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PARKING PRICES AND URBAN SPRAWL IN CANADIAN METROPOLITAN AREAS

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PREFACE

This dissertation is presented in the form of a thesis by publication. As a result, the fourth chapter of this research comprises an article that is currently being peer reviewed for publication in the journal *Research in Transportation Economics.*

It is worth noting that as the article is an abbreviated version of the dissertation, the content preceding the article will at times be repeated in lesser detail in the article itself.

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LIST OF ABBREVIATIONS, ACRONYMS AND VARIABLES

CBD	Central Business District
CC	City Center
CPI	Consumer Price Index
CMA	Census Metropolitan Area
GES	Gaz à Effet de Serre
GHG	Greenhouse Gases
GLS	Generalized Least Squares Regression
OPEC	Organization of the Petroleum Exporting Countries
R_a	Agricultural Rent
R_0	Land Rent
X_0	Intercept of Agricultural Rent and Land Rent
X_1	New Intercept of Agricultural Rent and Land Rent following a Decrease in Transportation Costs

RÉSUMÉ

L'étalement des villes en Amérique du Nord constitue une problématique importante pour les gouvernements en raison de ses multiples implications économiques et environnementales. Le développement urbain en périphérie des villes accroît notamment les coûts reliés aux infrastructures d'eau et de transport, en plus de restreindre l'efficacité du transport collectif et de contribuer à l'augmentation des gaz à effet de serre (GES). Cependant, plusieurs causes de ce phénomène sont souvent débattues dans la littérature scientifique et demeurent à étudier.

Notre article vise à déterminer les effets des coûts de transport sur l'étalement urbain. Pour ce faire, nous utilisons des données provenant de 10 régions métropolitaines canadiennes pour la période de 1996-2011 et procédons à une analyse de régression afin de tester le modèle d'évolution naturelle de Mieszkowki et Mills. En incluant des variables de contrôle comme le revenu, la population, et la valeur des terres agricoles, nous isolons l'effet qu'ont les coûts de l'essence et du stationnement sur l'étalement des villes. Deux mesures d'étalement seront utilisées dans notre recherche : la densité et la proximité. Nos résultats indiquent que des hausses des coûts de transport contribuent à ralentir l'étalement urbain. Cependant, ils demeurent insuffisants pour contrôler l'étendue des villes. Ceci étant dit, en établissant la relation entre les coûts de transport et l'étalement urbain, nous offrons une valable opportunité aux représentants gouvernementaux de restreindre ce phénomène.

Mots-clés: Étalement urbain, régions métropolitaines canadiennes, prix du stationnement, prix de l'essence, coûts de transport

ABSTRACT

Given that urban sprawl discourages effective public transportation, increases road and water infrastructure costs, and contributes to increases in greenhouse gas emissions (GHG) through greater vehicle miles travelled, the need to better comprehend this phenomenon and the factors that cause its growth are of paramount importance.

The objective of our research is to determine the potential effect of gasoline and parking prices on urban sprawl using data from ten Canadian metropolitan areas from 1996 to 2011. General Least Square regressions are used to test Mieszkowski and Mills' natural evolution model, which claims that four variables explain urban sprawl: population growth, median household income, the cost of surrounding agricultural land and transportation costs. Two measures of urban sprawl are assessed: density and proximity. Our results indicate that increasing transportation costs do have a negative effect on urban sprawl, and more precisely, that gasoline prices have a stronger effect than parking prices. However both these effects may not, by themselves, suffice to control sprawling cities. This being said, the presence of a relationship between transportation costs and urban sprawl provides a potentially valuable opportunity for policy-makers to manage sprawl.

Key words: Urban sprawl, Canadian metropolitan areas, parking prices, gasoline prices, and transportation costs

INTRODUCTION

Many contemporary urban development patterns found in North American cities are referred to as urban sprawl. These patterns are characterized by some degree of population and employment growth stagnation in established city centers while population tends to increases in surrounding peripheral regions, which themselves spread over broader areas. Evidence of this form of urban decentralization can be seen across the United States, where between 1950 and 1990, the proportion of metropolitan residents living in city centers decreased from 57% to 37% (Mieszkowski and Mills, 1993). Employment also followed suit as the proportion of jobs found in city centers went from 70% to 45% for that same time period. In their work, Glaeser and Kahn (2001) discuss the significant decrease in employment rates felt in city centers and predict that in following decades employment in central cities across North America will rarely comprise more than 20% of the total share of employment. This trend is also noticeable in Canada where between 2006 and 2010, population growth rates in suburban communities (8.3%) surpassed population growth rates of city centers (5.3%). In fact, during this same time period, Canadian peripheries of urban agglomerations registered soaring population growth rates of up to 50% in comparison with the country's total population growth rate of 5.9% (Turcotte, 2008). People now work and live in the suburbs: "in 1960 fewer Americans lived in suburbs than in central cities or the countryside. Ten years later the suburbs had overhauled both; by 2000 they contained more people than cities and countryside put together" (The Economist, 2008).

These numbers clearly illustrate the current trends taking place across North American cities, but do not explain the reasons behind these new tendencies. It is this aspect that will be further discussed in our research in which we will attempt to better understand the main causes of urban sprawl and especially grasp the effects of transportation costs.

A number of previous studies have sought to identify the causes of urban sprawl. Many (Brueckner, 1987; Burchfield *et al.* 2006; McGibany, 2004; McGrath, 2005; Mieszkowski and Mills, 1993; Nechyba and Walsh, 2004; Song and Zenou, 2006; Tanguay and Gingras, 2012; Wassmer, 2008) have tried to explain this contemporary form of planning by using the monocentric model developed by Alonso (1964), Mills (1967), and Muth (1969). In its rudimentary form, this mathematical model suggests that a household's housing costs will decrease as it moves further away from the city center, whereas its commuting expenses and transportation costs will increase. Using this model, authors have considered a range of different factors to better comprehend the determinants of urban sprawl: i) climate and topography (Burchfield *et al.,* 2006); ii) fiscalization of land use (Wassmer, 2002, 2006, 2008); iii) property taxes (Song and Zenou, 2006); iv) racial bias (Mieszkowski and Mills, 1993); and the most prominent factors regrouped under v) the natural evolution model (Brueckner and Fansler, 1983; Burchfield and al., 2006; McGibany, 2004; McGrath, 2005; Mieszkowski and Mills, 1993; Song and Zenou, 2006; Tanguay and Gingras, 2012; and Wassmer, 2002, 2006, 2008). This last model, coined the natural evolution model and often attributed to Mieszkowski and Mills, is largely based on Alonso, Muth and Mills' monocentric approach and uses four factors to explain urban sprawl: i) population size; ii) incomes; iii) agricultural rent and iv) transportation costs.

The present study concentrates on the factors associated with the natural evolution model, and as mentioned earlier, will especially focus on the effects of transportation costs. Previous readings (McGibany, 2004; Tanguay and Gingras, 2012) and observations will help us assume that an increase in transportation costs such as gasoline and parking prices might potentially motivate drivers to reduce their car usage. Furthermore, these prior readings and observations will lead us to hypothesize that if an increase in these prices can reduce car usage, they also have the potential to reduce urban sprawl since this concept is closely related to car usage. This second hypothesis is only conceivable if we consider and accept the positive relationship between urban sprawl and car usage.[1] The novelty of this analysis lies in the central focus on transportation costs and the use of parking price data to complement other analyses that have used gasoline prices.[2] By determining if an increase in transportation costs may help reduce urban sprawl, this study offers an opportunity for cities and government officials seeking to minimize the extent of sprawl and its many negative externalities.

As the automobile became more and more affordable for the middle class in the second half of the 20th century, transportation costs underwent a steady and substantial reduction in the form of journey costs, or time spent traveling, as individuals were able to travel further distances with a smaller investment of time. Thus individuals could live further away from central business districts (CBD's), which would reduce their housing costs without significantly increasing their journey time. This stability in travel duration over time was first empirically demonstrated by Zahavi in 1974. Portraying distance as a function of time and speed (Distance = Time x Speed), Zahavi showed how under the assumption of constant journey times, an increase in travel speed could only result in an increase in distances traveled. Nevertheless, the distance variable in Zahavi's equation can potentially be countered by increases in driving costs, including congestion and tolls, as well as gasoline and parking prices. All of these have been typically on the rise in recent decades (Kane *et al.* 2015).

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[1] Further information in regards to this relation can be found in work by Newman and Kenworthy (1999), in which they establish the positive relationship between urban sprawl and automobile dependency and clarify the process by which cities expand by continually prioritizing the automobile.

[2] Consider for instance the work of Tanguay and Gingras (2012) on the effects of gasoline prices on urban sprawl.

The cause of this rise in transportation costs is often attributed to an escalation in the average price of gasoline over the years. For example in real terms, gasoline prices in the United States more than doubled from $1.76 per gallon in 2002 to $3.73 per gallon in 2012 (U.S. Energy Information Administration, 2015). Other authors have challenged the automobile's assumed reduction in journey costs, demonstrating that increases in congestion levels have negatively affected travel times. The American Federal Highway Administration, reports that congestion levels now impact over two thirds of all vehicle travels in the United States, as opposed to under one third in 1982 (Urban Transport Tax Force, 2012, p. 11). Likewise, Canada's Ecofiscal Commission finds that the unpredictability and variance of travel time brought upon by congestion forces half of Montrealers to allocate upwards of 60 minutes towards getting to and from work every day (Canada's Ecofiscal Commission, 2015). A third component of transportation costs is the price of parking. Though often neglected in transportation cost calculations, parking prices have been increasing for decades and are now considered a substantial cost associated with owning a private vehicle. In downtown Calgary for instance, on-street parking now costs $5 per hour whereas less than twenty years ago, it was only $2.20.[3,4]

These examples provide evidence of a substantial increase in transportation costs and illustrate the potential misconception surrounding the cost effectiveness of living further away from the CBD. The objective of this study is thus to determine whether these increases in transportation costs have had an effect on urban sprawl in Canadian cities. Because urban sprawl inhibits effective public transportation, increases road and water infrastructure costs, and contribute to global warming (Wilson and Chakraborty, 2013), the need to better comprehend this phenomenon and the factors that cause its growth seem of paramount importance.

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[3] Information retrieved from email conversations with Rachel Knight from the *Calgary Parking Authority*, 2014. (Rachel.Knight@calgaryparking.com)

[4] On-street parking prices adjusted for inflation (2011 used as base year).

To test the effects of transportation costs on urban sprawl, we base our analysis on previous work by Tanguay and Gingras (2012), who, using the *natural evolution* model, conducted a study on the effects of gas prices on urban sprawl in Canadian cities. Their results indicated that on average, a 1% increase in the adjusted price of gasoline caused a decrease in low-density housing units by approximately 0.60% and an increase in the population living in the inner city by 0.32%, their indicators for urban sprawl. Similarly to Tanguay and Gingras (2012) and other studies (Burchfield *et al.* 2006; Molloy and Shan, 2013; Ortuño-Padilla and Fernández-Aracil, 2013), we perform a panel regression analysis using data from 10 Canadian metropolitan areas over a 16-year period. We measure urban sprawl using two dependent variables: density and proximity. Independent variables that are accounted for in our research are income, population, dwelling values, downtown parking prices (on-street and off-street), and gasoline prices. While our results do provide evidence of a negative relationship between transportation costs and urban sprawl in Canadian metropolitan areas, the magnitude of this relationship is somehow weaker than initially hypothesized.

In the next chapter, we define urban sprawl, identify the hypothesized causes of urban sprawl and discuss the different methods used to measure its extent. We then focus on transportation costs, emphasizing the novelty and importance of including parking prices in urban sprawl equations. The third section will elaborate our methodology and theoretical model. As this dissertation is presented in the form of a thesis by publication, we present our article comprising the results of our regressions as well as a discussion of these results in the fourth section. A brief summary and other concluding remarks will comprise the final section of this paper.

CHAPTER I

THE CONCEPT OF URBAN SPRAWL

1.1 Shaping Urban Sprawl

Before beginning to discuss urban sprawl it is imperative to reflect on cities and address the underlining forces that shape them. Often built at the intersection of major transportation routes, cities originally served as centers for storage, for manufacture and most importantly for trade. They allowed surrounding farmers to process and distribute their agricultural surpluses and were regularly founded around marketplaces to take advantage of agglomeration economies.[5] While continuing to facilitate trade, cities now also assume the role of communication centres and provide fertile grounds for human evolution, drawing a mixture of people, cultures, talents, and innovations (Ellis, 2011).

Interestingly, the size and form of cities has also evolved through time. As noted by Newman and Kenworthy (1999), the form of cities has largely been influenced by transport. The form of ancient cities was mostly based on walking. Restricted by the condition that destinations had to be reached in an average of half an hour or less,[6] the size of walking cities rarely surpassed 5 kilometers in diameter and were characterized by high levels of population density. Over time, and with the arrival of new technical advances, cities began to expand. The advent of trams and trains permitted faster travel and enabled cities to accommodate more people while

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[5] Agglomeration economies are the benefits that individuals or firms obtain when they locate near one another and are often attributed to transportation cost savings (Glaeser, 2010).

[6] Condition used by Newman and Kenworthy (1999) to incorporate the stability in travel duration previously noted by Zahavi (1974).

respecting the half hour travel average criteria. The form of this second type of city was mostly centered on railroads and tram routes, giving cities a spider-like appearance, and where density levels were considerably reduced. The third type of city followed the arrival of the automobile. Arguably the greatest factor to have influenced the shape and form of cities, the automobile enabled growth as far out as 50 kilometers in all directions and completely changed the appearance of cities forever. Subsequently faced with greater land supply, planners began building low-density housing on cheaper land often found at the outskirts of cities and towns and paved the road for the mass development of the suburbs.

Another noteworthy factor contributing to the popularization of the suburbs was the growing recognition of health hazards associated with excessive pollution from heavily industrialized city centers. Indeed, by relying on fossil fuels and industries to bolster their economies, cities became notorious for providing unhealthy living conditions. Environmental problems such as water contamination and air pollution became prominent concerns and "helped fuel the exodus from central cities, and contributed to the deconcentration of cities known as sprawl" (Frumkin *et al.*, 2004, p. 64). This, coupled with the arrival and popularization of the automobile, led to the birth of the phenomenon we now refer to as urban sprawl.

In order to determine the causes of urban sprawl, it is important to first define what we mean by urban sprawl and discuss the different dimensions that will be used to measure its extent. In this first chapter we show that there are several ways to define urban sprawl and an even greater number of ways to measure it, each with its own advantages and flaws.

1.2 Defining Urban Sprawl

The term "urban sprawl" has a variety of definitions. These definitions vary depending on the author and the field of study in which they are employed. For instance, some authors such as Brueckner and Fansler (1983), McGibany (2004), Burchfield *et al.* (2006), and Sun *et al.* (2007) use spatial features to define urban sprawl, claiming it is "characterized by vigorous spatial expansion of urban areas" (Brueckner and Fansler, 1983, p. 479). They emphasize the required travel distances and the size of urban areas: "Sprawl is often used to describe cities where people need to drive large distances to conduct their daily lives" (Burchfield *et al.* 2006, p. 607).

Other authors, such as Pendall (1999), Nechyba and Walsh (2004), Eidelman (2010), and Banai and DePriest (2014) rather describe urban sprawl as low-density areas: "The lower per capita consumption of land indicates a more compact development and less sprawl" (Banai and DePriest, 2014). They commonly use changes in population and dwelling density to measure the extent of sprawl.

A third noteworthy definition is the center-periphery opposition put forth by Bussière and Dallaire (1994), Chapain and Polèse (2000) and Bordeau-Lepage (2009). This idea underlines the importance and presence of displacement of residential and commercial sites from city centers to peripheral regions: "Cities expand, with population and employment increasing more on the periphery than in the center of the city" (Bordeau-Lepage, 2009, p.13). Similar to this notion is the definition postulated by Wassmer (2000), in which he describes urban sprawl as "another word for a certain type of metropolitan decentralization or suburbanization" and follows by adding: "suburbanization occurs over time when a larger percentage of a metropolitan area's residential and/or business activity takes place outside of its central locations" (Wassmer, 2000, p. 2).

In his later work, Wassmer (2002) reexamines suburbanization – which he believes to be a direct substitute to urban sprawl – and explains how, according to economists, suburbanization is a process determined by household's residential location decisions. These residential location decisions are in turn determined through weighing the private benefits of a suburban, decentralized location (potentially better schools, cheaper land, newer infrastructures, etc.) against the private costs of this same suburban location (longer commute times, less walking distance amenities, etc.). If private benefits outweigh private costs, households will decide to live further away from the city center, regardless of the fact that this may not be an optimal solution given the external costs of congestion and pollution.

This array of definitions exemplifies the lack of consensus surrounding the concept of urban sprawl and ways to measure its extent. Each definition considers a different aspect of this phenomenon and conveys different variables to measure its scope. As a way to solve this problem, Galster *et al.* (2001) created a conceptual definition of urban sprawl based on eight aspects often associated with sprawl. This definition is the one that will be favoured in this work because it considers the possibility that there can be different types of sprawl and because it also defines sprawl as a process of development and believes in its constant mutation over time. Bearing in mind that our research will focus on transportation costs, let us now move to examining the numerous ways of measuring urban sprawl proposed in this conceptual definition.[7]

1.3 Measuring Urban Sprawl

As mentioned earlier, there are several definitions of urban sprawl and because of this, there are also numerous ways to measure it. Galster *et al.* (2001) have divided

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[7] The applicability of these definitions in a Canadian context is reflected by their usage in previous Canadian studies: Sun *et al.* (2007) for spatial expansion, and Eidelman (2010) for low-density areas.

these measures into eight dimensions: centrality, clustering, concentration, continuity, density, mixed uses, nuclearity, and proximity.

1.3.1 Centrality

In accordance with Bussière and Dallaire (1994), Gordon and Richardson (1996), McDonald and McMillen (2000), Felsenstein (2002), and Nechyba and Walsh (2004), we define centrality by the percentage of a metropolitan area's population living in the city center. This allows us to take the relative weight of the population per urban area into consideration. This approach has previously been used in the past (Gordon and Richardson, 1996; McDonald and McMillen, 2000; Felsenstein, 2002; and Nechyba and Walsh, 2004) to analyze cases of decentralization in urban regions of the United States. To measure centrality, Douglas and Denton (1988) propose using Geographic Information Systems software to draw series of concentric rings from the city center. The cumulative population of each ring is then computed to determine centrality.

Other authors, such as Galster *et al.* (2001) and Wassmer (2000, 2002), rather define centrality in relation to land usage, concluding that centrality is "the degree to which observations of a given land use are located near the central business district," (Galster *et al.* 2001, p. 701) thus concluding that urban areas are decentralized when a greater distance is required to cover the same proportion of development. It is worth noting that measuring sizes of urban regions to better understand urban sprawl is in no way a new approach and has been abundantly used in the past. Brueckner and Fansler (1983), McGibany (2004), McGrath (2005), and Song and Zenou (2006), to name a few, have used this sizing method in their econometric models to comprehend different aspects of urban sprawl.

1.3.2 Clustering

In order to measure urban sprawl, Gordon and Richardson (1997) have used clustering. Clustering measures the degree to which an urban area is bunched together in order to minimize the amount of developable land need to contain residential development. As explained by Jaeger *et al.* (2010, p. 400), "the degree of urban sprawl will depend on how strongly clumped or dispersed the patches of urban area and buildings are." Unlike density and concentration, which focus on development patterns across sections of an urban area, clustering considers development within a section of an urban area. Urban sprawl has been associated with areas of low concentration and therefore no clustering of houses or services. Sprawled neighbourhoods are often evenly dispersed and do not display patterns of cluster.

