 48:244-255.

Atreya, A., S. Ferreira, and W. Kriesel. 2013. Forgetting the Flood? An Analysis of the Flood Risk Discount over Time. *Land Economics* 89:677-596.

Bin, O., C.E. Landry, and G.F. Meyer. 2009. Riparian Buffers and Hedonic Prices: A Quasi-Experimental Analysis of Residential Property Values in the Neuse River Basin. *American Journal of Agricultural Economics* 91:1067-1079.

Bockstael, N.E. 1996. Modeling Economics and Ecology: The Importance of a Spatial Perspective. *American Journal of Agricultural Economics* 78:1168-1180.

Bockstael, N.E., and K.E. McConnell. 2007. Environmental and Resource Valuation with Revealed Preferences: A Theoretical Guide to Empirical Models: Springer Science and Business Media.

Boennec, R.m.L., and F.d.r. Salladarré. 2017. The Impact of Air Pollution and Noise on the Real Estate Market. The Case of the 2013 European Green Capital: Nantes, France. *Ecological Economics* 138:82-89.

Bolitzer, B., and N.R. Netusil. 2000. The Impact of Open Spaces on Property Values in Portland, Oregon. *Journal of Environmental Management* 59:185-193.

Borchers, A.M., and J.M. Duke. 2012. Capitalization and Proximity to Agricultural and Natural Lands: Evidence from Delaware. *Journal of Environmental Management* 99:110-117.

Brown, D.W., and G.B. Wetherill. 1990. Statistical Process Control: Chapman and Hall.

Calgary Real Estate Board. 2018. Daily Housing Summary. http://www.creb.com/Housing_Statistics/Daily_Housing_Summary/?tab=2. (Accessed on February 28, 2018).

Cho, S.-H., N.C. Poudyal, and R.K. Roberts. 2008. Spatial analysis of the amenity value of green open space. *Ecological Economics* 66:403-416.

City of Calgary. 2002. Open Space Plan. https://www.calgary.ca/CSPS/Parks/Documents/Planning-and-Operations/open-space-plan.pdf?noredirect=1. (Accessed on March 22, 2018).

Geoghegan, J., L. Lynch, and S. Bucholtz. 2003. Capitalization of Open Spaces into Housing Values. *Agricultural and Resource Economics Review* 32:33-45.

Geoghegan, J., L.A. Wainger, and N.E. Bockstael. 1997. Spatial Landscape Indices in a Hedonic Framework: An Ecological Economics Analysis Using GIS. *Ecological Economics* 23:251-264.

Gnagey, M., and T. Grijalva. 2018. The Impact of Trails on Property Values: A Spatial Analysis. *The Annals of Regional Science* 60:73-97.

Government of Alberta. 2017c. Highlight of Alberta Economy. http://www.albertacanada.com/files/albertacanada/SP-EH_highlightsABEconomyPresentation.pdf. (Accessed on March 22, 2018).

Government of Alberta. 2018. Oil Prices. http://economicdashboard.alberta.ca/OilPrice. (Accessed on March 22, 2018).

Greenstone, M., and T. Gayer. 2009. Quasi-Experimental and Experimental Approaches to Environmental Economics. *Journal of Environmental Economics and Management* 57:21-44.

Halvorsen, R., and R. Palmquist. 1980. The Interpretation of Dummy Variables in Semilogarithmic Equations. *The American Economic Review* 70:474-475.

Heintzelman, M.D. 2010. The Value of Land Use Patterns and Preservation Policies. The University of Michigan.

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

Irwin, E.G. 2002. The Effects of Open Space on Residential Property Values. *Land Economics* 78:465-480.

Irwin, E.G., and N.E. Bockstael. 2001. The Problem of Identifying Land Use Spillovers: Measuring the Effects of Open Space in Residential Property Values. *American Journal of Agricultural Economics* 83:698-704.

Kelejian, H.H., and I.R. Prucha. 2007. HAC Estimation in a Spatial Framework. *Journal of Econometrics* 140:131-154.

Lansford, N.H., and L.L. Jones. 1995. Recreational and Aesthetic Value of Water Using Hedonic Price Analysis. *Journal of Agricultural and Resource Economics* 20:341-355.

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

LeSage, J., and R.K. Pace. 2009. Introduction to Spatial Econometrics.

Manski, C.F. 2013. Identification of Treatment Response with Social Interactions. *The Econometrics Journal* 16:S1-S23.

Mei, Y., D. Hite, and B. Sohngen. 2017. Demand for Urban Tree Cover: A Two-Stage Hedonic Price Analysis in California. *Forest Policy and Economics* 83:29-35.

Mitra, S.K., and J.-D.M. Saphores. 2016. The Value of Transportation Accessibility in a Least Developed Country City: The Case of Rajshahi City, Bangladesh. *Transportation Research Part A: Policy and Practice* 89:184-200.

Münch, A., S.P.P. Nielsen, V.J. Racz, and A.-M. Hjalager. 2016. Towards Multifunctionality of Rural Natural Environments? An Economic Valuation of the Extended Buffer Zones along Danish Rivers, Streams and Lakes. *Land Use Policy* 50:1-16.

No Kim, H., P.C. Boxall, and W.L. Adamowicz. 2016. The Demonstration and Capture of the Value of an Ecosystem Service: A Quasi-Experimental Hedonic Property Analysis. *American Journal of Agricultural Economics* 98:819-837.

Paterson, R.W., and K.J. Boyle. 2002. Out of Sight, Out of Mind? Using GIS to Incorporate Visibility in Hedonic Property Value Models. *Land Economics* 78:417-425.

Rubin, D.B. 1978. Bayesian Inference for Causal Effects: The Role of Randomization. *The Annals of statistics*:34-58.

Schläpfer, F., F. Waltert, L. Segura, and F. Kienast. 2015. Valuation of Landscape Amenities: A Hedonic Pricing Analysis of Housing Rents in Urban, Suburban and Periurban Switzerland. *Landscape and Urban Planning* 141:24-40.

Singh, A., J.-D. Saphores, and T. Bruckner. 2018. A Spatial Hedonic Analysis of the Housing Market around a Large, Failing Desert Lake: The Case of the Salton Sea in California. *Journal of Environmental Planning and Management*:1-21.

Stoms, D.M., P.A. Jantz, F.W. Davis, and G. DeAngelo. 2009. Strategic targeting of agricultural conservation easements as a growth management tool. *Land Use Policy* 26:1149-1161.

Tyrvainen, L. 2000. Property Prices and Urban Forest Amenities. *Journal of Environmental Economics and Management* 39:205-223.

Yoo, J., J. Browning, and K. Minesinger. 2017. Open Space Premium near Commercial Zones: A Case Study in the City of Corona, California. *International Journal of Urban Sciences*:1-12.

Chapter 4. Identifying the Effects of a Land-Use Policy on People's WTPs for Open Space under an Endogenous Switching Regression Model

4.1. Introduction

People value living in close proximity to open space since it provides us with amenities (Cho et al., 2008; Cho et al., 2009; Geoghegan, 2002; Irwin, 2002). However, implementation of new land-use policy potentially affects the probability of open space conversion in the near future. When people receive such information and change their expectations on open space, their WTPs for different types of open space may also be altered. In Alberta, property taxes are a primary source of revenue for municipalities to provide public services and finance local programs (Government of Alberta, 2010). Residential properties are assessed according to their market values. Since the value from open space amenities is a component of the market price, the amenity benefits resulting from open space will influence municipality governments' revenue (Borchers and Duke, 2012). Therefore, it is very important for governments to know whether their decisions on land use cause changes in benefit streams.

Under a set of hedonic price models, a few studies have discussed how values of environmental amenities vary over time. Due to rapid population and metropolitan growth in the US state of North Carolina, Smith et al. (2002) find that the estimated marginal value of open space declined from 1980 to 1998 because of the potential of conversion and reduction of open space in the future. Cho et al. (2009) find that the value of proximity to open space such as greenways and parks relative to lot size increased over time in the Knox County of Tennessee. In addition, Cho et al. (2011) investigate whether consumers' marginal willingness to pay for environmental landscape attributes changed from the 2000-2006 real estate boom to the 2008 recession in the Nashville-Davison

County of Tennessee. They conclude that WTPs for water view, developed open space and forest-land open space all decreased due to the change of economic conditions.

However, few if any studies have considered that property transactions may be not random. The housing data we observe is a result of house owners' "self-selection" into the market transaction. Simply dividing the data into different periods can therefore result in bias. The continuous growth policy was announced in September 2012 in Okotoks. The probability that a particular house owner decides to sell (or not to sell) after the announcement of the policy is affected by the owner's expectation regarding the impact of the policy on property values. Furthermore, the decision will also influence the supply in the real estate market thus affecting property values. Consequently, the house owner's decision whether to sell or not and property values are correlated.

Endogenous switching regression model is an approach to eliminate the self-selection bias. Similar to a Heckman selection model, it is usually used when people are not randomly selected into a treatment. This method is popular to explore food production issues, taking farmers' behavior into consideration (Akpalu and Normanyo, 2013; Asfaw et al., 2012; Di Falco et al., 2011; Huang et al., 2015). Regarding the endogeneity of a program, Shiferaw et al. (2014) discover that farm households who adopt improved wheat varieties are mostly high-educated in Ethiopia, and Hao et al. (2018) find that cooperative and non-cooperative farms have different food qualities and safety standards in China. All studies indicate that participants are not random and endogeneity of the program leads to biased results. Although such methods are commonly used to analyze data from a social survey, it is rare in studies of the real estate market, especially taking both demand and supply into consideration. Since housing transactions are actually the results of decisions from a homeowner and a homebuyer, problems in the real estate market become complicated. Only focusing on the housing demand, Manrique and Ojah (2003) and Choi and Min (2009) use this method to figure out how housing expenditure is influenced by the choice of buying or renting a house.

This study aims to compare WTPs for open space before and after the policy change, to figure out if open space values decrease. We incorporate a homeowner' decision whether to sell a property due to the new policy, and a hedonic price framework into the endogenous switching regression model, capturing all behaviors in the market. We find that individuals' WTPs for developable open space, such as forest, pasture and grassland, decrease due to the implementation of the new policy. Meanwhile, this pro-development policy has negative effects on property values.

This chapter makes several contributions. Firstly, there are several studies estimating WTP for open space, but few studies have discussed the impact of a policy on such values. Our study fills this gap to some extent. Secondly, we consider the self-selection problem while using two hedonic price models to qualify the change of individuals' WTP for open space. Ignoring this problem may lead to biased results and provide inaccurate information to municipalities. Thirdly, to our knowledge, few if any studies have incorporated the endogenous switching regression into a hedonic price framework.

The rest of this chapter is organized as follows. Section 4.2 presents the econometric framework and Section 4.3 describe the data we use. In Section 4.4, we specify the empirical model, estimate endogenous switching regression with robustness checks, and discuss the effects of the continuous growth policy on people's WTP for open space. We also explore its effects on property values to compare the result with what we report in Chapter 3. Section 4.5 draws conclusions.

4.2. The Econometric Framework

4.2.1. Endogenous Switching Regression Model

As discussed in Section 4.1, self-selection bias will affect the estimation of people's WTP for open space under the hedonic price model. In order to address such problem, we adopt an endogenous switching regression model (Maddala, 1983). It includes simultaneous equations with two stages. In our study, the first-stage represents supply behaviors. A probit model is used to evaluate whether a homeowner decides to sell a property or not after the implementation of the new policy. Let $U^* > 0$ be a latent variable denoting the utility of selling a house after the announcement of the continuous growth policy. The first-stage selection equation is specified as below:

$$U_i^* = Z_i\alpha + \eta_i \text{ with } U_i = \begin{cases} 1 & if\ U_i^* > 0 \\ 0 & otherwise \end{cases} \tag{1}$$

Where i denotes a property sale observation; α is a vector of parameters; Z_i is a vector of variables affecting the decision of selling the house; η_i is an error term with a mean of zero and a variance of σ_η^2; $U_i = 1$ implies the house is sold after the announcement of policy change; and $U_i = 0$ indicates it is not sold after the announcement[19].

[19] Since the dataset only includes latest housing transactions, all transactions before the policy change are actually those not sold after the policy change.

Coefficients in the selection Equation (1) can be estimated up to a scale factor, so σ_η^2 is assumed to be 1 (Maddala, 1983). Assuming $\eta \sim N(0, 1)$, Equation (1) is presented as below:

$$\Pr(U_i = 1|Z_i) = \Phi(Z_i\alpha) \tag{2}$$

where Pr is probability, and Φ is the Cumulative Distribution Function (CDF) of the standard normal distribution.

The second stage uses a hedonic price theoretical framework to estimate the determinants of property values before and after the policy change, conditional on the selection function. As mentioned in Chapter 2, the hedonic price model can be used to estimate people's WTP for attributes, so the second stage represents demand behavior. The decision of selling a house in the first stage influences housing transaction and housing price in the real estate market. In terms of housing transactions before and after the policy change, we specify two hedonic price equations as follows:

Regime 0 (Before the policy change)[20]: $P_{0i} = X_{0i}\beta_0 + \varepsilon_{0i} \qquad if \;\; U_i = 0$ (3a)

Regime 1 (After the policy change): $P_{1i} = X_{1i}\beta_1 + \varepsilon_{1i} \qquad if \;\; U_i = 1$ (3b)

where P is a property value; X is a vector of variables that influence property values; and β_0 and β_1 are vectors of unknown parameters.

Many studies assume that disturbances in Equation (1), (3a) and (3b) have a joint normal distribution with zero mean and a covariant matrix Σ (Akpalu and Normanyo, 2013; Di Falco et al., 2011; Shiferaw et al., 2014). Σ is specified as:

[20] In this chapter, "regime 0", and "the control group" are in which properties are sold before the policy change, while "regime 1" and 'the treatment group" are in which properties are sold after the policy change.

$$cov(\eta, \varepsilon_0, \varepsilon_1) = \begin{bmatrix} \sigma_\eta^2 & \sigma_{\eta 0} & \sigma_{\eta 1} \\ \sigma_{0\eta} & \sigma_0^2 & . \\ \sigma_{1\eta} & . & \sigma_1^2 \end{bmatrix}$$

where σ_η^2 is the variance of the error term in Equation (1), σ_0^2 and σ_1^2 are the variances of the error terms in Equation (3a) and (3b); $\sigma_{\eta 0}$ is the covariance of η_i and ε_{0i}; and $\sigma_{\eta 1}$ is the covariance of η_i and ε_{1i}. While property value P_{0i} and P_{1i} are not observed simultaneously, researchers do not define the covariance of ε_{0i} and ε_{1i} (Maddala, 1983; Shiferaw et al., 2014).

