The Effects of the COVID-19 Pandemic on Preferences for Parks and Personal Space

by

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Abstract

Lockdowns and other non-pharmaceutical interventions that were implemented to combat the COVID-19 Pandemic have had unintended yet profound consequences. One widely-reported consequence has been changes in people's perceptions of the value of nature and their personal dwelling spaces. Highly publicized anecdotes notwithstanding, the extent of change in people's preferences for environmental amenities and housing space remains uncertain. Also, how to accurately measure the preference changes is an open question, as conventional methods may not be applicable to this unprecedented event. These evidence gaps have further complicated efforts to address land use management challenges in rapidly growing urban areas such as those found in Western Canada, including Metro Vancouver, Edmonton, and Calgary. This thesis studies the effects of the Pandemic on homeowners' preferences for environmental amenities and housing space by analyzing changes in housing markets in these three cities. The research critically examines and employs two empirical strategies to a unique and extensive housing transaction dataset from the three regions recorded for the 2017 – 2021 period. Chapter 2 examines the case of Metro Vancouver, while Chapter 3 presents a comparative analysis from the two largest Albertan cities to expand the generalizability of the results. Different empirical approaches generate different results, with our preferred method indicating that changes in the values of open spaces and home attributes vary significantly across housing types and study regions. However, the prices of larger houses, overall, have appreciated most significantly since the Pandemic started. In Vancouver, houses, particularly lower-priced ones, in more heavily treed neighborhoods have become more expensive. This implies, compared to the pre-Pandemic period, the affordability of residence with urban vegetation has worsened, especially for the population who may already have limited access to environmental amenities. In sum, this thesis provides novel and timely insights into the unintended consequences of COVID-19 policies on the value of dwelling spaces and environmental amenities, as well as their potential impacts on the existing disparity in access to green spaces.

Preface

This thesis is an original work by Hotaka Kobori. No part of this thesis has been previously published.

Dedication

“*Natural resources, as the name implies, were not acquired by our own efforts, but are a trust from heaven. The richer our resources, the greater our responsibility for using them wisely & well.* · · ·

This good Alberta has some of the best land in the world. With judicious husbandry, it can support our growing population in generous comfort and contribute to the support of millions elsewhere. · · ·

In using science and technology to develop our great resources, let it be our care to preserve natural beauty, and to create a community notable for its cultural and spiritual qualities. Material progress will then follow of its own accord.”

- Robert Newton, the 4th President of the University of Alberta

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"*I gotta go see about a girl.*"

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Chapter 1 Thesis Introduction

1.1 Thesis Problem Statement

On their own, market mechanisms tend to underprovide goods that yield public benefits (Champ et al., 2003). Parks are good examples of public goods that generate benefits that are non-excludable and non-rivalrous (Tietenberg & Lewis, 2018, p. 28).

The high opportunity cost of maintaining developable land as open space often leads to their degradation through developments which, without regulations in place, can cause negative externalities, that is, unintended and uncompensated costs on others in society. As a result, cities tend to have lower than socially optimal levels of open spaces (Wu et al., 2023). In Canada, especially in urban areas, open spaces are under constant threats of development to accommodate population growth. A study by Statistics Canada shows that Canada's rapidly growing metropolitan areas have experienced salient declines in green spaces, including the metropolitan areas of Vancouver, Edmonton, and Calgary (EnviroStats, 2021).

In order to design evidence-based natural resource management and proper development policies, it is necessary to quantify the values of specific environmental amenities (Grafton et al., 2008). As such, a vast body of literature has been produced to measure people's preference for environmental amenities through non-market evaluation methods (Brander & Koetse, 2011; Yoo & Wagner, 2016).

However, the COVID-19 Pandemic has reportedly transformed people's preferences for nature and housing attributes, with many expressing greater appreciation for the values of parks and larger dwelling spaces (Park et al., 2022a; Bristowe & Heckert, 2023). For instance, a recent literature review has found that most Canadians reported using parks more frequently following lockdown measures (Eykelbosh & Chow, 2022). A real estate survey lists the top reason for purchasing a house during the Pandemic as the need for more space (Zolo, 2022).

These shifts in preference could, in turn, dilute the relevance of previous studies to the policymaking post Pandemic. Despite the widely publicized anecdotal evidence, little research has verified these changes in preferences. This empirical gap has made it more difficult for urban planners to address the challenges of balancing population growth and environmental conservation in rapidly growing Canadian metropolitan areas such as Metro Vancouver, Edmonton, and Calgary.

Additionally, if the intensified demands for environmental amenities, such as trees planted along residential streets, were larger for houses in the lower price range (e.g., the bottom 25% of the housing price range), this could have negative implications for green equity, which refers to a "*fair access to urban vegetation regardless of differentiating factors such as socioeconomic status*" (Nesbitt et al., 2018). The heightened preference for urban vegetation drives up the prices of less expensive houses in tree-intensive neighbourhoods, making it harder for prospective buyers to access urban vegetation, particularly those who may already have inadequate access to urban vegetation. The potential detrimental effects of the Pandemic on green equity pose further challenges for urban planners seeking to enhance resilience to climate change and promote the environmental justice (Honey-Rosés et al., 2020).

1.2 Thesis Objectives

Motivated to address these thesis problems outlined above, the objectives of this thesis are as follows.

1) To quantify the impacts of the Pandemic on the values of environmental amenities and home sizes in Canadian metropolitan areas.
2) To examine the heterogeneity in the changes in amenity values across different price segments of properties to assess the potential effects of the Pandemic on green equity.

1.3 Thesis Outline

This thesis is organized as follows. In Chapter 1, we provide an introduction that includes the Thesis Problem Statement, Thesis Objectives, and Thesis Outline. Chapter 2 provides a comprehensive review of relevant literature and background. Chapter 3 investigates the case study of the Metro Vancouver region. This chapter also contains a critique of methods, as well as an analysis using quantile regression. Chapter 4 conducts a comparative analysis of two Alberta metropolitan regions, Edmonton and Calgary, as our second case study. Chapter 5 presents a brief conclusion.

Chapter 2 Literature Review and Background

The goal of this chapter is to position this thesis within the existing literature on the COVID-19 Pandemic, hedonic literature on environmental amenities, and the challenges related to land use management in all study regions. To attain this objective, the following chapter presents a brief review of economic literature on COVID-19, related hedonic studies, and policies that have shaped and addressed these challenges. A firm understanding of both challenges and policies is crucial to contextualize our research on Pandemic effects on values of open space and housing size within broader urban development issues and land use policy frameworks. Specifically, it enhances our abilities to pair this research with literature on similar topics and regions, as well as with market forces that shape urban development.

Note that the following review was prepared in 2022. Given that the Pandemic is still an ongoing and evolving phenomenon, this thesis may not capture all recent developments. In this thesis, we employ the terms "post-Pandemic" or "after the Pandemic" to refer to the period after the onset of the Pandemic in March 2020. These terms are not intended to imply that the Pandemic has concluded, but rather to draw a contrast to the "pre-Pandemic" period, as commonly observed in the existing literature.

2.1 Economics of COVID-19 Pandemic

In the wake of the COVID-19 (coronavirus disease 2019) Pandemic, many non-pharmaceutical interventions were put into effect to curb the outbreaks, including in the Canadian provincial governments of British Columbia and Alberta (Wiersinga et al., 2020). Since then, there has been a significant expansion of research not only on the policies' effectiveness on case counts and mortality (Chu et al., 2020; Flaxman et al., 2020; Haug et al., 2020; Talic et al., 2021), but many dimensions of our lives that are afflicted by the Pandemic, including mental health (Pfefferbaum & North, 2020) and numerous socio-economic outcomes (Nicola et al., 2020; Flor et al., 2022).

Likewise, Economic research related to COVID-19 has grown exponentially (Brodeur et al., 2021b). The number of working papers about the COVID-19 Pandemic in the NBER working paper directory alone exceeded 700 about two years and a half into the onset of the Pandemic[1]. Given this congested "loading dock" of papers in the publication pipeline, the number of articles to be published is expected to accelerate for years to come (Parsons et al., 2022).

[1] https://www.nber.org/topics/covid-19?page=1&perPage=50 last accessed on Sep 21, 2022

One of the most popular topics in urban economics has been the impacts of Work-from-Home (WFH) on the amenity value of living close to business centers (Ramani & Bloom, 2021; Coven et al., 2022; Delventhal et al., 2022; Rosenthal et al., 2022; Van Nieuwerburgh, 2022; van Vuuren, 2022). To our knowledge, no studies have investigated the effects of the Pandemic on preference for housing sizes.

Behavior changes induced by the Pandemic and related policies have also had salient impacts on the environment. Such impacts have been widely documented in the field of Environmental Science, as shown by Sharifi and Khavarian-Garmsir (2020)'s comprehensive review. Researchers have also analyzed the effects of environmental factors on COVID-19 outcomes (cases, mortality, and mental health) and found that green spaces alleviated negative outcomes (Spotswood et al., 2021; Labib et al., 2022; Yang et al., 2022).

Similarly, it has been a key agenda for environmental economists to examine the Pandemic's impacts on various environmental outcomes (Helm, 2020; Ashworth et al., 2022). Some examples include investigating the Pandemic's impacts on air pollution (Brodeur et al., 2021a; Dang & Trinh, 2021; Isphording & Pestel, 2021; Persico & Johnson, 2021; Zhang et al., 2021) or perceptions of water quality (Parsons et al., 2022). However, there has been only a limited number of studies that explored the impacts of the Pandemic on how people use and value green spaces (Rice et al., 2020; Landry et al., 2021). In a review that highlights early research of COVID-19 by environmental economists, Ashworth et al. (2022) identify the ancillary effects of COVID-19 measures on amenity values as one of the outstanding questions in the field worthy of further exploration. This thesis addresses this open question.

2.2 Hedonic Literature on Environmental Amenities

There is no shortage of hedonic literature evaluating the value of environmental amenities, as summarized by comprehensive literature reviews in Boyle and Kiel (2001); Brander and Koetse (2011); Yoo and Wagner (2016); Chen et al. (2019). The studies included in these reviews have investigated the amenity and disamenity values of various types of open spaces that are capitalized into housing prices, such as urban green spaces, blue spaces like rivers and lakes, and agricultural lands (Irwin, 2002; Klaiber & Phaneuf, 2010; Hu et al., 2022). Specifically, Anderson and West (2006) found that different types of parks, such as neighborhood parks and special parks like regional parks that provide greater recreational value, possess distinct amenity values. Furthermore, the recent availability of satellite data has enabled numerous studies to investigate the value of tree canopies, as exemplified by Netusil et al. (2010);

Siriwardena et al. (2016); Han et al. (2021). These studies have generally found positive effects on property values.

In Canada, the number of hedonic studies that evaluated environmental amenities has been limited, and the proportion of hedonic research within the non-market evaluation field has gradually declined, primarily due to data availability constraints (Macaskill & Lloyd-Smith, 2022). Nonetheless, there are some hedonic studies conducted in our study regions of British Columbia (Ries & Somerville, 2010) and Alberta (Boxall et al., 2005; No Kim et al., 2016; Cao et al., 2021; Hu et al., 2022). While these studies have focused on specific regions or segments surrounding metropolitan areas within their respective regions, no research has investigated the entire Metro Vancouver or the city of Calgary, nor compared different markets.

2.3 Land Use Management Challenges in Metropolitan Vancouver Region

The following section introduces key land use planning challenges facing Metropolitan Vancouver. These challenges are namely managing land use 1) to accommodate population growth while protecting its natural environment, and 2) to enhance resilience to climate change.

Metropolitan Vancouver Regional District (MVRD), often shortened to Metro Vancouver, is an amalgamation of twenty-one municipalities established in 1967 by the British Columbia Provincial Regional District legislation (Taylor et al., 2014). Its urban spatial structure can be broadly categorized as polycentric, with numerous subcentres besides the Vancouver Central Business District (CBD) (Sweet et al., 2017). Geographically, the region is situated in the southwestern corner of the British Columbia mainland, surrounded by the Salish Sea, bisected by the Fraser River, and flanked by the Coast Mountains to the north (Metro Vancouver, 2022).

The region's geography has physically limited the room for urban expansion and has necessitated a compact development pattern. Largely thanks to two prominent planners, H. Peter Oberlander, "*a father of regional planning on the Lower Mainland*" and James Wood Wilson, Metro Vancouver's urban development plans have always been guided by two planning principles; 1) protection of agricultural lands and 2) a dense urban development pattern (Cameron & Harcourt, 2009; Taylor et al., 2014; Taylor, 2019). Appendix A offers detailed accounts of the historical evolution of its policies. Metro Vancouver's current plan "Metro Vancouver 2040", which was introduced in 2011, is currently being updated to "Metro Vancouver 2050".

One of the development planning challenges mentioned in the 2050 plan is accommodating population growth while protecting its natural environment (Metro Vancouver, 2022). Metro Vancouver's servicing region encompasses approximately 2.7 million people, which is expected to double by 2040, making the region one of the most compactly settled urban areas in Canada (Condon et al., 2010; Frank & Bigazzi, 2019). The region's total area is approximately 285,600 hectares, but only 90,300 hectares or 32% of the total land is designated for residential, commercial or industrial uses (Tomlinson & Spiller, 2018). This regulatory constraint on lands available for development is rooted in two land use designation policies implemented to protect agricultural lands and ecologically important areas, namely Agricultural Land Reserve and Urban Containment Boundaries. These two frameworks together define geographical boundaries within which future development cannot take place (Taylor et al., 2014; Frank & Bigazzi, 2019). Appendix A elaborates on respective policies in more detail.

Despite these regulatory boundaries that constrain inhabitable lands, Vancouver's restrictive zoning has often favoured low-density residential built forms (Mendez & Quastel, 2015; Gordon, 2016). While most recent population growth has been absorbed by the intensification of the existing built-up area, the vast majority of the City of Vancouver is still zoned for low-density land uses (Taylor et al., 2014). As an illustration[2], it is estimated that almost 80% of residential land is used by only 35% of households, while the remaining 65% of people live on 19% of the land (Lee, 2022). This zoning limits supplies of housing and intensifies the scarcity of land, which appreciates the wealth of existing owners while exacerbating the affordability of housing. Moreover, the potential increase in demand for larger living spaces during the Pandemic could put additional pressure on the already scarce supply of land in Metro Vancouver, which is known to be one of the least affordable places to live in North America (Ley & Lynch, 2020).

In addition to managing population growth while protecting its nature, Metro Vancouver also confronts the challenge of enhancing its resilience to climate change (Metro Vancouver, 2022). The region is constantly at risk of natural hazards, including earthquakes, flooding and, recently, extreme heat waves (MetroVancouver, 2011; Stewart et al., 2017). Those impacts are projected to become more frequent and severe as climate change progresses, such as higher risks of flooding, and more and longer summer drought periods (MetroVancouver, 2011; Owrangi et al., 2015; Metro Vancouver, 2022).

[2] See (amazing) UBC Sociology Zoning's interactive map for visualization (https://zoning.sociology.ubc.ca/).

In fact, the region has already experienced severe economic consequences of natural disasters. Insurance claims data show that recent years have seen more frequent and severe weather events (Greaves, 2021). For example, an atmospheric river caused widespread flooding that resulted in $687 million loss for insured damages alone (IBC, 2022). According to one estimate, major coastal flooding in the Lower Mainland could inundate 54,700 hectares and cause $25 billion in losses in the year 2100 (Fraser Basin Council, 2016).

These climate change impacts disproportionately affect the most vulnerable populations. For instance, tree canopy can mitigate urban heat waves, but studies have shown that communities in poor socio-economic standings in Vancouver are more likely to have poor environmental endowments (Jarvis et al., 2020; Ng et al., 2021; Eyster & Beckage, 2022). In the 2009 heat wave, victims were disproportionally old and poor (Stewart et al., 2017). The 2021 heat wave resulted in 619 deaths in British Columbia, with the majority of victims coming from socially and materially deprived neighbourhoods (BCCoronersService, 2021). Additionally, the lockdown has highlighted the issue of green equity as marginalized communities have often found it difficult to access green spaces, which are essential for coping with the stresses of the Pandemic (Eykelbosh & Chow, 2022). Therefore, regional planners face an urgent need to strengthen the resilience of the built environment and infrastructure to address these inequalities.

One of the policies outlined in the 2050 plan to mitigate increasing climate change-related risks is to provide "*equitable access to green spaces*" (Metro Vancouver, 2022). However, if the Pandemic has worsened the affordability of urban vegetation, it may inhibit authorities' efforts to ameliorate existing inequality in access to urban vegetation.

In summary, the combination of these regulatory and geographic constraints, rapid population pressure, as well as climate change, has created a continuous need for astute evidence-based planning of land use for Metro Vancouver. However, its member authorities are concerned whether its regional land use policies are adequately adapted to address the pre-existing land use challenges exacerbated by the Pandemic[3]. To ensure policymaking in Metro Vancouver continue to be well-informed by evidence, it is

[3] http://www.metrovancouver.org/services/regional-planning/PlanningPublications/Metro2050Issue-ResponseTable.pdf. For example, City of Vancouver "*Given the uncertainty and its impact in the long term on office space demand and housing design with more flexible 'live-work' possibilities, the preamble should reference this shift and the importance of building resilience.*". Vancouver Coastal Health "*Over the course of the COVID-19 pandemic, it has become even more evident that we all – individually and organizationally – have a responsibility to help address equity issues.*"

essential to understand the impacts of the Pandemic on people's perceptions of land and environmental amenities.

2.4 Land Use Management Challenges in Edmonton and Calgary Regions

A prominent challenge that both Edmonton and Calgary regions face is an urban sprawl that causes serious fragmentation and conversion of agricultural lands.

In the province of Alberta, there are two major metropolitan areas centred around the mandate areas of the Edmonton Metropolitan Region Board (EMRB) (formerly known as Capital Region) and the Calgary Metropolitan Region Board (CMRB) (formerly known as Calgary Regional Partnership).

One notable difference between the two cities is their urban structure. Edmonton hosts government services and oil and gas related processing activities which have historically been located in Edmonton's surrounding municipalities, such as Fort Saskatchewan, whereas Calgary has developed as the business hub of Alberta (Taylor et al., 2014). This differentiation in spatial diffusion of economic activity has resulted in contrasting urban spatial structures. Calgary's economic model is monocentric with its CBD and subcentres containing 34% and 5% of regional jobs respectively. On the other hand, Edmonton's economic activities are dispersed across the region, with its CBD and subcentre containing 21% and 18% of regional jobs respectively (Sweet et al., 2017).

While there are some dissimilar features between the two regions, they are both situated in the heartland of the vast Canadian agricultural and natural landscape. This means that these two cities face virtually no physical constraints for urban expansion. Consequently, both Edmonton and Calgary experienced outward expansion and urban sprawls, which have caused a serious loss, conversion, and fragmentation of prime agricultural lands and naturally vegetated areas (Martellozzo et al., 2015).

Urban expansion in both regions has been partly due to a lack of provincial agriculture reserve legislation that left responsibility for agricultural land policies to municipalities. Without stand-alone agricultural land management policies in place, urban encroachment on ex-urban lands to accommodate population and land-intensive economic growth aggravated the loss of prime agricultural lands (Beckie et al., 2013; Qiu et al., 2015; Powell, 2021). However, surveys of Alberta citizens have suggested that this lack of coherent guidelines may not align with their preferences for the conservation and preservation of agricultural lands in the areas around the cities (Wang & Swallow, 2016; Luo et al., 2022).