1.3.3 Concentration

In line with Galster *et al.* (2001), the concentration dimension measures the degree to which an urban development is proportionately distributed. It measures the arrangement of houses and jobs to see if they are evenly distributed in a certain area. Areas with a low concentration dimension, where housing and job developments are more evenly distributed, are often prone to sprawl.

This measure should be jointly used when exercising concentration measures since concentration measures alone cannot distinguish between two 100 square-kilometer areas in which the housing units of one are located in a few high-density areas and another in which the housing units are evenly distributed throughout the entire area.

1.3.4 Continuity

Continuity measures the extent to which developable land around city centers has been built upon in an unbroken fashion. This dimension is largely cited in scientific literature, and authors (Clawson, 1962; Harvey and Clark 1965; Ewing 1997; Burchfield *et al.,* 2006; Jaeger *et al.,* 2010) often associate discontinuity with urban sprawl. This dimension is a means of determining if parcels of land around city centers contain enough housing units to be considered as having high levels of continuity. To measure continuity Galster *et al.* (2001) use a one-half-mile-square grid and consider it to have a high level of continuity if it contains 10 or more housing units or 50 or more employees. If, on the other hand, they do not display high levels of continuity, they are to be considered as a discontinuity from the city center, also known as leapfrog development[8], and can be associated with urban sprawl.

1.3.5 Density

In order to determine density, studies, such as Wassmer (2008), have used population density, by way of dividing the number of people in an area by the size of the area. Others, Galster *et al.* (2001), Song and Knapp (2004) and Turcotte (2008) have favoured the usage of variables related to dwellings to measure density, maintaining that dwelling measures are more appropriate since they take land usage into consideration. Tanguay and Gingras (2012) further support this view by discouraging the usage of population to measure urban density as it uses the entire size of a CMA in its calculation and will include uninhabited areas such as airports, parks and rivers, which may falsify results. To this end, Galster *et al.* (2001) calculated density by measuring the number of housing units per area of developed land. Turcotte (2008) also applies housing measurements in his reports and considers not only the quantity

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[8] Leapfrog developments are observed when suburban residential zones skip an area, leaving a region vacant or non-developed between them and the city center (Burchfield *et al.*, 2006)

of dwellings, but also their types in order to determine an area's density. To justify the calculation of density by housing type Turcotte cites Harris (2004) who believes that in North America, the presence of single and semi-detached housing units in a district is an important feature that distinguishes residential suburbs from their urban counterparts. Song and Knapp (2004) use a fairly similar approach, but measure density through three different facets of housing: median area of single family housing plots, number of single family dwellings and median area of floor per single family housing unit.

1.3.6 Mixed Uses

Mixed uses measure the extent to which two or more different land uses coincide within a certain urban area. Galster *et al.* (2001) measure this dimension by comparing the average density of housing units to the average density of non-residential units in a same one-half-mile-square grid. The more an area portrays a mixture of uses, the less individuals have to travel to accommodate all their needs. This characteristic of land use is often associated with central and denser neighbourhoods. An area that contains a single land use (residential for instance) and therefore represents the lowest degrees of mixed land usage is consequently more sprawl-prone in this dimension. This characteristic of sprawl is supported in work by Frumkin *et al.* (2004) in which they argue that the segregation of land usage, often found in North American suburbs, results from the advent of zoning regulations in the first quarter of the twentieth century, and has direct implications on individuals' travel behaviours.

1.3.7 Nuclearity

In accordance with Galster *et al.* (2001), nuclearity measures the extent to which an urban area exhibits mononuclear patterns of development. Mononuclear developments are urban areas displaying high levels of intensity and activity in their CBD. This pattern of development is in opposition with polynuclear developments, which present several areas of intensity (other than the CBD) and contain a substantial proportion of the total activities of that region. Polynuclear patterns of development are often related to urban sprawl since they decrease the density of neighbourhoods in the vicinity of the CBD and increase the density of neighbourhoods adjacent to outer and less significant activity hubs.

1.3.8 Proximity

In line with Bussière and Dallaire (1994) and Galster *et al.* (2001) proximity can be measured using commuting distances, or the geographic distance between two points.[9] In order to estimate proximity, Galster *et al.* (2001) recommend using the mean distance to get to and from work. Accordingly, areas in which people must travel longer distances to get from their home to work display lower proximity levels. For their part, Bussière and Dallaire (1994) show that decentralization (of both population and employment), as well as increases in automobile dependency are both responsible for increases in mean distance for home to work travels in urban areas for the period between 1960 to 1980.

Now that we have established the different dimensions used to measure the extent of urban sprawl, in the next chapter, we present the recurrent factors identified in economic literature to explain this phenomenon.

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[9] Commuting distance defined the distance between the geographic mean of a certain point in a neighbourhood and the geographic mean of the CBD.

CHAPTER II

LITERATURE REVIEW

2.1 The Causes of Urban Sprawl

Traditionally, urban economists have relied on monocentric city models pioneered in the 1960s by Alonso (1964), Mills (1967, 1972) and Muth (1969) to explain urban sprawl expansion. These models claim that as a household moves further away from the city center its housing costs diminish whereas its journey costs increase. Brueckner (1987) later coined this model the Muth-Mills model and through its key components, studied the effects of exogenous variables on land usage, using natural evolution factors as independent variables. The Muth-Mills model assumes that households aim to maximize their utility according to their choice of residential location. The model opposes housing costs (in monetary units) to distances from the CBD and it displays the monetary differences between agricultural rent and developed land rent as distance from the centre increases. A horizontal line portrays agricultural rent[10] (R_a) and a decreasing exponential function describes land rent (R_0). This implies that the straight line and curve will cross at a certain point (X_0) and it is at this point that Muth and Mills' conclude that the city limits will be located, as seen in Figure 2.1.

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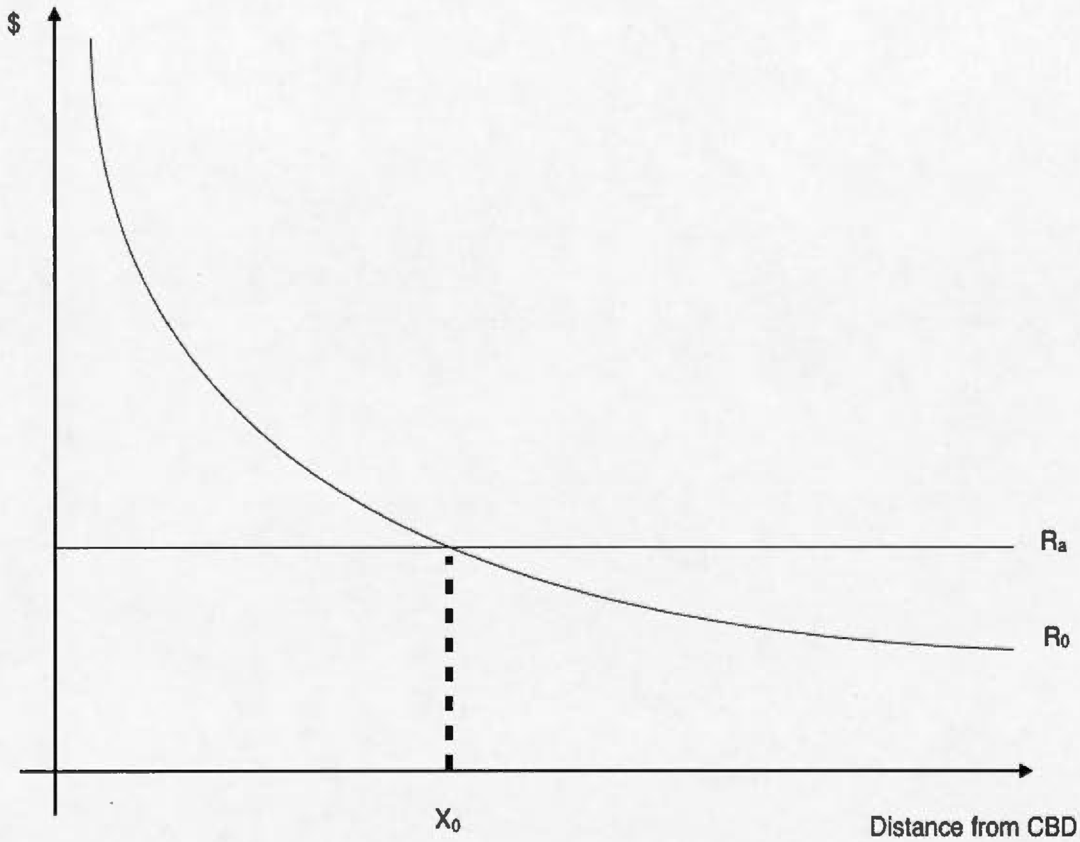
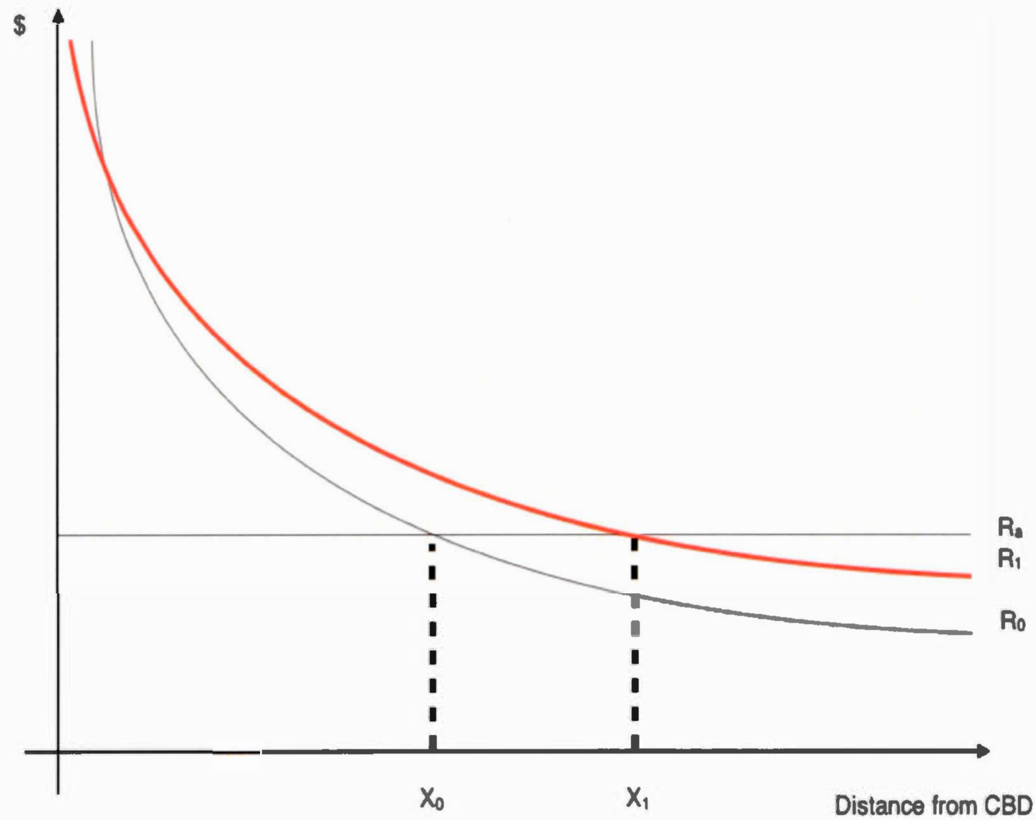
[10] Agricultural rent is depicted by a horizontal line as it is assumed to be unaffected by its distance to the CBD.

Figure 2.1
Property values, agricultural land values and the city limits



Variations in city limits are also easily depicted through the monocentric model. Consider for instance the effects of a decrease in transportation costs. Following this decrease, the advantages of living near the city center would be reduced, whereas the cost of housing beyond X_0 would be increased due to a sudden upsurge in demand. To portray this decrease in housing costs near the city center and simultaneous increase in housing costs in relative suburban areas, the land rent curve would have to flatten, as depicted by R_1 in Figure 2.2. This in turn, would cause the city limits to move outwards to X_1. Thus, according to this model, lowering transportation costs would cause cities to sprawl and vice versa.

Figure 2.2
Decrease in transportation costs, property values and the city limits



Several authors have used the monocentric model as a baseline while building similar models to explain urban sprawl. For instance in 1983, Brueckner and Fansler applied the monocentric model to structure a regression analysis and explain the spatial expansions observed in the 1970s in 40 urbanized areas of the United-States. They studied the relationship between the size of urbanized areas and the journey cost of home to work travels. Their findings mostly confirmed the Muth-Mills model as they found that population, income, and agricultural land prices were determinants of the extent of urban sprawl. Interestingly, transportation costs, which were indirectly measured by the percentage of commuters that use public transportation and by the percentage of households that own one or more automobiles, did not offer significant results. They view urban sprawl as an orderly market process and deem population, income, agricultural land price and transportation costs as the most relevant variables to explain this phenomenon. Building upon their work, Mieszkowski and Mills (1993) later labeled the four driving causes of suburbanization established by Brueckner and Fansler as the "natural evolution factors." These factors, as well as the monocentric model, have since been used extensively with authors differentiating themselves through their measuring approaches and through their choice of additional variables. For instance in 2006, Song and Zenou added a property tax variable to the natural evolution factors in order to determine whether this form of taxation plays a substantial role in the development of urban sprawl. Using elasticities they establish that the effect on consumers outweighed the effect on developers and that an increase in property taxes by 1% would lead to a decrease in urban sprawl by 0.4%. Another example of variable addition would be Wassmer (2008) who, similarly to Brueckner and Fansler, analyzed the journey costs of home to work travels to estimate automobile dependency and the overall size of urbanized areas. Using population density and the size of urban areas as dependent variables, he covered 452 urban areas in the United States for the year 2000. To measure automobile dependency, Wassmer applied the monocentric model and tested for all four natural evolution factors. In addition to these factors he added several socioeconomic variables to capture the demographics of his studied areas. A noteworthy addendum to Mieszkowski and Mills' natural evolution factors conveyed through Wassmer's work is the fiscalization of land use, which suggests that land use decisions and new developments are partially based on encouraging revenue production and fiscal surplus for municipalities. His results indicate that a 1% increase in household car ownership will lead to and increase in the size of urban areas by 0.05% and a population density reduction of 0.07%. His findings also reveal that natural evolution factors play the greatest role in determining the extent of an area's urban sprawl.

McGrath (2005) also used the natural evolution variables to explain urban sprawl. He estimates that these factors explain 88% of the variation in size of metropolitan areas. A particularity about his study is that he uses the consumer price index of private vehicles to measure transportation costs. His results indicate that population differences explain nearly 80% of the variation in the dependant variable (elasticity of urban land area with respect to population growth is 0.76), and that the elasticity of urban areas with respect to other variables are much lower, (income: 0.33, transportation costs: 0.28, and agricultural land values: 0.1) and therefore, that other independent variables are clearly less important than population growth in determining the extent of urban sprawl. McGrath hypothesises that the remaining 12% of variation in size of metropolitan areas, which is not explained by natural evolution factors, might, in part, be due to businesses leaving city centers for peripheral regions.

McGrath's results inferring the central role of population in sprawl equations were later refuted by Burchfield *et al.* (2006) who, using remote sensing data (satellite imagery and sensors), measured the percentage of non-developed land per square kilometer of residential area. Their results suggested that the effects of population growth on sprawl are often ambiguous. They explained how on one hand, when population grows rapidly, households anticipate that the neighbouring non-developed areas will quickly be transformed into houses and do not want to risk facing higher journey costs to move to areas of similar density. Whereas on the other hand, when population grows slowly developers anticipate that housing demand will diminish and prefer waiting before developing further away non-developed areas. Consequently preferring to develop lower risk projects near city centers. Burchfield *et al.* (2006) rather conclude that geographic characteristics are the leading cause for leapfrog development, their proxy for sprawl. They conclude that physical geography is the leading cause for leapfrog development and that geography alone accounts for up to 25% of cross-city variation in urban sprawl. The remarkable uniqueness of this study is that data is retrieved from outer space which allows for a whole new perspective on urban sprawl and drives researchers to use different measure and dimension of sprawl in order to determine its extent.

Another plausible theory for explaining the extent of urban sprawl in North American cities is the "flight from blight" approach. This second theory, devised by Mieszkowski and Mills (1993) suggests that higher tax rates, higher crime rates, decaying infrastructure, low-performing public schools, and a greater presence of poor and minorities, which are all thought to be more present in central cities and inner-ring suburbs, have contributed to the decentralization of urban areas. The flight from blight hypothesis maintains that richer households, which can afford to move to the suburbs, will do so in order to benefit from safer neighbourhoods, better schools, nicer environments and similar neighbours. Advocates of this theory look past natural causes of sprawl and concentrate on individuals' desire to avoid real and perceived blight found in city centers. They acknowledge that racial bias and the growing desire to live in homogenous neighbourhoods cause urban sprawl. Nevertheless, a strong body of evidence exists to dismantle the usage of the "flight from blight" hypothesis outside of the United States maintaining that these realities are seldom rare in other countries and henceforth that this hypothesis is non-relevant while considering sprawl in cities outside the United States (Marshall, 2001).

There exists a large array of possible approaches to measure the concept of urban sprawl and numerous variables are responsible for determining the conditions and reasoning behind household location decisions. In the following section we present transportation cost variables and examine how they may impact the size and density of urban areas.

2.2 Transportation Costs

It is widely agreed upon that "one of the cardinal features of sprawl is driving, reflecting a well-established, close relationship between lower density development and more automobile travel" (Frumkin, 2002, p.117). Building upon this assertion, many authors have demonstrated the negative relationship between transportation costs and the size of metropolitan areas (Brueckner and Fansler, 1983; Mieszkowski and Mills, 1993; Wheaton, 1998; Newman and Kenworthy, 1999; McGibany, 2004; McGrath, 2005; Burchfield *et al.,* 2006; Song and Zenou, 2006; Wassmer, 2008; Ayala *et al.,* 2012; Tanguay and Gingras, 2012). To name a few, Tanguay and Gingras (2012) run a panel regression in the 12 largest Canadian metropolitan areas for the period of 1986 to 2006. Controlling for other natural evolution variables such as population, median income, and agricultural land prices, they show that an increase in transportation costs, expressed through higher gasoline prices, will contribute to reducing urban sprawl in Canadian cities. Their results indicate that a 1% increase in gasoline prices will, on average, lead to a decrease in low-density housing units by 0.60% and an increase in the population living in the inner city by 0.32%. Similarly, McGibany (2004) builds upon Brueckner and Fansler's (1983) monocentric model uses gasoline prices as a proxy for transportation costs. Using the natural evolution factors as control variables, he test whether gasoline prices are negatively correlated to the size of urban areas. His results indicate that, all else being held constant, urban areas in states that have raised their gasoline excise taxes by 1 cent in the late 1980s are 4.7 square miles smaller than their counterparts in states that did not raise the gasoline excise tax. Also worth noting is Newman and Kenworthy's (1999) extensive work on automobile dependency through which they confirm the presence of lower population densities in suburban neighbourhoods and attribute this to transportation factors. Using population density as an indicator for sprawl, they establish conclusive results both on an inner city and regional level and show that as per capita gasoline consumption increases, as is often the case in suburban neighbourhoods due to the lack of alternative modes of transportation, population density decreases.