Although unconditional expected values of ε_{0i} and ε_{1i} are zero, conditional expected values are not. According to correlations between the error term in the selection equation (1) and outcome functions (3a) and (3b), expected values of ε_{0i} and ε_{1i} conditional on the sample selection can be defined as below:

$$\text{Regime 0: } E(\varepsilon_{0i}|U_i = 0) = -\sigma_{0\eta} \frac{\phi(Z_i\alpha)}{1-\Phi(Z_i\alpha)} \tag{4a}$$

$$\text{Regime 1: } E(\varepsilon_{1i}|U_i = 1) = \sigma_{1\eta} \frac{\phi(Z_i\alpha)}{\Phi(Z_i\alpha)} \tag{4b}$$

where $\phi(.)$ is the standard normal probability density function, and $\Phi(.)$ is the standard normal cumulative density function. We define $-\frac{\phi(Z_i\alpha)}{1-\Phi(Z_i\alpha)} = \lambda_{0i}$, and $\frac{\phi(Z_i\alpha)}{\Phi(Z_i\alpha)} = \lambda_{1i}$, which are the Inverse Mills Ratios (IMR) (Di Falco et al., 2011; Heckman et al., 2001).

There are different ways to estimate the endogenous switching regression model. Compared to the two-stage least squares, the full information maximum likelihood (FIML) method is more efficient (Lee et al., 1986; Lee, 1978; Wilde and Ranney, 2000). We thus adopt the FIML approach. The logarithmic likelihood function is represented as:

$$\ln L = \sum_{i=1}^{N}\{ U_i \left[\ln \phi \left(\frac{\varepsilon_{1i}}{\sigma_1}\right) - \ln \sigma_1 + \ln \Phi(\theta_{1i})\right] + (1 - U_i) \left[\ln \phi \left(\frac{\varepsilon_{0i}}{\sigma_0}\right) - \ln \sigma_0 + \ln \Phi(\theta_{0i})\right]\} \quad (5)$$

where $\theta_{ji} = \frac{Z_i\alpha + \rho_j\varepsilon_{ji}/\sigma_j}{2\sqrt{1-\rho_j^2}}$ ($j = 0, 1$), and ρ_j is the correlation coefficient of η_i and ε_{0i}, or ε_{1i} separately.

4.2.2. Effects of the Land-Use Policy on Property Values

In order to figure out the policy effects on property values, we focus on all property transactions after the announcement of the policy. Endogenous switching regression model above can be used to estimate the average effects of this policy (Heckman et al., 2001; Mishra et al., 2017; Powers, 2007). Section 4.2.1 implies $E(\varepsilon_{1i}|U_i = 1)$ and $E(\varepsilon_{0i}|U_i = 0)$ are non-zero, so expected property values conditional on the sample selection can be defined as below:

$$E(P_{1i}|U_i = 1) = X_{1i}\beta_1 + \sigma_{1\eta}\lambda_{1i} \quad (6a)$$

$$E(P_{0i}|U_i = 1) = X_{1i}\beta_0 + \sigma_{0\eta}\lambda_{1i} \quad (6b)$$

In terms of all property transactions after the implementation of the land-use policy, Equation (6a) represents the actual expectation observed in the sample, and Equation (6b) is counterfactual property values. Specifically, Equation (6a) is the expected property value of the transaction with the policy, while Equation (6b) is the expected property value of the transaction if there is no such policy, which is the hypothetical case.

The policy's effects on property values can be calculated as:

$$E(P_{1i}|U_i = 1) - E(P_{0i}|U_i = 1) = X_{1i}(\beta_1 - \beta_0) + (\sigma_{1\eta} - \sigma_{0\eta})\lambda_{1i} \quad (7)$$

Equation (7) denotes the new policy's effects on housing transactions after the policy change.

4.3. Data Description

Different from what we used in Chapter 3, the study area in this chapter is constrained to the boundaries of the Town of Okotoks. This restriction can reveal more precise WTPs for open space in the Town of Okotoks, and also control macroeconomic influences to some extent[21].

Histograms of real property value before and after the policy change are presented in Figure 4.1. Compared to the one before the policy change, the distribution after the policy change is right shifted, which implies property values are higher. Therefore, properties with characteristics different from those before the policy change may be transacted, leading to the self-selection problem.

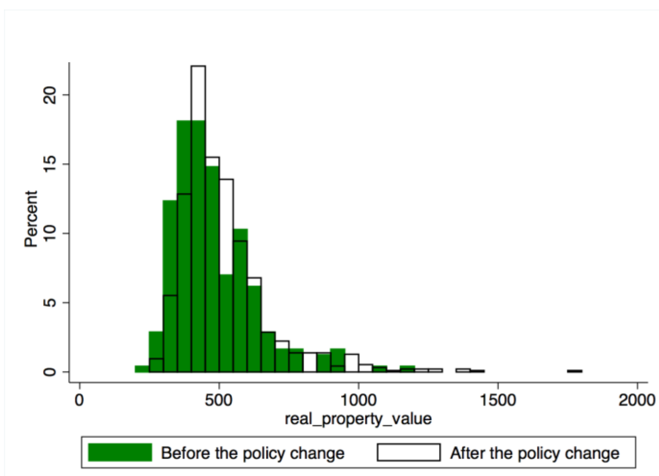


Figure 4.1. Real Property Value ($CAD 1000) Distributions before and after the Policy Change

[21] We only use a time dummy to represent the policy instrument, so a larger area would mean more uncontrolled effects.

All variables in this chapter are the same as in Chapter 3. The continuous growth policy was announced in September 2012, so the policy instrument is a time dummy after the policy implementation. There are 243 observations before the policy change, and 942 observations after the policy change. Compared to property transactions before the announcement of the policy, Table 4.1 shows that properties after the policy change are better equipped and also have higher values, on average. Most importantly, we argue that the new policy threatens developable lands, and stimulates the conversion to developed uses. Except for acres of park within a 200-meter buffer, transacted properties have more acres of developable open space after the policy change. This finding is consistent with our expectation, which indicates homeowners prefer to sell properties with potential developable open space, and retain properties with permanent lands (parks).

Table 4.1. Descriptive Statistics of Variables Included in the Endogenous Switching Regression

	Total sample		Regime 0 Before the policy change		Regime 1 After the policy change	
Variable	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
Sales price (2016$CAD)	508,549	162,780	477,541	145,056	516,548	166,182
Forest (Acres)	0.1146	0.2689	0.0731	0.1789	0.1253	0.2867
Pasture (Acres)	0.0204	0.1616	0.0067	0.0674	0.0239	0.1778
Cropland (Acres)	0.8082	2.4101	0.5835	2.0259	0.8662	2.4974
Grassland (Acres)	0.7555	1.4633	0.4931	1.0129	0.8231	1.5518

Park (Acres)	4.2192	3.4436	4.5438	3.5079	4.1354	3.4237
Living area (Square feet)	1,849.7392	517.5421	1,825.5514	501.5767	1,855.9788	521.6596
Lot size (Square feet)	6,394.4852	1.23E+04	5,282.0453	1,745.1881	6,681.4522	1.37E+04
Condition (1/0)	0.8456	0.3615	0.7037	0.4576	0.8822	0.3226
Basement (1/0)	0.5924	0.4916	0.5844	0.4938	0.5945	0.4913
Bathroom	2.8017	0.7097	3.1523	0.6844	2.7113	0.6880
Bedroom	2.8549	0.6544	2.9300	0.6024	2.8355	0.6661
Garage	1.9257	0.6202	1.8642	0.6696	1.9416	0.6062
Age	11.0354	12.2844	8.8477	10.9630	11.5998	12.5464
Calgary (Metres)	3.93E+04	1,326.6124	3.92E+04	1,319.5182	3.93E+04	1,328.6487
Hospital (Metres)	1,960.4075	1,181.6963	1,809.7944	1,125.2921	1,999.2599	1,193.3086
Water (Metres)	401.8729	242.1341	408.9934	241.0797	400.036	242.499
School quality (1/0)	0.4785	0.4997	0.4691	0.5001	0.4809	0.4999
Density	11.2035	3.5242	11.9157	3.3205	11.0198	3.5534
% of high school certificates	27.5897	5.6400	27.8244	4.4863	27.5292	5.9017
% of post-secondary education	57.5475	6.2645	57.4436	5.6844	57.5743	6.4082
Employment rate (%)	72.8231	5.2504	73.2086	4.9557	72.7237	5.3218
Low median household income (1/0)	0.0878	0.2831	0.0782	0.269	0.0902	0.2867

High median household income (1/0)	0.0143	0.1190	0.0165	0.1275	0.0138	0.1167
Season (1/0)	0.5899	0.4921	0.6667	0.4724	0.5701	0.4953
Sample size	1,185		243		942	

4.4. Results

4.4.1. Specification

Because of the identification problem, the endogenous switching regression model requires the number of variables (Z_i) in the selection equation (1) to be larger than the number of variables (X_i) in the outcome functions (Lee et al., 1986; Lee, 1978; Maddala, 1983). While all variables in Table 4.1 are included in the selection equation, we only consider variables which significantly affect property values in the outcome functions. As was done in the model presented in Chapter 3, this endogenous switching regression model uses the double log in the outcome functions. All continuous non-zero independent variables are logarithmic. Appendix G shows the specification of variables in the two stages.

4.4.2. Pre-Tests under an OLS Regression

Based on variables in Appendix G, we use two OLS regressions before and after the policy change, to test for multicollinearity, heteroscedasticity and normality of the error terms.

Estimations of parameters would be inefficient due to the presence of multicollinearity and heteroscedasticity. Hair et al. (1998) state that multicollinearity can be tested by variance inflation factors (VIFs). VIF>10 indicates serious multicollinearity. We calculate mean VIFs in Table 4.2, which are less than 10. In addition, residual plots in Figure 4.2 show that variance becomes larger as fitted value increases, so heteroscedasticity may exist. As illustrated in Maddala and Lahiri (1992), the Breusch-Pagan test can be used to test for heteroscedasticity. The test results in Table 4.2 indicate that the null hypothesis of homoscedasticity is rejected. Unobserved demographic factors affecting property values may have different patterns in different districts, leading to heteroscedastic error terms in the hedonic price models.

Moreover, since the endogenous switching regression is based on the normal distribution assumption, we want to test whether normal distributions are satisfied. Compared to normal distributions, the residuals of both regimes in Figure 4.3 present leptokurtosis. Meanwhile, in order to test for normality, Shapiro and Wilk (1965) put forward the Shapiro-Wilk W test, through which we reject normal distributions in Table 4.2. If we ignore this problem, estimations will be biased.

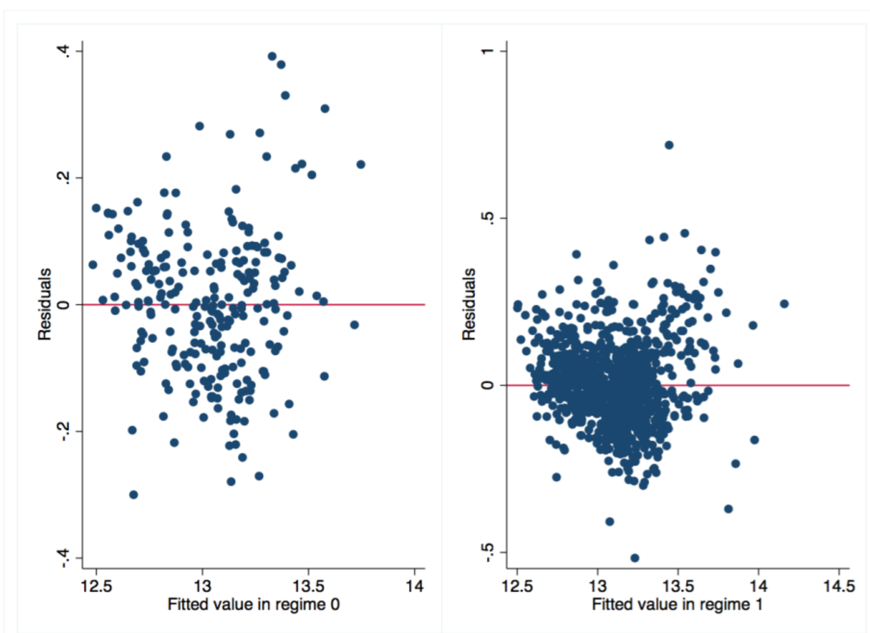


Figure 4.2. Residual Plots of OLS Regressions before and after the Policy Change

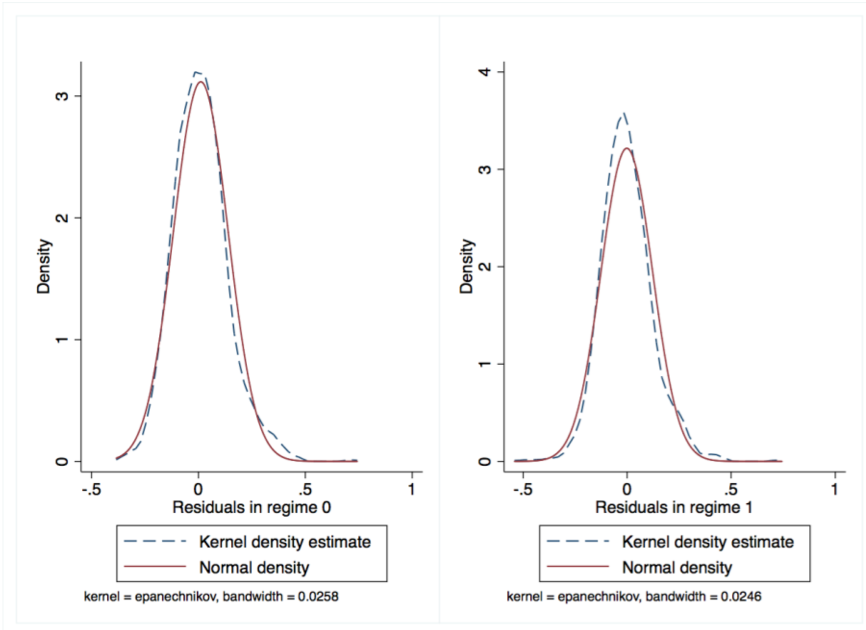


Figure 4.3. Residual Distributions of OLS Regressions before and after the Policy Change

Table 4.2. Pre-Tests before and after the Policy Change

	(1) Regime 0		(2) Regime 1	
Tests	Statistics	*P* value	Statistics	*P* value
Multicollinearity (VIF)	1.47	-	1.45	-
Heteroscedasticity (χ^2)	9.98	0.0003	39.79	0.0000
Normality (z)	6.331	0.0000	11.990	0.0000

4.4.3. Endogenous Switching Regression Results

Before performing the endogenous switching regression model, we estimate under an OLS regression. Results in Table 4.3 imply the policy has no significant effects on property values.