To illustrate the magnitude of urban sprawls, between 2001 and 2011, three quarters of newly built dwellings (the majority of which are single family detached) in both Calgary and Edmonton were located in greenfield suburb areas (Taylor et al., 2014). From 1990 to 2010, the Calgary region experienced the largest population growth in Canada, with most of this growth absorbed by exurban areas, which doubled the population density in these areas (Han et al., 2020). During approximately the same time frame, in the Edmonton region alone, about 7.1% of agricultural lands were converted to developed uses: of the total 42,905 hectares of land newly converted into development, 89% were agricultural lands (Wang & Qiu, 2017).

The challenge is not only the total quantity of agricultural land being lost, but also that high quality agricultural lands are lost while naturally vegetated areas are being cleared for crop agriculture (Martellozzo et al., 2015). For example, from 2000 to 2012, approximately 68.4% of agricultural land converted was in the top two highest-quality categories of agricultural lands (Alberta Land Institute, 2014). At the same time, approximately 36,000 hectares of forested area were cleared of trees in the Edmonton metropolitan region (Wang & Qiu, 2017).

To combat urban sprawl, Calgary has adopted high-intensity development strategies while Edmonton has traditionally favored low-density development patterns (Qiu et al., 2022). Appendix A offers a detailed comparison of recent growth plans from Calgary and Edmonton. Between 2001 and 2011, Calgary's growth management strategies were found effective in intensifying development in the inner suburban areas (Han, 2019). However, given the expected future population growth in both regions, urban sprawl continues to be a challenge for both regions (Taylor et al., 2014; Han, 2019). On top of that, the elevated demand for larger living spaces during the lockdown may have accelerated pre-existing urban flight trends, reinforcing the need for better regional development management schemes post Pandemic (Coven et al., 2022). Our study aims to provide empirical evidence to support the development of such a growth strategy post Pandemic.

2.5 Summary

The objective of this section was to situate our research within existing literature and broader urban development policy contexts. To conclude, our research into the unintended effects of COVID-19 policies on values of open spaces and housing size broadly aligns with Economists' efforts to quantify the impacts of these policies. We have also highlighted the importance of understanding the Pandemic’s impacts on how people use and value land to effectively address key land use challenges in each study region.

Chapter 3. Metro Vancouver

3.1 Introduction

The COVID-19 Pandemic and related health measures have drastically transformed all aspects of our lives; it has also reshaped our perceptions of the things we are used to.

During the Pandemic, most people had to work and entertain at home, and children needed to learn virtually from home. Our own house has thus literally become a one-stop that integrates various functions beyond sheltering, such as work, study, and entertainment. Naturally, people need more space to accommodate these activities. Predictably, there is a greater demand for the size of dwelling space.

At the same time, due to the closures of many indoor venues and concerns about the spread of the virus in enclosed spaces, many of us, especially those with pets and children, reduced indoor activities and turned to outdoor activities in search of leisure and comfort. When everything else was shut down and went remote, people rediscovered attachments to their surrounding nature. Hence, it is only natural that people might place greater value on easy access to open spaces post Pandemic.

Despite these anecdotal evidence and widespread reporting on unintended yet significant effects of COVID policies on preferences for living areas and access to open space, only a handful of research has so far analyzed the shifts in preferences. While little research has studied changes in amenity values of open spaces after the lockdown, little research on the impact of COVID-19 on people's preferences for housing size. To our knowledge, no studies have investigated both (i.e., the impact of the Pandemic on people's preferences for dwelling size and access to open space) simultaneously. Our research fills these gaps.

The key objective of our research is to examine the impacts of the Pandemic on preferences for the size of private space and open space by applying the hedonic property-value model. We further employ quantile regression to investigate heterogeneous changes in amenity values across the spectrum of housing prices. Empirical investigation uses the Metro Vancouver metropolitan area as a case study. Regional urban planning has faced the challenge of accommodating growing populations within geographically constrained areas while also enhancing natural environments to mitigate the intensifying climate change impacts, which disproportionately affect the vulnerable population. The potential

Pandemic-induced preference changes illustrated above have brought another layer of complexity into its urban planning.

Our research contributes to several strands of literature. We are the first to investigate the effects of the Pandemic on the values of both open space and home sizes using a more suitable empirical technique. Our method, which will be explained in detail in the Method section, allows us to identify the multifaceted effects of the Pandemic on various amenities. Furthermore, our study reveals the disproportionate and unintended consequences of the Pandemic on green equity, as we demonstrate that only lower-priced houses in a greener neighbourhood have become more expensive post Pandemic.

The remainder of this paper is structured as follows. The next subsection provides a brief overview of the relevant literature. Section 2 briefly outlines a theoretical framework, which is followed by empirical frameworks in Section 3. Section 4 elaborates on data and descriptive statistics. Section 5 showcases the results. Finally, section 6 concludes this Metro Vancouver chapter.

3.1.1 A Brief Literature Review

There is a vast body of hedonic studies on the values of housing attributes and environmental amenities (McConnell & Walls, 2005; Brander & Koetse, 2011; Yoo & Wagner, 2016). However, the Pandemic-induced preference changes could potentially dilute the relevance of these studies for policymaking after 2020. While little research is done on the impacts of the Pandemic on preferences for home sizes, some research have already analyzed the effects of lockdown on the revealed values of open space. Irwin and Livy (2021) investigated the effects of lockdowns on (dis)amenity value of living close to major roads and open spaces in Baltimore, US by using a conventional difference-in-difference (DiD) strategy. Applying a similar method, Cheung and Fernandez (2021) focused on open spaces and blues spaces in Auckland, New Zealand while allowing the effect of Pandemics to vary across multiple periods of lockdowns. The results from these previous studies are nuanced in that they did not identify any significant increases in WTPs for environmental amenities, which is somewhat contradictory to the supposedly enhanced appreciation for nature during lockdown reported by surveys and research (Eykelbosh & Chow, 2022; Park et al., 2022b).

Most critically, the model specification of existing studies assumes the Pandemic only changed environmental amenity values, but not values associated with other amenities such as house sizes and proximity to the central business district (CBD). This assumption is inconsistent with our intuition that the Pandemic has changed amenity values. It is also at odds with the aforementioned anecdotal evidence, as well as with recent Urban Economics literature[4] that have suggested the changes in the amenity values of residing close to CBD post-Pandemic (Van Nieuwerburgh, 2022; van Vuuren, 2022). This potential violation of the model's assumption undermines the credibility of the conclusions drawn from the studies (Kuminoff & Pope, 2014; Banzhaf, 2021). The absence of prescriptive literature thus necessitates us to carefully examine potential approaches and delve into a suitable method that can reveal comprehensive pictures of the impacts of the Pandemic on the values of housing sizes and environmental amenities.

3.1.2 A Brief Background on Study Region

As discussed in detail in the introduction, for the Metropolitan Vancouver region in British Columbia, Canada, it has been a challenge to manage geographically and regulatory constrained areas to accommodate rapid population growth and mitigate intensifying climate change impact, which disproportionately affects vulnerable populations. In response, the regional growth plan *Metro 2050* is being updated. However, some member planning authorities raised concerns about the plan's adaptability to lifestyle changes post Pandemic and disparities in access to green spaces, which were particularly highlighted during the lockdowns. Therefore, it is imperative to analyze the impacts of the Pandemic on shifts in people's preference and the affordability of urban vegetation to address these concerns and design an effective countermeasure for the unique challenges posed to Metro Vancouver.

3.2 Theoretical Framework

To recap, our objective is to document the changes in the values of environmental amenities and housing sizes. Because there is no market that quantifies and traces the prices of environmental amenities, we utilize a revealed preference method to retrieve changes in amenity values reflected in housing prices across pre/post Pandemic periods. Our research avails a hedonic property-value method conceptualized by Rosen (1974) to model how houses are priced.

The following section briefly introduces the theory of the hedonic method and its underlying assumptions. While it may seem too basic and insipid for some, it is important to thoroughly understand

[4] As theses literatures also employ a popular approach DiD, they also assume WTPs for open spaces and lot sizes remain unaltered by the Pandemic.

the assumptions as they form the foundation for the empirical approaches that follow, and recent hedonic research have often neglected to consider them, leading to incorrect applications of a popular method.

The model envisions buyers choosing houses in the markets based on their characteristics. Faced with a menu of housing prices, housing attributes (e.g., living area, number of bathrooms) and locational amenities (e.g., distance to parks, air quality), what they decided to buy informs us their willingness-to-pay(WTP) for each attribute and amenity (Bishop et al., 2020).

We follow notations typically used in the literature such as Kuminoff and Pope (2014); Banzhaf (2021). For starters, at a point of time (t), a household (i) with time specific income y_i^t and preference a_i^t are to choose a whole set of houses with a typical house h with a price of p_h. This can be modelled as the following utility maximization problem

$$\max_{p_h, g, x} U_i^t(y_i - p_h, \boldsymbol{g}_h, \boldsymbol{x}_h; a) \tag{1}$$

where U_i^t is twice differentiable indirect utility function that is increasing in y_i (i.e., $\partial U_i^t / \partial y_i^t > 0$). $\boldsymbol{g}$ is a vector of attribute of interests (e.g., living areas, distance to the parks), and $\boldsymbol{x}$ is a vector of other housing attributes (e.g., number of bedrooms) except $\boldsymbol{g}$.

At any given point of time t, prices of house are determined based on the level of $\boldsymbol{g}$ and $\boldsymbol{x}$ on the time specific equilibrium price function, expressed as a generic parametric function of $\boldsymbol{g}, \boldsymbol{x}$ and a vector of parameters ω.

$$p_h^t = p^t(\boldsymbol{g}_h^t, \boldsymbol{x}_h^t; \omega) \tag{2}$$

Household satisfying first order condition for an amenity g, which is an element of $\boldsymbol{g}$, gives us

$$\frac{\partial U_i^t}{\partial g} = -\frac{\partial U_i^t}{\partial p}\frac{\partial p^t}{\partial g}$$

Or given $-\frac{\partial U_i^t}{\partial p} = \frac{\partial U_i^t}{\partial y}$,

$$\frac{\partial p^t}{\partial g} = \frac{\partial U_i^t}{\partial g} \Big/ \frac{\partial U_i^t}{\partial y} \tag{3}$$

Which is to say that the household will choose a level of g at which WTP for an additional unit of g equals to the derivative of price function with respect to g or marginal implicit price of g.

Similarly, on supply side, a landlord who is also a price taker faces following profit maximization problem

$$\max_{x} \pi_h = p_h - c_h(\boldsymbol{g}_h, \boldsymbol{x}_h; \beta) \tag{4}$$

where $c_h(\boldsymbol{g}_h, \boldsymbol{x}_h; \beta)$ is twice differentialable cost function and β is a vector of parameters that model idiosyncratic costs of producers[5]. The first-order condition for an attribute x_r is

$$\frac{\partial p^t}{\partial x_r} = \frac{\partial c_h}{\partial x_r} \tag{5}$$

Thus, an attribute is supplied at a level where marginal revenue is equal to marginal cost of supplying an additional unit of x_r. Therefore, equilibrium is achieved when eq.(3) and eq.(5) are satisfied for all consumers and producers. The whole system implicitly defines the equilibrium hedonic price function that clears market at each time period (Kuminoff & Pope, 2014).

The standard hedonic model assumes that price taking consumers have perfect information and are myopic i.e., they do not incorporate the future development of prices or provisioning of amenities[6] as indicated by time specific utilities functions in eq.(1). This also implicitly assures no anticipation. In other words, the consumers are assumed to care about only the current state of housing markets, but not the potential effects that evolving Pandemic situations could have in the future housing markets.

Another critical underlying assumption in hedonic models is that ω, parameters describing the shape of on the hedonic price function are also determined by structural parameters. To reflect the model primitives, the price function can be expressed as

$$p_h^t(\boldsymbol{g}_h^t, \boldsymbol{x}_h^t; \omega) \equiv p^t\left(\boldsymbol{g}_h^t, \boldsymbol{x}_h^t; \omega(a, b, c)\right) \tag{6}$$

[5] This model assumes that cost function is time invariant though this can be relaxed. As (Kuminoff & Pope, 2014) notes, for simplify g is assumed to be exogenous, but the outcomes of this section is not influenced endogeneity of g so as long g is assumed to be determined by exogeneous factors outside of this model.
[6] For models that incorporate forward looking behaviours, see (Bishop & Murphy, 2019).

where a, b, c are parameter vectors that describe the distribution of consumer type $R(y, a) \sim a$, the distribution of supplier type, $S(\beta) \sim b$ and the spatial distribution of the public amenity, $T(g) \sim c$. Therefore, any shocks to distributions of income and preferences, technology, or public amenities can change the equilibrium price function across time periods, consequently changing the revealed WTP for a good g (Kuminoff & Pope, 2014). Accordingly, this theoretical foundation above elaborates why the Pandemic can shift the pre-Pandemic equilibrium price function to a new equilibrium post-Pandemic via altering a in numerous channels such as Lay-offs, WFH, and lockdowns. However, a popular empirical approach used to estimate the effect of Pandemics disregards these foundations of the hedonic model, questioning the credibility of the results obtained.

3.3 Empirical Framework

In what follows, we adhere to standard practice in the relevant literatures by using the following notations. The dependent variable is inflation-adjusted property price of house i located in community c transacted at time t denoted by p_{ict}. A vector of the variables of interests are denoted by $\boldsymbol{g}$ (e.g., living areas, lot sizes and environmental amenities) and other characteristics are denoted by $\boldsymbol{x}$, unless otherwise specified. β is a vector of coefficients on variables of interests and γ' is a for other attributes. Let $postCOVID_i$ be an indicator variable that takes 1 if house i was transacted in post-Pandemic period (i.e., after March 2020), otherwise 0.

Following Bishop et al. (2020)'s guidelines and literatures, dependent variable is log transformed so are the other independent variables if deemed appropriate[7]. Also, following their guidelines, all the standard errors are robust and clustered at census tract level to reflect heteroskedasticity and autocorrelation often present in housing transaction data. We define ζ_c and η_t as spatial (neighbourhood) and temporal fixed effects (year and quarter) to correct for potential omitted variable bias and control for potential seasonal and annual shifts in housing markets.

Finally, for all the methods outlined below, we estimate the model for SFD samples and CAR samples separately based on the assumption that there exist distinct equilibria for each housing style as suggested in the literature (de Araujo & Cheng, 2017).

[7] All the explanatory variables except dummies and variables measured in percentages. This practice acknowledges non-linear relationship between price and variable of interests and complementarities among public amenities (Bishop et al., 2020).

3.3.1 Difference-in-Difference (TWFE)

To date, a dominating strategy used in the literature to estimate the Pandemic's capitalization effects is Difference-in-Difference (DiD) design (Cheung & Fernandez, 2021; Irwin & Livy, 2021). Unfortunately, this popular may not be appropriate for this application due to several identification challenges. In order to elaborate the challenges, we first briefly review the framework.

3.3.1.i) A Theoretical Framework

A typical application of DiD research design in hedonic studies exploits a (quasi-) random shock that partitions houses into four groups based on i) treatment status (treated or control) and ii) time periods (pre-treatment or post-treatment). Examples of such treatments include the US Clean Air Act (Chay & Greenstone, 2005), the opening/closure of industrial plants (Currie et al., 2015), the arrival of sexual offenders (Linden & Rockoff, 2008) Expansion of Airport's runaway (Winke, 2017) just to name a few.

Similarly, researchers have adopted this popular design by interpreting the lockdown as an exogenous shock to preference for environmental amenities. Specifically, in Irwin and Livy (2021) study, houses are considered to be affected by changes in preferences for amenities if they possess rich environmental endowments, such as being located near parks. As in typical DiD in hedonic studies, Irwin and Livy (2021) used a classic two-way fixed effects (TWFE) estimator to model the Pandemic's capitalization effect as shown below,

$$p_{it} = \beta_0 + \beta_1 TREAT_i + \beta_2 postCOVID_i + \pi TREAT_i * postCOVID_i + \gamma' \boldsymbol{x}_i + \zeta_c + \eta_t + u_{it} \qquad (7)$$

following (Haninger et al., 2017)'s notation, where $TREAT_i$ is an indicator variable that denotes assignment to treatment group (i.e., $TREAT_i = 1$ if house i has good environmental endowments) and $postCOVID_i$ is also an indicator variable that denotes post Pandemic period (i.e., $postCOVID_i = 1$ if house i was bought after March, 2020). Therefore, β_1 is Treatment Period Fixed Effect, representing the average price difference between houses with prime environmental endowment and those without. β_2 is Treatment Group Fixed Effect, representing the average price difference between houses traded before the lockdown and those traded after. π is a coefficient of interest, which denotes the average treatment effect on treated (ATT). ATT captures the difference in the environmental amenity value pre/post Pandemic, which provides an estimate for a valuation change attributable to the COVID policies.

For simplicity, consider only two time periods of t, pre and post treatment period denoted by 0,1 respectively. The expected ATT is then equivalent to

$$\hat{\pi} = \mathbb{E}\left[p_1^{a^*} \middle| TREAT = 1, X\right] - \mathbb{E}\left[p_1^{a'} \middle| TREAT = 1, X\right]$$

Under a certain set of assumptions discussed later, ATT is identified as

$$\pi = \left(\mathbb{E}\left[p_1^{a^*} \middle| TREAT = 1\right] - \mathbb{E}\left[p_0^{a'} \middle| TREAT = 1\right]\right) - \left(\mathbb{E}\left[p_1^{a'} \middle| TREAT = 0\right] - \mathbb{E}\left[p_0^{a'} \middle| TREAT = 0\right]\right)$$

where a^* and a' superscripts on p indicate the counterfactual treatment status that realizes regardless of actual state wherein a^* represents the presence of the Pandemic and a' the absence of the Pandemic.

3.3.1.iii) Challenges with Conventional Difference-in-Difference

Although the previous studies applied DiD, this method is not suitable to evaluate the impacts of the Pandemic on amenity values as it confronts several identification challenges, ultimately leading to incorrect conclusions about the impacts of the Pandemic. The key challenges are namely 1) a potential violation of Parallel Trend Assumption (PTA) and 2) a potential violation of stationary hedonic price function assumption. The Appendix B explains other challenges associated with this approach.

Challenge #1 Potential Parallel Trend Assumption (PTA) violations

One of the key identification assumptions of DiD is Parallel Trend Assumption which is expressed as follows.

$$\left(\mathbb{E}\left[p_1^{a'} \middle| TREAT = 1\right] - \mathbb{E}\left[p_0^{a'} \middle| TREAT = 1\right]\right) = \left(\mathbb{E}\left[p_1^{a'} \middle| TREAT = 0\right] - \mathbb{E}\left[p_0^{a'} \middle| TREAT = 0\right]\right)$$

To put in the context of our study, this assumption posits that the prices of houses with superior access to parks would have moved the same as those with subpar access in the absence of the Pandemic. However, this assumption may not be plausible as the houses with prime environmental endowment are found to appreciate at a faster rate than those without, as green premiums accrue over time (Aroul & Rodriguez, 2017; Cadena & Thomson, 2021). This potential violation potentially undermines the credibility of the impacts of the Pandemic because the estimated ATT i.e., the observed increase in prices of houses with superior environmental endowments, may just well be the accruing green premiums that would have increased the prices of houses with environmental endowments in the absence of the Pandemic[8].