Another extensively studied element of transportation costs is congestion (Brueckner, 2000; Anas and Rhee, 2006; Ayala *et al.*, 2012). Again, the underlying logic is that if congestion can increase transportation costs, it can also potentially contain urban sprawl. O'Sullivan (2007) measured the extent of this cost in the United States in 2003 and estimated that by adding the value of lost time to the value of wasted fuel due to delays and slow traffic, the annual cost of congestion was of $63 billion (O'Sulllivan, 2007, p. 210). In his work, Brueckner (1987) describes how congestion costs are not perceived as being born by individual commuters, but rather by the total population of commuters, and that this reduces the incentive for commuters to take these costs into consideration. Brueckner maintains that since drivers never take the true costs of congestion into consideration, this market failure can lead to too much urban sprawl. Other authors demonstrate the ambiguous causality between congestion and urban sprawl, showing that while congestion may cause urban sprawl, it is also caused by it. Using a spatial general equilibrium model, Anas and Rhee (2006) determine that un-priced traffic congestion does create urban sprawl, and also causes longer daily travels by up to 13%.

Though both these transportation costs are clearly relevant in predicting the extent of urban sprawl, very little research has been done on the potential effect of other transportation costs, such as car insurances, maintenance fees, and parking prices. It is to this last transportation cost component that we now turn.

2.3 Parking Prices

As mentioned by Shoup (2011), because only the wealthy could afford to own an automobile in the early years of the twentieth century, parking provision was not considered an issue. The demand for on-street parking never outweighed the supply, and the concept of paying for parking, let alone searching for parking, was unheard of. When car ownership became more widely accessible in the 1910s and 1920s, parking gradually became problematic. Although it took another fifteen years before Oklahoma City implemented the first parking meter in America in 1935, zoning modifications appeared much earlier. Rapidly, cities across North America began incorporating minimum parking requirements in their zoning regulations, forcing all new developments to include a sufficient number of parking spaces so as to minimize spillover effects[11] on on-street parking. At first, the results were excellent. One mayor even proudly reported, "We consider zoning for parking our greatest advance [...] In brief, it calls for all new buildings to make a provision for parking space required for its own uses" (Mogren and Smith, 1952, p. 27). Unfortunately, the benefits of this "great advance" were short lived. Influenced by the growing accessibility of the automobile in the following decades and the subsequent culture of driving, city planners believed that the majority of travel would be made by car and thus required more parking spaces to accommodate this higher demand. Needless to say, demand escalated quickly, and in a vicious cycle, planners rapidly adjusted their requirements on each new development, forcing them to supply a parking lot big enough to satisfy its own peak parking demand. Though these peak parking demand requirements did effectively prevent the dreaded on-street parking spillover effect, they also inadvertently encouraged car usage by offering free parking whenever necessary. In fact, it is now estimated that 99% of parking in the United States is free (Shoup, 2011), and similar figures have been measured for Canada (IBI Groups, 2005).[12] This in turn largely influenced individual traveling decisions and actively discouraged

[11] A spillover effect is defined by an event occurring in a certain context due to something else occurring in a completely different context. In the case of parking, the spillover effect would be individuals parking where they are not allowed (i.e. in front of a fire hydrant), due to lack of available space.

[12] It is estimates that more than 80 percent of Canadian employees enjoy free or heavily subsidized parking at work (IBI Group, 2005).

other forms of transportation. Another problem arising from this abundance of free parking is an undeniable sense of entitlement; drivers, no longer accustomed to paying for parking, now often view free parking as a "civil right" (Cohen, 2014). Resistance towards increasing the price of parking or even implementing a cost on previously free parking has proved to be difficult and politically unpopular, leaving governments no choice, but to massively subsidize parking. The extent of these subsidies is largely unknown, yet some researchers have estimated these parking subsidies in 2002 to be as high as $127 billion in the United States alone (Shoup, 2011, p. 2). By highly subsidizing on-street parking and requiring overly abundant off-street parking in zoning requirements, cities across North America are favouring car usage and indirectly increasing air pollution, gasoline consumption, traffic congestion, and plausibly, urban sprawl.

Recently, whether city officials are grasping the magnitude of this problem or merely recognizing an untapped source of needed revenues, they are beginning to increase the price of on-street parking and modify the outdated zoning regulations to better represent the true cost of parking. These efforts are encouraging, and there is strong evidence that commuters are responding to these increases in the price of parking. For instance, in Los Angeles, when one firm's formerly free off-street parking fees rose to $28.75 per month, the number of single-occupant vehicles dropped by 44% (Small, 1992). In another study, Hensher and King (2001) found that increasing the price of parking by 10% would increase the transit mode share in Sydney Australia by 2.9%. While long term housing decisions may not be directly affected by office parking prices, some movers and newcomers could consider this additional cost in choosing the location of their new home.

These examples illustrate how parking prices can increase transportation costs and in doing so alter driving habits; nevertheless, parking prices are too often disregarded from urban sprawl calculations. Taking parking's recurrence and overall share of journey costs into account it should be considered an essential variable. To this end, Shoup claims that parking "is the unstudied link between transportation and land use" (Shoup, 2011, p.3), and that this oversight has "distorted the markets for both transportation and land use." Shoup is not the only scholar to mention this lack of interest and understanding in relation to parking; however, he is the only one to quantify and convincingly express the magnitude of this variable in relation to urban sprawl:

> Although parking is a passive part of the transportation system, it strongly affects trip generation, mode choice, land use, urban design, and urban form. Even without parking requirements, cars would have reshaped cities during the past century, because they greatly reduce time and monetary cost of traveling. The lower cost of traveling has reduced urban density and the demand for public transit. Reductions in transit service further increase the demand for cars, and the cycle continues. Parking requirements do not cause this cumulative process, but by ensuring that parking remains free they have exacerbated it" (Shoup, 2011, p.129).

Our hypothesis is that as commuters recognize that they will have to absorb the additional increase in transportation costs brought upon by a rise in off-street and on-street parking prices, they will potentially reconsider their choice of living in suburban neighbourhoods. This study is unique in incorporating parking prices in its models in order to capture a larger share of total transportation costs and determine their effect on urban sprawl. In the next chapter we examine the variables that are used to conduct our econometric model and explain the reasoning behind this choice.

CHAPTER III

DATA AND METHODOLOGY

3.1 Introduction

The objective of this chapter is to present the methodology that allowed us to explore our research objectives. First, we discuss the theoretical scheme and framework of our research. Second we situate our case study and describe the method used to define urban boundaries. Third, we present the sources of our data sets and discuss the data used in our research. Fourth we explain and justify our choice of dependant and independent variables, and fifth, we describe the econometric model used in our research.

3.2 Theoretical Scheme and Framework

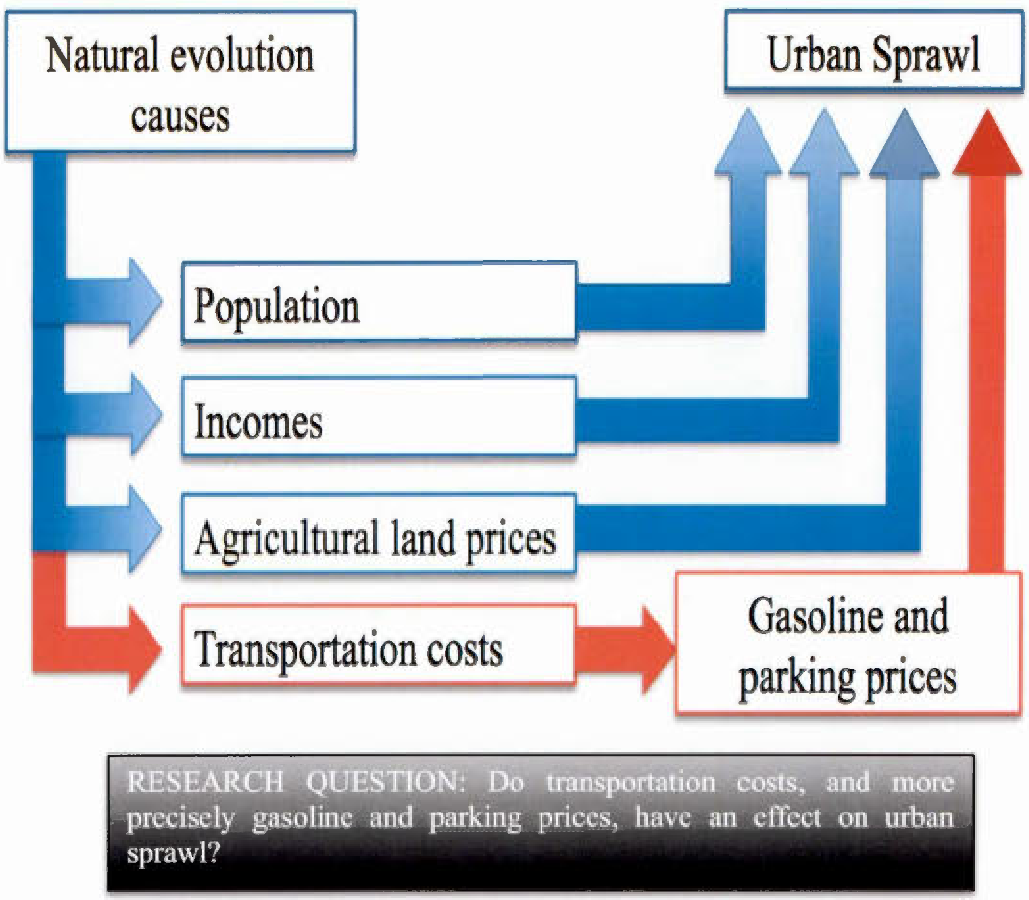
In this study, we empirically explore the causes of urban sprawl to determine the potential significance and influence of two important markers of transportation costs; gasoline and parking prices.

Urban economic theory provides the framework for this analysis. We primarily referred to the natural evolution model coined by Mieszkowski and Mills to determine the causes of urban sprawl and used the Muth-Mills monocentric model (refer to Figure 2.1) to understand the effect of exogenous variables on land usages. This choice of model is supported by Tanguay and Gingras (2012), who emphasis the monocentric attributes of Canadian cities, and recommend using monocentric rather than polycentric models while studying a Canadian context. By taking this economic perspective, we acknowledge our decision to distance ourselves from the sociological approach known as the "flight from blight model." This choice was supported by the lack of conclusive evidence conveyed in studies conducted elsewhere than in the United States (Marshall, 2001). Furthermore our primary interest was to understand how the usage of urban transport pricing instruments could be used to manage urban sprawl. We also recognize the presence of a third model used to explain low-density sprawl entitled "fiscalization of land use" and developed by Wassmer (2002). However, even though this model uses economic instruments such as revenue production and fiscal surpluses, we did not include it in our study because it did not consider these instruments in an urban transport perspective.

The four factors presented in the Mieszkowski and Mills natural evolution model (population, income, agricultural rent and transportation costs) are all explored in depth in our research with particular attention being given to transportation costs. To determine the significance of transportation costs in the equation of urban sprawl, we first identified the costs (in the form of expenses or negative externalities) that were to be included in this category. Based on relevant and available data, we decided to consider two transportation costs in our study: the price of gasoline and parking. While there are many other direct and indirect costs associated with driving, we chose to only consider driving costs that were variable across time and areas, recurring for most urban travels, and perceived by drivers simultaneously. Other costs that were not included in our research, but that deserve further explanation are congestion, environmental externalities, registration fees and the cost of buying a vehicle itself. Congestion costs and environmental externalities, although highly pertinent, were not included in our study because of the uncertainty and lack of agreement concerning their estimation and measurement. Moreover, these costs were not included because drivers do not, for the most part, perceive them as a cost. As mentioned by Zegras (1997) and the Urban Transportation Task Force: "Congestion results from a disconnection between the costs of travel as perceived by the individual driver and the true costs that are borne by the economy and society at large. Individual drivers do not see the social costs of congestion" (Urban Transportation Task Force, 2012, p. 11). A third justification for refrained to use congestion as a variable of interest in our analysis was the ambiguous causality between congestion and urban sprawl; congestion can both lead to sprawl and be a consequence of it.

Because they are fixed costs, registration costs as well as the cost of buying a vehicle were not included in our study. From an economic perspective, fixed costs are seen as expenses that are non-related to the level of good or service being used. Inversely, variable costs such as purchasing gasoline or parking are related to distance traveled or trip frequency.

Figure 3.1
Theoretical framework



By using this economic framework and by including control variables (population, agricultural land prices, and median income) we believe that our research and our model will be robust and will thereby minimize the risk of statistical errors. In turn, this assures us of the significance of our results and provides valid responses to our research objective and hypothesis. In the next section we examine the variables that will be used to conduct our econometric model and explain the reasoning behind this choice of model.

3.3 Description of Case Study

To test our hypotheses we based our research on the Mieszkowski and Mills' natural evolution model. By adding and improving factors to this model we were able to adapt it to a Canadian context. Our study solely focused on sizeable Canadian cities[13] and uses census metropolitan areas (CMAs) to define studied zones. This method of city delimitation has been widely used in the past; notable authors are Bussière & Dallaire (1994) and McGrath (2005). Other authors (Brueckner & Fansler, 1983; Galster *et al.*, 2001; Song & Zenou, 2006; and Wassmer, 2008) have preferred the use of urbanized area measurements to define city limits. Because our research objectives were primarily based on quantifying urban sprawl, we foresaw problems with using this second methodology. Urbanized areas are, by definition, measured using a minimum density threshold, and we believed this could potentially compromise our results, given that any measurable sprawl below this threshold would not be considered. In our view, census metropolitan areas are better suited for our framework, as they do not disappear over time; only their size may vary, depending on population fluctuations: "[...] once an area becomes a CMA, it is retained as a CMA even if its total population declines below 100,000 or the population of its core

[13] By sizeable Canadian cities I mean cities that comprise a population of over 200 000 citizens. City selection is primarily based on availability of the data.

falls below 50,000" (Statistics Canada, 2014a). This feature allows us to compare sprawl indicators over long periods of time.

The number of CMAs to be used in our study was based on the availability of the data and on population size. Focusing mostly on available data from Statistics Canada's five year censuses, we included 10 Canadian CMAs: Halifax (Nova Scotia), Montreal (Quebec), Ottawa-Gatineau (Ontario/Quebec), Toronto (Ontario), Winnipeg (Manitoba), Regina (Saskatchewan), Calgary (Alberta), Edmonton (Alberta), Vancouver (British-Columbia) and Victoria (British-Columbia). The location and size of these CMAs is presented in Figure 3.2.

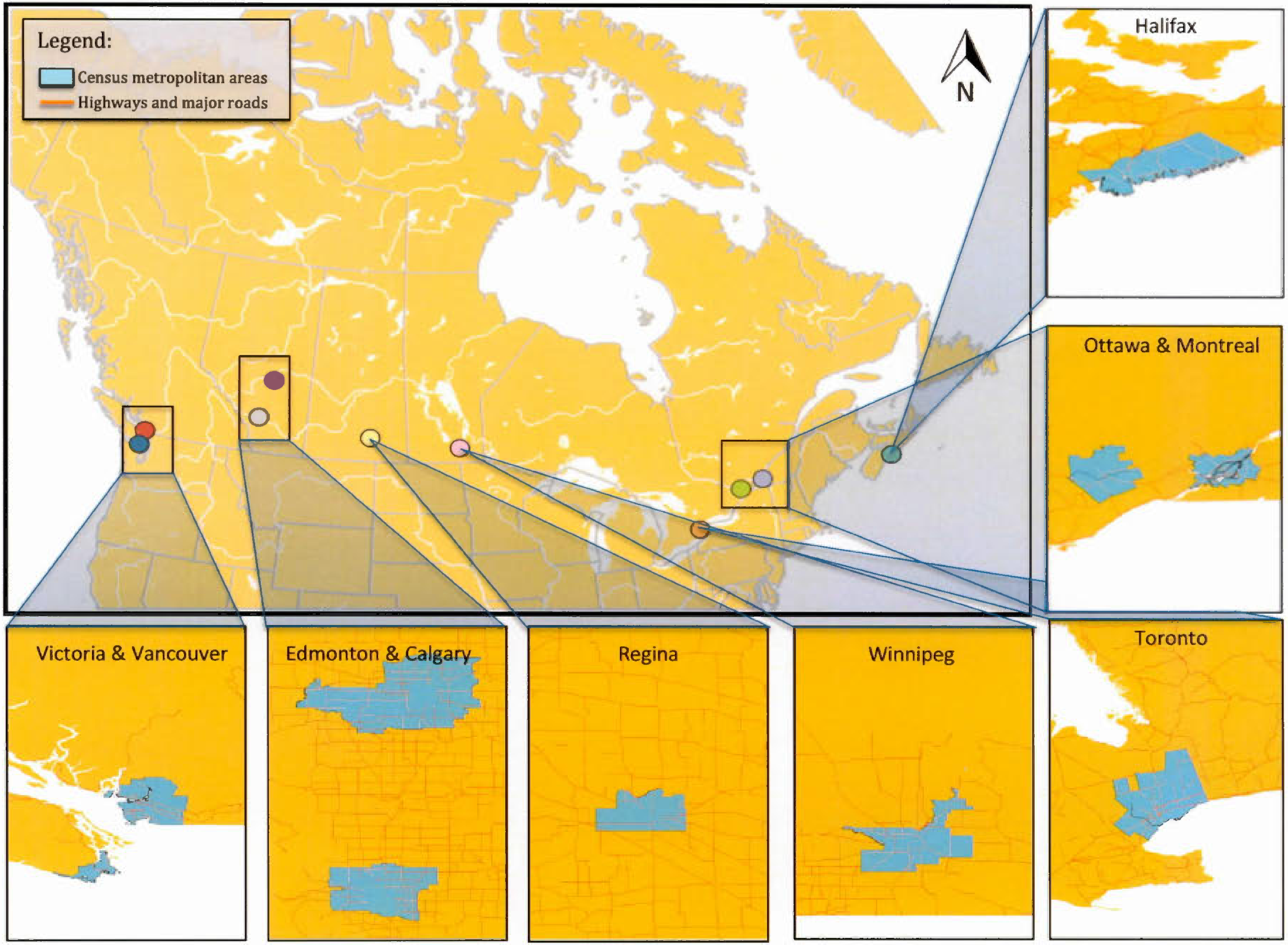


Figure 3.2
10 Canadian CMAs included in the study (projection: NAD83; scale: 1:150 000; source: Natural Resources Canada, 2015)

3.4 Data Description

We used data sets spanning a period of 16 years ranging from 1996 to 2011. This period of analysis was primarily based on data availability. Although the majority of our data was retrieved from the Statistics Canada censuses, we used other variables that were measured annually, such as median household income, gasoline prices and parking prices, and therefore conducted the research on an annual rather than quinquennial basis. The drawback with this choice of range was that we were faced with incomplete census-related data sets. To address this problem, there were several alternatives. The first option was to disregard the years for which data was incomplete and only use the four years for which we had complete data (census years: 1996, 2001, 2006 and 2011). The second option, as suggested by Studenmund (2001), was to include every year and to estimate the missing values by means of interpolation (taking the mean of the adjacent values). To ensure the robustness of our research, our study considered both option to address missing data and conducted two different types of regressions accordingly.[14] The first type of regression will comprise 160 data points (10 cities for a period of 16 years), whereas the second type of regression will comprise 40 (10 cities, but only for the four census years).