Table 4.3. OLS Estimation Results with a Dummy Variable of Policy Change based on the Whole Sample

Variable	OLS
Forest	0.0437***
	(0.0139)
Pasture	0.0240
	(0.0230)
Grassland	0.0083***
	(0.0027)
Log (living area)	0.7153***
	(0.0204)
Log (lot size)	0.0942***
	(0.0071)
Condition	0.0501***
	(0.0108)
Basement	0.0902***
	(0.0078)
Bathroom	-0.0390***
	(0.0072)
Bedroom	-0.0968***
	(0.0066)
Garage	0.0712***
	(0.0070)
Log (hospital)	0.0454***
	(0.0058)
Policy change	0.0119
	(0.0098)
Constant	6.7382***
	(0.1313)
Observations	1,185
R^2	0.7964

Note: ***, **, and * denotes significance level at 10%, 5% and 1%;
Standard errors are in parentheses.

Now we consider the endogenous switching regression. Section 4.4.2 implies the error terms under two regimes are heteroscedastic and not normal-distributed. Ignoring heteroscedasticity affects the efficiency of estimation. In order to eliminate this problem, we use robust standard errors. In addition, a flexible distribution, student's t, is considered for the error terms of outcome functions (Hasebe, 2013).

Under FIML, we get results in Table 4.4. Following Hasebe (2013), we conduct a Wald test. The P value indicates two stages are not independent, so the parameters in OLS regression in Table 4.3 are biased. The second column presents the results of the selection equation. As mentioned in Section 4.2.1, the first stage presents the homeowners' decision of selling a house, which is affected by the implementation of the continuous growth policy. We postulate that this new policy influences people's expectation on the conversion of developable lands. It is possible that those lands would be converted into urban uses in the near future. There are five variables denoting types of open space. We assume forest, pasture, cropland, and grassland as developable open space, while park is permanent open space. The coefficient on forest is significantly positive. People are more likely to sell properties which have more acres of forest within the 200-meter buffer. Other types of developable open space also have positive effects on the decision to sell, but are not statistically significant. Meanwhile, people are less likely to sell a property that has more acres of park within the 200-meter ring. These results are as expected. Because of the continuous growth policy, the housing market in Okotoks tends to have more properties surrounded by developable open space. However, effects of structural, locational and neighbourhood attributes are not certain. For example, people are more likely to sell a house with a good condition since it is demanded in the market. At the same time, they want to sell a house that is older. Different incentives influence signs of those variables.

Most importantly, we want to discuss the outcome functions in the second stage. The third and fourth columns are hedonic price model results before and after the policy change. Considering that we only have 243 observations before the policy change, the sample size may reduce the statistical significance of the estimations. Forest and grassland have positive impacts on housing prices. Taking the regime 0 as the base, we find the property value will increase by 8.27%, and by 1.50% if the house has one more acre of forest or grassland within its 200-meter buffer, respectively. Although the coefficient on pasture before the policy change is statistically insignificant, the effect of pasture on housing price decreases from regime 0 to regime 1[22]. Since estimation of hedonic price model can be used to estimate people's willingness to pay for different characteristics approximately, people value forest and grassland more before the policy change. The willingness to pay for developable open space decreases with the policy. This will be discussed in detail in Section 4.4.5. In addition, signs of other variables are the same as we find in Chapter 3. Compared to the regime 0, almost all structural characteristics have greater effects on the housing price after the policy change. For example, the housing price will increase more when the square feet of living area increase by 1%.

$\rho_{0\eta}$ and $\rho_{1\eta}$ are significant, which means that we fail to reject the hypothesis of sample selection bias (Akpalu and Normanyo, 2013; Kim et al., 2000). The positive correlation of η_i and ε_{1i} indicates the selection is positively associated with property values after the policy change, on average. Conversely, the selection and property values are negatively correlated before the policy change.

[22] Since 98% observations have zero value on variable of pasture before the policy change, the variance of its coefficient is very large to influence the efficiency.

In addition, considering that the variable of pasture before the policy change does not get enough variance, we aggregate pasture and cropland into agricultural land then estimate again in Appendix I. The parameter of agricultural land in regime 0 becomes significantly positive and greater than in regime 1.

Table 4.4. Estimation Results of an Endogenous Switching Regression

	Log (sales price)		
Variable	Selection	Regime 0	Regime 1
Forest	0.5302***	0.0867*	0.0567***
	(0.1823)	(0.0465)	(0.0153)
Pasture	0.4420	0.0474	0.0356**
	(0.4013)	(0.0495)	(0.0173)
Cropland	0.0022		
	(0.0174)		
Grassland	0.0102	0.0176**	0.0108***
	(0.0354)	(0.0070)	(0.0024)
Park	-0.0400***		
	(0.0120)		
Log (living area)	1.5248***	0.6345***	0.7568***
	(0.2834)	(0.0546)	(0.0317)
Log (lot size)	-0.0734	0.1056**	0.0741***
	(0.1830)	(0.0505)	(0.0266)
Condition (1/0)	0.7366***	0.0435*	0.0727***
	(0.1426)	(0.0243)	(0.0154)
Basement (1/0)	0.2583***	0.0898***	0.0875***
	(0.0972)	(0.0179)	(0.0094)
Bathroom	-0.7694***	-0.0220	-0.0947***
	(0.0986)	(0.0184)	(0.0107)

Bedroom	-0.1551	-0.0625***	-0.0885***
	(0.1019)	(0.0179)	(0.0094)
Garage	-0.0000	0.0632***	0.0752***
	(0.1074)	(0.0129)	(0.0128)
Age	0.0348***		
	(0.0086)		
Log (Calgary)	5.1100***		
	(1.6766)		
Log (hospital)	0.3885***	0.0537***	0.0378***
	(0.0814)	(0.0131)	(0.0072)
Log (water)	0.1568***		
	(0.0557)		
School quality (1/0)	0.2100**		
	(0.0993)		
Density	-0.0029		
	(0.0113)		
% of high school certificate	0.0242**		
	(0.0117)		
% of postsecondary education	0.0147		
	(0.0127)		
Employment rate	0.0088		
	(0.0125)		
Low median household income (1/0)	0.1118		
	(0.2558)		
High median household income (1/0)	-0.0421		
	(0.2933)		
Season	-0.3450***		
	(0.0730)		
Constant	-68.1382***	7.0200***	6.7250***
	(18.4325)	(0.4761)	(0.2714)
$\rho_{0\eta}$	-0.1380*		

	(0.1929)
$\rho_{1\eta}$	0.9363***
	(0.0190)
Wald test of independence:	
Wald statistic: 24245.646; *P* value=0.000	

Note: ***, **, and * denotes significance level at 10%, 5% and 1%;

Robust standard errors are in parentheses.

4.4.4. Robustness Checks

In order to make sure our results are robust to modeling, we assume different distributions on of η_i, ε_{0i} and ε_{1i} , then perform two endogenous switching regressions separately.

The previous regression is based on a probit model in the selection equation. It assumes a standard normal distribution of the error term. Now we rewrite Equation (1) as a logistic function (Wooldridge, 2015):

$$\Pr(U_i = 1|Z_i) = F(Z_i) = \frac{1}{1+e^{-Z_i\alpha}} \tag{8a}$$

$$g(F(Z_i)) = \ln(\frac{F(Z_i)}{1-F(Z_i)}) = Z_i\alpha \tag{8b}$$

where g(.) is the logit function.

After the adjustment, we obtain another set of results as reported in Appendix H (1).

What's more, the standard endogenous switching regression model assumes joint normality (Maddala, 1983). We adopt the copula approach to allow for different joint distributions given marginal distributions (Grotkowska et al., 2016; Hasebe, 2013). Taking η and ε_1 as an example, we let $M(\eta)$ and $M(\varepsilon_1)$ be their marginal CDFs, and $M(\eta, \varepsilon_1)$ be a bivariate joint CDF. Their relation can be specified as:

$$M(\eta, \varepsilon_1) = C\{M(\eta), M(\varepsilon_1);\ \theta\}$$

where C(.) is a copula function coupling $M(\eta)$ and $M(\varepsilon_1)$ to generate a bivariate joint CDF and θ denotes the degree of dependence.

There are different copula functions, such as FGM, Plackett, and others from the Archimedean family (Cherubini et al., 2004). The copula function for η and ε_0 may differ from the one for η and ε_1. After trying different combinations of the set of the copula, we choose Plackett for regime 0 and Clayton for regime 1 according to greatest log likelihood function value. Results are presented in Appendix H (2). Comparing those two endogenous switching regression models with the basic model in Table 4.4, we get similar outcomes. Significance and magnitude of the explanatory variables keep almost constant. Therefore, we conclude that our results are robust.

4.4.5. Effects of the Continuous Growth Policy

The main interest of our study is to evaluate whether people's WTP for open space is affected by the new policy. According to Chapter 2, WTP can be approximately revealed from the marginal effect under a hedonic price model. Since we get two hedonic price models before and after the policy change by the endogenous switching regression, WTPs for an acre of forest, pasture and grassland are calculated in Table 4.5, based on Equation (16) in Chapter 3 (Cho et al., 2011). In terms of the average housing price in the Town of Okotoks ($CAD 508,549.3), the sixth column indicates WTPs for one acre of forest, pasture and grassland decline after the announcement of the policy. The continuous growth policy threatens developable lands thus reducing people's expectation of their value.

Furthermore, we also calculate changes of WTPs in Appendix I, which aggregates pasture and cropland into agricultural land. The results are shown in Appendix J. The differences of WTPs for forest and grassland are similar to Table 4.5. Although the WTP for agricultural land still decreases, the values in regime 0 and regime 1 are much smaller than in Table 4.5. As discussed in Chapter 3, croplands may produce some disamenities such as dust and odors from fertilizers, therefore, the aggregated value of pasture and cropland decreases.

Table 4.5. Comparison of WTPs for Forest, Pasture and Grassland before and after the Policy Change

	(1) Regime 0		(2) Regime 1		
Open space	Coef.	WTP ($CAD/Acre)	Coef.	WTP ($CAD/Acre)	Difference ($CAD/Acre)
Forest	0.0867	44,091	0.0567	28,835	15,256
Pasture	0.0474	24,105	0.0356	18,104	6,001
Grassland	0.0176	8,950	0.0108	5,492	3,458

In addition, the endogenous switching regression can also be used to discuss whether the new policy has an influence on property values. Regarding housing transaction after the policy change, the average effect can be obtained from Equation (7). Meanwhile, the dependent variable in our study is logarithmic. Lee (1978) adjusts Equation (7) into an average percentage change as below:

$$p = \frac{100}{\#(J)} \sum_{i \in J} \{ (e^{ln\hat{P}_{1i}} | U_i = 1) - (e^{ln\hat{P}_{0i}} | U_i = 1) \} / \ (e^{ln\hat{P}_{0i}} | U_i = 1) \tag{9a}$$

$$p = \frac{100}{\#(J)} \sum_{i \in J} (e^{X_{1i}\hat{\beta}_1 + \hat{\sigma}_{1\eta}\lambda_{1i}} - e^{X_{1i}\hat{\beta}_0 + \hat{\sigma}_{0\eta}\lambda_{1i}}) \ / \ e^{X_{1i}\hat{\beta}_0 + \hat{\sigma}_{0\eta}\lambda_{1i}} \tag{9b}$$

Where p is the average percentage effect; $ln\hat{P}_{0i}$ and $ln\hat{P}_{1i}$ are the predicted property values from Table 4.4; and J is numbers of properties under regime 1.

Based on the Equation 9(b), we get the average percentage change is -4.2160%, while the results of the DID model discussed in Chapter 3 is -5.2793%. They are quite close, conforming the negative effects of this continuous growth policy on property values.

4.5. Conclusions

This chapter takes self-selection in house sale into consideration. The housing transactions that occur after the implementation of the new policy are not random. Since the new policy has impacts on property values, a homeowner's decision whether to sell or not is also affected by this policy. Using a time dummy to divide all observations into two groups before and after the policy change, we estimate two hedonic price models under the endogenous switching framework. Types of explanatory variables are still the same as in Chapter 3. Pre-tests indicate that the error terms of the second stage are heteroscedastic and not normal distributed, so we estimate by robust standard errors and student's t distribution. In order to demonstrate the robustness of our results, we consider two different distributions.

The first-stage results indicate due to the policy change, homeowners are more prone to selling properties with more acres of forests, but less likely to sell those surrounded by more acres of parks, within its 200-meter buffer. People predict the conversion of developable open space is approaching, so they sell those houses to avoid the reduction of those values and to avoid the nuisance of having construction nearby. Hedonic price models in the second stage imply people's WTPs for different housing attributes. Because of the announcement of the new policy, people's WTP for an acre of forest, pasture and grassland decreases by $CAD 15,256, $CAD 6,001 and $CAD 3,458 respectively. In addition, the continuous growth policy has negative effects on housing prices. All else equal, property values decline by 4.2160% on average, after the implementation of such policy.