Challenge #2 Potential Violation of Stationary Hedonic Price Function (STUVA)

A more critical challenge with the current approach is a violation of the stationary hedonic price assumption that conventional DiD in hedonic studies implicitly imposes (Bishop et al., 2020). This assumption essentially requires the hedonic price function to be in a static equilibrium, such that the gradient of hedonic functions denoted γ' representing WTP for other attributes and amenities are not to be influenced by the Pandemic[9]. This implies the COVID health measures such as lockdowns and WFH did not alter WTPs for living areas nor proximity to CBD.

However, if the Pandemic did in fact shift the equilibrium, the model fails to estimate accurate capitalization effects as it ignores the changes in hedonic function (Banzhaf, 2021). To illustrate, suppose that the Pandemic alters the gradients of hedonic function to such an extent that γ' differs from those under the counterfactual scenario (i.e., no Pandemic). Then, the conditional expectation for the treated group is then expressed as,

$$\mathbb{E}\left[p_1^{a'} \middle| TREAT = 1, X\right] = \beta_0 + \beta_1 + \beta_2 + \gamma^{a'\prime}\boldsymbol{x} + u_{it}$$
$$\mathbb{E}\left[p_1^{a^*} \middle| TREAT = 1, X\right] = \beta_0 + \beta_1 + \beta_2 + \pi + \gamma^{a^*\prime}\boldsymbol{x} + u_{it}$$

Because ATT is obtained as the difference between two potential outcomes for the treated group,

$$\hat{\pi} = \mathbb{E}\left[p_1^{a^*} \middle| TREAT = 1, X\right] - \mathbb{E}\left[p_1^{a'} \middle| TREAT = 1, X\right]$$

It then follows that,

$$\hat{\pi} = \pi + (\gamma^{a^*} - \gamma^{a'})'\boldsymbol{x}$$

[8] Recent advancements in DiD literatures allows this assumption to be partially tested and be relaxed (Rambachan & Roth, 2019; De Chaisemartin & D'Haultfoeuille, 2022).

[9] This can be seen as Stable Unit Treatment Value Assumption (SUTVA) violation, particularly non-inference assumption as it rules out general equilibrium effect (Banzhaf, 2021). In short, when the Pandemic changes in hedonic price function, it creates a "bad control" as it contaminates the prices of control groups. Appendix B elaborates on this in detail.

For TFWE to estimate an unbiased ATT (i.e., $\pi = \hat{\pi}$), the hedonic price gradients need to be invariant to whether the Pandemic had unfolded in March 2020 (i.e., $\gamma^{a^*} - \gamma^{a'} = 0$). However, our intuition, numerous anecdotal evidence as well as Urban Economics literatures tell us that COVID policies have changed preference for other housing attributes such as for living areas and proximity to CBD (Van Nieuwerburgh, 2022). Besides, the underlying theory of hedonic models suggests that any shocks to preference can shift the hedonic equilibrium, as discussed in 3.2. As a result, ATT could be biased as it may conflate with the changes in other price gradients, an issue referred to as conflation bias by Kuminoff and Pope (2014). For instance, a positive capitalization effect of the Pandemic on houses near agricultural land may conflate intensified values for remoteness from downtown due to WFH or larger houses or even both.

3.3.2.iii) Our Model Specification

Despite these challenges, we nevertheless follow the current literature and estimate their model specification just to contrast DiD model's results with our preferred model's results.

We extend the model eq.(7) by expanding the number of treatment groups to capture heterogeneous the impacts of the Pandemic on different environmental amenity values. Specifically, we categorize the impacts of the Pandemic based on i) types of environmental amenities a house is endowed with (e.g., green space, tree canopy and Blue Spaces such as rivers) and ii) prime/subprime level of the endowment (e.g., proximity to open space and intensity of tree canopy). Our (full) model is as follows.

$$\begin{aligned} p_{ict} = \beta_0 + \beta_1 postCOVID_i + \\ \sum_j^J \beta_j^{Prime} TREAT_{ij}^{Prime} + \beta_j^{Subp} TREAT_{ij}^{Subp} + \left(\pi_j^{Prime} TREAT_{ij}^{Prime} + \pi_j^{Subp} TREAT_{ij}^{Subp}\right) postCOVID_i \\ + \gamma' \boldsymbol{x}_{ict} + \zeta_c + \eta_t + u_{ict} \end{aligned} \tag{8}$$

where j subscript denotes the type of environmental amenity and J is a set of all the types of environmental amenity (s.t. $j \in J$). Superscripts *prime/subp* respectively denotes prime/subprime level of environmental endowment. Accordingly, $TREAT_{ij}^{Prime}$ and $TREAT_{ij}^{Subp}$ each takes one if house i is assigned to treatment given i's prime/subprime level of environmental amenity j, thus qualifying i to receive the price shock that is unique to environmental amenity j and its level of endowment.

As an illustration, a house A (B), located adjacent to (not adjacent, but in the vicinity of) parks, in tree intensive (deprived) neighbourhood, but remote from (adjacent to) Blue Spaces has the following profiles of impact categories: for $j \in$ [park, tree canopy, Blue Space], $TREAT_{Aj}^{Prime}$=(1,1,0), $TREAT_{Aj}^{Subp}$=(1,1,0), $TREAT_{Bj}^{Prime}$=(0,0,1), and $TREAT_{Bj}^{Subp}$=(1,0,1) respectively. Appendix B elaborates on this process in more detail. Essentially, this specification enables us to investigate various categories of the Pandemic impacts.

Note, because the current approach only focuses on environmental amenities, other housing attributes (e.g., housing sizes and proximity to CBD) are just used as controlling covariates in $\boldsymbol{x}_{ict}$ whose WTPs are assumed to be constant across pre/post Pandemic periods, which lead to incorrect the impacts of the Pandemic on amenity values as mentioned earlier.

3.3.2 Hedonic Difference Model

As shown above, DiD may not be the best tool to estimate the impacts of the Pandemic on amenity values. We thus apply an alternative model specification that simply takes a difference between two hedonic functions that are specific to pre/post Pandemic periods to gauge the changes in revealed amenity values.

Building upon the model framework used in Kuminoff and Pope (2014), we estimate the following model.

$$p_{ict} = a + a^{*}postCOVID_i + \beta\, g_{ict} + \beta^{*} g_{ict}postCOVID_i + \gamma'\boldsymbol{x}_i + \gamma^{*\prime}\boldsymbol{x}_i postCOVID_i + \zeta_c + \eta_t + \varepsilon_{ict} \quad (9)$$

where β^{*} are the coefficients of interest that represent the changes in WTPs for housing sizes and environmental amenities between pre/post Pandemic i.e., $\beta^{*} = \Delta\boldsymbol{\beta}$[10]. As rudimentary as it seems, this model specification estimates the unbiased changes in amenity values denoted by β^{*} with conditional zero mean assumption[11] and as long as there is no shock to any amenities nor other attributes $\Delta g_i = \Delta\boldsymbol{x}_i = 0$.

[10] Proof is offered in Appendix B.
[11] This is needed to estimate full parameters, but it could be the case where $\Delta\varepsilon$ could be correlated with g e.g., houses near parks appreciate in unobserved ways. A weaker conditional independence assumption ($\Delta\varepsilon \perp g_i|x$) would estimate unbiased estimate of β^{*}even if $\Delta\gamma'$ is biased as in Banzhaf (2021).

There are several advantages of this method over DiD specification, First, this model faces fewer and less stringent assumptions compared to DiD as it does not rely on potential outcome frameworks. Second, unlike DiD, this model allows price gradients to evolve over the Pandemic periods with the interaction terms between all the variables and $postCOVID_i$. Finally, it directly estimates and tests the changes in WTP across the Pandemic periods. Specifically, we test the null hypothesis of the temporal consistency of the price gradient pre-Pandemic vis-a-vis post Pandemic, i.e., $\mathrm{H}_0\ \beta^* = \beta^1 - \beta^0 = 0$. Alternatively, Kuminoff and Pope (2014) refer this as Time-Constant Gradient Assumption (TCGA).

While β^* represents changes in WTPs, a more intuitive interpretation of β^* is as follows. Consider two houses (A,B) only differentiated by the level of g (e.g., Tree Canopy) where A is in more treed neighbourhood such that $g_A > g_B$. If β^* is significant and positive, then it implies that A, more tree intensive house is priced now higher than B by the order of $\beta^*(g_A - g_B)$ because of the greater values on tree after the Pandemic. Moreover, α^* can be interpreted as a change in values associated with single family detached houses/condos themselves after the lockdown as it allows constant terms to differ across the COVID period. Henceforth, it is referred to as "COVID Period Fixed Effect", analogous to Treatment Period Fixed Effect from TWFE.

It is important to note that, besides the Pandemic induced preference changes, there are many other reasons why hedonic gradients can shift between pre-Pandemic period to post Pandemic period such as changes in demography or supplier types (Kuminoff & Pope, 2014). Lastly, because the model simply takes a difference of two hedonic functions, rather than counterfactuals, it merely records the changes in amenity values that occurred, not the changes that would not have occurred in the absence of the Pandemic.

3.3.3 Application of Quantile Regression

One of the objectives of this research is to evaluate the heterogeneous changes in amenity values across various price segments of housing. An increase in green premiums on lower-priced homes may make it more difficult for prospective buyers to purchase houses in areas with a higher concentration of trees, particularly those who already have limited access to urban vegetation after the Pandemic. As such, an analysis into the heterogeneous effects across the spectrum of housing prices is crucial for understanding the ramification of the Pandemic on green equity. One technique at our disposal is quantile regression (QR) which enables us to investigate heterogeneous effects at any given quantiles of housing prices (Koenker, 2017).

Thus, we utilize QR to our model eq.(9). Specifically, we estimate the following model specification

$$p_i(\tau) = a\,(\tau) + a^{*}postCOVID_i(\tau) + \beta\,(\tau)g_i + \beta^{*}(\tau)g_i postCOVID_i + \gamma\,'(\tau)x + \gamma^{*'}(\tau)xpostCOVID_i + \zeta_c + \varepsilon_i (10)$$

where τ denotes τ th quantile. The model thus estimates parameters for all the quantiles of housing prices, including the coefficients of interests β^{*} i.e., the change in WTP for environmental values and housing sizes, enabling us to analyze the changes in amenity values at given quantile of housing prices. For example, a statistically significant and positive $\beta^{*}(\tau)$ on tree canopy at the 25th quantile, but no significance at the 75th quantile would imply that only lower priced houses in more tree neighbourhood become more expensive compared to pre-Pandemic period, while there were no such effects on high-end houses.

3.4 Data and Descriptive Statistics

The property transaction data used in this research spans from January 2017 to March 2021, capturing approximately one year into the Pandemic. The data was collected and provided by Real Property Solutions (RPS). The original dataset contains transaction price, transaction date, geographical information, and basic structural information, such as living areas and housing style. The transaction prices were adjusted to the 2017 Canadian dollar using StatCan's Residential Property Price Index.

The original data consists of 200,690 observations, which accounts for about 52% of all the residential sales during 2017 to March 2021, according to authors' tabulation using data from BCREA (British Columbia Real Estate Association). Of these transactions, 86,382 (43%) observations are located within the Metro Vancouver region, or approximately 67% of all the residential transactions that occurred during the same time span[12]. Then the dataset was cleaned by removing outliers identified by the IQR method[13] and observations that missed key structural information. Finally, in total 60,024 transactions will be used for our analysis. Of 60,024, 29,348 (49%) were Single Family Detached (SFD) houses and the remaining 30,676 (51%) were Condominiums, Apartments and Row Houses (CAR).

[12] c.f. here

[13] More specifically, observations whose housing prices are three-halves times of interquartile ranges were removed following hedonic literatures (Smith & Huang, 1995).

The following several sections are divided based on broader categories of variables namely neighbourhood, locational, and environmental. For each variable, we outline how it was obtained and / or generated in Table 1, and the Descriptive Statistic is offered in Table 2. All geospatial analysis was operated with ArcGIS Desktop and as per American Economic Association's guideline[14], replication codes are available as part of the whole replication package on GitHub[15]. Appendix C displays various data visualizations depicting properties within our sample such as geographical distribution as well as average prices for each housing type.

Most neighbourhood variables were obtained using the 2016 census from Statistics Canada. All observations were assigned the neighbourhood characteristics of a specific census tract those observations were located in, including the average age of residents, levels of household income, educational attainment, as well as employment, following standard practices observed in hedonic literature such as Anderson and West (2006); Hu et al. (2022). Moreover, literatures note the linkage between school quality and housing prices in Vancouver (Ries & Somerville, 2010). Data on school quality and the schools' spatial location came from the Fraser Institute and the Government of Canada website, respectively. The nearest public elementary school's score has been assigned to each house. Crime records have been obtained from a privately-managed map, which contains geographical information about homicide. The number of homicide cases has been aggregated into census tract levels. Because the accuracy of this data is not guaranteed, we have also run models dropping this variable presented in Appendix D.

Locational variables were produced utilizing data from Metro Vancouver. Each house was assigned a Euclidian distance from the CBD (central business district i.e., Vancouver downtown), the nearest urban centres, the nearest SKY train station as well as major roads, following the earlier related studies such as Irwin and Livy (2021). Previous research suggested that there may have been changes in preference for public transportation in Metro Vancouver as its usage declined in the wake of the Pandemic (Kapatsila et al., 2022).

Environmental variables were also generated by relying on mainly two types of land use datasets, Land Use (LU) and Land Designation (LD). The distinction is that LU shows *de facto* usage of each parcel of land, whereas LD shows *de jure* usage for each parcel of land designated by Metro Vancouver. The literature is clear that different types of open spaces provide different premiums (Irwin, 2002; Klaiber &

[14] https://aeadataeditor.github.io/posts/2021-02-10-reproducible-gis#arcgis
[15] https://github.com/hotakakobori/MSc-Thesis-Replication

Phaneuf, 2010; Panduro & Veie, 2013). Therefore, utilizing the classification in these datasets, open spaces are then divided into four distinct categories to capture their unique amenity values capitalized into housing markets, namely 1) Urban Green Spaces, 2) Natural Areas, 3) Blue Spaces, and 4) Agricultural Land. Each house was given the distance to the nearest each type of open space. The difference between Urban Green Space and Natural Areas lies in protection status according to regional bylaws; Urban Green Space is typified neighbourhood parks, whereas Natural Areas are of ecological importance and are typified by large size urban forests such as Stanley Park. The literature has shown that different types of parks, such as neighborhood parks and special parks like regional parks bear distinct amenity values (Irwin, 2002; Anderson & West, 2006). Blue spaces include rivers and protected watersheds as these have been shown to possess amenity values that positively impact property values (Yoo & Wagner, 2016; Chen et al., 2019). Agricultural lands include areas designated for the Agricultural Land Reserve and the University of British Columbia Farm. This detailed categorization allows us to capture ecosystem services unique to each environmental amenity and intricate lockdown shocks to the values of each environmental amenity. Appendix C presents a visualization depicting the distribution of environmental amenities.

Furthermore, recent studies show the level of tree canopy is an important factor in housing prices given its numerous environmental and social benefits (Netusil et al., 2010; Sachs et al., 2022) Specifically, it enhances microclimatic conditions, such as mitigating urban heat island effect, leading to energy savings (Klaiber et al., 2017; Han et al., 2021; Eyster & Beckage, 2022). To capture the multidimensionality of urban vegetation beyond proximity and the type of nearest open space, each observation is assigned a percentage of the area covered by trees canopy at the dissemination block level, which is the smallest census division scale.

Finally, we designate the post Pandemic period ($postCOVID = 1$) as beginning after March 18, 2020, when the government of British Columbia declared a state of emergency; this approach is in line with existing literature that investigates the impacts of the COVID-19 pandemic, such as the works by Cheung and Fernandez (2021); Zhang et al. (2021). This also coincides with the World Health Organization's declaration of COVID-19 as a Pandemic and Canada's closure of international flights on March 16 (Detsky & Bogoch, 2020).

While we treat the entire time window after March 18, 2020, as the post Pandemic period, the BC authorities introduced several stages of COVID policies that differed in stringency. Literature advise incorporating the effects of dynamic and heterogeneous policies and their feedback loops (Goodman-Bacon & Marcus, 2020; Callaway & Li, 2021). To observe these guidelines, we control for the potential effects of various COVID policies on housing markets by incorporating two dummy variables that each take one if the observation was transacted 1) during when the BC government eased restrictions until they raised the stringency level when the second wave hit. 2) after December 9, 2020, when the Canadian government approved a vaccine. The hypothesis underpinning this approach is that, due to these positive news and policy changes, the housing markets are likely to have become more active; as such, it is essential to account for these impacts. Henceforth, we collectively refer to these specific COVID policy period fixed effects as "COVID Policy Effects”.

Table 1. Variable Description: Metro Vancouver

Metro Vancouver: Variable Description

Variable Name	Detailed Description (Unit)	Source
Adjusted House Price	Transaction Price Adjusted to 2017 CAD using RPPI index by type	Brookfield Real Property Solutions, StatCan (Index)
Housing Attributes:		
lnLivingArea	Living Area (sq.ft)	Brookfield Real Property Solutions
lnLotSize	Lot Size (sq.ft)	
Age	Age of Property at the time of Transaction (years)	
Bathrooms	# of Full Bathroom	
Bedrooms	# of Full Bedroom	
Condition	Dummy Variable Which Takes 1 if Condition is "excellent" or "good", 0 Otherwise	
Basement	Dummy Variable Which Takes 1 if Basement is "finished", 0 Otherwise	
OneStory	Dummy Variable Which Takes 1 if property style is "One Story", 0 Otherwise	
AttachedGarage	Dummy Variable Which Takes 1 if parking type is "Detached Garage", 0 Otherwise	
TwoORMoreParking	Dummy Variable Which Takes 1 if parking count is 2 or more, 0 Otherwise	
Locational:		
lnDistCBD	Distance to Central Business District (m)	Open Data Catalogue, Metro Vancouver
lnDistUrbanCentre	Distance to the Nearest Urban Centre (m)	
lnDistMajorRoad	Distance to Major Roads (m)	StatCan
lnDistSky	Distance to the Nearest SkyTrain Station (m)	UBC Library
GoodSchool	Dummy Variable Which Takes 1 if the Nearest Public Elementary School is Good (score >7), 0 Otherwise	Fraser Institute (for Scores), StatCan (School Location)
Elder	Percentage of Population Aged Over 65	StatCan 2016 Census
LowIncomeRate	Percentage of Household whose Income is Less Than Medium Income After Tax	
HighIncomeRate	Percentage of Household whose Income is More Than $100,000 After Tax	
ImmiRate	Percentage of Immigrants	
EduPostSecRate	Percentage of People with at least Bachelor’s Degree	
LabUnempRate	Unemployment Rate	
Homi_1119	Dummy Variable Which Takes 1 if There Were More Than One Recorded Homicide Cases from 2011-2019, 0 Otherwise	Privately Managed Public Google Map
Environmental:		
lnDistUGS	Distance to the Nearest Urban Green Space (m)	Open Data Catalogue, Metro Vancouver
lnDistNaturalArea	Distance to the Nearest Natural Area (m)	
lnDistBlueSpace	Distance to the Nearest Blue Space (m)	
lnDistAgriculture	Distance to the Nearest Agriculture (m)	
TreeCanopy	Percentage of Tree Canopy at Census Dissemination Block	

Table 2. Descriptive Statistics: Metro Vancouver

Descriptive Statistics by Housing Type and Period
Pre-Pandemic (January 2017 - March 2020)
Post-Pandemic (March 2020 - March 2021)