3.5 Dependent Variables

Our dependent variables will reflect two core concepts of urban sprawl presented earlier in chapter 1: the presence of low-density areas and longer travel distances.

[14] We acknowledge the many changes and criticisms in regards to the 2011 Statistics Canada census, which stress its fallibility and often accentuate that "[The census] comes with the census equivalent of a surgeon General's warning: make any historical comparisons at your own risk"(Rennie, 2013). However, we chose to include this census in our study all the same because we consider the data used in our research to not be affected by these alterations.

This choice of variables is supported by their prominence in previous research and is a direct result of several data availability constraints.

3.5.1 Density

Our initial intention was to use population density as our measurement for urban density. This entailed dividing the number of individuals living in an urbanized area by its area, as seen in Wassmer (2008). However, because this method did not consider land usage, we chose not to use this measurement. As noted by Turcotte (2008), neighbourhoods have uneven population distributions due to portions of their territory being uninhabited, which can potentially result in inaccurate density measurement. For this reason, we used dwelling type variables as a mean to measure urban density. This approach was also used by Galster *et al.* (2001), Song and Zenou (2006), Turcotte (2008), and Tanguay and Gingras (2012). In contrast to population density, a housing density metric can better distinguish uneven population distributions by calculating the proportion of low-density housing in each CMA. Following Turcotte (2008), the combined share of single-detached houses, semi-detached houses and movable dwellings were considered as low-density housing. In North America, the presence of single and semi-detached housing units is an important feature that distinguishes residential suburbs from their urban counterparts (Harris, 2004) and therefore, a higher proportion of this type of dwelling would imply low-density housing and can be expected to be found in sprawled CMAs.

3.5.2 Proximity

In accordance with Bussière and Dallaire (1994), Galster *et al.* (2001), and Tanguay and Gingras (2012) we measured proximity using median commuting distances. Distances were measured using “the straight-line distance, in kilometers, between the respondent's residence and his or her usual workplace location" (Statistics Canada, 2014b). The reasoning for choosing this type of variable is that it is directly related to Statistics Canada's definition of a CMA: "To be included in the CMA or CA, other adjacent municipalities must have high degree of integration with the core, as measured by commuting flows" (Statistics Canada, 2014a). Median commuting distances were retrieved from Statistics Canada's quinquennial censuses (refer to Appendix A for more details).

3.6 Independent Variables

3.6.1 Gasoline Price

Natural Resources Canada provides an annual database for the price of fuel for CMAs across Canada and we used this to calculate the annual average retail price of gasoline[15] for each CMA. We also transformed our variable into real terms[16] to account for inflation and properly compare this variable through the 16 year period of our study (see Figure 3.3). We used the general Consumer price index (CPI) measure for all goods as all goods are partially or directly affected by the price of gasoline. As predicted in our theoretical framework, we expect gasoline prices to be negatively correlated with urban sprawl.

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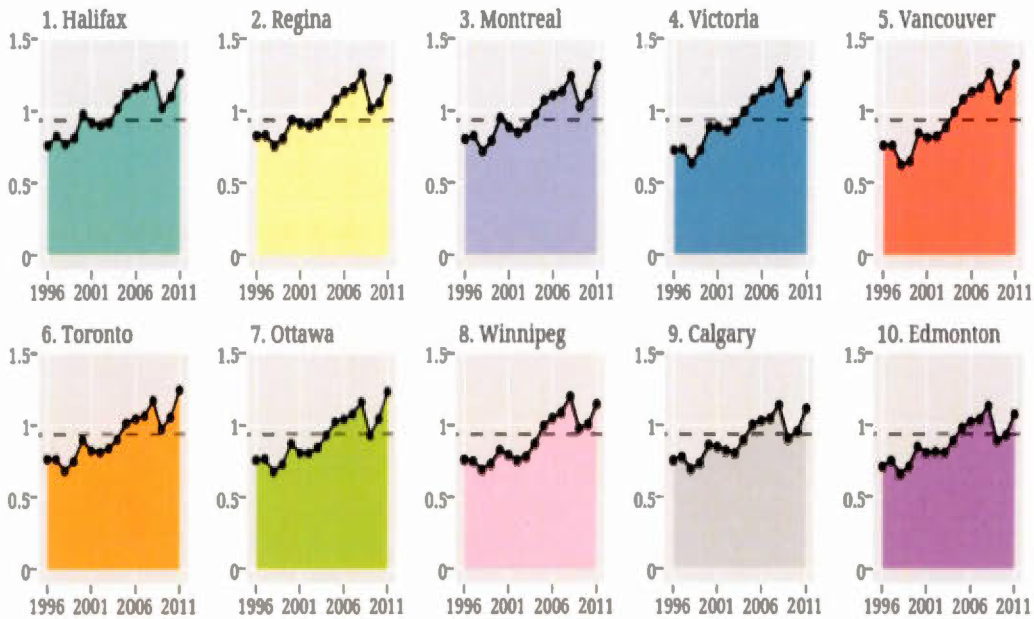
[15] The average retail price of gasoline includes all forms of taxes.

[16] The real annual retail price of gasoline was calculated using the CPI as follows: retail price of gasoline for year *X* * (CPI of base year/ CPI year *X)* (Wooldridge, 2013).

Figure 3.3

Real gas prices in Canadian cities



Source: Natural Resources Canada, 2015.

In Figure 3.3 we notice an increase in real gas prices for every studied Canadian city throughout the time period of our study with a discernible decrease in gas prices following the 2008 financial crisis. This considerable drop following the 2008 crisis is an important reminder that external factors, other than the direct demand for oil, can also affect the price of gasoline. For instance, it is believed that the Canada-wide oil price decline in 1998 was in large part due to another economic crisis in South-East Asia. Another example would be in 2001, where an increase in non-OPEC production coupled with a weakened US economy, not to mention September 11, put significant downward pressure on oil prices in the Canadian market once again (Williams, 2011). A dotted line depicts Canada's average gasoline price for the period of our study.

3.6.2 Parking Prices

Parking prices were measured using data collected from both the Colliers International website [17] and by individually contacting each CMAs' parking representatives. Colliers International is a commercial real estate company that provides yearly-unreserved[18] parking rate surveys for every large city in North America. The data thus refers to off-street parking prices and is available online (refer to Appendix A for more details). For public officials' data, emails were sent to city parking agencies with a request to forward yearly prices for on-street parking meters for the period of 1996 to 2011. All the cities contacted complied. In cities such as Vancouver, Toronto and Montreal where several parking meter rates were reported, we chose to only use downtown core rates, which are typically the most expensive. Given that six of the studied cities only charged for parking in their downtown core (Halifax, Ottawa, Winnipeg, Regina, Edmonton and Victoria), limiting our study to the downtown-parking rate in all of the cities increased the comparison compatibility amongst them. In line with our theoretical model, our hypothesis is that increasing the price of either type of parking will slow sprawl.

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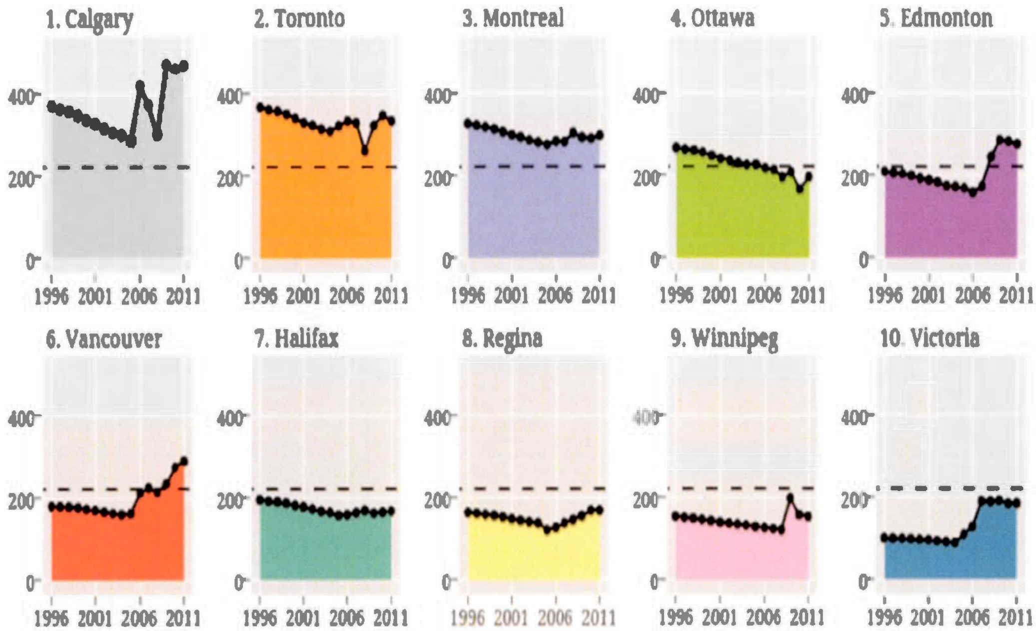
[17] Cook and Simonson, 2012.

[18] Unreserved parking means that the customer is guaranteed a space upon entry to the parking lot, but that he does not always park at the same space (Definition taken from Colliers International Parking Rate Survey (Cook and Simonson, 2012).

Figure 3.4
Off-street parking prices in Canadian cities ($/month)

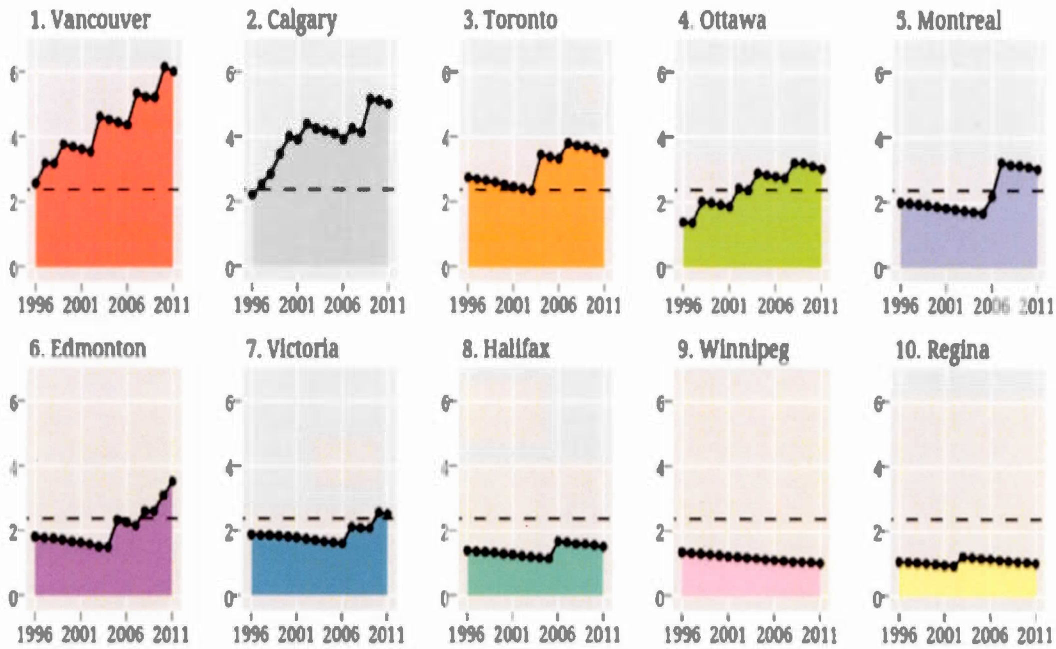


Source: Cook and Simonson, 2012.

In Figure 3.4 we notice a wide variation of off-street parking prices. Cities such as Calgary, Toronto and Montreal display parking prices well above $250 per month, whereas other cities, such as Regina, Winnipeg and Victoria cost bellow $200 per month. Additionally, although most of the studied cities show a slight decrease in off-street parking prices, some such as Calgary, Edmonton, Vancouver and Victoria indicate a rise in parking prices and may potentially have hindered sprawl. A dotted line depicts Canada's average off-street parking price for the period of our study; prices are in 2011 dollars.

Figure 3.5

On-street parking prices in Canadian cities ($/hour)



Source: data provided by city parking agencies

By looking at Figure 3.5 it is clear that there exists a wide variation in on-street parking prices amongst studied cities. Most cities systematically increase parking prices every few years, however, three cities in particular, Halifax, Winnipeg and Regina, have not significantly increased their prices throughout the period of our study, and have, as a result of inflation, seen a drop in real term parking prices. Once again, Canada's average on-street parking price is depicted in the figure and prices are in constant 2011 dollars.

3.6.3 Population

Population was measured using Statistics Canada's annual calculation of the CMAs' total population. Other authors have also used this variable in their work, including

Brueckner and Fansler (1983), Burchfield *et al.* (2006), McGrath (2005), and Tanguay and Gingras (2012). We anticipate that population is positively correlated to urban sprawl.

3.6.4 Agricultural Land rent

Agricultural land rents are closely linked to urban sprawl; whenever they increase, they impede urban sprawl. This factor has widely been cited in the past (Mieszkowski and Mills, 1993; McGrath, 2005; Song & Zenou, 2006) and is usually measured by the value of agricultural land. However, this data was not available on a CMA level in Canada and was therefore replaced by a proxy variable. Following Tanguay and Gingras (2012), we replaced agricultural land rent by a housing value ratio. To calculate this ratio, we divided the average cost of a two bedroom dwelling in the central city by the average cost of a two-bedroom dwelling in the entire CMA. This ratio gave us an estimate of the cost of land in the outer limits of the CMA as opposed to the cost of land in the downtown core. We predict that a high housing cost ratio will lead to more urban sprawl, as household tend locate themselves wherever rent is the cheapest.

3.6.5 Household Income

In order to analyze the effect of income on urban sprawl, most authors favor the use of per capita mean income (Brueckner and Fansler, 1983); however, we deemed that this measure lacks precision since it does not consider household dynamics, an important unit of decision-making for both housing and travel choices. For this reason, we chose instead to use median household incomes and adjusted for inflation using constant 2011 dollars. Although less frequently, household income measurements have been used to measure the effect of income on sprawl (Song and Zenou, 2006; Tanguay and Gingras, 2012). We anticipate median household income to be positively correlated with urban sprawl as space is considered to be a normal good[19] (Tanguay and Gingras, 2012; Serrano and Feldman, 2012). Following a rise in household income, we expect individuals to demand more space and therefore, larger properties. This type of housing is typically found in suburban neighbourhoods, and will therefore probably increase the extent of urban sprawl.

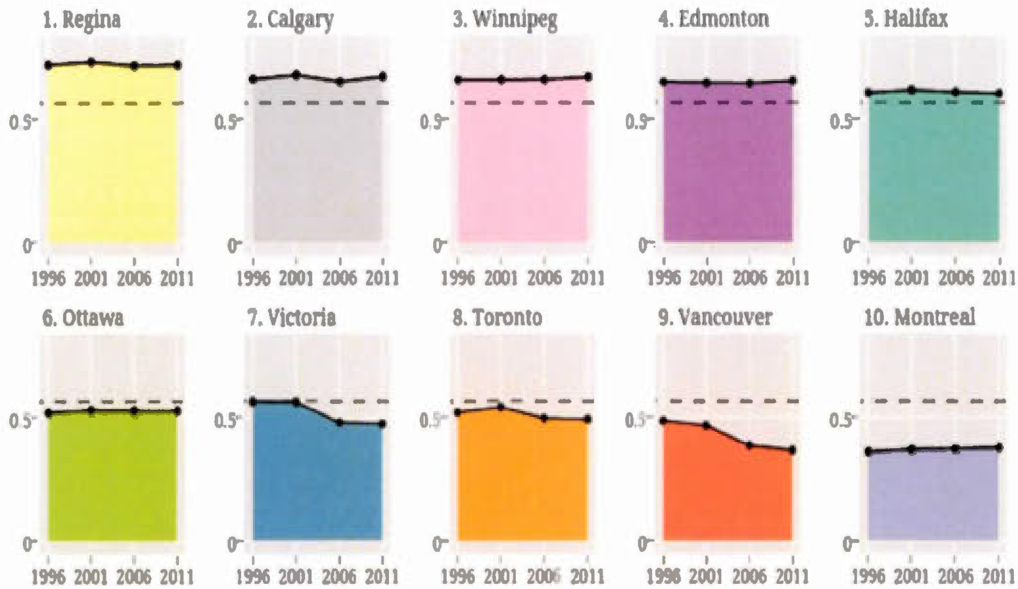
3.7 Descriptive Statistics

In Table 3.1 we present the descriptive statistics of the variables used in our regression analyses. Highlights for the two dependent variables over time are presented below in Figure 3.6 and 3.7.

Density (Percentage of low-density housing in the CMA): On average, 56.5% of housing units in our CMAs are considered to be low-density. Until recently, Montreal was considered the CMA with the smallest percentage of low-density housing, ranging from 36% to 38% in the period from 1996 to 2011; however in 2009, Following the construction of several condominium projects in its downtown core, Vancouver also began to displayed percentages as low as 36%. The CMA with the highest share of low-density housing is Regina, standing alone at 73% in 2001. Figure 3.6 displays census year data points and median lines for each CMA in our study.

[19] A good is said to be normal if it experiences an increase in demand following an increase in income.

Figure 3.6
Density: proportion of low-density housing in Canadian cities



Source: Statistics Canada, 2014a

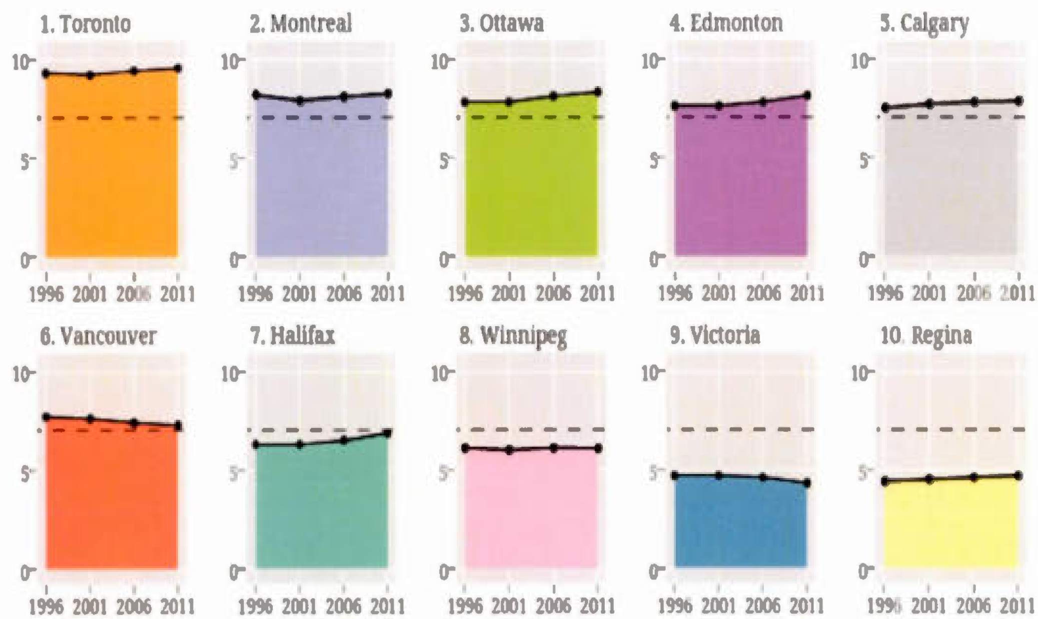
We observe that with the exception of two noticeable decreases found in Vancouver and Victoria, most CMAs present relatively stable shares of low-density housing throughout the time period of our study. This may, in part, be due to the province of British-Columbia offering a density incentive. Indeed, "density bonusing" as it is commonly named, enables developers in British-Columbia to surpass allowed housing density levels in exchange for providing amenities for the community and/or affordable housing units (Wilson and Zeeg, 2007).