4.6. References

Akpalu, W., and A.K. Normanyo. 2013. Illegal Fishing and Catch Potentials among Small-Scale Fishers: Application of An Endogenous Switching Regression Model. *Environment and Development Economics* 19:156-172.

Asfaw, S., B. Shiferaw, F. Simtowe, and L. Lipper. 2012. Impact of Modern Agricultural Technologies on Smallholder Welfare: Evidence from Tanzania and Ethiopia. *Food Policy* 37:283-295.

Borchers, A.M., and J.M. Duke. 2012. Capitalization and Proximity to Agricultural and Natural Lands: Evidence from Delaware. *Journal of Environmental Management* 99:110-117.

Cherubini, U., E. Luciano, and W. Vecchiato. 2004. Copula Methods in Finance: John Wiley and Sons.

Cho, S.-H., C.D. Clark, W.M. Park, and S.G. Kim. 2009. Spatial and Temporal Variation in the Housing Market Values of Lot Size and Open Space. *Land Economics* 85:51-73.

Cho, S.-H., S.G. Kim, and R.K. Roberts. 2011. Values of Environmental Landscape Amenities during the 2000-2006 Real Estate Boom and Subsequent 2008 Recession. *Journal of Environmental Planning and Management* 54:71-91.

Cho, S.-H., N.C. Poudyal, and R.K. Roberts. 2008. Spatial Analysis of the Amenity Value of Green Open Space. *Ecological Economics* 66:403-416.

Cho, S.H., D.M. Lambert, R.K. Roberts, and S.G. Kim. 2009. Moderating Urban Sprawl: Is There a Balance between Shared Open Space and Housing Parcel Size? *Journal of Economic Geography* 10:763-783.

Choi, P., and I. Min. 2009. Estimating Endogenous Switching Regression Model with a Flexible Parametric Distribution Function: Application to Korean Housing Demand. *Applied Economics* 41:3045-3055.

Di Falco, S., M. Veronesi, and M. Yesuf. 2011. Does Adaptation to Climate Change Provide Food Security? A Micro-Perspective from Ethiopia. *American Journal of Agricultural Economics* 93:829-846.

Geoghegan, J. 2002. The Value of Open Space in Residential Land Use. *Land Use Policy* 19:91-98.

Government of Alberta. 2010. Guide to Property Assessment and Taxation in Alberta. http://www.municipalaffairs.alberta.ca/documents/as/Guide%20to%20Property%20Assessment%20and%20Taxation%20in%20Alberta.pdf. (Accessed on March 22, 2018).

Grotkowska, G., L. Wincenciak, and T. Gajderowicz. 2016. Public-Private Wage Differential in a Post-Transition Economy: A Copula Approach to the Switching Regression Model. https://econpapers.repec.org/paper/warwpaper/2016-19.htm. (Accessed on February 28, 2018).

Hair, J.F., W.C. Black, B.J. Babin, R.E. Anderson, and R.L. Tatham. 1998. Multivariate Data Analysis: Prentice Hall Upper Saddle River, NJ.

Hao, J., J. Bihman, C. Gardebroek, N. Heerink, W. Heijman, and X. Huo. 2018. Cooperative Membership and Farmers' Choice of Marketing Channels: Evidence from Apple Farmers in Shaanxi and Shandong Provinces, China. *Food Policy* 74:53-64.

Hasebe, T. 2013. Copula-based Maximum-Likelihood Estimation of Sample-Selection Models. *The Stata Journal* 13:547-573.

Heckman, J., J.L. Tobias, and E. Vytlacil. 2001. Four Parameters of Interest in the Evaluation of Social Programs. *Southern Economic Association* 68:210-223.

Huang, J., Y. Wang, and J. Wang. 2015. Farmers' Adaptation to Extreme Weather Events through Farm Management and Its Impacts on the Mean and Risk of Rice Yield in China. *American Journal of Agricultural Economics* 97:602-617.

Irwin, E.G. 2002. The Effects of Open Space on Residential Property Values. *Land Economics* 78:465-480.

Kim, S.-Y., J. Rodolfo M. Nayga, and J. Oral Capps. 2000. The Effect of Food Label Use on Nutrient Intakes: An Endogenous Switching Regression Analysis. *Journal of Agricultural and Resource Economics* 25:215-231.

Lee, J.-Y., M.G. Brown, and B. Schwartz. 1986. The Demand for National Brand and Private Label Frozen Concentrated Orange Juice: A Switching Regression Analysis. *Western Journal of Agricultural Economics* 11:1-7.

Lee, L. 1978. Unionism and Wage Rates: A Simultaneous Equations Model with Qualitative and Limited Dependent Variables. *International Economic Review* 19:415-433.

Maddala, G.S. 1983. Limited Dependent and Qualitative Variables in Econometrics: Cambridge University Press.

Maddala, G.S., and K. Lahiri. 1992. Introduction to Econometrics: Macmillan New York.

Manrique, J., and K. Ojah. 2003. The Demand for Housing in Spain: An Endogenous Switching Regression Analysis. *Applied Economics* 35:323-336.

Mishra, A.K., A.R. Khanal, and V.O. Pede. 2017. Is Direct Seeded Rice a Boon for Economic Performance? Empirical Evidence from India. *Food Policy* 73:10-18.

Powers, D. 2007. Censored Regression, Sample Selection, Endogenous Switching, and Treatment-Effect Regression Models. https://pdfs.semanticscholar.org/c0e8/8bb7949ba7f9fc7d00090e2dee06b892b343.pdf. (Accessed on February 28, 2018).

Shapiro, S.S., and M.B. Wilk. 1965. An Analysis of Variance Test for Normality (Complete Samples). *Biometrika* 52:591-611.

Shiferaw, B., M. Kassie, M. Jaleta, and C. Yirga. 2014. Adoption of Improved Wheat Varieties and Impacts on Household Food Security in Ethiopia. *Food Policy* 44:272-284.

Smith, V.K., C. Poulos, and H. Kim. 2002. Treating Open Space as an Urban Amenity. *Resource and Energy Economics* 24:107-129.

Wilde, P.E., and C.K. Ranney. 2000. The Monthly Food Stamp Cycle: Shopping Frequency and Food Intake Decisions in an Endogenous Switching Regression Framework. *American Journal of Agricultural Economics* 82:200-213.

Wooldridge, J.M. 2015. Introductory Econometrics: A Modern Approach: Nelson Education.

Chapter 5. Conclusions

This thesis focuses on the evaluation of a municipal land-use policy which approves a larger urban population, using the Town of Okotoks in Alberta as a natural experiment. The Town relaxed a finite growth policy to a continuous growth policy in September 2012, which allows an accelerated conversion of open space. All analyses are based on single-family residential property transactions from 2010 to 2017. According to a hedonic price conceptual framework, we identify two effects of the pro-development policy. Incorporating this policy and sizes of different types of open space, such as forest, pasture, cropland, grassland and park, into a hedonic price model, we identify the impacts of the policy on property values. Estimating two hedonic price models before and after the policy change, conditional on homeowners' decision to sell a house, we identify whether this policy has effects on people's WTPs for open space. Through the impacts of the policy on property values, we will also know whether people value the pro-development policy, which is a good signal for the government to assess its benefits or costs when a new land-use policy is put forward. The following sections summarize our findings in each chapter, provide policy implications, discuss limitations and offer insights for future work.

5.1. Summary of Key Findings

Chapter 2 reviews relevant literature on the hedonic price model and presents the theory behind it. Stated preference methods such as choice experiments are more accurate than revealed preferences to capture people's WTP for non-market goods and services. They consider not only use values but also passive use values (Bockstael and McConnell, 2007). However, revealed preferences depend on individuals' actual behaviors, through which WTP is more valid. Hedonic price model is one of the revealed preference approaches. It capitalizes different characteristics into property value. The implicit price of an attribute is obtained in the first stage, while the marginal WTP should be revealed in the second stage based on households' characteristics (Bockstael and McConnell, 2007). Getting access to households' characteristics is difficult, so researchers usually use the first stage to approximately estimate the marginal WTP for an attribute (Geoghegan et al., 1997; Kuminoff et al., 2010; Ready and Abdalla, 2005).

Chapter 3 mainly aims to identify the effects of the continuous growth policy on property values. It also discusses WTPs for different types of open space, assuming they are constant before and after the announcement of the new policy. All observations are in the Town and four townships surrounding the Town. Open space variables are classified into the number of acres of forest, pasture, cropland, grassland and park within a 200-meter buffer of a property, respectively. Except for park, others are different uses of developable lands. In order to capture the implicit price of the policy, a quasi-experimental method, DID is taken into the double log hedonic price function. We assume that the treatment group includes all properties with developable open space in their 200-meter buffers. Furthermore, considering that properties in a real estate market are spatially correlated with their neighbours, we perform a spatial lag model under a S2SLS regression. The results indicate that the spatial effects exist. After calculating the marginal effects, we conclude that people value pasture but disvalue the new policy. People are willing to pay $CAD 19,589 for one more acre of pasture within a 200-meter buffer of a property, on average. However, they are willing to pay an average of $CAD 33,574 to avoid the implementation of the new policy. Equivalently, the housing price decreases by an average of 5.2793% due to the policy change.

Chapter 4 relaxes the assumption that WTPs for open spaces are constant and restricts observations to the Town of Okotoks. We mainly focus on whether WTPs for different types of open space change because of the announcement of the new policy. Properties sold after the policy change are not random. Considering the continuous growth policy opens up the possibility that developable lands would be converted in the near future, homeowners may expect price decreases for properties surrounded by developable lands. There may be more of those properties offered for sale after the policy change. In terms of the self-selection problem, we apply an endogenous switching regression in this chapter. The first stage is a probit model representing homeowners' decisions of selling a house after the implementation of the new policy. The second stage includes two hedonic price models before and after the policy, conditional on the first-stage function. Before estimation, we perform pre-tests and find that error terms in two hedonic price models are heteroscedastic and non-normal distributed. Therefore, a flexible student's t distribution and robust standard errors are used. The endogenous switching regression shows that the OLS estimation is biased. Moreover, robustness checks are performed under two new endogenous switching regressions with different distributions of error terms. The results are as expected. In the first stage, homeowners are more likely to sell the property surrounded by forest, while keeping the property with a park in its 200-meter buffer. In the second stage, homebuyers value developable open space such as forest, pasture and grassland in the Town. However, the WTPs decrease due to the policy change. The WTP for an acre of forest, pasture and grassland within a 200-meter buffer decreases by $CAD 15,256, $CAD 6,001 and $CAD 3,458 respectively. In addition, we also calculate the effects of this policy on property values. Property values decline by 4.2160% on average, after the implementation of such policy. It is very close to the average percentage change in Chapter 3 for a larger area around the town.

5.2. Policy Implications

The Government of Alberta (2000) recognizes that property tax, as one source of revenue, affects the operating as well as capital budgets for each municipal council. As cities are growing very fast, the demand for property tax is really high to meet obligations such as the provision of public services and infrastructure. McMillan and Dahlby (2014) indicate per capita property tax increased by 2.73 times in Alberta between 1994 and 2011.

Based on residential property transaction data in the hedonic price model, we have estimated people's WTPs for different attributes, which have indirect impacts on property tax (Atreya et al., 2013; Borchers and Duke, 2012; No Kim et al., 2016). The Town of Okotoks (2017b) presents the residential property tax rate is 0.7975% in 2017, so we can calculate the revenue change due to the announcement of the pro-development policy. In Chapter 3, we figure out that people are willing to pay $CAD 33,574 on average for avoiding the new pro-development policy. In other words, property prices decrease because of the new policy. Therefore, the new policy decreased the tax revenue by $CAD 268 per household per year compared to the counterfactual of no policy change. In Chapter 4, we mainly focus on whether there are benefit changes of open space resulting from the implementation of the new policy. We can estimate the loss of tax revenue that may result. There are 22 DAs in Okotoks. For example, in one specific DA (DA Code: 48061917) 61 of our sample properties were exchanged during our study period. On average, those 61 properties had 0.67 acres of forest, 2.95 acres of grassland, and zero pasture within its 200-meter buffer. Willingness to pay for that forest and grassland was reduced due to the policy (see Table 4.5). This loss of WTP for open space for those 61 properties would result in reductions in property tax collected from those properties by $CAD 4,994 for the loss of WTP for forest and $CAD 4,912 for the loss of WTP for grassland (See Appendix L).

Regarding the pro-development policy, although it may provide benefits such as tax revenue from new residential, industrial or commercial properties, it reduces the revenue from current properties. Therefore, the Town council has to consider the trade-offs between benefits and costs while putting forward a new land-use policy which promotes development.

5.3. Limitations and Future Research

This thesis still has some downsides. The first limitation is that two papers in Chapter 3 and Chapter 4 used different sizes of the study area. Chapter 3 focuses on the four townships surrounding the Town, while Chapter 4 only targets on the Town. The difference may affect the accuracy of the results. Since we perform spatial models in Chapter 3, the spatial effects imply observations outside Okotoks also have an indirect influence on those located within the boundary of the Town.

The second limitation is that the time dummy after the announcement of the new policy is not a perfect policy instrument for the analysis in Chapter 4. There may be other economic changes after September 2012, so the time dummy does not exactly capture the policy change. Identically, we cannot guarantee the treated group must receive the treatment after the time threshold. Individuals may take actions before the announcement of the policy as long as they expect the change, or they may realize the change after a time lag. Our results may thus be biased. In order to improve the quality of the policy instrument, it would be better to explore more deeply the municipal land-use policy changes in towns and cities across the province, trying to find municipalities with policy changes that affect just a specific group of properties within the jurisdiction.