	SFD		CAR		Total
Variables (Unit)	Pre	Post	Pre	Post	
Adjusted House Price (2017 CAD)	$1,408,680.06	$1,500,119.94	$680,031.78	$697,157.08	$1,045,580.11
	(636,546.37)	(620,889.97)	(278,626.51)	(283,422.28)	(612,198.47)
Housing Attributes:					
Living Area (ft^2)	2,007.54	2,129.14	1,035.42	1,074.57	1,524.18
	(815.13)	(879.95)	(405.44)	(423.31)	(815.62)
Lot Size (ft^2)	11,280.51	11,957.21			11,262.07
	(36,088.21)	(55,927.77)			(40,248.08)
Age of Property (years)	27.40	26.86	13.48	14.36	20.30
	(23.09)	(23.99)	(11.89)	(12.67)	(19.62)
Bathrooms	2.40	2.60	1.58	1.69	2.01
	(1.26)	(1.32)	(0.64)	(0.66)	(1.09)
Bedrooms	3.62	3.78	2.03	2.11	2.83
	(1.09)	(1.22)	(0.85)	(0.91)	(1.28)
Good Condition (0/1)	0.51	0.56	0.66	0.66	0.59
	(0.50)	(0.50)	(0.47)	(0.47)	(0.49)
Finished Basement (0/1)	0.43	0.45			0.23
	(0.49)	(0.50)			(0.42)
One Story Property (0/1)	0.18	0.13			0.21
	(0.38)	(0.34)			(0.41)
Garage Attached (0/1)	0.70	0.69			0.46
	(0.46)	(0.46)			(0.50)
Multiple Parking Spots (0/1)	0.60	0.61	0.25	0.28	0.42
	(0.49)	(0.49)	(0.43)	(0.45)	(0.49)
Locational:					
Distance to Central Business District (m)	21,007.17	19,969.39	13,889.46	14,013.52	17,285.67
	(12,073.19)	(12,047.84)	(10,843.78)	(11,097.42)	(11,987.36)
Distance to Urban Centre (m)	3,092.08	3,229.74	2,471.78	2,527.97	2,791.10
	(1,996.41)	(2,134.88)	(1,879.18)	(1,910.03)	(1,978.70)
Distance to Major Roads (m)	699.13	730.41	363.11	382.87	531.52
	(741.22)	(779.95)	(441.60)	(438.77)	(634.17)
Distance to SkyTrain Station (m)	5,597.28	5,875.00	2,934.62	3,276.89	4,284.26
	(5,009.48)	(5,113.42)	(3,987.94)	(4,266.26)	(4,736.68)
Neighbourhood:					
Good School Quality (0/1)	0.17	0.20	0.14	0.16	0.16
	(0.38)	(0.40)	(0.34)	(0.36)	(0.36)
Percentage of Elders	15.72	16.20	14.55	14.98	15.20
	(5.19)	(5.33)	(6.40)	(6.98)	(5.93)
Percentage of Low Income Households	15.57	15.66	23.45	23.18	19.59
	(6.03)	(5.84)	(9.73)	(9.61)	(9.00)
Percentage of High Income Households	33.68	34.39	22.74	23.39	28.20
	(9.82)	(9.86)	(10.49)	(10.51)	(11.56)
Percentage of Immigrants	37.56	38.03	43.72	43.15	40.71
	(14.21)	(14.01)	(14.25)	(14.56)	(14.55)
Percentage of College Educated	27.95	29.36	36.06	36.19	32.23
	(10.87)	(11.21)	(11.94)	(11.92)	(12.12)
Unemployment Rate	5.57	5.57	5.91	5.89	5.74
	(1.39)	(1.41)	(1.51)	(1.53)	(1.47)
High Crime Rate (0/1)	0.07	0.06	0.18	0.17	0.13
	(0.26)	(0.25)	(0.38)	(0.37)	(0.33)
Environmental:					
Distance to Urban Green Space (m)	132.49	132.96	117.70	118.18	125.01
	(135.96)	(127.80)	(103.37)	(96.64)	(119.46)
Distance to Natural Area (m)	1,057.43	1,066.75	777.82	783.67	915.75
	(1,122.86)	(1,131.42)	(800.60)	(801.12)	(982.56)
Distance to Blue Space (m)	1,585.69	1,578.93	1,358.37	1,394.80	1,471.37
	(993.49)	(1,014.59)	(1,021.64)	(1,035.16)	(1,016.82)
Distance to Agricultural Land (m)	3,698.04	3,945.69	4,383.67	4,401.86	4,071.69
	(3,685.95)	(3,893.04)	(3,169.22)	(3,279.13)	(3,474.25)
Percentage of Tree Canopy	26.44	27.47	19.18	20.26	22.90
	(17.97)	(18.66)	(15.82)	(16.68)	(17.42)
Observations	24,011	5,337	26,630	4,046	60,024
Proportion to Total Obs. (%)	40.00	8.89	44.37	6.74	
Proportion to Total Type (%)	81.81	18.19	86.81	13.19	

Note: Data are means with standard deviations in parentheses.
(0/1) indicates a dummy variable that takes 1 if true 0 otherwise

3.5 Results

Each following subsequent subsection reports results from a respective method, and these results are summarized and compared at the end of this result section. Note that SFD refers to single-family detached and CAR refers to Condominiums, Apartments and Row Houses. Recall that for all analyses, the dependent variable is logarithmized inflation-adjusted housing price. The explanatory variables of key interests are space attributes (Size of Living Areas, Lot Sizes and Distance to CBD), and environmental amenities (Distances to the nearest Urban Green Space, Natural Area, Blue Space, Agricultural Land, and Tree Canopy Area). Note that while not shown, other controlling variables are included in the estimation unless otherwise mentioned.

3.5.1 Difference-in-Difference (TWFE)

Table 3 reports the results obtained using DiD, a commonly used method for estimating the Pandemic capitalization effects as described, in eq.(8). Columns (1)-(4) report SFD results and (5) - (8) report for CAR. Columns (1) and (5) are the results of the naïve models that do not control for other covariates such as housing attributes. Columns (2) and (6) report models that control for other attributes, but only include the Prime endowment treatment group and Columns (3) and (7) repeat that for the Subprime endowment group. Finally, Columns (4) and (8) incorporate both Prime and Subprime groups.

As mentioned earlier, a conventional TWFE specification as in eq.(8) controls for two types of fixed effects, Treatment Period Fixed Effect and Treatment Group Fixed Effect. The former is presented at the top row, as indicated by $postCOVID$. The positive sign on this term in (1)-(4) suggests an increase in average housing prices for SFD post Pandemic. This aligns with our intuition as individuals may have preferred to have their own space rather than living in Condos and Apartments with shared spaces during the Pandemic.

The treatment group fixed effects control for the pre-existing price difference between the control group and each treatment group. Recall that these groups are categorized based on 1) the types of environmental amenities houses are endowed with and 2) the prime/subprime level of the endowment of those amenities. Specifically, for distance-based variables (UGS, Natural Areas, Blue Spaces and Agricultural Land) the level of the endowment is measured in terms of proximity, so the prime group is referred to as the adjacency group, and the subprime group is the vicinity group for easier understanding.

The results on treatment group fixed effects terms from the full model (4) & (8) provide insights into the effects of amenity values on housing prices. Model (4) shows that houses that are adjacent to UGS have a premium, but those that are only in the vicinity of UGS do not. Similarly, premiums of Blue Spaces are only present for adjacency groups, suggesting the geographical limits of the amenity values of Blue Spaces such as scenic views and recreational use values. These premiums, specific to houses that are situated closer to open spaces, are in agreement with the notion of distance decay where the benefits of amenities diminish with distance (Walsh et al., 2011; Łaszkiewicz et al., 2019). Surprisingly, there is a premium for living in the vicinity of agricultural lands, contradicting the discount for proximity to agricultural land often reported in the literature (Ready & Abdalla, 2005). Similarly, (8) indicates waterfront condos are found to command a premium. However, there were no significant premiums on any houses that are located near green spaces.

All interaction terms with post-COVID indicator and treatment group are ATTs, representing the average housing prices change for each treatment group after the Pandemic. (2)-(4) show that SFD houses that are located nearby agricultural lands have appreciated by approximately 2%. The full model (4) decomposes this change and shows that it is driven by the houses that are in the vicinity of agricultural lands, but not by houses that are adjacent to them. This suggests people may prefer a rustic lifestyle more post Pandemic while avoiding potential negative externalities from living too close to agricultural land (e.g., odor, noise etc.). The increase in prices for houses near agricultural lands aligns with the enhanced preference for country living in the reported news (Ireland, 2022). As for the case of CAR, the ATT on Blue Spaces across (5)-(8) is negative, but full model (8) shows that this negative change is not driven by the adjacency group, but rather the vicinity group. This suggests only condos located in the vicinity of Blue Spaces have depreciated, with no significant effects on waterfront condos. Besides, no significant effects of the lockdown were observed on other treatment groups. These nuanced results are similar to those found in previous research, which also used DiD to investigate the Pandemic's impacts on environmental amenity values (Irwin & Livy, 2021).

However, it is critical to note that these results could be biased if any of the underlying assumptions are violated. Most critically, as mentioned earlier, the estimated ATT may conflate the changes in WTPs for other covariates such living area, and proximity to CBD. Therefore, the intensified preference for agricultural land that we found may just well conflate a heightened preference for remote locations from CBD due to WFH as suggested by the Urban Economics literatures (Van Nieuwerburgh, 2022) or for larger houses to create office space.

Table 3 DiD: Metro Vancouver

Metro Vancouver: Difference-in-Difference Result

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	SFD				CAR			
Variables	Naïve	Prime	Subprime	Full	Naïve	Prime	Subprime	Full
Treatment Period Fixed Effect:								
postCOVID	.0113	.0223***	.02***	.0206***	-.0045	-.0047	.002	8.8e-04
	(.0115)	(.0061)	(.0065)	(.0065)	(.0157)	(.0077)	(.0091)	(.0092)
Treatment Group Fixed Effect:								
dumyUGS50m	-.0046	.0039		.0051*	.0069	-9.5e-04		-.0012
	(.0057)	(.003)		(.003)	(.0129)	(.0056)		(.0062)
dumyUGS100m	-.0242***		5.0e-04	-.0016	.0039		.0029	.0011
	(.0065)		(.0031)	(.0032)	(.0144)		(.0057)	(.0067)
dumyNA100m	-.007	-.0048		-.0084	.0079	.0085		.011
	(.01)	(.0069)		(.0062)	(.0209)	(.0109)		(.0108)
dumyNA250m	-8.3e-04		.0093	.0087	.0133		.0042	-.0044
	(.0086)		(.0061)	(.0053)	(.0165)		(.0084)	(.0085)
dumyBlue300m	.0346*	.0387***		.0375***	.0493**	.0337**		.027*
	(.0182)	(.0135)		(.012)	(.025)	(.0137)		(.0139)
dumyBlue600m	.0019		.0088	-7.7e-04	-.0143		.0283**	.0216*
	(.0128)		(.0087)	(.0074)	(.0287)		(.0113)	(.0115)
dumyAg500m	.0452***	-.0071		-.0058	.0501	.0107		.0155
	(.014)	(.0065)		(.0066)	(.0406)	(.0138)		(.014)
dumyAg1000m	.0477**		.0035	.0047	.0523**		-.0113	-.014
	(.0186)		(.0078)	(.0079)	(.0256)		(.0143)	(.0134)
TreeCanopyTop10%	.0308*	-.0075		-.0063	.0065	-.0367**		-.0203
	(.0173)	(.0077)		(.0079)	(.0307)	(.0154)		(.0174)
TreeCanopyTop25%	.0334***		-.0053	-.0027	.0105		-.0295**	-.0243*
	(.011)		(.0045)	(.0042)	(.018)		(.0115)	(.0125)
ATT:								
postCOVID × dumyUGS50m	-.0076	-3.3e-04		-.0022	.0074	.0097		.0094
	(.0101)	(.0057)		(.006)	(.0181)	(.0078)		(.0088)
postCOVID × dumyUGS100m	.0016		.0023	.0028	.0025		-4.8e-04	-.0035
	(.01)		(.0055)	(.0063)	(.0168)		(.0073)	(.0087)
postCOVID × dumyNA100m	.0029	.0049		.0073	-.0343	-.0239**		-.0181
	(.0146)	(.0093)		(.0096)	(.0213)	(.0103)		(.0114)
postCOVID × dumyNA250m	-.0101		-4.5e-04	-.0048	5.7e-04		-.0166**	-.0085
	(.0111)		(.007)	(.0082)	(.0197)		(.0082)	(.0094)
postCOVID × dumyBlue300m	.047*	.0269		.0252	-7.7e-04	-.0315***		-.0057
	(.0245)	(.0186)		(.0196)	(.0263)	(.0098)		(.0107)
postCOVID × dumyBlue600m	-.0189		.0144	.0025	-.042**		-.0286***	-.0266***
	(.0129)		(.0118)	(.0091)	(.0169)		(.008)	(.0091)
postCOVID × dumyAg500m	-.0093	.0235**		.0052	-.0141	.0157		.0079
	(.0184)	(.0099)		(.0107)	(.0297)	(.0131)		(.0141)
postCOVID × dumyAg1000m	.0313**		.0232***	.0208**	.0429**		.0105	.0074
	(.0154)		(.008)	(.0085)	(.0198)		(.0114)	(.013)
postCOVID × TreeCanopyTop10%	.0172	-.0014		7.5e-04	-.0015	.0184*		.0058
	(.0174)	(.0139)		(.0143)	(.0283)	(.0104)		(.0145)
postCOVID × TreeCanopyTop25%	.0043		-.0023	-.0027	-8.9e-04		.016**	.0146
	(.0114)		(.0084)	(.0072)	(.0202)		(.0081)	(.011)
Constant	13.54***	11.39***	11.45***	11.41***	12.91***	8.886***	8.953***	8.935***
	(.0185)	(.7115)	(.7202)	(.7105)	(.027)	(.0799)	(.4329)	(.4737)
Controls:								
Spatial Fixed Effect	✓	✓	✓	✓	✓	✓	✓	✓
Temporal Fixed Effect	✓	✓	✓	✓	✓	✓	✓	✓
COVID Policy Effect	✓	✓	✓	✓	✓	✓	✓	✓
Housing Attributes		✓	✓	✓		✓	✓	✓
Observations	29348	27389	27389	27389	30676	30662	30662	30662
R^2	0.659	0.883	0.883	0.883	0.469	0.859	0.859	0.859
Adjusted R^2	0.653	0.881	0.881	0.881	0.461	0.857	0.857	0.857
AIC	-871.7	-31803.2	-31716.2	-31806.8	9875.2	-30737.1	-30739.2	-30796.9
BIC	-614.8	-31507.4	-31420.4	-31428.8	10141.8	-30420.5	-30347.7	-30305.4

Note: Robust standard errors in parentheses are clustered at Census Tract level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Each column represents a separate regression. SFD and CAR refer to Single Family Detached and Condos, Apartments, and Row Houses respectively.
About 10% and 25% of samples belong to Prime and Subprime groups respectively.
Spatial Fixed Effects at Census Tract as well as municipality level.
Temporal Fixed Effects at year as well as quarter level.

3.5.2 Hedonic Difference

In Table 4, we present the results from our preferred model specification that estimates the change in WTP, as described in eq.(9). Note all the distance variables are logged, so coefficients on these represent elasticities. Model (1) and (4) do not incorporate what we refer to as "COVID Period Fixed Effect" shown at the top row. (3) and (6) also controls for "COVID Policy Effect" to absorb the potential impacts of the various stages of COVID policies as mentioned earlier.

Negative signs on COVID Period Fixed Effect in (4)-(6) imply a decrease in utilities living in CAR, likely stemming from a heightened aversion to living in shared spaces (e.g., elevators, hallways, laundry, etc.) in order to minimize contacts.

The first set of rows shows baseline price gradients or WTPs for the variables of interest in pre-Pandemic period. From SFD results (1) - (3), the premiums are on larger livings area, lot size, proximity on to CBD, Natural Areas, and Blue Spaces. These findings are generally in line with the other hedonic literatures (Irwin, 2002). The estimated discount on Agricultural Land is also consistent with previous research that found disamenity impacts of agricultural activities on property values (Ready & Abdalla, 2005; Hu et al., 2022). The negative sign on Tree Canopy seems to be contradictory to our intuition and existing literature (Han et al., 2021)[16], but possible explanations for this finding include: 1) the smaller canopy, the less extreme heat (Eyster & Beckage, 2022); 2) a larger tree canopy is associated with older communities; 3) maintenance costs; and 4) private green spaces without intensive tree cover, such as gardens, are preferred. In the case of CAR, models (4) - (6) indicate that larger Living Areas, and proximity to CBD, UGS, and Blue Space seem to have significant premiums.

The interaction terms with those space attributes and environmental amenities terms and $postCOVID$ signify the changes from the baseline price gradients in the post Pandemic period. The significance on these terms indicates a salient departure from price gradients in post COVID (i.e., $\beta^* = \beta^1 - \beta^0 \neq 0$), suggesting a violation of TCGA. Interpretation of these terms requires caution for distance variables. If the baseline is negative, indicating an amenity, a positive sign signifies a more gradual distance decay, while a negative sign indicates a steeper decay. Conversely, if the baseline is positive, representing a disamenity, a positive sign implies a steeper discount, and a negative sign suggests a more gradual discount as distance increases. For instance, a positive sign on the baseline as

[16] This discount on tree still lingers even after controlling for numerous cofounders that could be correlated with tree density such as population density.

well as on the change on proximity on Agricultural Land shows a steeper discount in (3). This indicates living closer to agricultural land, ceteris paribus, has become cheaper, which is the opposite of what TWFE showed earlier. The same goes for both green spaces USG and Natural Areas in which living close to them has become less costly on average. Living Area has become more expensive. This aligns with the surveys and news that have repeatedly noted intensified demands for larger spaces[17]. However, the value of lot size has become cheaper.

SFD results in (1) - (3) illustrate that WTP for proximity to Blue Spaces has become more expensive. Most notably, the value of tree coverage has appreciated significantly. This aligns with our intuition, as well as widely reported in surveys and much anecdotal evidence, which suggests that people appreciate urban vegetation during the lockdown (Eykelbosh & Chow, 2022). A potential reason for the heightened demand for improved air quality may be its notable impact as a contributing factor in COVID-19 outbreaks, as poor air quality has been associated with exacerbated health outcomes for those affected by the virus (Isphording & Pestel, 2021; Kang et al., 2021). From CAR results (4)-(6), there are no significant changes in price gradients, except for a weak indication of an increase in the amenity value of Living Area and a reduction in the amenity value of Natural Areas. Interestingly, for both SFD and CAR, despite WFH, the WTP for proximity to CBD did not change. This finding contradicts earlier findings from Urban Economics research that showed changes in the amenity value of proximity CBD (Ferreira & Wong, 2022).

We have conducted extensive robustness checks, which are presented in Appendix D. To give a brief summary, the strengthened preference for Tree Canopy and Blue Spaces as well as the escalated demand for larger living space remain to be significant throughout various robustness checks. Robustness checks include modifications in a) the timing of the post-Pandemic period, b) functional forms, c) scales of spatial fixed effects and clustering of errors, d) the measurement of variable of interest, e) controlling variables, f) price indices used to adjust housing prices, and g) the data timeframe. Furthermore, these changes were not observed prior to the Pandemic or in the placebo Pandemic scenario, which strengthens the claim that the Pandemic caused the changes in amenity values.