Proximity (Median commute distance): On average, the median commute distance for our CMAs is of 7.01 kilometers. Commute distances vary from a minimum of 4.32 kilometers in Victoria to a maximum of 9.55 kilometers in Toronto.[20] Interestingly, with the exception of Vancouver and Victoria, which present decreases in commuting

[20] Both the maximum and the minimum median commute distance are for 2011.

distances,[21] and of Winnipeg, which stays relatively constant across time, all the other cities display increases in median commute distances throughout the time period of our study (refer to Figure 3.7).

Figure 3.7
Proximity: median commute distance in Canadian cities (kilometers)



Source: Statistics Canada (2008) and Turcotte (2008)

Table 3.1 also displays descriptive statistics for each of our six independent variables. We observe that the average median household income for our selected CMAs is of $87 220, which is largely superior to the average Canadian median household income of $77 950 for the same time period. Montreal is the CMA that presents the lowest median household income throughout the period of our study, ranging from $67 700 in 1996 to $79 200 in 2011. We also notice a considerable range between the maximum and minimum values of parking price variables. This may result from a

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[21] Once again, this may, in part be due to "density bonusing" in the province of British-Columbia.

parking price discrepancy amongst Canadian cities. Indeed, most Canadian cities increase their parking prices systematically every few years, but some, probably due to the unpopular political nature of raising prices, choose to avoid this increase and instead see a reduction in parking prices as a result of inflation. Vancouver is the city that raised on-street parking prices the most during our study, increasing prices in five different occasions. Looking at off-street parking prices we notice a considerable difference as well. The average monthly price of off-street parking in Calgary is of $472.50 and is the highest observe in our study. Overall, we notice that large CMAs such as Toronto, Montreal, Vancouver and Calgary display higher off-street parking prices and are more likely to increase their on-street prices.

Table 3.1

Descriptive Statistics

Variables	Description and source	Number of obs.	Mean	Standard-deviation	Min.	Max.	Expected sign
Dependent Variables							
Density (%)	Proportion of low-density housing occupied in the CMA (Statistics Canada Census, 1996 to 2011).	160	56.5	11.0	36.1	73.1	Y^1
Proximity (km)	Median commute distance (kilometer) (Statistics Canada Census, 1996 to 2011).	160	7.01	1.49	4.32	9.55	Y^2
Independent Variables							
Total Gas Price ($)	Regular gas price at the pump per CMA including taxes.[1]	160	0.937	0.169	0.620	1.317	Y^1: (−) Y^2: (−)
Off-Street Parking Price ($)	Monthly Off-Street Parking rate from Colliers International.[2]	160	220.854	85.241	88.337	473.985	Y^1: (−) Y^2: (−)
On-Street Parking Price ($)	Hourly On-Street parking rate in downtown core.[3]	160	2.359	1.208	0.918	6.136	Y^1: (−) Y^2: (−)
Total Population (Person)	Total population of CMA (Statistics Canada Census, 1996 to 2011).	160	1563316	1534597	193652	5769759	Y^1: (+) Y^2: (+)
Housing Value Ratio (%)	Ratio of average value of housing in the city center (CC) to average value of dwellings in the CMA (Statistics Canada Census, 1996 to 2011).	160	104.0	11.9	83.5	134.3	Y^1: (+) Y^2: (+)
Household Income ($)	Median Household Income by CMA (Statistics Canada Census, 1996 to 2011).	160	87220	10357.24	67700	116900	Y^1: (+) Y^2: (+)

[1] Natural Resources Canada (Canada, 2015).

[2] Cook, J. and J. Simonson, 2012.

[3] Emails were sent to city parking agencies with a request to forward yearly prices for on-street parking meters for the period of 1996 to 2011. All the cities contacted complied.

3.8 Econometric Model

Log-log models were used to measure the causes of urban sprawl.[1] We estimate two separate sets of models using the following basic equation:

$\ln Y_{it} = \alpha + \beta \ln X_{it} + \varepsilon_{it}$ where:

Y = Dependent variables (Proportion of Low-Density Housing, Median commuting distance);

X = Independent variables (Gasoline prices, Off-street parking prices, On-street parking prices, Population, Housing cost ratio, Median household income);

α = Constant;

β = Variable specific coefficients;

ε = Error term;

i = Metropolitan areas (Halifax, Montreal, Ottawa, Toronto, Winnipeg, Regina, Calgary, Edmonton, Vancouver, Victoria);

t = Years (1996 to 2011);

3.8.1 Estimation Strategy

Several estimation methods can be used to measure panel regression equations. We explored three of these methods in our research: generalized least square (GLS), GLS with fixed effects, or random effects. To determine the most appropriate amongst these models, we first tested for the presence of individual effects using the Breusch-Pagan Lagrange multiplier test (see Appendix B). The null hypothesis of this test

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[1] This type of model expresses the value of both the dependent variable Y and the independent variables X in natural logarithms. The practical advantages of transforming variables into natural logarithms is that it converts non-linear parameters into linear parameters and portrays the elasticity of each independent variable in relation to the dependent variable through its estimated coefficients (Studenmund, 2001).

maintains that variance across entities is of zero and therefore that there is no significant difference across variables due to panel effects. If the null hypothesis is confirmed, it is recommended to use the GLS model with no independent effects, whereas if the presence of individual effects is established, the usage of fixed or random effect models is suggested instead. The benefit of using a fixed effects model when faced with individual effects is that it includes dummy variables in order to consider the particular characteristics of each metropolitan area; however, it also causes the loss of N-1 degrees of freedom (where N are CMAs), which in turn might make the estimation of our regression coefficients less efficient. The random effects model can provide substantial gains in estimating efficiency, but as noted by Oueslati *et al.* (2015, p. 1604) "[it] imposes a strong assumption that individual effects are not correlated with explanatory variables" and should therefore only be used whenever the entities are uncorrelated with the predictors (Oueslati *et al.,* 2015).

To determine which model to use when faced with individual effects, we performed a Hausman test (see Appendix B). This test considers the coefficients obtained in the random effects model and compares them to those obtained in a fixed effects model. The null hypothesis of this test assumes that the coefficients estimated by the random effects model are equal to those estimated by the fixed effects model. When the null hypothesis is confirmed, we should use the model with random effects (Hausman and Taylor, 1981). We report on the chosen approach for each regression model. Also reported with our regression outputs are the corresponding Wald Chi-square test results. The Wald Chi-square test statistic reports the squared ratio of the estimate to the standard error for each predictor and verifies the significance of our predictors (Lin *et al.*, 2005).

Using scatterplots and histograms, we determined that our variables were normally distributed and that *robust* and/or *cluster* options were not needed while regressing our datasets on Stata 13.1. Before regressing our datasets, we ran all variables through a correlation matrix in order to determine whether any strong correlations existed amongst variables. The Pearson linear correlation coefficients amongst sprawl predictors remained below 0.70 and were therefore considered non-problematic (see Appendix B).

We introduced a trend variable to capture all other factors that might have contributed to causing urban sprawl throughout the time period of our study. This variable tested whether our data followed any kind of linear direction through time. We later chose to remove this variable from our regressions, as it presented a Pearson linear correlation coefficient of 0.86 with regards to gasoline prices and caused problems of multicollinearity. Considering its strong correlation with the trend variable, gasoline prices were also capable of capturing any linear time related direction present in our dataset.

In the next chapter we will present the article as submitted to the journal *Research in Transportation Economics.*

CHAPTER IV

ARTICLE

As mentioned earlier, this dissertation is presented in the form of a thesis by publication. This chapter contains the article that is currently being peer reviewed for publication in the journal *Research in Transportation Economics*. The article is divided into four parts. First we identify the hypothesized causes of urban sprawl and discuss the different methods used to measure its extent. More precisely, in this section we i) explore the different definitions of urban sprawl; ii) examine the natural evolution model; iii) determine the causes of urban sprawl while iv) focusing on transportation costs and iv) emphasize the importance of including parking prices in urban sprawl equations. The second section elaborates the methodology of our research. We present the results of our regressions as well as a discussion of these results in the third section. A brief summary and concluding remarks comprises the final section of this article. It is worth noting that as the article is an abbreviated version of the dissertation, the content preceding the article will at times be repeated in lesser detail in the article itself. At this point, readers may go directly to page 68 in order to arrive at the "Results" section of this dissertation.

Transportation Costs and Urban Sprawl in Canadian Metropolitan Areas

Abstract

We conduct an econometric analysis of the potential impact of gasoline and parking prices on urban sprawl in ten Canadian metropolitan areas from 1996 to 2011. Two measures of urban sprawl related to density and proximity are used as dependent variables: the proportion of low-density housing and the median commute distance. We explain these measures by four main variables based on the natural evolution model: population growth, median household income, the cost of surrounding agricultural land, and transportation costs. We show that, *ceteris paribus*, higher parking and gasoline prices have contributed to reduce the extent of urban sprawl. On average, a 1% increase in gasoline prices has led to a decrease in low-density housing by 0.17% and to a 0.04% decrease in median commute distance. Furthermore, we show that a 1% increase in the price of off-street parking has led to a 0.12% decrease in low-density housing and to a 0.05% decrease in median commute distance. We argue that results for parking prices are relatively modest because much free parking is available.

Keywords: Urban sprawl, census metropolitan areas, parking prices, gasoline prices, suburbs.

Words in abstract: 168
Words in paper: 7379
Pages: 35 p.
Tables: 3
Figures: 3

4.1 Introduction

Many contemporary urban development patterns found in North American cities are referred to as urban sprawl. These patterns are characterized by some degree of population and employment growth stagnation in established city centers while population tends to increase in surrounding peripheral municipalities, which themselves spread over broader areas. Evidence of this form of development can be seen across North America, where within the 40 years following 1960, suburbs housed a greater share of the population than cities and countryside put together" (*The Economist*, 2008). Between 2006 and 2010, Canadian peripheries of census metropolitan areas (CMA) registered soaring population growth rates of up to 50% in comparison with the country's total population growth rate of 5.9% for that same period (Statistics Canada, 2014). What explains this current trend across Canadian cities, and what can be done about it? The objective of this study is to determine whether two types of transportation costs have had an effect on urban sprawl in Canadian cities. We base our analysis on previous work by Tanguay and Gingras (2012), who, using the natural evolution model, conducted a study on the effects of gas prices on urban sprawl in Canadian cities and showed that on average, a 1% increase in the price of gasoline caused a decrease in low-density housing by 0.60% and an increase in the population living in the inner city by 0.32%. Similarly to Tanguay and Gingras (2012) and other studies (Burchfield *et al.*, 2006; Molloy and Shan, 2013; Ortuño-Padilla and Fernández-Aracil, 2013), we perform a panel regression analysis using data from 10 Canadian metropolitan areas over a 16-year period. We measure urban sprawl using two dependent variables related to density and proximity. Main independent variables of interest include downtown parking prices (on-street and off-street), and gasoline prices.

In the next section, we identify the hypothesized causes of urban sprawl and discuss the different methods used to measure its extent. We then focus on transportation costs, emphasizing the novelty and importance of including parking prices in urban sprawl equations. After describing our methodology, we present the results of our regressions and discuss their implications. The conclusion follows.

4.2 Urban Sprawl and the Natural Evolution Theory

Definitions of urban sprawl vary depending on the authors and the fields of study in which they are employed. Authors such as Brueckner and Fansler (1983), McGibany (2004), Burchfield *et al.* (2006) and Sun *et al.* (2007) use spatial features to define urban sprawl, claiming for example that it is "characterized by vigorous spatial expansion of urban areas" (Brueckner and Fansler, 1983, p. 479). They also emphasize the required travel distances of such urban areas: "Sprawl is often used to describe cities where people need to drive large distances to conduct their daily lives" (Burchfield *et al.* 2006, p. 607).

Others, such as Nechyba and Walsh (2004), Pendall (1999), Eidelman (2010), and Banai and Priest (2014) rather describe urban sprawl by the growth of low-density areas: "By sprawl, we will mean the tendency toward lower city densities as city footprints expand" (Nechyba and Walsh, 2004, p. 178). They commonly use changes in population and dwelling density to measure the degree of sprawl.

A third noteworthy definition is the center-periphery opposition put forth by Bussière and Dallaire (1994), Chapain and Polèse (2000) and Bordeau-Lepage (2009). This idea underlines the importance and presence of displacement of residential and commercial sites from city centers to peripheral regions: "Cities expand, with population and employment increasing faster on the periphery than in the center of the city" (Bordeau-Lepage, 2009, p.13). Similarly, the definition proposed by Wassmer (2000), describes urban sprawl as "another word for a certain type of metropolitan decentralization or suburbanization" and follows by adding: "suburbanization occurs over time when a larger percentage of a metropolitan area's residential and/or business activity takes place outside of its central locations" (Wassmer, 2000, p. 2). Wassmer (2002) also re-examines suburbanization – which he believes to be a direct substitute to urban sprawl – and explains how, according to economists, suburbanization is a process determined by household's residential location decisions. These household decisions are in turn determined through weighing the private benefits of a suburban, decentralized location (e.g. cheaper land) against the private costs of this housing choice (e.g. longer commute times). If private benefits outweigh private costs, households will decide to live further away from the city center.

These definitions exemplify the lack of consensus surrounding the concept of urban sprawl and ways to measure its extent. Bearing in mind that our research focuses on transportation costs, two measurements for sprawl will be retained in our research: density and proximity.[26]

Traditionally, urban economists have relied on monocentric city models pioneered by Alonso (1964), Mills (1967, 1972) and Muth (1969) to explain urban expansion. These models claim that as households move further away from the city center, their housing costs diminish whereas their journey costs increase. Brueckner (1987) later coined this the Muth-Mills model and through its key components, studied the effects of exogenous variables on land usage, using natural evolution factors as independent variables. The Muth-Mills model assumes that households aim to maximize their utility according to their choice of residential location. As illustrated in figure 4.1, the model portrays housing costs (in monetary units) in relation to distances from the central business district (CBD), and displays the monetary differences between agricultural rent and developed land rent for each distance depicted. A horizontal line portrays agricultural rent[27] (R_a) and a decreasing exponential function describes land rent (R_0). This implies that R_a and R_0 intersect at a given point (X_0), where the city limits are located.

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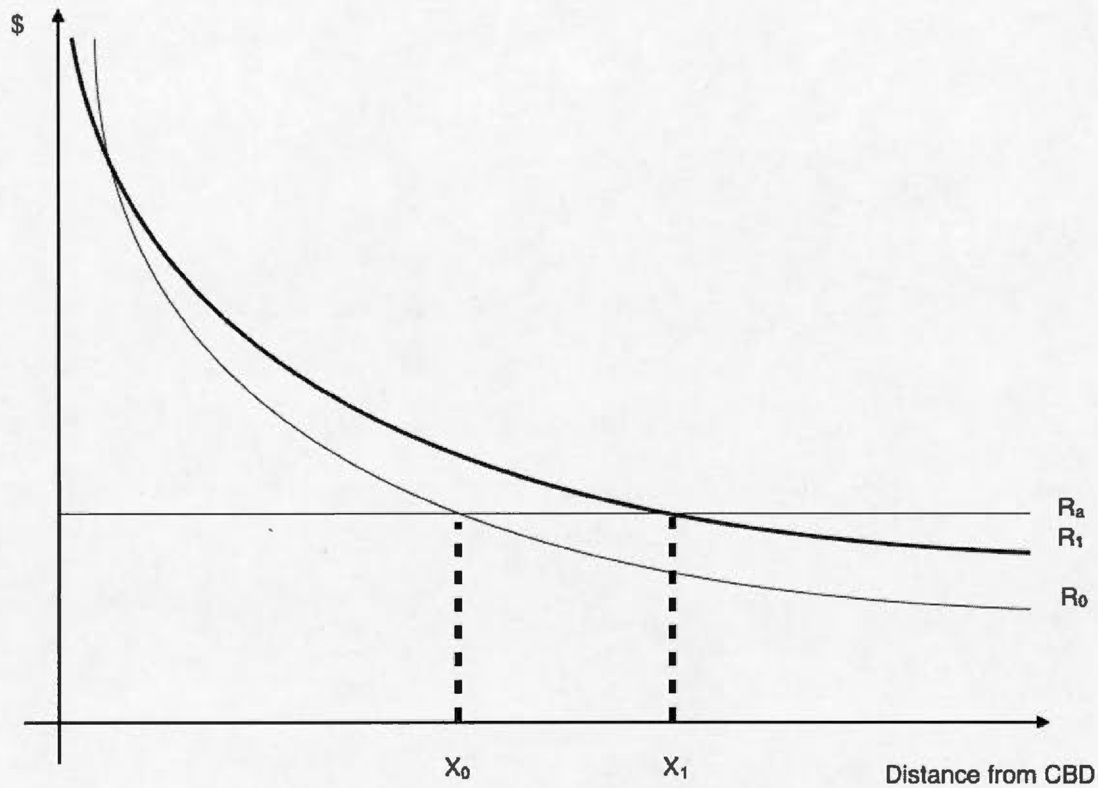
[26] The applicability of these definitions in a Canadian context is reflected by their usage in previous Canadian studies: Sun *et al.* (2007) for spatial expansion, and Eidelman (2010) for low-density areas.

[27] Agricultural rent is depicted by a horizontal line because it is unaffected by its distance to the CBD.

Figure 4.1
Property values, agricultural land value and the city limits



Variations in city limits are also easily depicted through the monocentric model. Consider for instance the effects of a decrease in transportation costs. Following this decrease, the advantages of living near the city center would be reduced and the cost of housing beyond X_0 would be increased. To portray this decrease in housing costs near the city center and simultaneously show the increase in those same costs in the relative suburban areas, the land rent curve would have to flatten, as depicted by R_1 in Figure 4.1. This in turn, would cause the city limits to move outwards to X_1. Thus, according to this model, all other things being constant, lowering transportation costs would cause cities to sprawl. The following section presents the socioeconomic variables of interest for this study and examines how they may impact the size and density of urban areas.

4.3 Transportation Costs

It is widely agreed upon that "one of the cardinal features of sprawl is driving, reflecting a well-established, close relationship between lower density development and more automobile travel" (Frumkin *et al.,* 2004, p.117). Empirical evidence of this association can be found in work by Travisi *et al.* (2010), in which they show that sprawl increases automobile dependency because its form supports a greater dispersion of activities and makes it necessary to spend more time travelling between activities. Many authors have demonstrated the negative relationship between transportation costs and the size of metropolitan areas (Brueckner and Fansler, 1983; Mieszkowski and Mills, 1993; Wheaton, 1998; McGibany, 2004; McGrath, 2005; Burchfield *et al.*, 2006; Song and Zenou, 2006; Wassmer, 2008; Ayala, 2012; Tanguay and Gingras, 2012). For example, McGibany (2004) used the natural evolution model to test the hypothesis that urban land areas are negatively related to gasoline prices and concluded that, all else being held constant, urban areas in states that had raised their gasoline excise taxes by 1 cent in the late 1980s were 4.7 square miles smaller than their counterparts in states that had not raised their gasoline excise tax. Newman and Kenworthy's (1999) work on automobile dependency argues that the greatest factor to have influenced the shape and form of cities is the automobile as it has enabled growth as far out as 50 kilometers in all directions and completely changed the appearance of cities. Using population density as an indicator for sprawl, they confirm the presence of lower population densities in suburban neighbourhoods and attribute this to transportation factors. As per capita gasoline consumption increases, as is often the case in suburban neighbourhoods due to a lack of alternative modes of transportation, population density decreases. Furthermore, these results were conclusive both on an inner city and regional level.