The evaluation of a land-use policy can be further investigated in the background of Alberta. First, since this thesis only chooses the Town of Okotoks as a natural experiment for the province to discuss the effects of the new land-use policy, we can extend it into other municipalities with similar policy histories. A discussion under more case studies will not only back up what we find in this thesis, but also make results more convincing. Second, although Chapter 3 considers a larger area instead of the Town, this thesis still mainly focuses on the effects of the policy on urban residents. The next step can be to explore the effects on rural residents and compare between urban and rural areas. Individuals living in the rural area may have different values for open spaces, thus a different perspective for the land-use policy. It will make the evaluation more comprehensive. Third, it is very important to perform more analysis of public finance on the basis of the results presented in the thesis. It will make our findings more meaningful and more practical. After estimating a hedonic price function, Atreya et al. (2013) set up three scenarios under different discount rates to discuss benefits and costs of a flood. Similarly, we can also evaluate the land-use policy with different scenarios of property tax rates. Last but not least, a choice experiment can be also considered instead of a hedonic price model. Although the methodology and empirical technique are complicated, a designed survey is more straightforward and comprehensive to reveal people's WTPs for a land-use policy and also different types of open space.

5.4. References

Atreya, A., S. Ferreira, and W. Kriesel. 2013. Forgetting the Flood? An Analysis of the Flood Risk Discount over Time. *Land Economics* 89:577-596.

Bockstael, N.E., and K.E. McConnell. 2007. Environmental and Resource Valuation with Revealed Preferences: A Theoretical Guide to Empirical Models: Springer Science and Business Media.

Borchers, A.M., and J.M. Duke. 2012. Capitalization and Proximity to Agricultural and Natural Lands: Evidence from Delaware. *Journal of Environmental Management* 99:110-117.

Geoghegan, J., L.A. Wainger, and N.E. Bockstael. 1997. Spatial Landscape Indices in a Hedonic Framework: An Ecological Economics Analysis Using GIS. *Ecological Economics* 23:251-264.

Government of Alberta. 2000. Municipal Government Act. http://www.qp.alberta.ca/documents/Acts/m26.pdf. (Accessed on March 9, 2018).

Kuminoff, N.V., C.F. Parmeter, and J.C. Pope. 2010. Which Hedonic Models Can We Trust to Recover the Marginal Willingness to Pay for Environmental Amenities. *Journal of Environmental Economics and Management*.

McMillan, M., and B. Dahlby. 2014. Do Local Governments Need Alternative Sources of Tax Revenue? An Assessment of the Options for Alberta Cities. *SPP Research Papers* 7.

No Kim, H., P.C. Boxall, and W.L. Adamowicz. 2016. The Demonstration and Capture of the Value of an Ecosystem Service: A Quasi-Experimental Hedonic Property Analysis. *American Journal of Agricultural Economics* 98:819-837.

Ready, R.C., and C.W. Abdalla. 2005. The Amenity and Disamenity Impacts of Agriculture: Estimates from a Hedonic Pricing Model. *American Journal of Agricultural Economics* 87:314-326.

Town of Okotoks. 2017b. A Bylaw of the Town of Okotoks in the Province of Alberta to Authorize Rates of Taxation to be Levied against Assessable Property and to Set Supplementary Property Tax Rates for the 2017 Tax Year. https://www.okotoks.ca/sites/default/files/pdfs/municipal-government/5.1%20Bylaw%2005-17%20Property%20and%20Supplemental%20Tax%20Rates%20second%20reading.pdf. (Accessed on March 9, 2018).

References

Abbott, J.K., and H.A. Klaiber. 2011. An Embarrassment of Riches: Confronting Omitted Variable Bias and Multi-Scale Capitalization in Hedonic Price Models. *The Review of Economics and Statistics* 93:1331-1342.

Agriculture and Agri-Food Canada. 2016. Annual Crop Inventory: Data Product Specifications. https://open.canada.ca/data/en/dataset/ba2645d5-4458-414d-b196-6303ac06c1c9. (Accessed on March 22, 2018).

Akpalu, W., and A.K. Normanyo. 2013. Illegal Fishing and Catch Potentials among Small-Scale Fishers: Application of An Endogenous Switching Regression Model. *Environment and Development Economics* 19:156-172.

Anselin, L. 2001. Spatial Econometrics. In *A Companion to Theoretical Econometrics.*

Anselin, L. 2002. Spatial Weights. http://www.dpi.inpe.br/gilberto/tutorials/software/geoda/tutorials/w8_weights.pdf. (Accessed on February 28, 2018).

Anselin, L., and A.K. Bera. 1998. Spatial Dependence in Linear Regression Models with an Introduction to Spatial Econometrics. *Statistics Textbooks and Monographs* 155:237-290.

Anselin, L., and N. Lozano-Gracia. 2008. Errors in Variables and Spatial Effects in Hedonic House Price Models of Ambient Air Quality. *Empirical Economics* 34:34.

Arduini, T., E. Patacchini, and E. Rainone. 2016. Identification and Estimation of Network Models with Heterogeneous Externalities. https://pdfs.semanticscholar.org/3d61/1d1c0b7c1a496e53bc822880fda37b2fbd76.pdf. (Accessed on March 22, 2018).

Asabere, P.K. 2014. The Value of Homes in Cluster Development Residential Districts: The Relative Significance of the Permanent Open Spaces Associated with Clusters. *The Journal of Real Estate Finance and Economics* 48:244-255.

Asfaw, S., B. Shiferaw, F. Simtowe, and L. Lipper. 2012. Impact of Modern Agricultural Technologies on Smallholder Welfare: Evidence from Tanzania and Ethiopia. *Food Policy* 37:283-295.

Atreya, A., S. Ferreira, and W. Kriesel. 2013. Forgetting the Flood? An Analysis of the Flood Risk Discount over Time. *Land Economics* 89:577-596.

Bateman, I., B. Day, I. Lake, and A. Lovett. 2001. The Effect of Road Traffic on Residential Property Values: A Literature Review and Hedonic Pricing Study: Scottish Executive.

Bhatta, B. 2010. Causes and Consequences of Urban Growth and Sprawl. In *Analysis of Urban Growth and Sprawl from Remote Sensing Data.* Springer Science and Business Media, pp. 17-36.

Bin, O., C.E. Landry, and G.F. Meyer. 2009. Riparian Buffers and Hedonic Prices: A Quasi-Experimental Analysis of Residential Property Values in the Neuse River Basin. *American Journal of Agricultural Economics* 91:1067-1079.

Bockstael, N.E. 1996. Modeling Economics and Ecology: The Importance of a Spatial Perspective. *American Journal of Agricultural Economics* 78:1168-1180.

Bockstael, N.E., and K.E. McConnell. 2007. Environmental and Resource Valuation with Revealed Preferences: A Theoretical Guide to Empirical Models: Springer Science and Business Media.

Boennec, R.m.L., and F.d.r. Salladarré. 2017. The Impact of Air Pollution and Noise on the Real Estate Market. The Case of the 2013 European Green Capital: Nantes, France. *Ecological Economics* 138:82-89.

Bolitzer, B., and N.R. Netusil. 2000. The Impact of Open Spaces on Property Values in Portland, Oregon. *Journal of Environmental Management* 59:185-193.

Borchers, A.M., and J.M. Duke. 2012. Capitalization and Proximity to Agricultural and Natural Lands: Evidence from Delaware. *Journal of Environmental Management* 99:110-117.

Bork, E. 2016. An Overview of Current Research on Environmental Goods and Services in Alberta Grasslands. https://rri.ualberta.ca/Portals/115/Documents/Presentations/Bork%20-%20Western%20Beef%20Development%20Center%20-%20Lanigan%20SK%20June%2021%202016.pdf?ver=2016-11-09-103031-627. (Accessed on April 6, 2018).

Bowman, T., J.C. Tyndall, J. Thompson, J. Kliebenstein, and J.P. Colletti. 2012. Multiple Approaches to Valuation of Conservation Design and Low-Impact Development Features in Residential Subdivisions. *Journal of Environmental Management* 104:101-113.

Boxall, P.C., W.H. Chan, and M.L. McMillan. 2005. The Impact of Oil and Natural Gas Facilities on Rural Residential Property Values: A Spatial Hedonic Analysis. *Resource and Energy Economics* 27:248-269.

Braden, J.B., and C.D. Kolstad. 1991. Measuring the Demand for Environmental Quality: Elsevier Science Pub. Co.

Brown, D.W., and G.B. Wetherill. 1990. Statistical Process Control: Chapman and Hall.

Calgary Real Estate Board. 2018. Daily Housing Summary. http://www.creb.com/Housing_Statistics/Daily_Housing_Summary/?tab=2. (Accessed on February 28, 2018).

Cherubini, U., E. Luciano, and W. Vecchiato. 2004. Copula Methods in Finance: John Wiley and Sons.

Cho, S.-H., C.D. Clark, W.M. Park, and S.G. Kim. 2009. Spatial and Temporal Variation in the Housing Market Values of Lot Size and Open Space. *Land Economics* 85:51-73.

Cho, S.-H., S.G. Kim, and R.K. Roberts. 2011. Values of Environmental Landscape Amenities during the 2000-2006 Real Estate Boom and Subsequent 2008 Recession. *Journal of Environmental Planning and Management* 54:71-91.

Cho, S.-H., N.C. Poudyal, and R.K. Roberts. 2008. Spatial Analysis of the Amenity Value of Green Open Space. *Ecological Economics* 66:403-416.

Cho, S.H., D.M. Lambert, R.K. Roberts, and S.G. Kim. 2009. Moderating Urban Sprawl: Is There a Balance between Shared Open Space and Housing Parcel Size? *Journal of Economic Geography* 10:763-783.

Choi, P., and I. Min. 2009. Estimating Endogenous Switching Regression Model with a Flexible Parametric Distribution Function: Application to Korean Housing Demand. *Applied Economics* 41:3045-3055.

City of Calgary. 2002. Open Space Plan. https://www.calgary.ca/CSPS/Parks/Documents/Planning-and-Operations/open-space-plan.pdf?noredirect=1. (Accessed on March 22, 2018).

Dekkers, J.E.C., and J.W.v.d. Straaten. 2009. Monetary Valuation of Aircraft Noise: A Hedonic Analysis around Amsterdam Airport. *Ecological Economics* 68:2850-2858.

Di Falco, S., M. Veronesi, and M. Yesuf. 2011. Does Adaptation to Climate Change Provide Food Security? A Micro-Perspective from Ethiopia. *American Journal of Agricultural Economics* 93:829-846.

Farja, Y. 2017. Price and Distributional Effects of Privately Provided Open Space in Urban Areas. *Landscape research* 42:543-557.

Farm Credit Canada. 2002. Farmland Values. http://publications.gc.ca/site/archivee-archived.html?url=http://publications.gc.ca/collections/collection_2017/fac-fcc/CC212-4-2002-2-eng.pdf. (Accessed on March 22, 2018).

Farm Credit Canada. 2017. 2016 FCC Farmland Values Report. https://www.fcc-fac.ca/content/dam/fcc/about-fcc/reports/farmland-values-report-2016.pdf. (Accessed on March 22, 2018).

Fernandez, L., B. Cutter, R. Sharma, and T. Scott. 2018. Land Preservation Policy Effect or Neighborhood Dynamics: A Repeat Sales Hedonic Matching Approach. *Journal of Environmental Economics and Management*.

Franco, S.F., and J.L. Macdonald. 2017. Measurement and Valuation of Urban Greenness: Remote Sensing and Hedonic Applications to Lisbon, Portugal. *Regional Science and Urban Economics*.

Geoghegan, J. 2002. The Value of Open Space in Residential Land Use. *Land Use Policy* 19:91-98.

Geoghegan, J., L. Lynch, and S. Bucholtz. 2003. Capitalization of Open Spaces into Housing Values. *Agricultural and Resource Economics Review* 32:33-45.

Geoghegan, J., L.A. Wainger, and N.E. Bockstael. 1997. Spatial Landscape Indices in a Hedonic Framework: An Ecological Economics Analysis Using GIS. *Ecological Economics* 23:251-264.

Gnagey, M., and T. Grijalva. 2018. The Impact of Trails on Property Values: A Spatial Analysis. *The Annals of Regional Science* 60:73-97.

Government of Alberta. 2000. Municipal Government Act. http://www.qp.alberta.ca/documents/Acts/m26.pdf. (Accessed on March 9, 2018).

Government of Alberta. 2008. Land Use Framework. https://www.edmonton.ca/city_government/documents/PDF/Alberta_Land_Use_Framework.pdf. (Accessed on February 28, 2018).

Government of Alberta. 2009. Alberta Land Stewardship Act. http://www.qp.alberta.ca/documents/Acts/A26P8.pdf. (Accessed on March 22, 2018).

Government of Alberta. 2010. Guide to Property Assessment and Taxation in Alberta. http://www.municipalaffairs.alberta.ca/documents/as/Guide%20to%20Property%20Assessment%20and%20Taxation%20in%20Alberta.pdf. (Accessed on March 22, 2018).

Government of Alberta. 2016a. Location and Geography. http://www.albertacanada.com/business/overview/location-and-geography.aspx. (Accessed on February 28, 2018).

Government of Alberta. 2016b. Forest Health and Adaptation in Alberta: Annual Report. https://open.alberta.ca/publications/2560-760x. (Accessed on February 28, 2018).

Government of Alberta. 2016c. Fragmentation and Conversion of Agricultural Land in Alberta http://www1.agric.gov.ab.ca/$Department/deptdocs.nsf/all/luf15507/$FILE/fragmentation-conversion2016-01-18.pdf. (Accessed on February 28, 2018).

Government of Alberta. 2017a. Quarterly Population Report. http://www.finance.alberta.ca/aboutalberta/osi/demographics/Population-Estimates/Quarterly-2017-2018/2017-3rdQuarter.pdf. (Accessed on February 28, 2018).

Government of Alberta. 2017b. Housing Starts. http://economicdashboard.alberta.ca/HousingStarts. (Accessed on March 22, 2018).

Government of Alberta. 2017c. Highlight of Alberta Economy. http://www.albertacanada.com/files/albertacanada/SP-EH_highlightsABEconomyPresentation.pdf. (Accessed on March 22, 2018).

Government of Alberta. 2017d. Natural Regions Shapefile. https://www.albertaparks.ca/albertaparksca/management-land-use/parks-system/. (Accessed on March 22, 2018).