[17] https://www.realtor.ca/blog/will-the-desire-for-larger-homes-be-a-permanent-change/20950/1361

Table 4. Hedonic Difference: Metro Vancouver

Metro Vancouver: Hedonic Difference

	(1)	(2)	(3)	(4)	(5)	(6)
	SFD			CAR		
Variables	Naïve	Base	COVID Policy	Naïve	Base	COVID Policy
postCOVID		.0163	.0041		-.2912*	-.2918*
		(.1267)	(.1281)		(.1655)	(.1653)
Baseline:						
lnLivingArea	.2642***	.2643***	.2644***	.6837***	.6806***	.6806***
	(.0089)	(.0088)	(.0088)	(.0246)	(.025)	(.025)
lnLotSize	.2183***	.2183***	.2184***			
	(.0111)	(.0111)	(.0111)			
lnDistCBD	-.1469**	-.1468**	-.1464**	-.0555***	-.0562***	-.0563***
	(.0623)	(.0624)	(.0623)	(.0214)	(.0213)	(.0213)
lnDistUGS	-7.4e-04	-7.3e-04	-7.3e-04	-.005*	-.005*	-.005*
	(.0015)	(.0015)	(.0015)	(.0026)	(.0026)	(.0026)
lnDistNaturalArea	-.0054*	-.0053*	-.0053*	-.0025	-.0025	-.0025
	(.0028)	(.0028)	(.0028)	(.0036)	(.0036)	(.0036)
lnDistBlueSpace	-.0156**	-.0155**	-.0156**	-.0214***	-.0215***	-.0215***
	(.0076)	(.0076)	(.0076)	(.0063)	(.0063)	(.0063)
lnDistAgriculture	.0103**	.0104**	.0103**	.0042	.0038	.0038
	(.0045)	(.0045)	(.0045)	(.0071)	(.0071)	(.0071)
TreeCanopy	-4.5e-04***	-4.5e-04***	-4.5e-04***	-.0014***	-.0014***	-.0014***
	(1.6e-04)	(1.5e-04)	(1.5e-04)	(2.8e-04)	(2.8e-04)	(2.8e-04)
Change from Baseline:						
postCOVID × lnLivingArea	.0397***	.039***	.0396***	.0144	.0403*	.04*
	(.0114)	(.0116)	(.0116)	(.0147)	(.0228)	(.0228)
postCOVID × lnLotSize	-.0193**	-.0194**	-.0196**			
	(.0079)	(.0081)	(.0081)			
postCOVID × lnDistCBD	.0061	.0055	.0054	-.0017	.0049	.0053
	(.0055)	(.0074)	(.0074)	(.0064)	(.0067)	(.0067)
postCOVID × lnDistUGS	.0062**	.0062**	.0063**	-4.0e-04	-3.2e-05	-1.7e-05
	(.0029)	(.0029)	(.0029)	(.0018)	(.0018)	(.0018)
postCOVID × lnDistNaturalArea	.0064**	.0064*	.0064*	.0047*	.0049*	.0049*
	(.0033)	(.0034)	(.0034)	(.0026)	(.0026)	(.0026)
postCOVID × lnDistBlueSpace	-.0087*	-.0089*	-.009*	.0026	.0037	.0038
	(.0049)	(.0046)	(.0046)	(.0034)	(.0036)	(.0036)
postCOVID × lnDistAgriculture	.0069***	.0068**	.0068**	1.8e-04	.0036	.0037
	(.0024)	(.0028)	(.0028)	(.0033)	(.0037)	(.0037)
postCOVID × TreeCanopy	6.3e-04**	6.4e-04**	6.5e-04***	1.9e-04	1.3e-04	1.3e-04
	(2.6e-04)	(2.5e-04)	(2.5e-04)	(2.3e-04)	(2.4e-04)	(2.4e-04)
Constant	11.39***	11.39***	11.38***	8.971***	8.999***	9***
	(.7238)	(.7279)	(.7277)	(.5791)	(.3692)	(.3504)
Controls:						
Spatial Fixed Effect	✓	✓	✓	✓	✓	✓
Temporal Fixed Effect	✓	✓	✓	✓	✓	✓
COVID Period Fixed Effect		✓	✓		✓	✓
COVID Policy Effect			✓			✓
Observations	27389	27389	27389	30662	30662	30662
R^2	0.885	0.885	0.885	0.862	0.862	0.862
Adjusted R^2	0.883	0.883	0.883	0.860	0.860	0.860
AIC	-32213.5	-32211.5	-32216.5	-31343.7	-31369.5	-31373.3
BIC	-31761.5	-31751.3	-31739.8	-30802.2	-30911.3	-30923.4

Note: Robust standard errors in parentheses are clustered at Census Tract level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Each column represents a separate regression. SFD and CAR refer to Single Family Detached and Condos, Apartments, and Row Houses respectively.
Spatial Fixed Effects at Census Tract as well as municipality level.
Temporal Fixed Effects at year as well as quarter level.

3.5.2. i) Robustness Checks

The robustness of the results from the previous section is evaluated. Specifically, Table 5 displays the outcomes obtained by re-estimating the models, excluding transactions that took place during the onset of the Pandemic and up to six weeks afterward (i.e., the beginning of May 2020). This is done because these property transactions might have been agreed upon before the Pandemic's fallout, potentially leading to a misassignment of these houses as being *treated* by the Pandemic-induced preference shifts. The analysis reveals that removing these transactions does not alter the findings presented in the previous sections.

Additionally, we have conducted extensive robustness checks, which are presented in Appendix D. To give a brief summary, the strengthened preference for Tree Canopy and Blue Spaces as well as the escalated demand for larger living space remain to be significant throughout various robustness checks. Robustness checks include modifications in a) the timing of the post-Pandemic period, b) functional forms, c) scales of spatial fixed effects and clustering of errors, d) the measurement of variable of interest, e) controlling variables, f) price indices used to adjust housing prices, and g) the data timeframe. Furthermore, these changes were not observed prior to the Pandemic or in the placebo Pandemic scenario, which strengthens the claim that the Pandemic caused the changes in amenity values.

Table 5 Hedonic Difference: Metro Vancouver: Robustness Check: Different Observations

Different Observations: Excluding Transactions in the First Two Months of Pandemic Onset (Mar. 2020 - May 2020)

	(1)	(2)	(3)	(4)
	SFD		CAR	
Variables				
postCOVID	.0582	.2447	-.3029*	-.2896
	(.1293)	(.2458)	(.1761)	(.1815)
Baseline:				
lnLivingArea	.2652***	.2649***	.6792***	.679***
	(.0089)	(.0088)	(.0251)	(.0252)
lnLotSize	.2184***	.2188***		
	(.0112)	(.0113)		
lnDistCBD	-.1434**	-.1414**	-.056***	-.0564***
	(.0627)	(.0628)	(.0216)	(.0216)
lnDistUGS	-5.1e-04	-5.7e-04	-.0051**	-.005*
	(.0015)	(.0015)	(.0026)	(.0026)
lnDistNaturalArea	-.0052*	-.0051*	-.0028	-.0027
	(.0028)	(.0029)	(.0037)	(.0037)
lnDistBlueSpace	-.016**	-.0156**	-.0219***	-.0216***
	(.0076)	(.0076)	(.0063)	(.0063)
lnDistAgriculture	.01**	.0106**	.0043	.0036
	(.0045)	(.0046)	(.007)	(.007)
TreeCanopy	-4.5e-04***	-4.1e-04***	-.0014***	-.0015***
	(1.5e-04)	(1.5e-04)	(2.8e-04)	(2.8e-04)
Change from Baseline:				
postCOVID × lnLivingArea	.037***	.0412***	.0439*	.0435*
	(.0121)	(.0118)	(.0237)	(.0237)
postCOVID × lnLotSize	-.0199**	-.0224***		
	(.0083)	(.0086)		
postCOVID × lnDistCBD	.0054	-.0013	.0046	.0082
	(.0076)	(.0222)	(.007)	(.0083)
postCOVID × lnDistUGS	.0056*	.0061**	-4.4e-04	-8.8e-04
	(.0032)	(.0031)	(.0019)	(.0018)
postCOVID × lnDistNaturalArea	.0062*	.0052*	.0057**	.0049
	(.0034)	(.0028)	(.0029)	(.0031)
postCOVID × lnDistBlueSpace	-.0096*	-.0114***	.004	.002
	(.0049)	(.0044)	(.0037)	(.0038)
postCOVID × lnDistAgriculture	.0065**	.002	.0036	.0103**
	(.0029)	(.0034)	(.0039)	(.0051)
postCOVID × TreeCanopy	6.3e-04**	4.3e-04**	1.2e-04	3.6e-04
	(2.6e-04)	(2.1e-04)	(2.3e-04)	(2.3e-04)
Constant	11.35***	11.31***	8.974***	8.99***
	(.7325)	(.736)	(.2378)	(.3382)
Controls:				
Spatial Fixed Effect	✓	✓	✓	✓
Temporal Fixed Effect	✓	✓	✓	✓
COVID Period Fixed Effect	✓	✓	✓	✓
COVID Policy Effect	✓	✓	✓	✓
Pandemic Period Spatial Fixed Effect		✓		✓
Observations	26767	26767	30011	30011
R^2	0.885	0.885	0.861	0.862
Adjusted R^2	0.883	0.883	0.859	0.859
AIC	-31461.4	-31502.1	-30603.4	-30661.1
BIC	-30986.0	-30944.8	-30138.1	-30254.0

Note: Robust standard errors in parentheses are clustered at Census Tract level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Each column represents a separate regression. SFD and CAR refers to Single Family Detached and Condos, Apartments, and Row Houses respectively.
Spatial Fixed Effects at Census Tract as well as municipality level.
Temporal Fixed Effects at year as well as quarter level.

3.5.3 Quantile Regression

All our analysis thus far focused on the changes in amenity value on an average house; and we have found, the price of average houses that have larger living spaces, are closer to Blue Spaces and are in more treed neighbourhoods have increased significantly. However, whether these changes were homogeneous across all price segments of houses remains unknown. This question can be addressed by applying quantile regression, which investigates the stratification of changes in amenity values across different ranges of housing prices.

Table 5 reports the estimation result of eq.(10). Results (1) and (3) show results for the 25^{th} quantile or houses in the bottom 25% of the housing price range (i.e., low-end of the house in the price distribution) and (2) and (4) show the 75^{Th} quantile but for top 25% (i.e., high-end houses) for both housing style, respectively.

The contrast is striking. The magnified premium on tree intensive neighbourhood has remained significant for only for low-end houses, but not high-end houses, suggesting that the increased green premium were more pronounced for lower priced houses. This means that only relatively lower priced houses in more treed neighbourhoods became more expensive, making it harder for low-income people to live in tree-intensive areas that provide many benefits including protection against extreme heat waves. Appendix D showcases plots depicting changes in amenity values across quartiles of housing prices for each housing style.

Table 6. Quantile Hedonic Difference: Metro Vancouver

Quantile Hedonic Difference

	(1)	(2)	(3)	(4)
	SFD		CAR	
Quantile (τ)	25% Low-end	75% High-end	25% Low-end	75% High-end
postCOVID	.9937***	.4371*	.0854	-.3755
	(.2192)	(.2314)	(.2522)	(.2743)
Baseline:				
lnLivingArea	.251***	.2597***	.6149***	.7213***
	(.0071)	(.0067)	(.0181)	(.0194)
lnLotSize	.1917***	.2541***		
	(.0048)	(.0052)		
lnDistCBD	-.0852***	-.091***	-.039***	-.0397***
	(.0115)	(.0115)	(.0095)	(.0116)
lnDistUGS	.0044***	.0018	-2.6e-04	-.0033
	(.0017)	(.0015)	(.0035)	(.0041)
lnDistNaturalArea	-.0022	-6.8e-05	-6.6e-04	-.0059*
	(.0017)	(.0015)	(.0039)	(.0034)
lnDistBlueSpace	.0112***	.0025	-.0117***	-.0105*
	(.0026)	(.003)	(.0041)	(.0059)
lnDistAgriculture	.0139***	.0131***	-.0073	.008*
	(.0021)	(.0021)	(.0046)	(.0044)
TreeCanopy	-.0011***	-8.0e-04***	-.0024***	-.0013***
	(1.4e-04)	(1.1e-04)	(3.0e-04)	(2.7e-04)
Change from Baseline:				
postCOVID × lnLivingArea	.0319**	.0351**	.0137	.0315
	(.0145)	(.0145)	(.0266)	(.0272)
postCOVID × lnLotSize	-.0238***	-.019**		
	(.0077)	(.0088)		
postCOVID × lnDistCBD	-.0725***	-.0298	.0022	.0261
	(.0175)	(.02)	(.0119)	(.0168)
postCOVID × lnDistUGS	.0038	.0037	-4.5e-04	-.0011
	(.0029)	(.004)	(.004)	(.0026)
postCOVID × lnDistNaturalArea	6.2e-04	.0051*	.0047	.008*
	(.0027)	(.003)	(.0051)	(.0046)
postCOVID × lnDistBlueSpace	-.0059	-.0047	.0032	-.0047
	(.0042)	(.0056)	(.007)	(.0055)
postCOVID × lnDistAgriculture	-.005	.003	.003	.0072
	(.0034)	(.0039)	(.0065)	(.0061)
postCOVID × TreeCanopy	4.2e-04**	2.7e-04	7.9e-04**	-2.4e-04
	(2.1e-04)	(2.2e-04)	(3.4e-04)	(3.0e-04)
Constant	10.12***	9.815***	8.896***	8.354***
	(.1415)	(.1375)	(.1778)	(.1996)
Controls:				
Spatial Fixed Effect	✓	✓	✓	✓
Temporal Fixed Effect	✓	✓	✓	✓
COVID Period Fixed Effect	✓	✓	✓	✓
COVID Policy Effect	✓	✓	✓	✓
Observations	27389	27389	30662	30662

Note: Robust standard errors in parentheses are clustered at Census Tract level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Each column represents a separate regression. SFD and CAR refer to Single Family Detached and Condos, Apartments, and Row Houses respectively.
Spatial Fixed Effects at municipality level.
Temporal Fixed Effects at year as well as quarter level.
Pandemic Period Spatial Fixed Effect is also controlled

3.5.4 Summary of Results

Finally, the results from all methods are summarized and compared in Table 6.

Table 7. Summary of Impact: Metro Vancouver

Metro Vancouver: Summary of Impact:
How Much Has WTP Changed?

Variable	SFD DiD	SFD HD	CAR DiD	CAR HD
Space Attributes:				
Living Area (ft^2)	-[1]	30.64	-	25.02
Lot Size (ft^2)	-	-2.8		
Distance to CBD (m)	-		-	
Environmental Amenities:				
Distance to UGS (m)		78.69		
Distance to Natural Areas (m)		7.83		
Distance to Blue Space (m)		-10.81	37.51[2]	
Distance to Agriculture (m)	-20.77[3]			1.46
Tree Canopy (%)		745.74		

Note: Each column represents welfare measures calculated using the estimads from corresponding method respectively. Only results with significance from the models with COVID Period Specific Spatial Fixed Effect are presented. SFD and CAR refer to Single Family Detached and Condos, Apartments, and Row Houses respectively.
Each number represents ***change*** in WTPs for respective amenity.
DiD: $[\exp(\pi_j - \frac{1}{2}(\pi_j)) - 1] \cdot \bar{p} \cdot TREAT_j \cdot 1/distance$
HD: β_g^*
[1] - indicates the model assumes this to be constant across pre/post Pandemic periods
[2] Calculated by DiD measures divided by $600m$
[3] Calculated by DiD measures divided by $1000m$

The results significantly vary between housing types and empirical strategies. On one hand, DiD method, which is widely used in previous literature, reports increased prices in SFD houses near agricultural lands and a decline in the prices of condos near Blue Spaces compared to pre-Pandemic period. In contrast, our preferred model presents a completely different picture. Specifically, the value of larger living areas as well as premiums for tree coverage and proximity to Blue Space have increased after the Pandemic and these results remain constant under various robustness checks, as shown in Appendix D. This discrepancy in the results highlights the importance of carefully evaluating methods for studying the impacts of the Pandemic on amenity values as an inappropriate choice of method results in incorrect conclusions. Furthermore, as shown in 2.5.3, we observed the heterogeneous changes in which only in lower priced houses, the values of trees have appreciated.

3.6 Concluding Remarks

In this chapter, we have analyzed changes in revealed values of housing sizes and environmental amenities in Metro Vancouver following the COVID-19 Pandemic of 2020. In doing so we have also critiqued the dominant strategy used in previous literature that can lead to different conclusions about the changes in amenity values post Pandemic. We also have applied quantile regression to analyze the heterogeneity in changes of those values given different price ranges of houses.

In conclusion, the findings from the Metro Vancouver case study have several implications that are specifically relevant to the region from our results.

First, the increase in the value of living space makes it harder for prospective buyers to obtain larger dwelling spaces in the already unaffordable housing markets of Metro Vancouver. This implies that policymakers may need to review zoning and land use regulations to ensure that they are consistent with changing housing preferences. For example, if more people are interested in larger homes, there may be a need for more land to be set aside for residential development via rezoning low-density areas or more flexibility in how the land can be used such as mixed-use developments given geographically and regulatory constraints on developable land in the region.

Our results show that in Metro Vancouver, individuals are willing to pay a premium for proximity to Blue Spaces (such as rivers, oceans, and protected watersheds) and for living in neighborhoods with a high density of tree canopy, compared to the pre-Pandemic period. The increased premium for environmental amenities highlights the importance of regional urban planning that conserves urban vegetation through land designation policies (e.g., Urban Containment Boundaries). On the other hand, the heightened demand for urban vegetation that drives prices of homes located in greener areas or closer to Blue Spaces also means the deterioration of affordability of environmental amenities, particularly for low-income populations. It is important for urban planners in Metro Vancouver to be aware of the of potential consequences the Pandemic-induced demands on the accessibility of urban vegetation. Furthermore, as tree canopy can help mitigate the intensifying climate change impacts (e.g., ameliorating heat island effects, air quality and stormwater runoffs) which disproportionately affect low-income and vulnerable populations, ensuring green equity is crucial to enhance the region's adaptability to climate change and achieving a just transition.

Finally, it is important to consider several limitations when interpreting the results of this study. Because these limitations are shared with the subsequent chapter on Edmonton and Calgary, these are discussed in great detail in the conclusion chapter, along with any broader implications of this research and recommendations for future research.

Chapter 4. Alberta

4.1 Introduction

The COVID-19 Pandemic and related measures have transformed our preference for housing style and open spaces. For example, due to the implementation of Work-From-Home (WFH) and lockdown policies, many individuals sought out suburban areas in search of larger spaces that can accommodate work, study and leisure activities (Ramani & Bloom, 2021). Additionally, due to the closures of many indoor venues and social distancing measures, people have sought outdoor recreation (Eykelbosh & Chow, 2022). These trends suggest people have come to appreciate the values of private dwelling space and the amenity values of open spaces.

These effects of the Pandemic on preferences for green spaces and housing sizes may vary significantly depending on the specific health measures implemented in each region, tailored to the local level of outbreaks. For example, in the jurisdictions where parks were closed due to high case counts, demands for private green space (e.g., backyards) might have increased, while demands for public green spaces may have been less affected due to uncertainties about the permanence of such policies. Therefore, to appropriately compare and summarize the impacts of the Pandemic on the values of open spaces and personal space, a comparative analysis of similar cities with similar profiles of COVID-19 policies is required.