Another extensively studied element of transportation costs is congestion (Brueckner, 1987; Anas and Rhee, 2006; Ayala, 2012). Again, the underlying logic is that if congestion can increase transportation costs, it can also potentially contain urban sprawl. O'Sullivan (2007) measured the extent of this cost in the United States in 2003 and estimated that by adding the value of lost time to the value of wasted fuel due to delays and slow traffic, the annual cost of congestion was of $63 billion (O'Sulllivan, 2007, p. 210). Other authors demonstrate the ambiguous causality between congestion and too much urban sprawl, showing that while congestion may cause urban sprawl, it is also caused by it. Using a spatial general equilibrium model, Anas and Rhee (2006) determined that un-priced traffic congestion did create urban sprawl, but could also in turn cause longer daily travels by up to 13%.

Though both these transportation costs are relevant in predicting the extent of urban sprawl, very little research has been done on the potential effect of other transportation costs, such as car insurances, maintenance fees, and parking prices. Our study provides novel evidence on the latter.

4.3.1 Parking Prices

It is estimated that in 2005, 99% of parking in the United States was free (Shoup, 2011). Similarly, in Canada, IBI Groups (2005) estimated that by 1999, more than 80% of employees enjoyed free or heavily subsidized parking at their workplace. Free workplace parking largely influences individuals' traveling decisions and discourages all other forms of commuting. This abundance of free parking leads to an undeniable sense of entitlement, since drivers are no longer accustomed to paying for parking and now often view free parking as a "civil right" (Cohen, 2014). Increasing the price of parking or even charging for previously free parking is difficult and politically unpopular, leading governments to subsidize parking. For instance, Shoup (2011, p. 2) estimated these subsidies to be as high as $127 billion in the United States alone. By highly subsidizing on-street parking and requiring overly abundant off-street parking in municipal zoning requirements, cities across North America are favoring car usage and indirectly increasing air pollution, gasoline consumption, traffic congestion, and plausibly, urban sprawl (Shoup, 2011). Fortunately, whether city officials are grasping the magnitude of this problem or merely recognizing an untapped source of needed revenues, they are beginning to increase the price of on-street parking and to modify outdated zoning regulations to better represent the true cost of parking. These efforts are encouraging, and there is strong evidence that commuters are responding to these increases in the price of parking. For instance, in Los Angeles, when one firm's formerly free off-street parking fees rose to $28.75 per month, the number of single-occupant vehicles dropped by 44% (Small, 1992). Hensher and King (2001) found that, all other things being equal, increasing the price of parking by 10% would increase the transit mode share in Sydney Australia by 2.9%. While long term housing decisions may not be directly affected by office parking prices, movers and newcomers will likely consider this additional cost in choosing the location of their new home.

These examples illustrate how parking prices can increase transportation costs and in doing so alter driving habits. Our hypothesis is that as commuters recognize that they will have to absorb the additional increase in transportation costs brought upon by a rise in off-street and on-street parking prices, they may reconsider their choice of living in suburban neighborhoods and potentially decide to move closer to the city center in order to benefit from better public transit infrastructures and active transportation routes. This in turn would reduce their need to commute downtown by car and ultimately reduce their need to pay for the increased parking fares. This study is unique in incorporating parking prices in its models in order to capture a larger share of total transportation costs and determine their effect on urban sprawl. In the next section we examine the variables that are used to conduct our econometric model and explain the reasoning behind this choice.

4.4 Methodology

Urban economic theory provides the framework for our analysis. We primarily refer to the natural evolution model coined by Mieszkowski and Mills to determine the causes of urban sprawl and use the Muth-Mills model to understand the effect of exogenous variables on land usages. By taking an economic perspective, we acknowledge our decision to distance ourselves from the sociological approach known as the flight from blight model. This choice was supported by the lack of conclusive evidence conveyed in studies conducted elsewhere than in the United States (Marshall, 2001). Furthermore, our primary interest was to understand how the usage of urban transport pricing instruments could be used to manage urban sprawl, it be by municipal, provincial or federal actors.

The four factors presented in the Mieszkowski and Mills' natural evolution model (population, income, agricultural rent and transportation costs) were all explored in our research with particular attention to transportation costs. Based on relevant and available data, we decided to consider two transportation costs in our study, the prices of gasoline and parking.[28]

4.4.1 Data

We restricted our study to ten sizeable Canadian cities and used CMA boundaries to define studied zones. This method of city delimitation has been widely used in the past (McGrath, 2005; Bussière and Dallaire, 1994). Other authors (Brueckner & Fansler, 1983; Galster *et al.*, 2001; Song & Zenou, 2006; Wassmer, 2008) have preferred the usage of urbanized area measurements to define city limits. Because our research objectives were primarily based on quantifying urban sprawl, we foresaw

[28] Congestion, although pertinent, was not included in our study because of the uncertainty and lack of agreement concerning its estimation and measurement at the aggregate level of metropolitan areas (Zegras, 1997; Urban Transportation Task Force, 2012). Moreover, no reliable congestion data was available for the period of our study and consistent across studied metropolitan areas.

problems with using this second methodology. Urbanized areas are, by definition, measured using a minimum population density threshold, and we believed this could potentially compromise our analysis, given that any measurable sprawl below this threshold would not be considered. In our view, CMAs are better suited for our framework, as only their size may vary, depending on population fluctuations: "[...] once an area becomes a CMA, it is retained as a CMA even if its total population declines below 100,000 or the population of its core falls below 50,000" (Statistics Canada, 2014). This feature allows us to compare sprawl indicators over time. The number of CMAs used in our study is primarily based on the availability of the data and on population size. Focusing mostly on available data from Statistics Canada's five year censuses, we included 10 Canadian CMAs (see Figure 4.2). We used data sets spanning a period of 16 years ranging from 1996 to 2011. This period of analysis was also based on the availability of other relevant data. We used other variables that were measured annually, such as median household income, gasoline prices and parking prices, and therefore conducted the research on an annual rather than quinquennial basis. The drawback with this choice of range was that we were faced with incomplete census-related data sets. To address this problem, there were several alternatives. The first option was to disregard the years for which data was incomplete and only use the four years for which we had complete data (census years: 1996, 2001, 2006 and 2011). The second option, as suggested by Studenmund (2001), was to include every year and to estimate the missing values by means of interpolation (taking the mean of the adjacent values and dividing gradually amongst missing variables). To ensure the robustness of our research, we considered both option and conducted two sets of regressions accordingly.

4.4.2 Dependent variables

Our dependent variables reflect two core concepts of urban sprawl presented in section 2: the presence of low-density housing areas (*density*) and longer travel distances (*proximity*).

Density: As noted by Turcotte (2008), neighborhoods have uneven population distributions due to portions of their territory being uninhabited, which can potentially result in inaccurate density measurement. For this reason, we used dwelling type variables as a mean to measure urban density while taking land usage into consideration. This approach was used by Galster (2001), Song and Zenou (2006), Turcotte (2008), and Tanguay and Gingras (2012). In contrast to population density, a housing density metric can better distinguish uneven population distributions by calculating the proportion of low-density housing in each CMA. Following Turcotte (2008), the combined share of single-detached houses, semi-detached houses and movable dwellings was considered as low-density housing. In North America, the presence of single and semi-detached housing units is an important feature that distinguishes residential suburbs from their urban counterparts (Harris, 2004).

Proximity: In accordance with Tanguay and Gingras (2012), Galster *et al.* (2001) and Bussière and Dallaire (1994), we measured proximity using the median commuting distance traveled by CMA residents to reach their workplace. The reasoning behind this choice of variable was twofold: first because commuting distance is directly related to Statistics Canada's definition of a CMA: "To be included in the CMA or CA, other adjacent municipalities must have high degree of integration with the core, as measured by commuting flows" (Statistics Canada, 2014), and second, because CMA central business districts continue to be important employment hubs, meaning that distance to and from these CBDs gives us a more accurate idea of the size of the metropolitan area.

4.4.3. Independent variables

Gasoline price: Natural Resources Canada provides an annual database for the price of fuel for CMAs across Canada and we used this to calculate the annual retail price of gasoline[29] for each CMA. We transformed our variable into real terms[30] to compare this variable through the 16-year study period. We used the general CPI measure for all goods as all goods are partially or directly affected by the price of gasoline. We expect gasoline prices to be negatively correlated with urban sprawl.

Parking prices: Parking prices were measured using data collected from both the Colliers International website and by individually contacting each CMA's parking representatives. Colliers International is a commercial real estate company that provides yearly unreserved parking[31] rate surveys for every large city in North America. The data thus refers to off-street parking prices and is available online.[32] For public official's data, emails were sent to city parking agencies with a request to forward yearly prices for on-street parking meters for the period of 1996 to 2011. All contacted cities complied. In cities such as Vancouver, Toronto and Montreal where several parking meter rates were reported, we chose to consistently use downtown core rates, which are typically the most expensive.[33] Given that six cities only charged for parking in their downtown core (Halifax, Ottawa, Winnipeg, Regina, Edmonton and Victoria), limiting our study to the downtown-parking rate in all of the cities increased comparability. We considered the possibility that downtown parking prices may be acting as a proxy for the size of cities, as parking prices tend to increase as cities get bigger. However, upon conducting a Pearson linear correlation

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[29] The average retail price of gasoline includes all taxes.

[30] The real annual retail price of gasoline was calculated using the Consumer Price Index (CPI) as follows: retail price of gasoline for year *X* * (CPI of base year/ CPI year *X*) (Wooldridge, 2013).

[31] Unreserved parking means that the customer is guaranteed a space upon entry to the parking lot, but that he does not always park at the same space (Definition taken from Colliers International Parking Rate Survey (Cook and Simonson, 2012).

[32] Cook and Simonson, 2012.

[33] Downtown core parking rates are measured on a regular workday (Monday to Friday), and during hours for which they are applicable (working hours).

matrix, we did not find downtown parking prices to be strongly correlated to the size of cities (size of city displaying a correlation coefficient of 0.42 with regards to downtown parking prices). Thereby justifying the usage of this variable in our research. We hypothesized that increasing the price of either type of parking will slow sprawl.

Population: Population was measured using Statistics Canada's annual calculation of the CMA's total population. Other authors have also used this variable, including Tanguay and Gingras (2012), Brueckner and Fansler (1983), Burchfield *et al.* (2006), and McGrath (2005). We expect population to be positively correlated to urban sprawl, as population growth will increase housing demand and will lead to the construction of new dwellings.

Agricultural land cost: Agricultural land costs, as measured by the value of agricultural land, are closely linked to urban sprawl; whenever they increase, they impede urban sprawl (Mieszkowski and Mills, 1993; McGrath, 2005; Song & Zenou, 2006). Unfortunately, this data was not available on a CMA level in Canada. Following Tanguay and Gingras (2012), we replaced agricultural land cost by a proxy variable: the housing value ratio. To calculate this ratio, we used Statistics Canada's five year censuses data and divided the average cost of a two bedroom dwelling in the central city by the average cost of a two-bedroom dwelling in the entire CMA. This ratio gave us an estimate of the cost of land in the outer limits of the CMA as opposed to the cost of land in the downtown core. We predict that high housing cost ratio will lead to more urban sprawl.

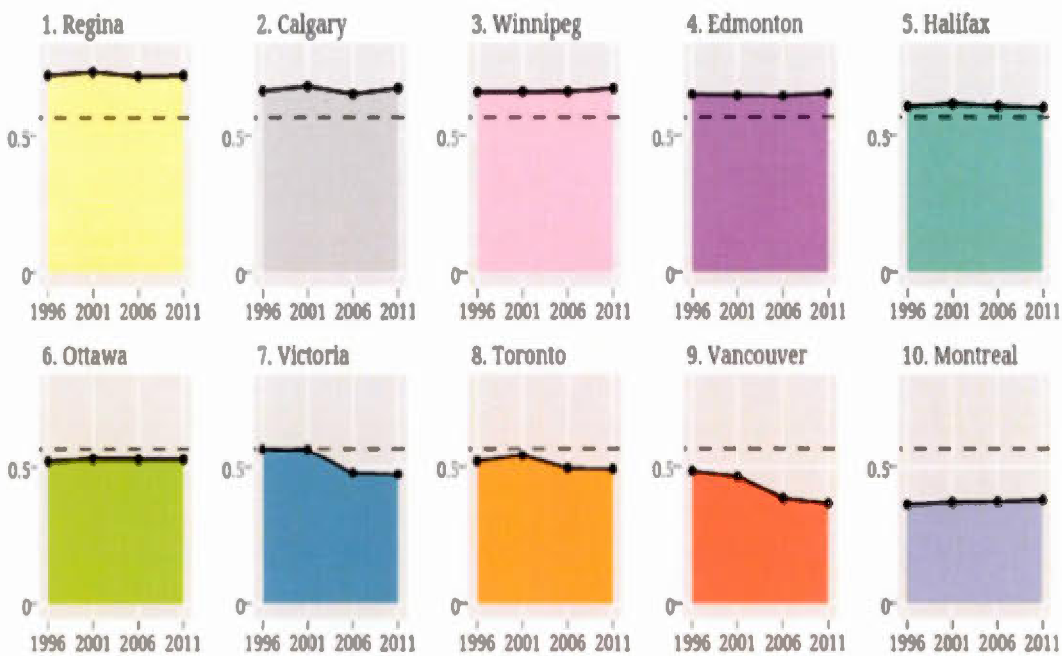
Household income: In order to analyze the effect of income on urban sprawl, most authors favor the use of per capita mean income (Brueckner and Fansler, 1983); however, we deemed that this measure lacks precision since it does not consider household dynamics, an important unit of decision-making for both housing and travel choices. For this reason, we used the median after-tax household incomes instead and adjusted for inflation using constant 2011 dollars. After-tax income measurements were also preferred because provincial tax structures vary considerably. Although less frequently, household income measurements have been used to measure the effect of income on sprawl (Song and Zenou, 2006; Tanguay and Gingras, 2012). We anticipate median household income to be positively correlated with urban sprawl as housing space has been shown to be a *normal good* (Tanguay and Gingras, 2012; Serrano and Feldman, 2012).[34] Following a rise in household income, we expect individuals to demand bigger houses and larger properties. This type of housing is typically found in suburban neighbourhoods, and will therefore probably increase the extent of urban sprawl.

4.4.4. Descriptive Statistics

In table 1, we present the descriptive statistics of the variables used in our regression analysis. City specific highlights for the two dependent variables are presented below. *Density (Percentage of low-density housing occupied in the CMA):* On average, 56.5% of housing units in our CMAs are considered to be low-density. Until recently, Montreal was considered the CMA with the smallest percentage of low-density housing, ranging from 36% to 38% in the period from 1996 to 2011; however in 2009, Vancouver displayed percentages as low as 36%. The CMA with the highest share of low-density housing is Regina, standing alone at 73%. Figure 4.2 presents census year data points for each CMA in our study.

[34] A good is said to be normal if it experiences an increase in demand following an increase in income.

Figure 4.2: *Proportion of low-density housing in Canadian cities*



Source: Statistics Canada, 2014a

We observe that, with the exception of two decreases in Vancouver and Victoria, most CMAs present constant shares of low-density housing throughout the studied time period.

Proximity (Median commute distance): On average, the median commute distance for our CMAs is 7 kilometers. Commute distances vary from a minimum of 4.32 kilometers in Victoria to a maximum of 9.55 kilometers in Toronto.[35] Interestingly, with the exception of Vancouver and Victoria, which present decreases in commuting distances, and of Winnipeg, which stays relatively constant across time, all the other cities display increases in median commute distances throughout the studied time period (see Figure 4.3).

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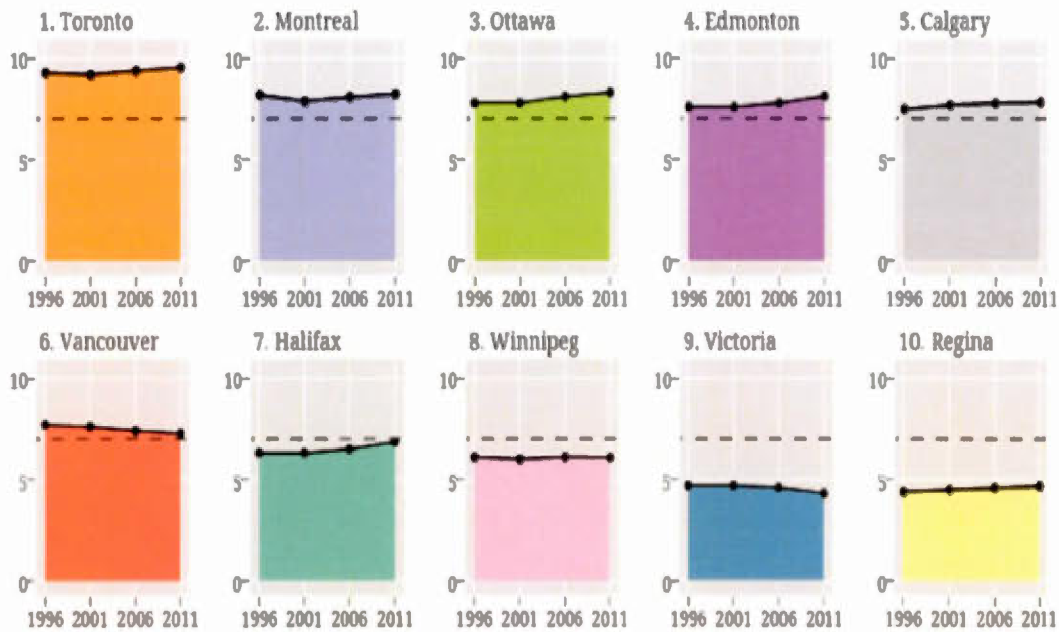
[35] Both the maximum and the minimum median commute distance are for 2011.

Figure 4.3: *Median commute distance in Canadian cities*



Source: Statistics Canada (2008) and Turcotte (2008)

Table 4.1

Descriptive Statistics

Variables	Description and source	Number of obs.	Mean	Standard-deviation	Min.	Max.	Expected sign
	Dependent Variables						
Density (%)	Proportion of low-density housing occupied in the CMA (Statistics Canada Census, 1996 to 2011).	160	56.5	11.0	36.1	73.1	Y^1
Proximity (km)	Median commute distance (kilometer) (Statistics Canada Census, 1996 to 2011).	160	7.01	1.49	4.32	9.55	Y^2
	Independent Variables						
Total Gas Price ($)	Regular gas price at the pump per CMA including taxes.[1]	160	0.937	0.169	0.620	1.317	Y^1: (–) Y^2: (–)
Off-Street Parking Price ($)	Monthly Off-Street Parking rate from Colliers International.[2]	160	220.854	85.241	88.337	473.985	Y^1: (–) Y^2: (–)
On-Street Parking Price ($)	Hourly On-Street parking rate in downtown core.[3]	160	2.359	1.208	0.918	6.136	Y^1: (–) Y^2: (–)
Total Population (Person)	Total population of CMA (Statistics Canada Census, 1996 to 2011).	160	1563316	1534597	193652	5769759	Y^1: (+) Y^2: (+)
Housing Value Ratio (%)	Ratio of average value of housing in the city center (CC) to average value of dwellings in the CMA (Statistics Canada Census, 1996 to 2011).	160	104.0	11.9	83.5	134.3	Y^1: (+) Y^2: (+)
Household Income ($)	Median Household Income by CMA (Statistics Canada Census, 1996 to 2011).	160	87220	10357.24	67700	116900	Y^1: (+) Y^2: (+)

[1] Natural Resources Canada (Canada, 2015).