Government of Alberta. 2018. Oil Prices. http://economicdashboard.alberta.ca/OilPrice. (Accessed on March 22, 2018).

Greenstone, M., and T. Gayer. 2009. Quasi-Experimental and Experimental Approaches to Environmental Economics. *Journal of Environmental Economics and Management* 57:21-44.

Grotkowska, G., L. Wincenciak, and T. Gajderowicz. 2016. Public-Private Wage Differential in a Post-Transition Economy: A Copula Approach to the Switching Regression Model. https://econpapers.repec.org/paper/warwpaper/2016-19.htm. (Accessed on February 28, 2018).

Hair, J.F., W.C. Black, B.J. Babin, R.E. Anderson, and R.L. Tatham. 1998. Multivariate Data Analysis: Prentice Hall Upper Saddle River, NJ.

Halvorsen, R., and R. Palmquist. 1980. The Interpretation of Dummy Variables in Semilogarithmic Equations. *The American Economic Review* 70:474-475.

Hao, J., J. Bihman, C. Gardebroek, N. Heerink, W. Heijman, and X. Huo. 2018. Cooperative Membership and Farmers' Choice of Marketing Channels: Evidence from Apple Farmers in Shaanxi and Shandong Provinces, China. *Food Policy* 74:53-64.

Hasebe, T. 2013. Copula-based Maximum-Likelihood Estimation of Sample-Selection Models. *The Stata Journal* 13:547-573.

Heckman, J., J.L. Tobias, and E. Vytlacil. 2001. Four Parameters of Interest in the Evaluation of Social Programs. *Southern Economic Association* 68:210-223.

Heintzelman, M.D. 2010. The Value of Land Use Patterns and Preservation Policies. The University of Michigan.

Huang, J., Y. Wang, and J. Wang. 2015. Farmers' Adaptation to Extreme Weather Events through Farm Management and Its Impacts on the Mean and Risk of Rice Yield in China. *American Journal of Agricultural Economics* 97:602-617.

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

Irwin, E.G. 2002. The Effects of Open Space on Residential Property Values. *Land Economics* 78:465-480.

Irwin, E.G., and N.E. Bockstael. 2001. The Problem of Identifying Land Use Spillovers: Measuring the Effects of Open Space in Residential Property Values. *American Journal of Agricultural Economics* 83:698-704.

Kelejian, H.H., and I.R. Prucha. 2007. HAC Estimation in a Spatial Framework. *Journal of Econometrics* 140:131-154.

Kim, C.W., T.T. Phipps, and L. Anselin. 2003. Measuring the Benefits of Air Quality Improvement: A Spatial Hedonic Approach. *Journal of Environmental Economics and Management* 45:24-39.

Kim, S.-Y., J. Rodolfo M. Nayga, and J. Oral Capps. 2000. The Effect of Food Label Use on Nutrient Intakes: An Endogenous Switching Regression Analysis. *Journal of Agricultural and Resource Economics* 25:215-231.

Kling, R.W., T.S. Findley, E. Gahramanov, and D.M. Theobald. 2015. Hedonic Valuation of Land Protection Methods: Implications for Cluster Development. *Journal of Economics and Finance* 39:782-806.

Kuminoff, N.V., C.F. Parmeter, and J.C. Pope. 2010. Which Hedonic Models Can We Trust to Recover the Marginal Willingness to Pay for Environmental Amenities. *Journal of Environmental Economics and Management*.

Lansford, N.H., and L.L. Jones. 1995. Recreational and Aesthetic Value of Water Using Hedonic Price Analysis. *Journal of Agricultural and Resource Economics* 20:341-355.

Lee, J.-Y., M.G. Brown, and B. Schwartz. 1986. The Demand for National Brand and Private Label Frozen Concentrated Orange Juice: A Switching Regression Analysis. *Western Journal of Agricultural Economics* 11:1-7.

Lee, L. 1978. Unionism and Wage Rates: A Simultaneous Equations Model with Qualitative and Limited Dependent Variables. *International Economic Review* 19:415-433.

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

LeSage, J., and R.K. Pace. 2009. Introduction to Spatial Econometrics.

Lofgren, H., and M. El-Said. 2001. Food Subsidies in Egypt: Reform Options, Distribution and Welfare. *Food Policy* 26:65-83.

Lynch, L., and X. Liu. 2007. Impact of Designated Preservation Areas on Rate of Preservation and Rate of Conversion: Preliminary Evidence. *American Journal of Agricultural Economics* 89:1205-1210.

Maddala, G.S. 1983. Limited Dependent and Qualitative Variables in Econometrics: Cambridge University Press.

Maddala, G.S., and K. Lahiri. 1992. Introduction to Econometrics: Macmillan New York.

Mahmoudi, P., D. Hatton MacDonald, N.D. Crossman, D.M. Summers, and J. Van der Hoek. 2013. Space Matters: The Importance of Amenity in Planning Metropolitan Growth. *Australian Journal of Agricultural and Resource Economics* 57:38-59.

Manrique, J., and K. Ojah. 2003. The Demand for Housing in Spain: An Endogenous Switching Regression Analysis. *Applied Economics* 35:323-336.

Manski, C.F. 2013. Identification of Treatment Response with Social Interactions. *The Econometrics Journal* 16:S1-S23.

McConnell, V., and M. Walls. 2005. The Value of Open Space: Evidence from Studies of Nonmarket Benefits: Resources for the Future Washington, DC.

McMillan, M., and B. Dahlby. 2014. Do Local Governments Need Alternative Sources of Tax Revenue? An Assessment of the Options for Alberta Cities. *SPP Research Papers* 7.

Mei, Y., D. Hite, and B. Sohngen. 2017. Demand for Urban Tree Cover: A Two-Stage Hedonic Price Analysis in California. *Forest Policy and Economics* 83:29-35.

Melichar, J., and K. Kaprová. 2013. Revealing Preferences of Prague's Homebuyers toward Greenery Amenities: The Empirical Evidence of Distance-Size Effect. *Landscape and Urban Planning* 109:56-66.

Mishra, A.K., A.R. Khanal, and V.O. Pede. 2017. Is Direct Seeded Rice a Boon for Economic Performance? Empirical Evidence from India. *Food Policy* 73:10-18.

Mitra, S.K., and J.-D.M. Saphores. 2016. The Value of Transportation Accessibility in a Least Developed Country City: The Case of Rajshahi City, Bangladesh. *Transportation Research Part A: Policy and Practice* 89:184-200.

Münch, A., S.P.P. Nielsen, V.J. Racz, and A.-M. Hjalager. 2016. Towards Multifunctionality of Rural Natural Environments? An Economic Valuation of the Extended Buffer Zones along Danish Rivers, Streams and Lakes. *Land Use Policy* 50:1-16.

Nature Conservancy of Canada. 2017. Prairie Grasslands Conservation Region. http://www.natureconservancy.ca/en/where-we-work/alberta/our-work/prairie-grasslands-conservation-region.html. (Accessed on March 22, 2018).

Netusil, N.R. 2013. Urban Environmental Amenities and Property Values: Does Ownership Matter? *Land Use Policy* 31:371-377.

Newburn, D.A., and J.S. Ferris. 2016. The Effect of Downzoning for Managing Residential Development and Density. *Land Economics* 92:220-236.

No Kim, H., P.C. Boxall, and W.L. Adamowicz. 2016. The Demonstration and Capture of the Value of an Ecosystem Service: A Quasi-Experimental Hedonic Property Analysis. *American Journal of Agricultural Economics* 98:819-837.

Ottensmann, J.R., S. Payton, and J. Man. 2008. Urban Location and Housing Prices within a Hedonic Model. *The Journal of Regional Analysis and Policy* 38:19-35.

Paterson, R.W., and K.J. Boyle. 2002. Out of Sight, Out of Mind? Using GIS to Incorporate Visibility in Hedonic Property Value Models. *Land Economics* 78:417-425.

Powers, D. 2007. Censored Regression, Sample Selection, Endogenous Switching, and Treatment-Effect Regression Models. https://pdfs.semanticscholar.org/c0e8/8bb7949ba7f9fc7d00090e2dee06b892b343.pdf. (Accessed on February 28, 2018).

Qiu, F., L. Laliberte, B. Swallow, and S. Jeffrey. 2015. Impacts of Fragmentation and Neighbor influences on Farmland Conversion: A Case Study of the Edmonton-Calgary Corridor, Canada. *Land Use Policy* 48:482-494.

Rangeland Research Institute. 2016. 2015-2016 Annual Report. https://rri.ualberta.ca/Portals/115/Documents/RRI-AnnualReport-2016.pdf?ver=2016-06-02-090131-697. (Accessed on April 6, 2018).

Raunikar, R., and J. Buongiorno. 2006. Willingness to Pay for Forest Amenities: The Case of Non-Industrial Owners in the South Central United States. *Ecological Economics* 56:132-143.

Ready, R.C., and C.W. Abdalla. 2005. The Amenity and Disamenity Impacts of Agriculture: Estimates from a Hedonic Pricing Model. *American Journal of Agricultural Economics* 87:314-326.

Rosen, S. 1974. Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition. *Journal of Political Economy* 82:34-35.

Rubin, D.B. 1978. Bayesian Inference for Causal Effects: The Role of Randomization. *The Annals of statistics*:34-58.

Sander, H., S. Polasky, and R.G. Haight. 2010. The Value of Urban Tree Cover: A Hedonic Property Price Model in Ramsey and Dakota Counties, Minnesota, USA. *Ecological Economics* 69:1646-1656.

Schläpfer, F., F. Waltert, L. Segura, and F. Kienast. 2015. Valuation of Landscape Amenities: A Hedonic Pricing Analysis of Housing Rents in Urban, Suburban and Periurban Switzerland. *Landscape and Urban Planning* 141:24-40.

Shapiro, S.S., and M.B. Wilk. 1965. An Analysis of Variance Test for Normality (Complete Samples). *Biometrika* 52:591-611.

Shiferaw, B., M. Kassie, M. Jaleta, and C. Yirga. 2014. Adoption of Improved Wheat Varieties and Impacts on Household Food Security in Ethiopia. *Food Policy* 44:272-284.

Singh, A., J.-D. Saphores, and T. Bruckner. 2018. A Spatial Hedonic Analysis of the Housing Market around a Large, Failing Desert Lake: The Case of the Salton Sea in California. *Journal of Environmental Planning and Management*:1-21.

Smith, V.K., C. Poulos, and H. Kim. 2002. Treating Open Space as an Urban Amenity. *Resource and Energy Economics* 24:107-129.

Stan, K.D., and A. Sanchez-Azofeifa. 2017. The Edmonton-Calgary Corridor: Simulating Future Land Cover Change under Potential Government Intervention. *Land Use Policy* 63:356-368.

Statistics Canada. 2011. Forest Land by Province and Territory. http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/envi34a-eng.htm. (Accessed on February 28, 2018).

Statistics Canada. 2011a. Boundary Files. https://www12.statcan.gc.ca/census-recensement/2011/geo/bound-limit/bound-limit-2011-eng.cfm. (Accessed on February 28, 2018).

Statistics Canada. 2016a. Value Per Acre of Farm Land and Building. http://www5.statcan.gc.ca/cansim/a26?lang=eng&id=20003. (Accessed on March 22, 2018).

Statistics Canada. 2016b. Population by Year, by Province and Territory. http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/demo02a-eng.htm. (Accessed on March 22, 2018).

Statistics Canada. 2016c. Census Profile. http://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/details/page.cfm?Lang=E&Geo1=POPC&Code1=0606&Geo2=PR&Code2=48&Data=Count&SearchText=Okotoks&SearchType=Begins&SearchPR=01&B1=All&GeoLevel=PR&GeoCode=0606&TABID=1. (Accessed on March 22, 2018).

Statistics Canada. 2017. Gross Domestic Product, Expenditure-Based, by Province and Territory. http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/econ15-eng.htm. (Accessed on February 28, 2018).

Stoms, D.M., P.A. Jantz, F.W. Davis, and G. DeAngelo. 2009. Strategic Targeting of Agricultural Conservation Easements as a Growth Management Tool. *Land Use Policy* 26:1149-1161.

Town of Okotoks. 1998a. Okotoks Municipal Development Plan. https://www.okotoks.ca/sites/default/files/pdfs/publications/MDP%20Consolidated%20June%202016.pdf. (Accessed on March 22, 2018).

Town of Okotoks. 1998b. Land Use Bylaw. https://www.okotoks.ca/sites/default/files/pdfs/publications/BY40-98%20Update%2020%20-%20July%202015.pdf. (Accessed on February 28, 2018).

Town of Okotoks. 2014. Town of Okotoks Growth Study and Financial Analysis. https://www.okotoks.ca/sites/default/files/pdfs/publications/Town%20of%20Okotoks%20Growth%20Study%20and%20Financial%20Assessment%202016.pdf. (Accessed on February 28, 2018).

Town of Okotoks. 2016. Land Use Map. https://www.okotoks.ca/municipal-government/publications-notices/town-publications/land-use-map. (Accessed on February 28, 2018).

Town of Okotoks. 2017a. Annexation. https://www.okotoks.ca/town-services/planning-development/planning/annexation. (Accessed on February 28, 2018).

Town of Okotoks. 2017b. A Bylaw of the Town of Okotoks in the Province of Alberta to Authorize Rates of Taxation to be Levied against Assessable Property and to Set Supplementary Property Tax Rates for the 2017 Tax Year. https://www.okotoks.ca/sites/default/files/pdfs/municipal-government/5.1%20Bylaw%2005-17%20Property%20and%20Supplemental%20Tax%20Rates%20second%20reading.pdf. (Accessed on March 9, 2018).

Tyrvainen, L. 2000. Property Prices and Urban Forest Amenities. *Journal of Environmental Economics and Management* 39:205-223.

Wang, H. 2015. Examination of Agricultural Land Conservation in the Alberta Capital Region, Canada. Master of Science, University of Alberta.

Wilde, P.E., and C.K. Ranney. 2000. The Monthly Food Stamp Cycle: Shopping Frequency and Food Intake Decisions in an Endogenous Switching Regression Framework. *American Journal of Agricultural Economics* 82:200-213.