However, nearly all previous literature on this topic has been limited to case studies of single areas with unique COVID policies, making it challenging to compare the Pandemic's effects on amenity values from a complex mixture of policy, space, and time, as we cannot hold the COVID policies constant. This also makes it hard to draw broader conclusions of the Pandemic that can be applied beyond the specific case. Additionally, meta-analyses of hedonic studies have noted the limitations of comparing the values of environmental amenities across studies due to variations in data and methods (McConnell & Walls, 2005; Brander & Koetse, 2011; Yoo & Wagner, 2016).

To make more generalizable observations about the Pandemic's impact on amenity values, we conduct a comparative analysis of the impacts of the Pandemic on the WTPs for open spaces and spaces attributes using the hedonic method in the twin cities of Alberta, Edmonton, and Calgary. This would enable us to control for variations in COVID-19 policies and data. Our study contributes to the literature by providing comparable measures of revealed values of open spaces across cities, and by providing the first comparative analysis of the Pandemic's impacts on amenity values to test heterogeneities in changes in values between the two similar regions.

The remainder of the chapter is structured as follows. First, short relevant background information is offered. The whole sections that outline a theoretical framework and empirical frameworks in Section 3 are the same as the previous chapter, thus significantly simplified. Section 4 explains data and provides descriptive statistics from each city. Section 5 showcases results and compares the results across cities. Section 6 concludes this chapter.

As expounded upon in Chapter 1, Edmonton, and Calgary, two major metropolitan areas in Alberta, are both situated in the heartland of the vast Canadian agricultural landscape. These two cities share numerous similarities, particularly in regard to their historical development patterns. Owning to their geography and provincial policies, both metropolitan areas have undergone an unconstrained suburban expansion that has resulted in severe fragmentations of prime agricultural lands. However, since 2010, the city of Calgary has adopted a compact growth model by encouraging densification to curb urban sprawl. Conversely, the city of Edmonton has just recently switched to a compact development strategy. While there is anecdotal evidence suggesting that the Pandemic and WFH have accelerated urban flights due to heightened demand for larger housing sizes, it has yet to be empirically verified. Analyzing shifts in people's preference for open space and personal dwelling space is therefore a key ingredient in updating their development policies post Pandemic to protect the vital agricultural lands post Pandemic era.

4.2 Theoretical Framework

Readers shall refer to Metro Vancouver's Section 2 for the hedonic model's theoretical framework.

4.3 Empirical Framework

We apply the same notations and empirical approaches as Chapter 2 to evaluate the effect of Pandemics on the values of environmental amenities and housing sizes. To recap, we estimate two following methods.

4.3.1 Difference-in-Difference (TWFE)

As in Chapter 2, we first estimate an extended TWFE model with multiple treatment groups as below.

$$p_{ict} = \beta_0 + \beta_1 postCOVID_i + \sum_j^J \beta_j^{Prime} TREAT_{i,j}^{Prime} + \beta_j^{Subp} TREAT_{i,j}^{Subp} + (\pi_j^{Prime} TREAT_{ij}^{Prime} + \pi_j^{Subp} TREAT_{ij}^{Subp}) postCOVID_i + \gamma' \boldsymbol{x}_i + \zeta_c + \eta_t + u_{it} \quad (11)$$

Where J denotes a set of all the environmental amenities. $TREAT_{i,j}^{Prime}$ and $TREAT_{i,j}^{Subp}$ are indicator variables that each indicates house i is treated with a shock to preference for environmental amenity j because i is endowed with prime/subprime level of environmental amenity j. The coefficients of interests are π which represent ATT or the average price changes for each respective treatment groups. However, ATT estimated might be biased as this model specification confronts some identification issues elaborated in great deal in the 3.3.1.ii)

4.3.2 Hedonic Difference

Necessitated to apply a more suitable model, we then run the following model that directly estimates changes in amenity values by differencing the hedonic pricing functions across pre/post Pandemic periods. Specifically,

$$p_i(\tau) = a(\tau) + a^* postCOVID_i(\tau) + \beta(\tau) g_i + \beta^*(\tau) g_i postCOVID_i + \gamma'(\tau) x + \gamma^{*\prime}(\tau) x postCOVID_i + \zeta_c + \varepsilon_i \quad (12)$$

where β^* and γ^* represent the changes from the baseline pre-Pandemic period price gradients β and γ' for the variables of interests as well as other variables.

4.4 Data and Descriptive Statistics

This section explains the data and provides descriptive statistics for both cities. For both Edmonton and Calgary, the property transaction data records the transactions that occurred from January 2017 through March 2021, capturing circa one year into the Pandemic. The data was collected and provided by Real Property Solutions (RPS). The original dataset contains transaction price, transaction date, geographical information, and basic structural information such as the property style of each house. The transaction prices were adjusted to the 2017 Canadian dollar by using Housing Price Index published by Canadian

Real Estate Association. We then cleaned the dataset by removing outliers identified by the IQR method and observations that missed key structural attributes for each city's dataset.

As mentioned earlier, one of the challenges in conducting comparative studies across multiple municipalities is ensuring the comparability of data as different measurements of data could influence the results. Thus, one contribution of this research is to standardize data formats and measurement, so that the results are directly comparable even across different jurisdictions.

For both regions, we defined the post-Pandemic period ($postCOVID = 1$) as beginning after March 16, 2020, when the Alberta government declared a state of emergency. The government announced stages of restriction easements from May 13 until November 25, 2020, when the province was facing a second wave of infections. To control the potential effects of these special measures, along with the federal government's approval of a vaccine on December 9, 2020, we introduced two sets of indicator variables for houses transacted during these periods. These dummy variables are together referred to as "COVID Policy Effects".

The subsequent sections describe different categories of variables, namely neighbourhood, locational, and environmental, for each city. Table 7 & 9 summarize the following contents in one table for each city. Table 8 & 10 present descriptive statistics.

For both regions, most of neighbourhood variables were obtained using the 2016 census from Statistics Canada. All observations were assigned neighbourhood characteristics of a specific census tract where those observations are located in. Data on school quality came from Fraser Institute.

4.4.1 Edmonton

Almost all the data specific to the city of Edmonton has been obtained through City of Edmonton's Open Data portal. Crime data were aggregated into neighbourhood level from 2011 to 2019[18]. We only tabulated homicide cases, following the literatures that showed only serious crimes impact housing prices (Ihlanfeldt & Mayock, 2010). We then transformed the data into a dummy variable indicating the top 20% of high criminal communities. Locational Variables which include the Euclidian distances from the

[18] Current criminal record map from EPS only shows the cases of 40 days. We constructed our original criminal record map that traces historical evolution of crime of all forms at neighbourhood level. This data is publicly available as with other datasets.

Edmonton central business district (CBD), the nearest urban centres such as transit centres, the nearest train station as well as major roads to each observation have been assigned to each observation.

Environmental variables were generated using multiple land use datasets from the City of Edmonton, primarily the Land Use (LU) and Zoning datasets. The LU dataset reflects the actual land use of each parcel in Edmonton, as determined through satellite data and human verification, while the Zoning dataset specifies the legally permitted uses of each parcel based on local bylaws. In other words, the LU dataset reflects the *de facto* or current use of land in the city, while the Zoning dataset outlines the *de jure*, or planned use of land.

As in Metro Vancouver case, open spaces were divided into four categories, 1) Urban Green Spaces 2) Natural Areas 3) Blue Spaces 4) Agricultural Land. Specifically, green spaces are divided into two types UGS and Natural Areas based on their protection status in the bylaws.

The detailed classification process is as follows. We first prepare Natural Areas by combining “Natural Area Protection Zone” from the Zoning dataset with North Saskatchewan River Valley and Ravine Protection (NSRVRSP) Zoning Overlays. We then prepare a generic green space layer that contains all the green spaces in Edmonton by merging Park dataset with “Park, Recreation and Public Education” classification from the LU dataset. The overlap with Natural Areas was then removed to generate Urban Green Space layer. Agricultural lands are extracted from the LU data that includes the University of Alberta farm; the overlaps with UGS and NA were removed. Blue Spaces that include North Saskatchewan River, lakes, creeks, and wetlands were from hydrography data in Edmonton, with man-made hydrography excluded. As shown, our open space layers are mutually exclusive and collectively exhaustive.

Because tree canopy coverage data was not available, we utilized the best data set in our disposal, detailed data on every tree located on public lands, to construct neighbourhood level tree coverage. The process is as follows. The most common specie of tree on record in Edmonton is Green ash. In order to convert this point data into coverage, we created a 2.8m radius buffer around each tree following the studies on Green ash with similar stem diameters (Remphrey et al., 1987). The sum of these areas (i.e., proxy for each tree’s coverage) was then aggregated into census dissemination block level. The ratio of this approximated tree canopy area to the total area or Tree Canopy Area was assigned to each observation located within the block.

Table 8. Variable Description: Edmonton

Edmonton: Variable Description		
Variable Name	Detailed Description (Unit)	Source
Adjusted House Price	Transaction Price Adjusted to 2017 CAD using Home Price Index	Brookfield Real Property Solutions, CREA (Index)
Housing Attributes:		
lnLivingArea	Living Area (sq. ft)	Brookfield Real Property Solutions
lnLotSize	Lot Size (sq. ft)	
Age	Age of Property at the time of Transaction (years)	
Bathrooms	# of Full Bathroom	
Bedrooms	# of Full Bedroom	
Condition	Dummy Variable Which Takes 1 if Condition is "excellent" or "good", 0 Otherwise	
Basement	Dummy Variable Which Takes 1 if Basement is "finished", 0 Otherwise	
OneStory	Dummy Variable Which Takes 1 if property style is "One Story", 0 Otherwise	
AttachedGarage	Dummy Variable Which Takes 1 if parking type is "Detached Garage", 0 Otherwise	
TwoORMoreParking	Dummy Variable Which Takes 1 if parking count is 2 or more, 0 Otherwise	
Locational:		
lnDistCBD	Distance to Central Business District (m)	City of Edmonton's Open Data Portal
lnDistUranCentre	Distance to the Nearest Major Transit Centre (m)	City of Edmonton's Open Data Portal
lnDistMajorRoad	Distance to Major Roads (m)	StatCan
lnDistLRT	Distance to the Nearest LRT Station (m)	City of Edmonton's Open Data Portal
GoodSchool	Dummy Variable Which Takes 1 if the Nearest Elementary School is Good, 0 Otherwise	Fraser Institute (for Scores), City of Calgary's Open Data Portal (School Location)
Elder	Percentage of Population Aged Over 65	StatCan 2016 Census
LowIncomeRate	Percentage of Household whose Income is Less Than Medium Income After Tax	
HighIncomeRate	Percentage of Household whose Income is More Than $100,000 After Tax	
ImmiRate	Percentage of Immigrants	
EduPostSecRate	Percentage of People with at least Bachelor's Degree	
LabUnempRate	Unemployment Rate	
Homi_1119	Dummy Variable Which Takes 1 if There Were More Than One Recorded Homicide Cases from 2011-2019, 0 Otherwise	City of Edmonton's Open Data Portal
Environmental:		
lnDistUGS	Distance to the Nearest Urban Green Space (m)	City of Edmonton's Open Data Portal
lnDistNaturalArea	Distance to the Nearest Natural Area (m)	City of Edmonton's Open Data Portal
lnDistBlueSpace	Distance to the Nearest Blue Space (m)	City of Edmonton's Open Data Portal
lnDistAgriculture	Distance to the Nearest Agriculture (m)	City of Edmonton's Open Data Portal
TreeCanopy	Percentage of Tree Canopy at Census Dissemination Block	City of Edmonton's Open Data Portal

Table 9. Descriptive Statistics: Edmonton

Edmonton: Descriptive Statistics by Housing Type and Period
Pre-Pandemic (January 2017 - March 2020)
Post-Pandemic (March 2020 - March 2021)

	SFD		CAR		Total
Variables (Unit)	Pre	Post	Pre	Post	
Adjusted House Price (2017 CAD)	450,714.91	461,122.27	268,552.74	264,555.79	407,391.63
	(161,816.65)	(167,855.98)	(112,755.39)	(111,163.66)	(171,433.87)
Housing Attributes:					
Living Area (ft^2)	1,581.58	1,625.72	1,064.23	1,039.94	1,459.82
	(600.93)	(652.88)	(458.86)	(267.54)	(615.61)
Lot Size (ft^2)	6,421.64	5,665.95			6,494.25
	(27,083.10)	(5,558.99)			(26,578.20)
Age of Property (years)	22.76	23.77	14.78	17.57	21.02
	(21.59)	(23.23)	(13.54)	(14.57)	(20.45)
Bathrooms	1.63	1.70	1.54	1.61	1.62
	(0.65)	(0.64)	(0.63)	(0.51)	(0.64)
Bedrooms	2.95	2.95	2.13	2.16	2.75
	(0.86)	(0.67)	(0.73)	(0.76)	(0.88)
Good Condition (0/1)	0.52	0.51	0.55	0.48	0.52
	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)
Finished Basement (0/1)	0.65	0.69			0.53
	(0.48)	(0.46)			(0.50)
One Story Property (0/1)	0.23	0.23			0.29
	(0.42)	(0.42)			(0.45)
Garage Attached (0/1)	0.36	0.39			0.31
	(0.48)	(0.49)			(0.46)
Multiple Parking Spots (0/1)	0.77	0.81	0.21	0.22	0.64
	(0.42)	(0.39)	(0.41)	(0.42)	(0.48)
Locational:					
Distance to Central Business District (m)	8,763.54	9,010.04	7,454.54	7,296.67	8,468.07
	(3,733.54)	(3,754.85)	(4,668.06)	(4,733.48)	(4,029.81)
Distance to Urban Centre (m)	1,374.54	1,410.35	1,252.26	1,300.97	1,350.45
	(815.77)	(823.32)	(701.34)	(708.28)	(792.28)
Distance to Major Roads (m)	402.91	415.82	301.77	283.90	379.19
	(375.98)	(396.34)	(332.56)	(308.74)	(370.48)
Distance to LRT Station (m)	4,669.96	4,797.01	3,636.45	3,398.90	4,425.22
	(2,718.26)	(2,811.99)	(2,829.59)	(2,797.15)	(2,795.05)
Neighbourhood:					
Good School Quality (0/1)	0.33	0.31	0.33	0.31	0.33
	(0.47)	(0.46)	(0.47)	(0.46)	(0.47)
Percentage of Elders	11.97	11.61	12.22	12.09	11.99
	(6.09)	(6.10)	(7.14)	(6.75)	(6.35)
Percentage of Low Income Households	17.52	16.75	22.68	23.39	18.71
	(9.35)	(8.89)	(11.26)	(11.13)	(10.06)
Percentage of High Income Households	38.44	39.26	31.19	29.86	36.73
	(13.11)	(12.68)	(14.07)	(13.81)	(13.69)
Percentage of Immigrants	28.69	28.90	29.94	30.16	29.03
	(9.65)	(9.71)	(7.98)	(7.95)	(9.30)
Percentage of College Educated	28.60	28.63	33.23	32.69	29.72
	(12.36)	(12.37)	(13.02)	(13.13)	(12.68)
Unemployment Rate	8.44	8.33	8.31	8.47	8.40
	(2.03)	(2.10)	(1.90)	(1.94)	(2.01)
High Crime Rate (0/1)	0.12	0.12	0.32	0.35	0.17
	(0.33)	(0.32)	(0.47)	(0.48)	(0.37)
Environmental:					
Distance to Urban Green Space (m)	123.39	123.08	111.81	118.06	120.73
	(118.46)	(106.21)	(90.44)	(125.55)	(112.02)
Distance to Natural Area (m)	1,147.02	1,141.81	958.94	912.76	1,099.09
	(972.49)	(994.09)	(816.49)	(782.72)	(942.19)
Distance to Blue Space (m)	1,170.22	1,150.17	1,067.64	1,031.28	1,141.73
	(887.35)	(896.18)	(729.70)	(729.39)	(853.83)
Distance to Agricultural Land (m)	1,897.33	1,841.73	2,222.93	2,330.07	1,973.65
	(1,418.96)	(1,452.67)	(1,502.04)	(1,608.51)	(1,454.98)
Percentage of Tree Canopy	2.60	2.58	3.02	2.84	2.69
	(2.29)	(2.25)	(2.29)	(2.17)	(2.29)
Observations	10,275	1,867	3,402	512	16,056
Proportion to Total Obs. (%)	63.99	11.63	21.19	3.19	
Proportion to Total Type (%)	84.62	15.38	86.92	13.08	

Note: Data are means with standard deviations in parentheses.
(0/1) indicates a dummy variable that takes 1 if true 0 otherwise

4.4.2 Calgary

Like Edmonton, the majority of data has been obtained through the City of Calgary's Open Data. Criminal records at the neighbourhood level from 2012-2019 were used to construct a crime indicator variable. Unfortunately, data solely focused on homicide cases was not available, thus we tallied cases that include other forms of violent crimes. We then converted this data to a dummy variable that indicates communities with high criminal activity. Locational variables such as Euclidian distance from the CBD (central business district i.e., Calgary downtown), the nearest urban centres (Activity Centre), the nearest train station as well as major roads have been assigned to each observation.

We generated environmental variables using data from the city's portal, specifically, Land Cover (LC) and Land Use District (LUD) datasets. Analogous to Edmonton's land use datasets, the distinction between these datasets is *de facto* vs *de jure* use of land where LC shows how each parcel of land is currently being (using satellite data and verified by humans) used and LUD tells us how each parcel of land should be used according to bylaws. However, the combination of these two alone does not provide a complete picture of Calgary's open spaces, as some largest parks fall under special bylaws categories or are managed by different jurisdictions. Thus, we needed to combine other sources of land use data such as park site datasets to construct more comprehensive datasets.

Open spaces were again divided into four categories, 1) Urban Green Spaces 2) Natural Areas 3) Blue Spaces 4) Agricultural Land. The detailed process for generating the environmental amenities layer is as follows. We first prepared Natural Area which is composed of LUD's "Urban Nature" and "Habitat" dataset that shows large, urban forests (e.g., Nose Hill Park). We then created a generic green space that contains all the green spaces in Calgary using LUD's "Park, Recreation and Public Education" and "Park Sites". We then remove overlaps between them to make these two types of green spaces mutually exclusive. Blue Spaces include Bow rivers, and protected watersheds. Agricultural lands are extracted LC dataset, but the overlaps UGS and NA have been removed.

Finally, using high-quality canopy data at the dissemination block level, the smallest census division scale, each observation is assigned the tree canopy area of the block where the house is located.