[2] Cook, J. and J. Simonson, 2012.

[3] Emails were sent to city parking agencies with a request to forward yearly prices for on-street parking meters for the period of 1996 to 2011. All the cities contacted complied.

4.4.5 Econometric Model

Log-log models were used to measure the causes of urban sprawl.[1] We estimate two separate sets of models using the following basic equation:

$\ln Y_{it} = \alpha + \beta \ln X_{it} + \varepsilon_{it}$ where:

Y = Dependent variables (Proportion of Low-Density Housing, Median commuting distance);

X = Independent variables (Gasoline prices, Off-street parking prices, On-street parking prices, Population, Housing cost ratio, Median household income);

α = Constant;

β = Variable specific coefficients;

ε = Error term;

i = Metropolitan areas (Halifax, Montreal, Ottawa, Toronto, Winnipeg, Regina, Calgary, Edmonton, Vancouver, Victoria);

t = Years (1996 to 2011);

Estimation Strategy: Several estimation methods can be used in panel regression equations. We explored three of these methods in our research: generalized least square (GLS), GLS with fixed effects, or random effects. To determine the most appropriate amongst these models, we first tested for the presence of individual effects using the Breusch-Pagan Lagrange multiplier test. The null hypothesis of this test maintains that variance across entities is of zero and therefore that there is no significant difference across variables due to panel effects. If the null hypothesis is confirmed, it is recommended to use the GLS model, whereas if the presence of individual effects is established, the usage of fixed or random effect models is suggested instead. The benefit of using a fixed effects model when faced with

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[1] This type of model expresses the value of both the dependent variable Y and the independent variables X in natural logarithms. The practical advantages of transforming variables into natural logarithms is that it converts non-linear parameters into linear parameters and portrays the elasticity of each independent variable in relation to the dependent variable through its estimated coefficients (Studenmund, 2001).

individual effects is that it includes dummy variables in order to consider the particular characteristics of each metropolitan area. However, it also causes the loss of N-1 degrees of freedom (where N are CMAs), which in turn might make the estimation of our regression coefficients less efficient. The random effects model can provide substantial gains in estimating efficiency, but as noted by Oueslati *et al.* (2015, p. 1604) "[it] imposes a strong assumption that individual effects are not correlated with explanatory variables" and should therefore only be used whenever the entities are uncorrelated with the predictors (Oueslati *et al.,* 2015).

To determine which model to use when faced with individual effects, we performed a Hausman test. This test considers the coefficients obtained in the random effects model and compares them to those obtained in a similarly specified fixed effects model. The null hypothesis of this test maintains that the coefficients estimated by the random effects model are equal to those estimated by the fixed effects model. When the null hypothesis is confirmed, we should use the model with random effects (Hausman and Taylor, 1981). We report on the chosen approach for each regression model. Also reported with our regression outputs are the corresponding Wald Chi-square test results. The Wald Chi-square test statistic reports the squared ratio of the estimate to the standard error for each predictor and verifies the significance of our predictors (Lin *et al.*, 2005).

Using histograms as well as measure of Skewness and Kurtosis, we determined that our variables were normally distributed. In order to capture all other factors that might have contributed to causing urban sprawl throughout the time period of our study, we introduced a trend variable. We later chose to remove this variable from our regressions because it had a Pearson coefficient of 0.86 relative to gasoline prices and caused problems of multicollinearity. Considering its strong correlation with the trend variable, gasoline prices were also capable of capturing any linear direction present in our dataset.

To address concerns regarding a gradual effect of transportation costs on our indicators of urban sprawl we added lag variables to our regressions. Testing for a 1, 3, and 5 year(s) lag period, we observe no statistically significant effects; other coefficients remained significant with their respective signs unchanged. Therefore, because no gradual effects were observed and incorporating lag variables considerably reduces the number of observations, we ultimately decided not to include them in our paper.

4.5 Results

4.5.1 Dependent Variable: *Density* (Proportion of Low-Density Housing)

We present in Table 4.2 the results of our first models in which the proportion of low-density housing is used as a dependent variable. These models span over a period of 16 years (1996-2011).

In model 1, we measured the effects of transportation cost variables and other control variables: total population, housing value ratio, and household income. The Breusch-Pagan Lagrange Multiplier test confirmed the presence of individual effects. Subsequently, we computed the Hausman test to determine whether to use the fixed effects or the random effects model and determined that the random effects model was appropriate. In addition to displaying a relatively high R-square (0.46), many independent variables present significant results: gas prices, off-street parking prices, population, and household income. As expected, gas prices and off-street parking prices both showed negative and highly significant coefficients. As both variables increase, the proportion of low-density housing decreases. Average households faced with an increase in gasoline prices and off-street parking prices, may attempt to reduce these costs by relocating themselves closer to the city center, where high density housing is often found. Household income on the other hand, displays a positive coefficient and is therefore positively related to the proportion of low-density housing. For instance, according to our results, a 1% increase in median household income leads to a 0.24% increase in low-density housing. Individuals desire larger properties as their wealth increases, something that can more easily be achieved in sprawling urban environments. Population shows a negative coefficient in this first equation, which goes against our initial expectation. This unexpected result had previously been reported by Burchfield *et al.* (2006) and Tanguay and Gingras (2012), leading them to conclude that the effects of population growth on sprawl was unclear. According to them, cities faced with population growth will often expand because developers anticipate an increase in housing demand and build on undeveloped land often found at the city outskirts. However, households in search of low-density neighborhoods might predict the effects of this same population growth, and anticipating that neighboring undeveloped areas will quickly be transformed into residential developments, will decide not to risk facing higher journey costs for similar neighborhood density. This notion conforms to our dependent variable and measure for urban sprawl (the proportion of low-density housing). It is worth bearing in mind that these two effects will be present while measuring urban sprawl with proximity as our dependent variable as well.

In model 2, we removed all non-significant variables and only retained gas prices, off-street parking prices, total population, and household income. The R-square remains stable (0.45) and variables maintained highly significant results. Gas prices, off-street parking prices and household income remained at the 99.9% confidence interval, whereas total population increased its significance to the 99% confidence interval and maintained a negative coefficient.

To ensure the robustness of our results, we disregarded the years for which our data was incomplete and in model 3 chose to only use the four census years (1996, 2001, 2006 and 2011). Despite reducing our number of observations ($N = 40$), this third model was built without interpolation and is important to ensure the validity of our results. As in model 2, the four variables of interest (gas prices, off-street parking prices, total population and household income) displayed significant coefficients and signs that confirm our hypothesis. These same four variables showed greater coefficients in this third model, revealing a stronger relationship with low-density housing.

With respect to this study's focus, these models present several significant results. To get an idea of the magnitude of our results, we report those found in model 2 (which was built upon findings from model 1 and confirmed by results obtained in model 3). Firstly, a 1% increase in gasoline prices has led to an approximate decrease of 0.17% in the proportion of low-density housing. Secondly, a 1% increase in off-street parking prices has caused a decrease in the proportion of low-density housing by 0.12%. Thirdly, a 1% increase in total population has led to a decrease in low-density housing by 0.09%. Fourthly, a 1% increase in median household income has caused a 0.24% increase in the proportion of low-density housing, *ceteris paribus*.

Table 4.2: GLS of *Density* (proportion of low density housing) with Random Effects

Independent Variables	**Model 1** **All variables**	**Model 2** **Significant variables**	**Model 3** **No interpolation**
Gas price	-0.171*** (0.022)	-0.172*** (0.021)	-0.238*** (0.056)
Parking Price (Off-street)	-0.122*** (0.017)	-0.124*** (0.016)	-0.137** (0.043)
Parking Price (On-street)	-0.008 (0.016)		
Population	-0.079* (0.037)	-0.086** (0.035)	-0.096* (0.044)
Housing Ratio (CC/CMA)[40]	-0.018 (0.067)		
Household Income	0.240*** (0.044)	0.237*** (0.044)	0.401*** (0.107)
Constant	-0.105 (0.186)	-0.066 (0.171)	-0.291 (0.332)

[40] Ratio of average value of housing in the city center (CC) to average value of dwellings in the CMA (Statistics Canada Census, 1996 to 2011).

R-Squared	0.4564	0.4491	0.5013
Wald Chi-Square	175.16***	176.79***	49.24***
Observations	160	160	40
Breusch-Pagan test	H0: Var (μ) = 0 Chi-Square = 577.40 Prob > chi-Square = 0.0000		
Hausman test	H0: Equality of coefficients Chi-Square = 15.26 Prob > chi-Square = 0.0093		

[a] Statistical significance: ***= 99.9%; ** = 99%; * = 95%.
[b] Standard Error between brackets.

4.5.2 Dependent Variable: *Proximity* (Median commuting distance)

Our second set of models explores the drivers of median commuting distance (Table 4.3). The Breusch-Pagan Lagrange Multiplier test confirms the presence of individual effects and the Hausman test demonstrates the need to estimate models with random effects.

In model 1, we regress using all six independent variables (gas prices, off-street parking prices, on-street parking prices, total population, housing value ratio, and household income). Five variables present statistically significant coefficients (95% level or higher). The first is gasoline prices, which display a negative coefficient: as gasoline prices rise, median commuting distances are shorter. In other words, faced with higher gasoline prices, average households will attempt to reduce their transportation costs by diminishing their commute distances. The second significant variable is off-street parking prices. This implies that commuters are influenced by the price of off-street parking prices, as a 1% increase in off-street parking prices has led to a 1% decrease in median commuting distances. Population is positively correlated to median commuting distance: a 1% increase in total population has led to an approximate increase in median commute distance by 0.15%.[41] Housing value ratio displays a positive coefficient, which attests its positive relationship with median commuting distance. As the value of dwellings increases in the city center in relation to the value of dwellings in the entire CMA, commuters are more likely to live further away and in doing so, are more likely to increase their median commuting distance. Finally, a 1% increase in household income is associated with a 0.06% increase in the median commute distance. The R-square of this model is 0.72.

In model 2, we retain only the five variables to have displayed significant results in model 1. All retained variables remain significant at the 95% and 99.9% confidence interval accordingly. The R-square of this model remains high at 0.73.

Once again, to assure the robustness of our results we disregarded the years for which our data was incomplete and in model 3 chose to only use the four years for which we had complete data. Despite a similar R-square (0.75), results were somewhat inconsistent with model 2. With the exception of total population, all other variables were no longer significant. Total population remains positively related to median commute distance at the 99.9% confidence interval.

In summary, our results for this second set of models are mitigated. Gasoline prices and off-street parking prices present significant negative results in models 1 and 2, but do not display significant results when excluding years with interpolated data in model 3. Similar results are found for housing value ratio and household income variables. The only variable to display consistent significant results throughout this set of models is total population, which displays a robust positive relationship with median commute distance.

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[41] Although this result supports our initial hypothesis, it is worth mentioning that total population, as seen with low-density housing, is an ambiguous variable and its results must be regarded accordingly.

Table 1.3: GLS of *Proximity* (median commute distance) with Random Effects

Independent Variables	Model 1 All variables	Model 2 Significant variables	Model 3 No interpolation
Gas price	-0.044*** (0.110)	-0.044*** (0.011)	-0.072 (0.038)
Parking Price (Off-street)	-0.054*** (0.008)	-0.053*** (0.008)	-0.059 (0.030)
Parking Price (On-street)	0.009 (0.008)		
Population	0.145*** (0.024)	0.162*** (0.021)	0.212*** (0.031)
Housing Ratio (CC/CMA)[42]	0.126*** (0.034)	0.123*** (0.034)	0.069 (0.102)
Household Income	0.064** (0.023)	0.063** (0.023)	0.074 (0.073)
Constant	1.399 (0.112)	1.325 (0.099)	1.104 (0.231)
R-Squared	0.7233	0.7285	0.7500
Wald Chi-Square	159.15***	161.10***	55.74***
Observations	160	160	40

Breusch-Pagan test	H0: Var (μ) = 0 Chi-Square = 623.14 Prob > chi-Square = 0.0000
Hausman test	H0: Equality of coefficients Chi-Square = 16.35 Prob > chi-Square = 0.0120

[a] Statistical significance: ***= 99.9%; ** = 99%; * = 95%.
[b] Standard Error between brackets.

[42] Ratio of average value of housing in the city center (CC) to average value of dwellings in the CMA (Statistics Canada Census, 1996 to 2011).

4.6 Discussion

Our results provide evidence of a negative relationship between transportation costs and two measures of urban sprawl in Canadian metropolitan areas. However, the magnitude of the relationship is somehow weaker than previous results found in Tanguay and Gingras (2012). This is perhaps due to the studied sample, the addition of parking variables or the time period. This is especially true of the novel addition of parking cost variables. On-street parking prices did not present significant effects on both urban sprawl measures. Furthermore, off-street parking prices, although showing statistically significant coefficients in density (Models 1, 2 and 3 of Table 4.2), and in proximity (Model 1 and 2 of Table 4.3), did not present strong coefficients and ultimately their effect was perceived as a minor cause for urban sprawl indicators. Therefore, while the sign and significance of off-street parking prices does confirm our initial hypothesis, using this variable as a lever may not be sufficient in order to reduce urban sprawl. For instance, according to our models, an increase of 10% in off-street parking prices from C$220.85[43] per month to C$242.94 per month would lead to a decrease in low-density housing by 1.2% (from 56.5% to 55.8%) and to slight decrease in median commuting distance by 0.5% (from 7.01 km to 6.975 km).

In our view, the marginalization of parking price variables is in large part due to the high share of free parking outside central areas of cities and employer-paid parking subsidies. In fact, the Canadian Urban Transit Association (CUTA) estimates that roughly 80 percent of auto commuters receive free or subsidized parking in Canada (CUTA, 2002). This form of subsidy is a tax-exempt benefit that can only be claimed if employees drive to work. Consequently, by offering free parking, employers are in fact encouraging car usage. Furthermore, offering free parking skews any anticipated demand response resulting from changes in on-street or off-street parking prices. This bias was first foreseen by parking specialist Donald Shoup, who rationalized that

[43] Mean off-street parking prices and mean low-density housing were used in theses calculations (see descriptive statistics, Table 1).

"because commuters who park free at work do not respond to changes in the market price of parking, most transportation models underestimate how parking prices affect the mode choice of commuters who must pay these prices" (Shoup, 2005, p. 6). This may be also the case in our models, where parking price variables exhibit a modest effect on urban sprawl.

Gasoline prices also present statistically significant coefficients in density (Models 1, 2, and 3 of Table 4.2) and in proximity (Models 1 and 2 of Table 4.3), and offer slightly higher results.[44] This suggests that adjusting gasoline prices through taxes might be a more effective tool at containing the extent of urban sprawl. Nevertheless, considering its coefficients, the increase in gasoline price would have to be substantial in order to reflect a change in the overall size of urbanized areas. For instance, all other things being equal, an increase in gasoline prices by 10%, from C$0.94 per liter to C$1.03 per liter, would lead to a decrease in low-density housing by 1.7% (from 56.5% to 55.5%) and a small decrease in median commute distance by 0.44% (from 7.01 km to 6.98 km).

Obviously other variables have an effect on our two indicators of urban sprawl as well. In our first set of models total population and median household income offer statistically significant coefficients and present a small negative relationship and a strong positive relationship to low-density housing respectively. In the second set of models total population and median household income both show significant results and are both positively correlated with median commute distance. Housing value ratio display significant positive results.

Given these results, a relevant continuation to this study would be to examine the extent of employer-paid parking subsidies in Canadian cities to analyze their effect on commuters' behavior. This study could be improved by including other independent variables such as congestion costs, insurance rates, car maintenance fees, and road fees, in order to capture a larger fraction of the overall effect of transportation costs

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[44] Higher results found when using density as our dependent variable, results are similar to off-street parking when using proximity as our dependent variable.

on urban sprawl. As of 2010, reliable congestion data is now available (e.g. Tomtom) and should be included in future studies especially considering the cost (in the form of expenses and negative externalities) that congestion entails.

Furthermore, although we consider the relationship between transportation costs and urban sprawl to be uni-directional in this paper, we concede that it remains debatable and ambiguous. We assume this causality because it is implied in our choice of economic model. Indeed, the negative relationship between transportation costs and urban sprawl is inferred in the premise of the monocentric model (Alonso, 1964; Mills, 1967, 1972; Muth, 1969). In accordance with this model, higher transportation costs will increase the overall cost of living far from the CBD and, ceteris paribus, will lead more households to live in or near central neighbourhoods. Thus, by basing our paper on this model we assume the uni-directional relationship between transportation costs and urban sprawl to be true. Moreover, we do not consider that an increase in downtown parking prices will increase the share of employers locating outside of city centers as research shown by Marsden (2006) fails to demonstrate any clear negative effect to support the assumption that high parking prices makes centers less attractive.

Lastly, although several conclusions can be drawn from the comparison of these 10 Canadian metropolitan areas, it is worth noting that these metropolitan areas remain unique and that their size and arrangement are also influenced by other economic and geographic characteristics. For instance, due to its location between the Pacific Ocean and the Coastal Mountain Range, the city of Vancouver is left with few options but to build upwards in order to accommodate its population growth. This constraining geography limits Vancouver's horizontal growth and hinders sprawl (albeit considerable development has occurred along the Fraser valley).[45] Another example

[45] Because of its geographic constraints, Vancouver has mostly sprawled towards the Fraser Valley. In fact, between 2006 and 2011, the census subdivision of Vancouver only increased its population by 4.4% whereas Fraser Valley census subdivisions, such as Richmond (9.2%), Surrey (18.6%), and Langley (11.2%), experienced much higher population growth rates for that same time period (statistics Canada, 2015).

is the city of Halifax, which in 1996 merged with several neighboring municipalities to reduce duplicate services and save on public expenses, and by doing so largely expanded the size of its metropolitan area (McDavid, 2008). These cases illustrate the singularity of metropolitan areas and emphasize the many other factors that must be taken into consideration while attempting to determine the causes of urban sprawl.

4.7 Conclusion

In our study we analyzed the effects of transportation costs on urban sprawl in 10 Canadian metropolitan areas for the period of 1996 to 2011, while controlling for other natural evolution factors. We used two indicators of sprawl related to density and proximity to determine if parking prices (on-street and off-street), as well as gasoline prices have had an effect on urban sprawl. Our results indicate that both off-street parking prices and gasoline prices had an effect on urban sprawl, but that their effects were modest and that gasoline prices had a greater effect on sprawl than off-street parking prices. We did not find on-street parking prices to have a significant effect on determining the proportion of low-density housing nor to have an effect on the median commute distance. We show that on average, a 1% increase in gasoline prices led to a decrease in low-density housing by roughly 0.17%, and to decrease in median commute distance by 0.04%. Furthermore, we show that a 1% increase in the price of off-street parking has led to a decrease in median commute distance by 0.05% and to a decrease in low-density housing by 0.12%. Results for parking prices are relatively modest because much free parking remains available. We believe that parking prices would be more efficient in contributing to reduce the extent of urban sprawl if employers adopted a parking cash-out policy. Considering the few existing tools available to influence city sprawl, transportation costs can contribute to the management of sprawl when other travel reduction objectives are also sought.