Wooldridge, J.M. 2015. Introductory Econometrics: A Modern Approach: Nelson Education.

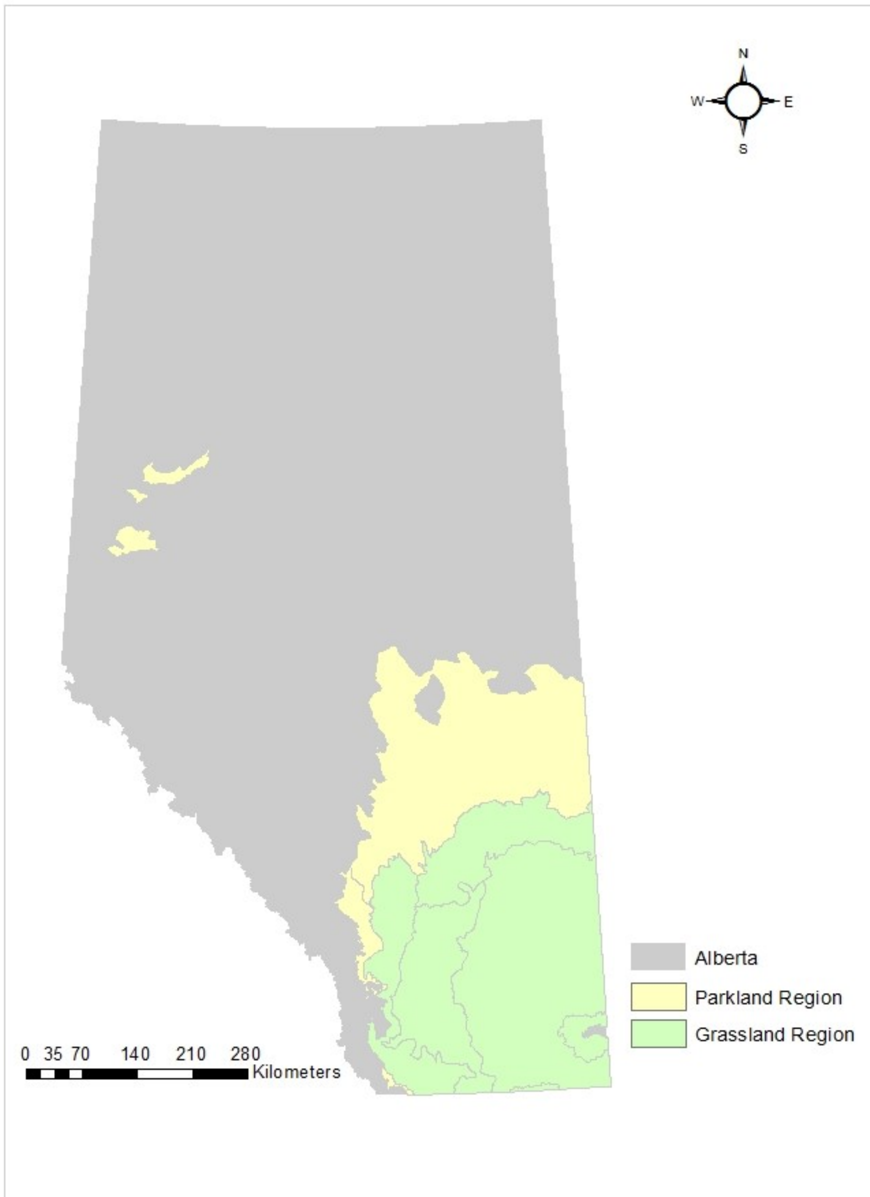
Xiao, Y., Z. Li, and C. Webster. 2016. Estimating the Mediating Effect of Privately-Supplied Green Space on the Relationship between Urban Public Green Space and Property Value: Evidence from Shanghai, China. *Land Use Policy* 54:439-447.

Yoo, J., J. Browning, and K. Minesinger. 2017. Open Space Premium near Commercial Zones: A Case Study in the City of Corona, California. *International Journal of Urban Sciences*:1-12.

Yoo, S., and J.E. Wagner. 2016. A Review of the Hedonic Literatures in Environmental Amenities from Open Space: A Traditional Econometric vs. Spatial Econometric Model. *International Journal of Urban Sciences* 20:141-166.

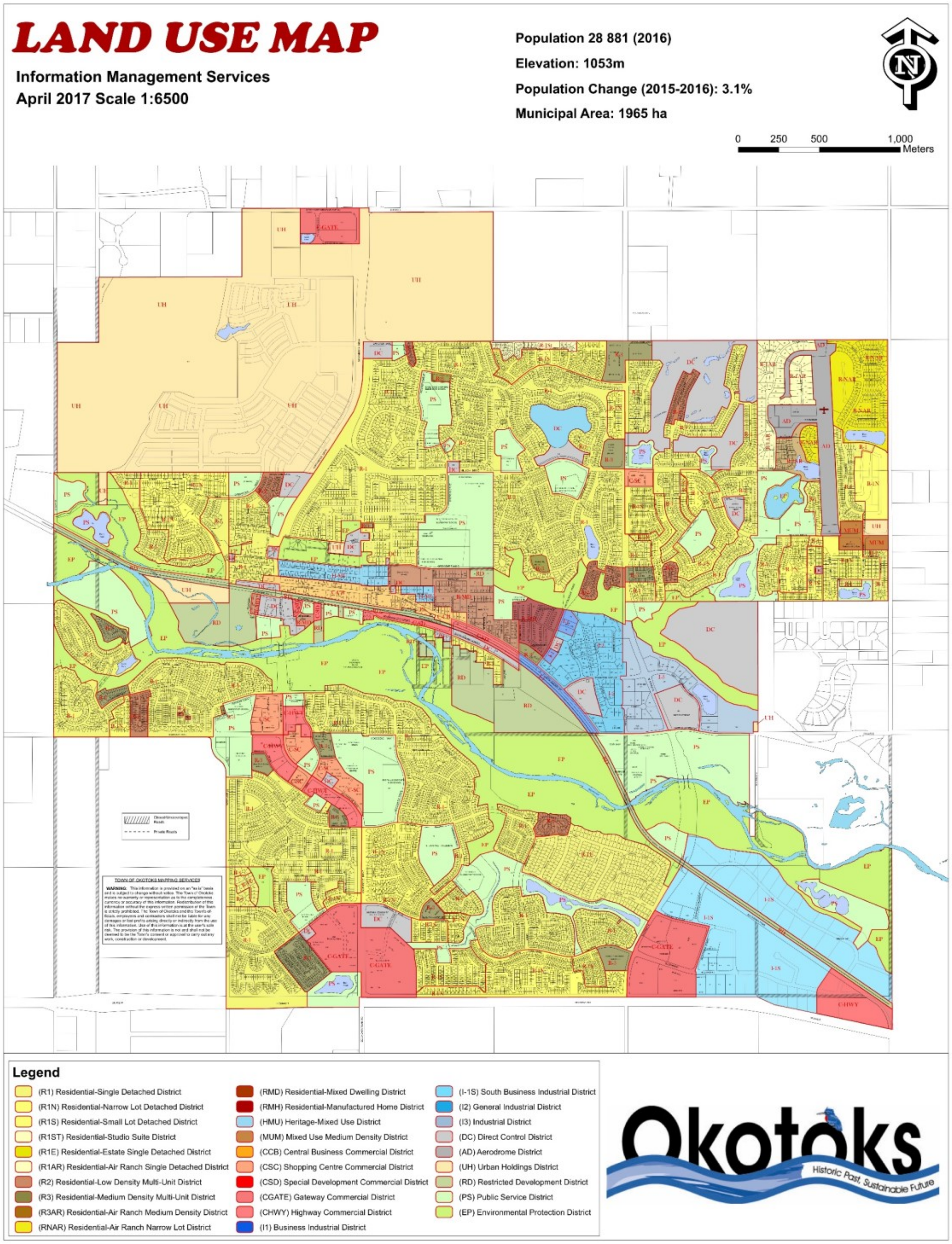
Yusuf, A.A., and B.P. Resosudarmo. 2009. Does Clean Air Matter in Developing Countries' Megacities? A Hedonic Price Analysis of the Jakarta Housing Market, Indonesia. *Ecological Economics* 68:1398-1407.

Appendix A: Map of Grassland and Parkland Regions in Alberta



Data Source: (*Government of Alberta, 2017c*)

Appendix B: Land-Use Map of the Town of Okotoks



Source: (*Town of Okotoks, 2016*)

Appendix C: R^2 and Adjusted R^2 of OLS Regressions under Four Different Functional Forms in Chapter 3

Functional form	R^2	Adjusted R^2
Linear	0.8212	0.8172
Double log	0.8738	0.8710
Log linear	0.8655	0.8625
Linear log	0.7759	0.7709

Appendix D: Estimation Results based on an OLS Regression without Accounting for the Policy Treatment in Chapter 3

Variables	Coefficients
Forest	0.0130***
	(0.0048)
Pasture	0.0256*
	(0.0138)
Cropland	-0.0025
	(0.0016)
Grassland	3e-04
	(0.0018)
Park	1e-04
	(0.0013)
Log (living area)	0.7466***
	(0.0201)
Log (lot size)	0.0785***
	(0.0064)
Condition (1/0)	0.0437***
	(0.0113)
Basement (1/0)	0.1045***
	(0.0084)
Bathroom	-0.0429***
	(0.0075)
Bedroom	-0.0917***
	(0.0062)
Garage	0.0464***
	(0.0061)
Age	-0.0022***
	(5e-04)
Log (Calgary)	-0.3535***

	(0.0464)
Log (hospital)	0.0324***
	(0.0073)
Log (water)	-0.0285***
	(0.0057)
School quality (1/0)	-0.0050
	(0.0095)
Log (density)	-0.0397***
	(0.0079)
% of high school certificate	9e-04
	(0.0011)
% of postsecondary education	1e-04
	(0.0012)
Employment rate	0.0021*
	(0.0011)
Low median household income (1/0)	0.0098
	(0.0231)
High median household income (1/0)	-0.0182
	(0.0239)
Season	0.0165**
	(0.0077)
Constant	10.6682***
	(0.5540)
Fixed effects	Y

Note: ***, **, and * denotes significance level at 10%, 5% and 1%;

Standard errors are in parentheses.

Appendix E: Results of Maximum Likelihood Estimation without Accounting for the Policy Treatment in Chapter 3

Variables	Direct Impact	Indirect Impact	Total Impact
Forest	0.0077	0.0016	0.0094
	(1.6692)	(1.6445)	(1.6703)
Pasture	0.0271**	0.0056**	0.0327**
	(1.9902)	(1.9674)	(1.9945)
Cropland	-0.002	-4e-04	-0.0024
	(-1.2202)	(-1.1985)	(-1.219)
Grassland	-0.0017	-4e-04	-0.0020
	(-0.9849)	(-0.9731)	(-0.9844)
Park	5e-04	1e-04	6e-04
	(0.376)	(0.3745)	(0.3761)
Log (living area)	0.6779***	0.1408***	0.8187***
	(33.6647)	(9.5621)	(32.6611)
Log (lot size)	0.076***	0.0158***	0.0918***
	(12.2699)	(7.4945)	(12.0641)
Condition (1/0)	0.0423***	0.0088***	0.0511***
	(3.9873)	(3.6558)	(3.9787)
Basement (1/0)	0.1033***	0.0215***	0.1247***
	(12.4915)	(7.2389)	(12.0346)
Bathroom	-0.0377***	-0.0078***	-0.0455***
	(-5.3977)	(-4.6847)	(-5.3814)
Bedroom	-0.082***	-0.017***	-0.0990***
	(-13.8486)	(-7.982)	(-13.6954)
Garage	0.0405***	0.0084***	0.0489***
	(6.9051)	(5.734)	(6.918)
Age	-0.002***	-4e-04***	-0.0024***
	(-4.3823)	(-4.0442)	(-4.3894)
Log (Calgary)	-0.2929***	-0.0608***	-0.3537***

	(-6.5629)	(-5.6168)	(-6.5958)
Log (hospital)	0.0196***	0.004***	0.0236***
	(2.7729)	(2.761)	(2.7908)
Log (water)	-0.0222***	-0.0046***	-0.0268***
	(-4.0172)	(-3.8898)	(-4.0521)
School quality (1/0)	-0.0107	-0.0022	-0.0129
	(-1.1534)	(-1.1346)	(-1.1522)
Log (density)	-0.0274***	-0.0057***	-0.0330***
	(-3.5026)	(-3.468)	(-3.5358)
% of high school certificate	7e-04	1e-04	8e-04
	(0.6197)	(0.6108)	(0.6189)
% of postsecondary education	-1e-04	0	-1e-04
	(-0.0559)	(-0.0617)	(-0.0569)
Employment rate	0.0012	3e-04	0.0015
	(1.2335)	(1.2224)	(1.2341)
Low median household income (1/0)	0.0082	0.0017	0.0099
	(0.3793)	(0.3749)	(0.3789)
High median household income (1/0)	-0.0307	-0.0064	-0.0371
	(-1.3323)	(-1.3031)	(-1.3302)
Season	0.0156**	0.0032**	0.0188**
	(2.1134)	(2.0705)	(2.1152)
ρ	0.1838***		

Note: ***, **, and * denotes significance level at 10%, 5% and 1%;

Z-values are in parentheses.