Table 10. Variable Description: Calgary

Calgary: Variable Description

Variable Name	Detailed Description (Unit)	Source
Adjusted House Price	Transaction Price Adjusted to 2017 CAD using Home Price Index	Brookfield Real Property Solutions, CREA (Index)
Housing Attributes:		
lnLivingArea	Living Area (sq. ft)	Brookfield Real Property Solutions
lnLotSize	Lot Size (sq. ft)	
Age	Age of Property at the time of Transaction (years)	
Bathrooms	# of Full Bathroom	
Bedrooms	# of Full Bedroom	
Condition	Dummy Variable Which Takes 1 if Condition is "excellent" or "good", 0 Otherwise	
Basement	Dummy Variable Which Takes 1 if Basement is "finished", 0 Otherwise	
OneStory	Dummy Variable Which Takes 1 if property style is "One Story", 0 Otherwise	
AttachedGarage	Dummy Variable Which Takes 1 if parking type is "Detached Garage", 0 Otherwise	
TwoORMoreParking	Dummy Variable Which Takes 1 if parking count is 2 or more, 0 Otherwise	
Locational:		
lnDistCBD	Distance to Central Business District (m)	City of Calgary's Open Data Portal
lnDistUranCentre	Distance to the Nearest Major Acitivity Centre (m)	City of Calgary's Open Data Portal
lnDistMajorRoad	Distance to Major Roads (m)	City of Calgary's Open Data Portal
lnDistLRT	Distance to the Nearest LRT Station (m)	City of Calgary's Open Data Portal
GoodSchool	Dummy Variable Which Takes 1 if the Nearest Elementary School is Good, 0 Otherwise	Fraser Institute (for Scores), City of Calgary's Open Data Portal (School Location)
Elder	Percentage of Population Aged Over 65	StatCan 2016 Census
LowIncomeRate	Percentage of Household whose Income is Less Than Medium Income After Tax	
HighIncomeRate	Percentage of Household whose Income is More Than $100,000 After Tax	
ImmiRate	Percentage of Immigrants	
EduPostSecRate	Percentage of People with at least Bachelor's Degree	
LabUnempRate	Unemployment Rate	
Homi_1119	Dummy Variable Which Takes 1 if There Were More Than One Recorded Homicide Cases from 2011-2019, 0 Otherwise	City of Calgary's Open Data Portal
Environmental:		
lnDistUGS	Distance to the Nearest Urban Green Space (m)	City of Calgary's Open Data Portal
lnDistNaturalArea	Distance to the Nearest Natural Area (m)	City of Calgary's Open Data Portal
lnDistBlueSpace	Distance to the Nearest Blue Space (m)	City of Calgary's Open Data Portal
lnDistAgriculture	Distance to the Nearest Agriculture (m)	City of Calgary's Open Data Portal
TreeCanopy	Percentage of Tree Canopy at Census Dissemination Block	City of Calgary's Open Data Portal

Table 11. Descriptive Statistics: Calgary

Calgary: Descriptive Statistics by Housing Type and Period
Pre-Pandemic (January 2017 - March 2020)
Post-Pandemic (March 2020 - March 2021)

	SFD		CAR		Total
Variables (Unit)	Pre	Post	Pre	Post	
Adjusted House Price (2017 CAD)	578,701.57	585,168.46	331,183.05	319,745.86	519,086.08
	(224,243.19)	(229,173.10)	(139,415.57)	(137,650.77)	(233,471.09)
Housing Attributes:					
Living Area (ft^2)	1,701.04	1,706.07	1,038.85	1,038.88	1,541.07
	(581.29)	(579.70)	(387.88)	(448.60)	(611.88)
Lot Size (ft^2)	5,628.55	5,216.18			5,721.51
	(15,748.12)	(4,133.52)			(18,813.98)
Age of Property (years)	27.16	29.43	18.27	19.46	25.29
	(21.75)	(22.72)	(16.25)	(15.91)	(21.04)
Bathrooms	1.96	2.01	1.61	1.65	1.88
	(0.69)	(0.69)	(0.56)	(0.57)	(0.68)
Bedrooms	2.94	2.94	2.05	2.08	2.72
	(0.63)	(0.63)	(0.73)	(0.68)	(0.75)
Good Condition (0/1)	0.63	0.52	0.61	0.55	0.61
	(0.48)	(0.50)	(0.49)	(0.50)	(0.49)
Finished Basement (0/1)	0.74	0.78			0.61
	(0.44)	(0.41)			(0.49)
One Story Property (0/1)	0.07	0.07			0.14
	(0.26)	(0.25)			(0.34)
Garage Attached (0/1)	0.50	0.47			0.46
	(0.50)	(0.50)			(0.50)
Multiple Parking Spots (0/1)	0.76	0.76	0.19	0.17	0.62
	(0.43)	(0.43)	(0.39)	(0.38)	(0.49)
Locational:					
Distance to Central Business District (m)	10,926.68	10,767.68	8,080.65	8,348.26	10,226.69
	(4,748.13)	(4,749.14)	(5,929.57)	(5,995.93)	(5,201.72)
Distance to Urban Centre (m)	2,161.75	2,107.82	2,132.79	2,156.94	2,149.41
	(992.80)	(1,003.64)	(1,052.85)	(1,057.59)	(1,009.14)
Distance to Major Roads (m)	301.85	302.90	182.86	178.30	272.99
	(191.30)	(191.15)	(169.43)	(159.03)	(192.89)
Distance to LRT Station (m)	3,386.34	3,329.34	2,505.75	2,502.62	3,166.40
	(2,560.16)	(2,580.25)	(2,560.94)	(2,556.10)	(2,589.51)
Neighbourhood:					
Good School Quality (0/1)	0.54	0.55	0.48	0.48	0.53
	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)
Percentage of Elders	10.82	10.89	11.35	11.16	10.95
	(5.87)	(5.86)	(5.97)	(5.75)	(5.89)
Percentage of Low Income Households	14.87	15.09	20.87	20.81	16.35
	(7.46)	(7.47)	(9.92)	(10.14)	(8.53)
Percentage of High Income Households	45.00	44.59	36.42	36.08	42.87
	(14.03)	(13.89)	(12.81)	(12.71)	(14.21)
Percentage of Immigrants	29.35	29.05	30.14	30.75	29.53
	(11.89)	(11.87)	(11.04)	(11.53)	(11.71)
Percentage of College Educated	35.27	35.28	40.11	39.81	36.44
	(12.13)	(12.31)	(12.36)	(12.01)	(12.37)
Unemployment Rate	9.31	9.34	9.12	9.16	9.27
	(1.62)	(1.62)	(1.65)	(1.69)	(1.63)
High Crime Rate (0/1)	0.16	0.16	0.26	0.27	0.19
	(0.37)	(0.36)	(0.44)	(0.44)	(0.39)
Environmental:					
Distance to Urban Green Space (m)	89.96	90.93	107.52	108.53	94.36
	(67.61)	(77.30)	(88.14)	(82.99)	(74.39)
Distance to Natural Area (m)	548.49	553.12	529.71	522.75	544.25
	(599.13)	(592.94)	(537.75)	(509.33)	(583.44)
Distance to Blue Space (m)	659.03	660.92	619.22	615.43	649.48
	(462.78)	(456.59)	(465.26)	(470.56)	(463.15)
Distance to Agricultural Land (m)	3,326.15	3,418.20	4,663.53	4,524.64	3,656.64
	(2,372.23)	(2,386.85)	(2,974.04)	(2,979.26)	(2,594.30)
Percentage of Tree Canopy	11.92	12.07	10.15	9.52	11.49
	(8.36)	(8.34)	(8.11)	(7.85)	(8.33)
Observations	15,689	2,710	5,187	701	24,287
Proportion to Total Obs. (%)	64.60	11.16	21.36	2.89	
Proportion to Total Type (%)	85.27	14.73	88.09	11.91	

Note: Data are means with standard deviations in parentheses.
(0/1) indicates a dummy variable that takes 1 if true 0 otherwise

4.5 Results

Each following subsection shows the results from respective methods. The section is concluded with a summary of the results. Recall that for all analyses, the dependent variable is logarithmized inflation-adjusted housing price. Explanatory variables of key interests are space variables (Size of Living Areas, Lot Sizes and Distance to) as well as environmental variables (Distances to the nearest Urban Green Space, Natural Area, Blue Space, Agricultural Land respectively and Tree Canopy Area).

4.5.1 Difference-in-Difference

Table 11 and Table 12 report the results from a conventional difference-in-difference approach modeled by TWFE as in eq.(11) from Edmonton and Calgary, respectively.

The top row as indicated by $postCOVID$ which controls treatment period fixed effect that represent for the average price shift for post treatment period group regardless of their treatment status. Note that there are ten distinct treatment group fixed effects differentiated based on a) types of environmental amenities each house has been endowed with (namely UGS, Natural Areas, Blue Spaces, Agriculture, and Tree Canopy) and b) the magnitude of the endowment (prime and subprime endowment measured in proximity to open spaces and intensity of tree canopy). These classifications purport to capture a) heterogeneous ecosystem service values that each type and level of endowment and b) complex the impacts of the Pandemic on the values of each environmental amenity, capitalized in housing prices.

Columns (1) and (5) report the results from the naïve models that do not control for other housing attributes. Columns (2) and (6) report models that control for other attributes but only control for the Prime group fixed effects, and Columns (3) and (7) repeat that only for the Subprime group. Finally, Columns (4) and (8) incorporate both Prime and Subprime groups. Since prime and subprime for open spaces variables are determined by the proximity, prime and subprime groups for open spaces are thus referred as Adjacency and Vicinity for a more intuitive explanation of results.

4.5.1. i) Edmonton

In Table 11, there are some insights from group fixed effect terms. For SFD results in (2) to (4), there are premiums on the proximity to UGS. Column (4), which decomposes this proximity premium into

Adjacency and Vicinity effects indicates that only the Vicinity group bears positive effects on the housing price at a 10% significance level. This aligns with previous research that found distance decay on green premiums (Yoo & Wagner, 2016; Hu et al., 2022). Likewise, the proximity premiums apply to Natural Area. The decomposition from (4) reveals that Adjacency has more weight, accounting for about 5% of the increase in housing values, compared to 4% for the Vicinity group. This suggests that being located near Natural Areas provides more value to houses than UGS. This is consistent with the idea that people are willing to pay more to live close to Natural Areas with greater ecosystem services (e.g., the North Saskatchewan River system is one of the biggest networks of Urban Natural Areas in Canada)[19]. Blue Spaces are only positive for the Vicinity group. Somewhat surprisingly, being in the vicinity, not being adjacent to, Agricultural Lands has discounts, contradicting our hypothesis about NIMBY effects of agricultural activities. For CAR results in (4)-(8), as in SFD, Waterfront CARs have premiums of about 8%. Both types of green spaces have positive impacts on CAR prices, but as shown in (8), only UGS's Vicinity and Natural Area's Adjacency are found to add value to CAR.

The ATT block represents the average change in housing prices for the treatment group that resulted from the lockdown-induced changes in the value of each type of environmental amenity. The results across SFD models (2)-(4), as well as CAR models (6)-(8) demonstrate that almost all ATT terms are not significant, except CAR's Natural Area Adjacency which implies that the lockdown made the prices of CARs faced to Natural Areas about 8% lower.

[19] https://www.edmonton.ca/activities_parks_recreation/parks_rivervalley/river-valley-parks

Table 12. DiD: Edmonton

Edmonton: Difference-in-Difference Result

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	SFD				CAR			
Variables	Naïve	Prime	Subprime	Full	Naïve	Prime	Subprime	Full
Treatment Period Fixed Effect:								
postCOVID	.0116	-.0117	-.0067	-.0054	-.065	-.017	-.0212	-.0212
	(.0213)	(.0116)	(.0117)	(.0116)	(.0663)	(.0319)	(.0369)	(.0373)
Treatment Group Fixed Effect:								
dumyUGS50m	.028***	.0124***		.0076	.0038	.0131		-.0046
	(.0092)	(.0037)		(.0046)	(.0322)	(.0139)		(.0175)
dumyUGS100m	.0167		.0142***	.0092*	.0433		.0299**	.0306*
	(.0107)		(.004)	(.0048)	(.0268)		(.0135)	(.0158)
dumyNA100m	.1196***	.0694***		.048***	.0696	.0928***		.0936***
	(.023)	(.0117)		(.0149)	(.0596)	(.0271)		(.0262)
dumyNA250m	.1006***		.0514***	.0389***	.0304		.0544	-.0044
	(.0183)		(.0073)	(.01)	(.0721)		(.0427)	(.0387)
dumyBlue300m	-.0011	.0102		-.0083	.1106**	.0697**		.0811**
	(.0184)	(.0071)		(.0088)	(.0525)	(.0298)		(.0312)
dumyBlue600m	.0237*		.0112**	.0118**	7.2e-04		.0111	-.0165
	(.014)		(.0056)	(.0059)	(.0537)		(.0381)	(.0393)
dumyAg500m	-.0073	-.013		-.0073	.0491	-.0398*		-.0308
	(.0206)	(.0081)		(.0058)	(.0391)	(.0218)		(.024)
dumyAg1000m	-.0205		-.0249*	-.0229*	-.0023		-.024	-.0076
	(.0288)		(.0135)	(.0132)	(.0503)		(.0314)	(.0346)
TreeCanopyTop10%	.0057	8.5e-04		.0028	-.0805	-.0433		-.0511
	(.0237)	(.0082)		(.0092)	(.0717)	(.0293)		(.0424)
TreeCanopyTop25%	-.0184		-.0029	-.0035	.0343		-.0203	.0026
	(.014)		(.0059)	(.0061)	(.0564)		(.0297)	(.0385)
ATT:								
postCOVID × dumyUGS50m	-.0042	.0021		.0063	.0621	.0309		.0175
	(.0188)	(.0071)		(.0093)	(.0445)	(.0215)		(.0272)
postCOVID × dumyUGS100m	.0126		-4.8e-04	-.0051	-.0054		.0228	.0129
	(.0166)		(.0068)	(.0086)	(.0486)		(.0217)	(.0272)
postCOVID × dumyNA100m	-.0349	.0145		.0159	-.1302*	-.0634***		-.0805*
	(.0326)	(.0173)		(.0209)	(.0707)	(.0242)		(.0441)
postCOVID × dumyNA250m	.0749***		.0113	.0022	.0633		-.0251	.0245
	(.022)		(.0133)	(.018)	(.0671)		(.0267)	(.0373)
postCOVID × dumyBlue300m	.023	.0089		.0157	-.0061	-.0236		-.0393
	(.0229)	(.0101)		(.013)	(.0703)	(.0343)		(.0445)
postCOVID × dumyBlue600m	-.0234		-.0085	-.012	-.0121		-.0091	.0057
	(.017)		(.0072)	(.0074)	(.0521)		(.0302)	(.0362)
postCOVID × dumyAg500m	-.0222	-1.7e-04		-.0017	.0445	.034		.0071
	(.0179)	(.0066)		(.0096)	(.0614)	(.0342)		(.0477)
postCOVID × dumyAg1000m	.0013		.001	.0021	-.0361		.0281	.0234
	(.0152)		(.0064)	(.0089)	(.0551)		(.0211)	(.0321)
postCOVID × TreeCanopyTop10%	-.0279	-.0031		.0102	-5.8e-04	-.0223		.02
	(.0299)	(.0117)		(.0161)	(.0757)	(.0313)		(.0495)
postCOVID × TreeCanopyTop25%	.0073		-.0136	-.0175	-.0685		-.0353	-.0474
	(.0189)		(.0099)	(.013)	(.0681)		(.0295)	(.0438)
Constant	12.92***	8.969***	9.199***	9.199***	11.98***	7.791***	7.358***	7.497***
	(.0085)	(.38)	(.356)	(.3562)	(.0311)	(.7575)	(.7809)	(.7825)
Controls:								
Spatial Fixed Effect	✓	✓	✓	✓	✓	✓	✓	✓
Temporal Fixed Effect	✓	✓	✓	✓	✓	✓	✓	✓
COVID Policy Effect	✓	✓	✓	✓	✓	✓	✓	✓
Housing Attributes		✓	✓	✓		✓	✓	✓
Observations	12142	11928	11928	11928	3914	3913	3913	3913
R^2	0.532	0.842	0.843	0.844	0.433	0.751	0.748	0.752
Adjusted R^2	0.523	0.839	0.840	0.841	0.403	0.738	0.734	0.738
AIC	-1184.9	-14623.4	-14658.5	-14713.5	1863.9	-1350.5	-1304.0	-1348.2
BIC	-970.2	-14350.1	-14377.8	-14358.9	2045.8	-1149.8	-1103.3	-1084.8

Note: Robust standard errors in parentheses are clustered at Census Tract level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Each column represents a separate regression. SFD and CAR refers to Single Family Detached and Condos, Apartments, and Row Houses respectively.
About 10% and 25% of samples belong to Prime and Subprime groups respectively.
Spatial Fixed Effects at Census Tract level.
Temporal Fixed Effects at year as well as quarter level.

4.5.1. ii) Calgary

In Table 12, the group fixed effects across (2)-(4) show that UGS bears premium, but full model (4) shows that such premium is mainly derived from being adjacent to UGS, increasing the SFD price by about 1.2%. Similarly, there is a premium on living close to Natural Areas. The full decomposition from model (4) shows that being adjacent to Natural Areas elevates the house price by about 5%. Thus, comparing two green spaces, Natural Areas is shown to have higher values capitalized into markets, just like Edmonton. These findings are in accord with previous research that has shown that open spaces with higher levels of protection have greater premiums capitalized (Irwin, 2002). As expected, Blue Areas increase the value of waterfront houses by about 2%, which is more than double the effect of the Vicinity group. As in Edmonton's case, no effects were observed for Agricultural Lands. As CAR, (8) shows that similar premiums are on houses adjacent to UGS and Natural Areas, counter to SFD's results. We did not find any premiums associated with Blue Spaces, but rather being in the vicinity of Blue Space reduces the housing values by about 4%. For SFD, being located in neighbourhoods with exceptional tree coverage has a premium for houses in both top decile groups and quantile groups. However, we did not observe this in the CAR sample.

As in the case of Edmonton, ATT terms do not have any significant effects, except for Agriculture Adjacency for CAR. This indicates that the Pandemic made the prices of CAR located within 500m of agricultural lands higher by about 5%.

However, these estimads above may be biased as there are potential violations of assumptions of DiD, mentioned in 2.3.1.iii). Critically, each ATT may conflate other changes in hedonic price functions. For instance, the intensified preference for Agriculture for CAR that we observed above may well reflect the heightened WTP WTPs for remoteness from CBD due to WFH or for larger living areas. Thus, we cannot be confident these results reflect true Pandemic capitalization effects on amenity values.