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CHAPTER V

DISCUSSION AND ANALYSIS

5.1 Discussion and Statistical Inference

Our regression analyses clearly establish a causal relationship between an increase in transportation costs, expressed through higher gasoline and off-street parking prices, and a deceleration in urban sprawl. However, on-street parking prices, our third transportation cost variable, do not have a statistically significant effect on any of our two urban sprawl indicators: the proportion of low-density housing and median commute distance. Initially, this seemed disconcerting as we assumed that a rise in on-street parking prices would cause commuters' transportation costs to increase and subsequently reduce urban sprawl. Nevertheless, this premise was rejected as our results indicated that a deceleration in urban sprawl was not achieved through an increase in on-street parking prices. We believe this to be in large part due to a few cities not significantly increasing their on-street parking prices throughout the period of our study; by maintaining relatively low and stable on-street parking prices, cities such as Halifax, Winnipeg and Regina offset the anticipated overall demand response arising from an increase in on-street parking prices and did not benefit from the potential positive effect that increasing these prices may have on sprawl. To verify this theory, we recreated our regression models and discarded cities that had not increased their on-street parking prices at least twice in the 16-year period of our study (Halifax, Winnipeg and Regina). Although our new regression results suggested a similar insignificant coefficient for on-street parking prices while using the proportion of low-density housing as our dependent variable, they presented a statistically significant coefficient when using the median commute distance as our dependent variable.[46] A 10% increase in on-street parking prices from C$2.36 per month to C$2.60 per month has led to a decrease in median commute distance by 0.7% (from 7.01 km to 6.96 km).[47] Thus, by discarding cities with low and stable on-street parking prices, we established the presence of a negative relationship between on-street parking prices and median commute distance.

In Tables 5.1 and 5.2 we present the expected change in our urban sprawl indicators resulting from a 10% increase in statistically significant independent variables.[48]

Starting with Table 5.1, we notice that a 10% increase in gasoline and off-street parking prices has led to a 0.96% and 0.68% decrease in the proportion of low-density housing accordingly. Household income displays a positive regression coefficient and suggests that a 10% increase in household income has led to a 1.36% increase in the proportion of low-density housing. Though individually insufficient to offset the effects of a 10% increase in median household income, when used conjointly, transportation costs may potentially be used to counter the effects of household income as together, they reduce the proportion of low-density housing by 1.64%[49] [50]. Furthermore, it is unlikely that median household income will increase as quickly as transportation costs, as gasoline and parking prices have steadily risen faster than median household income in the past. By way of example, consider the period between the years 2010 and 2013, in which gasoline and parking prices rose

[46] When using median commute distance as our dependent variable, on-street parking prices display statistically significant negative results at the 99% confidence interval.

[47] Mean on-street parking prices and mean commuting distances were used in theses calculations (see descriptive statistics, Table 3.1).

[48] Keeping all other independent variables constant.

[49] It is worth noting that due to unequal income distribution, some individuals will face higher increases in household income than in transportation costs, which in turn may lead them to locate further away from the city center.

[50] Decrease in the proportion of low-density housing by 0.96% from gasoline price and by 0.68% from off-street parking price, together totaling a decrease of 1.64% (See Table 5.1 for details).

by 19.2%, in comparison with median household income, which increased by 9.5%.[51] This view is supported by Frigon (2007) who, using data from Statistics Canada, established that Canadians' gasoline purchasing power has been decreasing since 1986.

In Table 5.2, the exercise is repeated for median commute distance. We observe a high positive coefficient for population indicating that a 10% increase in population will lead to a 0.11 km increase in median commute distance. Once again, transportation costs on their own do not suffice to counter the effect of a 10% increase in total population, yet increased conjointly, gasoline and parking prices should theoretically counterbalance this effect. Moreover, despite showing a significant positive relationship to median commute distance in these regressions, population is considered ambiguous and can be responsible for both an increase and a decrease in the extent of urban sprawl,[52] thus population coefficients should be considered accordingly.

Table 2.1

Expected change in low-density housing resulting from a 10% increase in statistically significant independent variables

Statistically significant independent variable	Regression coefficient	Expected change for average CMA (56.5%)
Gas prices	-0.17	-0.96% +
Off-street parking prices	-0.12	-0.68%
Transportation costs		-1.64%
Population	-0.09	-0.51%
Household income	0.24	1.36%

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[51] Statistics Canada CANSIM Tables 380-0085 and 111-0009.

[52] Refer to section 5.2. Dependent Variable: *Proximity* (median commuting distance) for more information

Table 5.2

Expected change in median commute distances resulting from a 10% increase in statistically significant independent variables

Statistically significant independent variable	Regression coefficient	Expected change for average CMA (7.01km)
Gas prices	-0.04	-0.03km +
Off-street parking prices	-0.05	-0.04km +
On-street parking prices[53]	-0.07	-0.05km
Transportation costs		-0.12km
Population	0.16	0.11km
Housing ration (CC/CMA)	0.12	0.08km
Household income	0.06	0.04km

While our results corroborate those obtained by Tanguay and Gingras (2012) in finding a statistically significant negative relationship between transportation costs and urban sprawl, they stand in contrast to those found by Brueckner and Fansler (1983). Our view is that this disparity is likely formed by the divergence in our choice of transportation costs variables. To capture the effect of transportation costs we focused on gasoline and parking prices, whereas Brueckner and Fansler (1983) chose to use the percentage of commuters that use public transportation and the percentage of households that own one or more automobiles. These noticeable differences most probably led to inconsistencies and potentially caused transportation costs in their study to not be statistically different from zero. An interesting addition to our study would be to include public transportation usage as well as car ownership levels in order to better comprehend the role of automobile ownership and travel in urban sprawl equations.

Given these results, we cannot overlook the fact that there exists a relationship between parking prices and urban sprawl, but admittedly it is weak. We believe this to be in large part due to the amount of free parking that remains readily available in

[53] On-street parking prices are only statistically significant if we remove Halifax, Winnipeg and Regina.

Canadian cities. This is especially true with regards to parking at the workplace, which remains free for over 80% of employees in Canada (IBI Groups, 2005). This form of employer-paid parking subsidy is a tax-exempt benefit that can only be claimed if employees drive to work. Consequently, by offering free parking, employers are unintentionally encouraging car usage. Furthermore, offering free parking skews any anticipated demand response resulting from changes in on-street or off-street parking prices. A relevant continuation of this study would be to examine the extent of employer-paid parking subsidies in Canadian cities to analyze the effect on commuters' travel behaviour.

CONCLUSION

We analyzed the effects of transportation costs on urban sprawl in 10 Canadian metropolitan areas for the period of 1996 to 2011, while controlling for other natural evolution factors. We used two indicators of sprawl related to density and proximity, to determine if parking prices (on-street and off-street) as well as gasoline prices have an effect on urban sprawl. Using generalized least square estimation methods with random effects we obtained statistically significant results and concluded that both gasoline and off-street parking prices do have an effect on urban sprawl. According to obtained coefficients, effects seem modest. We found gasoline prices to have a greater effect on sprawl than off-street parking prices. We showed that on average, ceteris paribus, an increase in gasoline prices by 10%, from C$0.94 per liter to C$1.03 per liter, has led to a decrease in low-density housing by 1.7% (from 56.5% to 55.5%) and potentially to a decrease in median commute distance by 0.44% (from 7.01 km to 6.98 km). Furthermore, we showed that an increase of 10% in off-street parking prices from C$220.85 per month to C$242.94 per month has led to a decrease in low-density housing by 1.2% (from 56.5% to 55.8%) and perhaps even to a decrease in median commute distance by 0.5% (from 7.01 km to 6.975 km). Contrary to our hypothesis, we did not find that on-street parking prices had a significant effect on our indicators of urban sprawl. This may result from our choice to only consider downtown parking prices in order to increase comparison compatibility, but we mainly attribute this to a few cities not significantly increasing their on-street parking prices throughout the period of our study. In fact, when discarding cities with very little variation in on-street parking prices from our regressions, we arrive to statistically significant results: a 10% increase in on-street parking prices from C$2.36 per month to C$2.60 per month would lead to a decrease in median commute distance by 0.7% (from 7.01 km to 6.96 km), thus establishing the presence of a negative relationship between on-street parking prices and median commute distance when correcting for cases with no parking price fluctuation.

Although several conclusions can be drawn from the comparison of these 10 Canadian metropolitan areas, it is worth noting that these metropolitan areas remain unique and that their size and arrangement are also influenced by other economic and geographic characteristics. For instance, due to its location between the Pacific Ocean and the Coastal Mountain Range, the city of Vancouver is left with few options but to build upwards in order to accommodate its population growth. This constraining geography limits Vancouver's horizontal growth and hinders sprawl (albeit considerable development has occurred along the Fraser valley).[54] Additionally the "density bonusing" policy, implemented in British-Columbia, may also play a role in the overall growth of Vancouver as it enables developers to conditionally surpass the allowed housing density regulations. Another example would be the city of Toronto, which is located on Lake Ontario and is arguably a polycentric city (Relph, 2014). By shifting a significant portion of its jobs supply to sub-centers in the periphery, Toronto has been able to decrease its median commute distance while simultaneously increasing its overall size. This type of city layout impedes the usage of commuting distances as a measure of urban sprawl and might in turn skew our proximity variable. Nevertheless, previous studies (Tanguay and Gingras, 2012) have pointed out the monocentric attributes of Canadian cities and have shown monocentric models to be more appropriate than polycentric models while studying a Canadian context.

[54] Because of its geographic constraints, Vancouver has mostly sprawled towards the Fraser Valley. In fact, between 2006 and 2011, the census subdivision of Vancouver only increased its population by 4.4% whereas Fraser Valley census subdivisions, such as Richmond (9.2%), Surrey (18.6%), and Langley (11.2%), experienced much higher population growth rates for that same time period (statistics Canada, 2014b).

Both these cases illustrate the singularity of metropolitan areas and emphasize the many other factors that must be taken into consideration while attempting to determine the causes of urban sprawl.

In conclusion, we believe that parking prices would be more effective in containing urban sprawl if they were regulated and recognized as an effective tool to modulate travel behaviours. A first policy worth exploring would be the parking cash-out alternative. This type of policy gives employees the option between receiving free parking at their workplace or instead, receiving its equivalence in the form of a monetary compensation. This way, employees might reconsider their modal choice decisions and opt for greener alternatives when traveling to work. Additionally, by reducing car dependency, the parking cash-out policy might incite individuals to live closer to the city center and in doing so, reduce urban sprawl. Another parking strategy that should be examined is taxation. Whereas governments conventionally subsidize on-street parking, this is not the case for private parking lots. Indeed, viewing surface parking lots as an inefficient use of space that should be discouraged, governments often impose a tax on these lots to reflect their opportunity cost. The rationale is that by increasing parking tax rates, parking lots will become less profitable and part of the tax will be transferred to consumers, which in turn will increase transportation costs and potentially reduce car usage (Feitelson and Rotem, 2004). The study could be improved by including other independent variables such as congestion costs, insurance rates, car maintenance fees, and tolls, in order to capture a larger fraction of the overall effect of transportation costs on urban sprawl. A starting point for future research could be to include geographic information systems, as this approach would supplement results established through our density and proximity measures.

Whether to alleviate traffic congestions or merely recognizing an untapped source of needed revenue, city officials are beginning to increase transportation costs and ultimately diminish the economic incentive of commuting by car. In addition to its positive implications on traffic congestion and car usage, increasing transportation costs may contribute to effectively containing urban sprawl. Considering the few existing tools available to influence sprawl, city officials should pay closer attention to transportation costs, as increasing them may actually contribute to the management of sprawl when other travel reduction objectives are also sought.

APPENDIX A

INDEPENDENT VARIABLES

Off street parking prices:

Colliers International off-street parking price surveys were only available from 2004 onwards;[55] therefore, we calculated the missing values in years prior to 2004 using two estimation methods. The first was to take the last available data points from year 2004 and adjust their value for prior years using the CMA's consumer price index (CPI). The second method consisted of subtracting the 2004 price from the 2011 off-street parking price and then dividing that amount by 7 (number of years between 2004 and 2011), to determine the average annual price increase. This average price was then subtracted for each year prior to 2004 in order to give us that year's average off-street parking price. These prices were also adjusted using the CMA's CPI. We finally chose to use the first estimation method in our study rather than the second as subtracting the average price increase caused earlier variables to become unreasonably small. For instance, using the second method, the city of Victoria's 1996 off-street parking price became virtually free of charge.

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[55] Off-street parking prices for the city of Winnipeg were only available from 2006 onwards. We chose to use another source to compensate for the 2 missing years. This source stated that off-street parking prices were located between $80 and $150 per month, we chose to use $115, the mean value. Data retrieved from: http://www.theforks.com/uploads/ck/files/Publications/FNP_DowntownView.pdf

Median commute distance:

In our study, proximity was measured using Statistics Canada's median commute distance measured in kilometers. Unfortunately, in its 2011 census, Statistics Canada altered the measuring unit of commute distance, changing it from kilometers to minutes. Statistics Canada provided no conversion procedures and attempt to convert minutes into kilometers were hindered by unknown congestion levels. Therefore cross-multiplications[56] were used to generate the missing values for 2011.

[56] By cross-multiplications we mean multiplying the numerator of each side by the denominator of the other side in order to uncover the missing value.

APPENDIX B

STATISTIC CHARACTERISTICS AND TEST RESULTS

Endogeneity:

Endogeneity arises when one or more of the independent variables are correlated with the error term. Typically this results from one of the three following causes: measurement errors, omitted variables, or simultaneity (Verbeek, 2008). Given our choice of variables (see Table 3.1), we consider endogeneity issues to be highly unlikely in our study. For instance, there is no reason to believe that parking price variables (off-street and on-street) are influenced by our dependent variables; changes in the proportion of low-density housing or in the median commute distance do not provoke a variation in parking prices. Fluctuations in demand are what mainly cause changes in parking prices.[57] The same can be said with gasoline prices, which are predominantly determined through crude oil prices[58] and not by our indicators for sprawl. Regarding other independent variables, such as total population and median household income, it is also unlikely that they are influenced by our dependent variables. The only variable that we identified as conceivably being caused by our dependent variables is the housing price ratio variable. This is due to the proportion of low-density housing that is calculated using housing types (single, semi-detached and mobile homes) and how these housing types may influence the average housing

[57] As see in Calgary, where zones with high occupancy saw their rates soar, whereas zones with low usage saw their prices plummet (Potkins, 2013).

[58] Natural resources Canada states that the price difference between Canadian gasoline and American gasoline is mainly due to federal and provincial/state taxes. Excluding taxes, gasoline prices would essentially be the same. (http://www.nrcan.gc.ca/eneene/sources/pripri/difdif-eng.php)

value in a CMA. For that reason, the housing price ratio variable is not included in models 2 and 3 of Table 4.2.

Correlation:

Using scatterplots and histograms, we determined that our variables were normally distributed and therefore that the Pearson correlation matrix was the preferred method to measure correlation.

	Trend	GasPrice	OnStreet	OffStreet	Population	HousRatio	Income
Trend	1.0000						
GasPrice	0.8580	1.0000					
OnStreet	0.3133	0.2197	1.0000				
OffStreet	0.0625	-0.0258	0.5695	1.0000			
Population	0.0748	0.0559	0.4197	0.6132	1.0000		
HousRatio	-0.0766	0.0016	0.3739	0.2318	0.3641	1.0000	
Income	0.5916	0.4259	0.3273	0.2299	-0.0633	-0.0978	1.0000

In order to capture all other factors that might have contributed to causing urban sprawl throughout the time period of our study, we introduced a trend variable. We later chose to remove this variable from our regressions, seeing that it presented a Pearson linear correlation coefficient of 0.8580 with regards to gasoline prices and would most likely cause problems of multicollinearity. Considering its strong correlation with the trend variable, gasoline prices were also capable of capturing any linear direction present in our dataset.

All other Pearson linear correlation coefficients amongst sprawl variables remained below 0.70 and were therefore considered non-problematic.

Breusch and Pagan Lagrangian multiplier test for random effects:

A) Dependent variable: Housing density

```
log_HousingDensity[City,t] = Xb + u[City] + e[City,t]
      Estimated results:
                         |       Var     sd = sqrt(Var)
        ---------+-----------------------------
    log_HousingDensity |   .0438055       .2092977
                     e |   .0009135        .030224
                     u |     .01276       .1129601

      Test:   Var(u) = 0
                           chibar2(01) =    585.45
                         Prob > chibar2 =    0.0000
```

Small P-value, so we reject the null hypothesis. Presence of individual effects is established; the usage of a fixed or random effect model is suggested.

B) Dependent variable: Proximity

```
log_Proximity[City,t] = Xb + u[City] + e[City,t]
     Estimated results:
                        |       Var     sd = sqrt(Var)
       ---------+-----------------------------
          log_Proximity |   .0537626       .2318677
                      e |   .0002086       .0144432
                      u |   .0087767       .0936843

     Test:   Var(u) = 0
                          chibar2(01) =    623.14
                        Prob > chibar2 =    0.0000
```

Small P-value, so we reject the null hypothesis. Presence of individual effects is established; the usage of a fixed or random effect model is suggested.

Hausman test:

A) Dependent variable: Housing density

	(b) fixed	(B) random	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
log_GasPrice	-.1757965	-.1699194	-.0058771	.0060132
log_OffSPark	-.1250449	-.121925	-.0031198	.
log_OnSParki	-.0143936	-.0077731	-.0066206	.0058568
log_Populati	-.0143501	-.0836912	.069341	.0582478
log_Income	.2098824	.2434006	-.0335182	.0173301

```
b = consistent under Ho and Ha; obtained from xtreg
B = inconsistent under Ha, efficient under Ho; obtained from xtreg

    Test:  Ho:  difference in coefficients not systematic

                  chi2(5) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =    -0.83
```

Negative Chi-square result. Must therefore use a robust version of the test. (xtoverid option on Stata 13.1). Here are new results.

```
Test of overidentifying restrictions: fixed vs random effects
Cross-section time-series model: xtreg re
Sargan-Hansen statistic  15.260  Chi-sq(5)    P-value = 0.0093
```

Small P-value, null hypothesis is confirmed. We must therefore use the model with random effects.

B) Dependent variable: Proximity

	(b) fixed	(B) random	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
log_GasPrice	-.0327279	-.0444906	.0117627	.
log_OffSpark	-.0539071	-.0536804	-.0002267	.
log_OnSParki	.0195662	.0092474	.0103188	.
log_Populati	.0537586	.1448898	-.0911312	.0224015
log_HouseRat	.1507390	.1263549	.0243842	.
log_Income	.0940049	.0639756	.0300293	.0028293

b = consistent under Ho and Ha; obtained from xtreg

B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

$$\text{chi2}(6) = (b-B)'[(V_b-V_B)^{(-1)}](b-B) = 16.35$$

Prob>chi2 = 0.0120

Small P-value (bellow 0.05), null hypothesis is confirmed. We must therefore use the model with random effects.

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