Appendix F: Results of Maximum Likelihood Estimation Accounting for the Policy Treatment in Chapter 3

Variables	Direct Impact	Indirect Impact	Total Impact
Developable open space (1/0)	0.0486**	0.0100**	0.0586**
	(2.4742)	(2.4271)	(2.4808)
Policy implementation time (1/0)	0.0862***	0.0179***	0.1041***
	(2.6711)	(2.5561)	(2.6682)
DID (causal effect of the policy) (1/0)	-0.0470**	-0.0097**	-0.0568**
	(-2.1755)	(-2.1064)	(-2.1736)
Forest	0.0073	0.0015	0.0088
	(1.5546)	(1.5417)	(1.5569)
Pasture	0.0283**	0.0059**	0.0342**
	(2.0615)	(1.9809)	(2.0559)
Cropland	-0.0024	-5e-04	-0.0029
	(-1.5163)	(-1.4973)	(-1.5171)
Grassland	-0.0020	-4e-04	-0.0025
	(-1.1967)	(-1.1769)	(-1.1955)
Park	3e-04	1e-04	3e-04
	(0.2043)	(0.2081)	(0.2051)
Log (living area)	0.6763***	0.1400***	0.8163***
	(33.762)	(9.5443)	(32.434)
Log (lot size)	0.0761***	0.0158***	0.0918***
	(12.0186)	(7.4867)	(11.8358)
Condition (1/0)	0.0394***	0.0082***	0.0476***
	(3.6274)	(3.3817)	(3.6239)
Basement (1/0)	0.1040***	0.0215***	0.1256***
	(13.0035)	(7.5884)	(12.6937)
Bathroom	-0.0368***	-0.0076***	-0.0444***
	(-5.0027)	(-4.4255)	(-4.9901)
Bedroom	-0.0818***	-0.0169***	-0.0988***

	(-14.1632)	(-8.0493)	(-14.0058)
Garage	0.0402***	0.0083***	0.0485***
	(7.0904)	(5.8318)	(7.0994)
Age	-0.002***	-4e-04***	-0.0024***
	(-4.4616)	(-4.1954)	(-4.4874)
Log (Calgary)	-0.29848***	-0.0617***	-0.3601***
	(-6.5937)	(-5.7679)	(-6.6658)
Log (hospital)	0.0200***	0.0041***	0.0241***
	(2.7623)	(2.7057)	(2.7727)
Log (water)	-0.0220***	-0.0045***	-0.0265***
	(-4.0776)	(-3.8569)	(-4.0967)
School quality (1/0)	-0.0130	-0.0027	-0.0157
	(-1.395)	(-1.3728)	(-1.3946)
Log (density)	-0.0261***	-0.0054***	-0.0315***
	(-3.4186)	(-3.3382)	(-3.441)
% of high school certificate	5e-04	1e-04	6e-04
	(0.4483)	(0.4476)	(0.4486)
% of postsecondary education	-5e-04	-1e-04	-5e-04
	(-0.3737)	(-0.3666)	(-0.3728)
Employment rate	0.0013	3e-04	0.0016
	(1.2978)	(1.284)	(1.2983)
Low median household income (1/0)	0.0045	9e-04	0.0054
	(0.2094)	(0.2087)	(0.2094)
High median household income (1/0)	-0.0259	-0.0054	-0.0313
	(-1.1091)	(-1.093)	(-1.1084)
Season	0.0188***	0.0039***	0.0227***
	(2.5424)	(2.4222)	(2.5359)
ρ	0.1816*		

Note: ***, **, and * denotes significance level at 10%, 5% and 1%;

Z-values are in parentheses.

Appendix G: Model Specification in Chapter 4

Variable name	(1) Selection equation	(2) Outcome functions
Dependent variable		
Log (sales price)	-	
Independent variable		
Forest		
Pasture		
Cropland		-
Grassland		
Park		-
Log (living area)		
Log (lot size)		
Condition (1/0)		
Basement (1/0)		
Bathroom		
Bedroom		
Garage		
Age		-
Log (Calgary)		-
Log (hospital)		
Log (water)		-
School quality (1/0)		-
Density		-
% of high school certificates		-
% of post-secondary education		-
Employment rate (%)		-
Low median household income (1/0)		-

High median household income (1/0)	-
Season (1/0)	-

Note: (-) means the variable is excluded.

Appendix H: Robustness Checks in Chapter 4

	(1) logit			(2) Plackett-Clayton		
Variable	Selection	Regime 0	Regime 1	Selection	Regime 0	Regime 1
Forest	0.9493***	0.0875*	0.0573***	0.9778**	0.0864*	0.0571***
	(0.3370)	(0.0466)	(0.0150)	(0.4352)	(0.0489)	(0.0150)
Pasture	0.5827	0.0478	0.0356**	0.7003	0.0416	0.0362**
	(0.7346)	(0.0499)	(0.0173)	(0.6764)	(0.0509)	(0.0172)
Cropland	0.0118			0.0079		
	(0.0328)			(0.0380)		
Grassland	0.0308	0.0175**	0.0108***	0.0211	0.0169**	0.0111***
	(0.0669)	(0.0070)	(0.0024)	(0.0677)	(0.0073)	(0.0024)
Park	-0.0724***			-0.0735***		
	(0.0220)			(0.0247)		
Log (living	2.7135***	0.6367***	0.7563***	3.1163***	0.6219***	0.7450***
area)	(0.5523)	(0.0534)	(0.0319)	(0.5205)	(0.0629)	(0.0306)
Log (lot size)	-0.1630	0.1052**	0.0750***	-0.1157	0.1016**	0.0757***
	(0.3188)	(0.0499)	(0.0270)	(0.2686)	(0.0475)	(0.0231)
Condition	1.3143***	0.0440*	0.0702***	1.4332***	0.0259	0.0668***
(1/0)	(0.2505)	(0.0245)	(0.0154)	(0.2626)	(0.0599)	(0.0147)
Basement	0.3984**	0.0902***	0.0852***	0.4836***	0.0862***	0.0853***
(1/0)	(0.1776)	(0.0178)	(0.0093)	(0.1680)	(0.0197)	(0.0091)
Bathroom	-1.3537***	-0.0226	-0.0938***	-1.4786***	-0.0106	-0.0895***
	(0.1877)	(0.0181)	(0.0108)	(0.1686)	(0.0377)	(0.0104)
Bedroom	-0.3387*	-0.0626***	-0.0891***	-0.3966**	-0.0599***	-0.0879***
	(0.2035)	(0.0179)	(0.0095)	(0.2016)	(0.0208)	(0.0094)
Garage	0.0694	0.0629***	0.0753***	-0.0798	0.0650***	0.0777***
	(0.1892)	(0.0129)	(0.0128)	(0.1900)	(0.0139)	(0.0125)
Age	0.0740***			0.0776***		
	(0.0153)			(0.0141)		
Log (Calgary)	9.8872***			10.4339***		

	(3.1874)			(3.3778)		
Log (hospital)	0.6800***	0.0540***	0.0365***	0.6658***	0.0480*	0.0334***
	(0.1450)	(0.0130)	(0.0071)	(0.1469)	(0.0254)	(0.0068)
Log (water)	0.2887***			0.3019***		
	(0.1030)			(0.1040)		
School quality	0.3335*			0.4453**		
(1/0)	(0.1943)			(0.2115)		
Density	-0.0118			-0.0147		
	(0.0216)			(0.0241)		
% of high	0.0312			0.0404*		
school	(0.0218)			(0.0212)		
certificate						
% of	0.0246			0.0335		
postsecondary	(0.0241)			(0.0246)		
education						
Employment	0.0198			0.0227		
rate	(0.0237)			(0.0248)		
Low median	0.2141			0.1966		
household	(0.5034)			(0.5099)		
income (1/0)						
High median	-0.0414			-0.4097		
household	(0.6015)			(0.6596)		
income (1/0)						
Season	-0.6460***			-0.6400***		
	(0.1350)			(0.1620)		
Constant	-129.2583***	7.0083***	6.7345***	-138.7296***	7.1264***	6.8198***
	(35.1442)	(0.4695)	(0.2678)	(36.8820)	(0.5394)	(0.2466)
$\rho_{0\eta}$	-0.1252			-0.2868		
	(0.1896)			(0.6851)		
$\rho_{1\eta}$	0.9278***			3.8654***		
	(0.0214)			(0.8990)		

Note: ***, **, and * denotes significance level at 10%, 5% and 1%;

Robust standard errors are in parentheses.

Appendix I: Estimation Results with an Aggregation of Pasture and Cropland in Chapter 4

	Log (sales price)		
Variable	Selection	Regime0	Regime1
Forest	0.5403***	0.0893*	0.0582***
	(0.1826)	(0.0462)	(0.0155)
Agricultural land	0.0193	0.0066**	0.0027
	(0.0197)	(0.0029)	(0.0017)
Grassland	0.0113	0.0152**	0.0112***
	(0.0353)	(0.0067)	(0.0024)
Park	-0.0403***		
	(0.0119)		
Log (living area)	1.5129***	0.6420***	0.7541***
	(0.2820)	(0.0533)	(0.0315)
Log (lot size)	-0.0803	0.1000**	0.0742***
	(0.1826)	(0.0430)	(0.0263)
Condition (1/0)	0.7298***	0.0422*	0.0727***
	(0.1423)	(0.0235)	(0.0154)
Basement (1/0)	0.2587***	0.0901***	0.0885***
	(0.0973)	(0.0171)	(0.0095)
Bathroom	-0.7687***	-0.0260	-0.0959***
	(0.0980)	(0.0180)	(0.0108)
Bedroom	-0.1585	-0.0676***	-0.0873***
	(0.1020)	(0.0164)	(0.0095)
Garage	-0.0010	0.0652***	0.0739***
	(0.1063)	(0.0128)	(0.0124)
Age	0.0352***		
	(0.0084)		
Log (Calgary)	4.9610***		
	(1.6741)		
Log (hospital)	0.3932***	0.0540***	0.0387***

	(0.0818)	(0.0126)	(0.0071)
Log (water)	0.1568***		
	(0.0558)		
School quality (1/0)	0.1993**		
	(0.0987)		
Density	-0.0023		
	(0.0115)		
% of high school certificate	0.0243**		
	(0.0117)		
% of postsecondary education	0.0159		
	(0.0128)		
Employment rate	0.0079		
	(0.0124)		
Low median household income (1/0)	0.1126		
	(0.2557)		
High median household income (1/0)	-0.0578		
	(0.2911)		
Season	-0.3398***		
	(0.0732)		
Constant	-66.4559***	7.0338***	6.7364***
	(18.4012)	(0.4387)	(0.2712)
$\rho_{0\eta}$	-0.1141*		
	(0.1889)		
$\rho_{1\eta}$	0.9371***		
	(0.0186)		

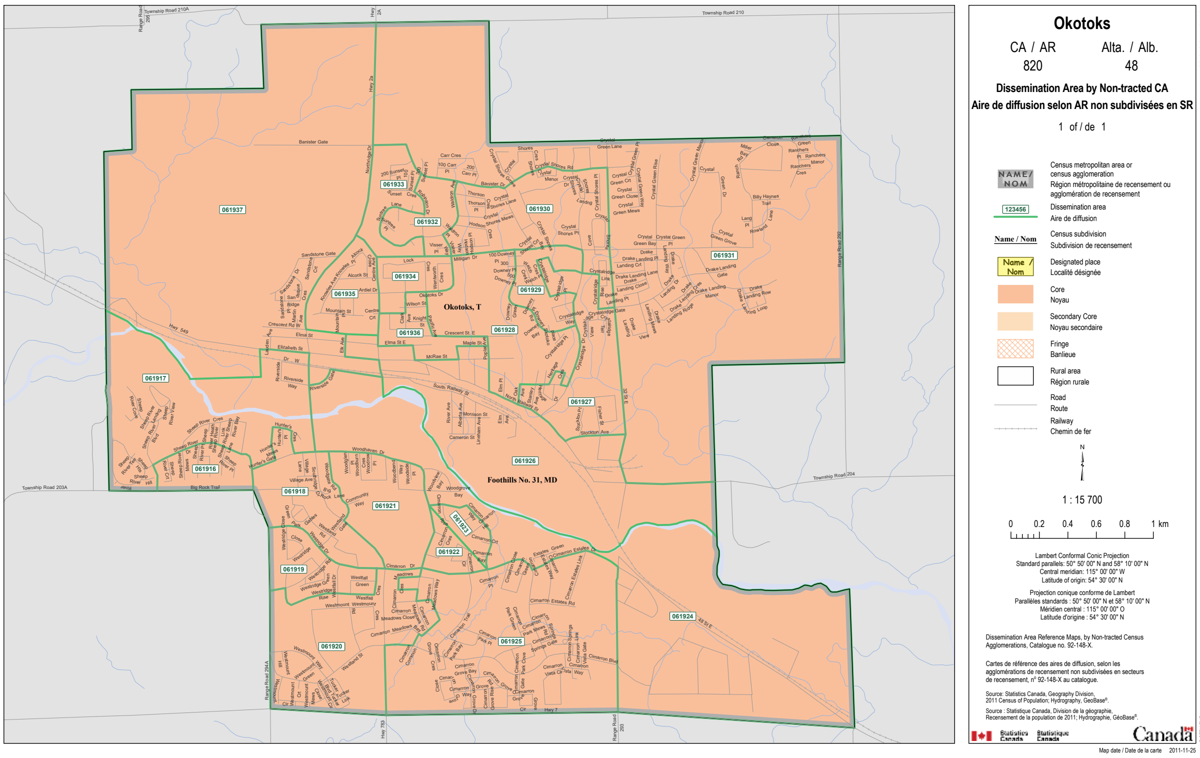
Note: ***, **, and * denotes significance level at 10%, 5% and 1%;

Robust standard errors are in parentheses.

Appendix J: WTP for Forest, Agricultural Land and Grassland under the New Classification of Open Space in Chapter 4

Open space	(1) Regime 0		(2) Regime 1		Difference ($CAD/Acre)
	Coef.	WTP ($CAD/Acre)	Coef.	WTP ($CAD/Acre)	
Forest	0.0893	45,413	0.0582	29,598	15,815
Agricultural land	0.0066	3,356	0.0027	1,373	1,983
Grassland	0.0152	7,730	0.0112	5,696	2,034

Appendix K: Dissemination Area Map for the Town of Okotoks



Source: (*Statistics Canada, 2011a*)

Appendix L: Comparison of Tax Revenues from Open Space before and after the Policy Change in a Specific DA

Open space	(1) Regime 0		(2) Regime 1		Difference of Tax ($CAD)
	WTP ($CAD)	Tax ($CAD)	WTP ($CAD)	Tax ($CAD)	
Forest	1,810,069	14,435	1,183,764	9,441	4,994
Grassland	1,607,034	12,816	991,109	7,904	4,912