Table 13. DiD: Calgary

Calgary: Difference-in-Difference Result

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	SFD				CAR			
Variables	Naïve	Prime	Subprime	Full	Naïve	Prime	Subprime	Full
Treatment Period Fixed Effect:								
postCOVID	-.0235	-.0068	-.0062	-.0082	-.0207	-.0019	.0017	.0037
	(.0184)	(.0092)	(.0106)	(.0105)	(.0372)	(.0242)	(.0263)	(.0253)
Treatment Group Fixed Effect:								
dumyUGS50m	.0263***	.0119***		.0122***	.0463*	.0209		.0238*
	(.0061)	(.0027)		(.0028)	(.0267)	(.0135)		(.0143)
dumyUGS100m	.0169***		.012***	2.2e-04	-.0029		.0093	-.0055
	(.0062)		(.0028)	(.0027)	(.0317)		(.0141)	(.0162)
dumyNA100m	.1058***	.0526***		.0493***	.0785***	.0196		.0297*
	(.0173)	(.0094)		(.0092)	(.0293)	(.0151)		(.0165)
dumyNA250m	.0324***		.026***	.0065	-.0651**		-.0118	-.0229
	(.0111)		(.0056)	(.0045)	(.0311)		(.0134)	(.0144)
dumyBlue300m	.0663***	.0236***		.02***	.0263	2.5e-04		.0142
	(.0115)	(.0046)		(.0045)	(.036)	(.0157)		(.0169)
dumyBlue600m	.0233**		.0112***	.007*	-.1148**		-.0378*	-.0417**
	(.0103)		(.0043)	(.004)	(.0524)		(.0203)	(.0198)
dumyAg500m	.0092	.0092*		.0066	.0752	.0116		.0071
	(.0253)	(.0054)		(.0055)	(.0541)	(.0195)		(.0224)
dumyAg1000m	-.0029		.0109	.0089	-.0259		-3.5e-04	7.0e-06
	(.0201)		(.0093)	(.0094)	(.0476)		(.0248)	(.0269)
TreeCanopyTop10%	.0588***	.0301***		.0213***	.0816	.0149		.0324
	(.013)	(.0065)		(.0067)	(.0591)	(.0209)		(.0281)
TreeCanopyTop25%	.0392***		.0253***	.017***	.0425		-.0046	-.0177
	(.0101)		(.0054)	(.0054)	(.0468)		(.0171)	(.0227)
ATT:								
postCOVID × dumyUGS50m	.0082	9.1e-04		-.002	.0241	.0083		.0119
	(.0122)	(.006)		(.0067)	(.0358)	(.0217)		(.0235)
postCOVID × dumyUGS100m	.0034		.0037	.005	.0138		-.0072	-.0088
	(.0122)		(.0058)	(.0066)	(.0295)		(.0206)	(.0211)
postCOVID × dumyNA100m	-.004	-7.9e-04		.001	.0292	.0074		.0033
	(.0153)	(.0081)		(.0094)	(.0473)	(.0396)		(.0381)
postCOVID × dumyNA250m	.0017		-.0023	-.0053	.0174		.0183	.0042
	(.0129)		(.0068)	(.008)	(.035)		(.0204)	(.0202)
postCOVID × dumyBlue300m	.0084	.0145*		.012	.0139	.0141		.0247
	(.0157)	(.0077)		(.009)	(.0372)	(.0209)		(.0238)
postCOVID × dumyBlue600m	.0015		.0099	.0048	.0043		-.0087	-.0187
	(.012)		(.0067)	(.0073)	(.0317)		(.0186)	(.0197)
postCOVID × dumyAg500m	.0261	.0153*		.0101	.0869	.0388**		.0538*
	(.0234)	(.0092)		(.0093)	(.0528)	(.0184)		(.0281)
postCOVID × dumyAg1000m	-.0032		.0064	.0033	-.0428		.0151	-.0037
	(.0119)		(.0062)	(.0062)	(.0408)		(.0248)	(.0288)
postCOVID × TreeCanopyTop10%	.0221	-.0036		.0023	-.0139	.034		-.0056
	(.0226)	(.0107)		(.0127)	(.0817)	(.0288)		(.0483)
postCOVID × TreeCanopyTop25%	-.011		-.0075	-.0068	.0433		.041*	.0401
	(.0142)		(.007)	(.0084)	(.049)		(.0235)	(.0382)
Constant	13.62***	6.953***	7.064***	6.872***	13.28***	8.095***	7.332***	9.71***
	(.0275)	(.7005)	(.7189)	(.7104)	(4.1e-12)	(1.782)	(1.904)	(2.007)
Controls:								
Spatial Fixed Effect	✓	✓	✓	✓	✓	✓	✓	✓
Temporal Fixed Effect	✓	✓	✓	✓	✓	✓	✓	✓
COVID Policy Effect	✓	✓	✓	✓	✓	✓	✓	✓
Housing Attributes		✓	✓	✓		✓	✓	✓
Observations	18399	18148	18148	18148	5888	5887	5887	5887
R^2	0.607	0.873	0.871	0.873	0.403	0.808	0.808	0.809
Adjusted R^2	0.601	0.871	0.869	0.871	0.379	0.800	0.800	0.801
AIC	-3372.7	-24220.7	-23917.1	-24245.3	2665.1	-3996.1	-3995.1	-4016.7
BIC	-3138.0	-23939.7	-23636.0	-23886.2	2865.5	-3775.6	-3774.6	-3729.5

Note: Robust standard errors in parentheses are clustered at Census Tract level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Each column represents a separate regression. SFD and CAR refers to Single Family Detached and Condos, Apartments, and Row Houses respectively.
About 10% and 25% of samples belong to Prime and Subprime groups respectively.
Spatial Fixed Effects at Census Tract level.
Temporal Fixed Effects at year as well as quarter level.

4.5.2 Hedonic Difference Model

Tables 13 and 14 present the results from our preferred model specification eq.(12) that estimates changes in amenity values for Edmonton and Calgary samples, respectively. (1) and (4) do not control for "COVID Period Fixed Effect", shown in the top row. For instance, a negative sign on this term for CAR may indicate disutilities associated with living in shared spaces (e.g., elevators, hallways, laundry etc.) to minimize contact during the outbreaks. Moreover, model (3) also controls for potential heterogeneous Pandemic policy effects (e.g., relaxing COVID restrictions) mentioned earlier.

4.5.2.i) Edmonton

In Table 13, the baseline in SFD results (1)-(3) show that the larger living area, lot size, as well as proximity to CBD, and Natural Area bear significant premiums which align with the DiD results earlier. These findings are also in line with previous hedonic research in Edmonton (Hu et al., 2022). As for CAR, the larger living area, proximity to downtown as well as Blue Spaces are important positive determinates of prices. The COVID Period Fixed Effect on CAR is negative and significant, an indication of people's disutility associated with living in condos and row houses that entail sharing spaces.

However, no significant changes from these baselines were found across all model specifications, except for the increased preference for Living Area for CAR. This result suggests that there is an additional surcharge on having larger living space for CARs in Edmonton after the lockdown. This is in alignment with our intuitions and the news that report higher appreciation for larger spaces. Interestingly, the living areas as well as lot sizes have stayed unchanged for SFD which we don't observe in any other cities. Also, the premiums on Natural Areas have shrunken for CAR.

Table 14. Hedonic Difference: Edmonton.

Edmonton: Hedonic Difference

Variables	(1) SFD Naïve	(2) SFD Base	(3) SFD COVID Policy	(4) CAR Naïve	(5) CAR Base	(6) CAR COVID Policy
postCOVID		.0173	.0155		-1.877**	-1.888**
		(.4367)	(.4379)		(.7509)	(.7613)
Baseline:						
lnLivingArea	.5418***	.5419***	.5418***	.6147***	.6***	.5998***
	(.0308)	(.0307)	(.0307)	(.0767)	(.0782)	(.0782)
lnLotSize	.0749***	.075***	.075***			
	(.0077)	(.0076)	(.0076)			
lnDistCBD	-.1053*	-.1052*	-.1055*	-.0825*	-.0877*	-.0892**
	(.0626)	(.0634)	(.0634)	(.0453)	(.0445)	(.0442)
lnDistUGS	3.5e-07	4.8e-06	2.0e-05	-.0038	-.0046	-.0045
	(.0014)	(.0014)	(.0014)	(.0061)	(.0061)	(.0061)
lnDistNaturalArea	-.0276***	-.0276***	-.0276***	-.0156	-.0161	-.0161
	(.004)	(.004)	(.004)	(.0129)	(.0129)	(.0129)
lnDistBlueSpace	-.0038	-.0037	-.0038	-.0368*	-.0383**	-.0381**
	(.0054)	(.0053)	(.0053)	(.0187)	(.0188)	(.0188)
lnDistAgriculture	.0039	.0039	.0039	.0143	.0122	.012
	(.0034)	(.0033)	(.0033)	(.0096)	(.0094)	(.0093)
TreeCanopy	1.9e-04	1.9e-04	2.0e-04	-.0064	-.0065	-.0065
	(.0012)	(.0012)	(.0012)	(.0045)	(.0045)	(.0045)
Change from Baseline:						
postCOVID × lnLivingArea	-.014	-.0146	-.0132	.072	.2312**	.2328**
	(.0622)	(.0748)	(.0748)	(.0613)	(.1001)	(.1011)
postCOVID × lnLotSize	.0182	.018	.0183			
	(.0158)	(.0153)	(.0153)			
postCOVID × lnDistCBD	.0032	.0024	-3.8e-05	.0098	.0476	.0461
	(.0243)	(.0172)	(.0173)	(.0286)	(.0319)	(.0328)
postCOVID × lnDistUGS	-.0033	-.0033	-.0033	-.0154	-.0063	-.0076
	(.0035)	(.0037)	(.0037)	(.0117)	(.0113)	(.0113)
postCOVID × lnDistNaturalArea	-.0081	-.0081	-.0078	.0192	.027**	.0263*
	(.0068)	(.0065)	(.0065)	(.0146)	(.0135)	(.0135)
postCOVID × lnDistBlueSpace	.0102	.0101	.0099	-.0139	-.0051	-.0045
	(.0078)	(.008)	(.008)	(.0245)	(.0224)	(.0222)
postCOVID × lnDistAgriculture	-.0039	-.004	-.0042	-.0147	-.0058	-.0055
	(.004)	(.0034)	(.0034)	(.0104)	(.0088)	(.0089)
postCOVID × TreeCanopy	-.0014	-.0014	-.0015	-.0065	-.004	-.0042
	(.0016)	(.0016)	(.0016)	(.0072)	(.0074)	(.0075)
Constant	9.9***	9.898***	9.901***	8.057***	8.236***	8.229***
	(.3667)	(.3651)	(.3655)	(.6744)	(.6631)	(.6602)
Controls:						
Spatial Fixed Effect	✓	✓	✓	✓	✓	✓
Temporal Fixed Effect	✓	✓	✓	✓	✓	✓
COVID Period Fixed Effect		✓	✓		✓	✓
COVID Policy Effect			✓			✓
Observations	11928	11928	11928	3913	3913	3913
R^2	0.844	0.844	0.844	0.751	0.752	0.752
Adjusted R^2	0.841	0.841	0.841	0.737	0.738	0.738
AIC	-14693.5	-14691.5	-14690.9	-1321.4	-1333.8	-1334.8
BIC	-14265.0	-14255.7	-14240.3	-1020.3	-1026.4	-1014.9

Note: Robust standard errors in parentheses are clustered at Census Tract level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Each column represents a separate regression. SFD and CAR refers to Single Family Detached and Condos, Apartments, and Row Houses respectively.
Spatial Fixed Effects at Census Tract as well as municipality level.
Temporal Fixed Effects at year as well as quarter level.

4.5.2.ii) Calgary

In Table 14, in SFD results (1)-(3), the baseline coefficients indicate that the larger living area, lot size, as well as proximity to Natural Area and to Blue Area bring premier values on houses, as in Edmonton's case. Interestingly, proximity to Agricultural Land bears significant premiums. This is probably a result of the fact that properties located on the outskirts of cities where agricultural activities occur tend to be more expensive. Like DiD's results, the intensity of Tree Canopy in neighborhood has been linked to superior values on houses located in the neighborhood, which is consistent with the literature (Han et al., 2021). As for CAR, the larger living area and tree canopy are significant factors, but the sign on the tree canopy is the opposite compared to SFD. The non-significance on several amenities is probably due to the fixed effect scale as there is not much variance in some amenities of interest within the census tract and thus effects are subsumed in fixed effects (Abbott & Klaiber, 2011); see Appendix D for the results of regressions with a coarser level of spatial fixed effects.

The changes from the baseline result reveal intriguing insights. For SFD, lot sizes have garnered greater premiums after the lockdown[20]. This increased demand for larger spaces conforms to our expectations, as during lockdowns, many people have realized the benefits of having more space for activities such as gardening while spending more time at home. Research affirms that households with children engage in urban horticulture more frequently post Pandemic (Chenarides et al., 2021). In addition to the elevated premiums on larger lot sizes, no significant changes were observed.

[20] We did not observe similar trends before the Pandemic (c.f. Appendix for pre-existing trend test)

Table 15. Hedonic Difference: Calgary

Calgary: Hedonic Difference

	(1)	(2)	(3)	(4)	(5)	(6)
	SFD			CAR		
Variables	Naïve	Base	COVID Policy	Naïve	Base	COVID Policy
postCOVID		-.372	-.3794		.9836	.9956
		(.2398)	(.2404)		(.833)	(.8403)
Baseline:						
lnLivingArea	.582***	.5799***	.5799***	.6268***	.6344***	.6344***
	(.0194)	(.0195)	(.0195)	(.0531)	(.05)	(.0499)
lnLotSize	.1519***	.1512***	.1513***			
	(.015)	(.015)	(.015)			
lnDistCBD	-.0493	-.0518	-.051	-.0634	-.0589	-.0599
	(.0467)	(.047)	(.047)	(.0724)	(.0726)	(.0727)
lnDistUGS	-.001	-.0011	-.0011	-.0037	-.0037	-.0037
	(8.7e-04)	(8.6e-04)	(8.6e-04)	(.0037)	(.0038)	(.0038)
lnDistNaturalArea	-.0134***	-.0135***	-.0135***	-.0032	-.003	-.003
	(.0038)	(.0038)	(.0038)	(.0042)	(.0042)	(.0042)
lnDistBlueSpace	-.0289***	-.0292***	-.0292***	7.8e-04	.0013	.0012
	(.0045)	(.0046)	(.0046)	(.0097)	(.0097)	(.0097)
lnDistAgriculture	-.003	-.0033*	-.0033*	.0026	.0074	.0074
	(.0019)	(.0019)	(.0019)	(.0108)	(.0111)	(.0111)
TreeCanopy	.0019***	.0019***	.0019***	-.0028*	-.0028*	-.0028*
	(3.8e-04)	(3.8e-04)	(3.8e-04)	(.0015)	(.0015)	(.0015)
Change from Baseline:						
postCOVID × lnLivingArea	.0064	.0216	.0215	-.0555	-.114	-.1119
	(.0229)	(.0243)	(.0242)	(.08)	(.1174)	(.119)
postCOVID × lnLotSize	.0494*	.055*	.0549*			
	(.0265)	(.0282)	(.028)			
postCOVID × lnDistCBD	-.0131	4.1e-04	.001	.0011	-.0352	-.0368
	(.0104)	(.0117)	(.0118)	(.0346)	(.0228)	(.0231)
postCOVID × lnDistUGS	-9.3e-04	-6.2e-04	-6.7e-04	.0048	.0039	.0032
	(.0017)	(.0017)	(.0017)	(.0046)	(.0049)	(.005)
postCOVID × lnDistNaturalArea	-5.3e-04	5.3e-04	4.6e-04	-.0033	-.0038	-.0033
	(.0032)	(.0033)	(.0033)	(.0057)	(.006)	(.006)
postCOVID × lnDistBlueSpace	-.0077	-.0053	-.0053	-.0025	-.0075	-.0078
	(.0048)	(.0047)	(.0047)	(.0115)	(.0114)	(.0113)
postCOVID × lnDistAgriculture	-.0048**	-.0037**	-.0037**	.005	-.0034	-.0027
	(.0021)	(.0018)	(.0018)	(.013)	(.0121)	(.0119)
postCOVID × TreeCanopy	-3.4e-04	-2.5e-04	-2.2e-04	3.8e-04	3.5e-04	3.0e-04
	(6.0e-04)	(6.0e-04)	(5.9e-04)	(.0014)	(.0014)	(.0014)
Constant	6.887***	6.962***	6.954***	7.659***	8.873***	8.826***
	(.6881)	(.6949)	(.6948)	(2.6)	(2.833)	(2.826)
Controls:						
Spatial Fixed Effect	✓	✓	✓	✓	✓	✓
Temporal Fixed Effect	✓	✓	✓	✓	✓	✓
COVID Period Fixed Effect		✓	✓		✓	✓
COVID Policy Effect			✓			✓
Observations	18148	18148	18148	5887	5887	5887
R^2	0.874	0.874	0.874	0.809	0.810	0.810
Adjusted R^2	0.872	0.872	0.872	0.801	0.801	0.801
AIC	-24328.5	-24331.4	-24329.7	-4012.0	-4013.6	-4015.3
BIC	-23899.2	-23894.2	-23869.1	-3684.7	-3666.2	-3661.3

Note: Robust standard errors in parentheses are clustered at Census Tract level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Each column represents a separate regression. SFD and CAR refers to Single Family Detached and Condos, Apartments, and Row Houses respectively.
Spatial Fixed Effects at Census Tract as well as municipality level.
Temporal Fixed Effects at year as well as quarter level.

4.5.3 Summary of Results

Finally, we summarize the results from each method for each city respectively in Table 15. We briefly compare and discuss each city's results below.

Table 16. Summary of Impact: A Comparison across Methods and City

Edmonton and Calgary: Summary of Impact:
How Much Has WTP Changed?

	Edmonton				Calgary			
	SFD		CAR		SFD		CAR	
	DiD	HD	DiD	HD	DiD	HD	DiD	HD
Space Attributes:								
Living Area (ft^2)	-[1]		-	\$61.41	-		-	
Lot Size (ft^2)	-		-		-	\$6.21	-	
Distance to CBD (m)	-		-		-		-	
Environmental Amenities:								
Distance to UGS (m)								
Distance to Natural Areas (m)			-\$316.11[2]					
Distance to Blue Space (m)								
Distance to Agriculture (m)							\$24.46[3]	
Tree Canopy (%)								

Note: Each column represents welfare measures calculated using the estimads from corresponding method respectively. Only results with significance are presented. SFD and CAR refer to Single Family Detached and Condos, Apartments, and Row Houses respectively.
Each number represents ***change*** in WTPs for respective amenity.
DiD: $[\exp(\pi_j - \frac{1}{2}(\pi_j)) - 1] \cdot \bar{p} \cdot TREAT_j \cdot 1/distance$
HD: β_g^*
[1] - indicates the model assumes this to be constant across pre/post Pandemic periods
[2] Calculated by DiD measures divided by $100m$
[3] Calculated by DiD measures divided by $500m$

Additionally, the robustness checks are provided in Appendix D. Particularly, the pre-existing trend test shows the appreciation in WTP for larger space was not observed in Calgary's SFD prior to the Pandemic year, but there was appreciation in WTP for larger space in Edmonton's CAR's.

4.5.3. i) Comparison of DiD

To summarize the Pandemic capitalization estimated via DiD from both cities, no significant effects were confirmed across all the treatment effects for SFD. For CAR, the price of houses adjacent to Natural Areas has declined in Edmonton, but no such effect was observed for Calgary. On the other hand, the value of CARs which are located adjacent to Agricultural Land has appreciated in Calgary, but not in Edmonton. However, all these effects are barely significant. The insignificance on treatment effects mirrors similar studies that also investigated the Pandemic capitalization effects on environmental amenity values using DiD such as (Cheung & Fernandez, 2021; Irwin & Livy, 2021).

4.5.3. ii) Comparison of HD

The results from HD of Edmonton and Calgary are contrasted. For both Edmonton and Calgary, the environmental amenities values did not experience any changes. These results combined weakly support TCGA or the WTP for environmental amenities have stayed relatively stable across pre/post Pandemic periods. This is at odds with numerous testimonials of higher appreciation toward nature during the lockdowns from the surveys such as (Eykelbosh & Chow, 2022). However, the values of living area and lot have appreciated for Edmonton's CAR and Calgary's SFD, respectively. These results demonstrate that people are willing to pay more for larger dwelling spaces after the lockdowns.

Because there are numerous reasons why price gradients shift besides the Pandemic induced preference shocks (e.g., changes in distributions of demography, income, and amenities), this discrepancy in findings across cities thus could be attributed to numerous differences in changes experienced by two cities. As Kuminoff and Pope (2014) have noted, determining the contribution of each factor to the results will require solving a demand system for lot sizes and other amenities; we leave this task to future research.

4.6 Concluding Remarks

This research investigated and compared how the Pandemic has impacted the revealed values of housing sizes and environmental amenities in the case of Edmonton and Calgary, two major Alberta cities under the influence of homogenous Pandemic policies. Overall, the impacts were homogeneous in a way that we did not find any significant changes in environmental amenity value in both cities from the Pandemic. However, our result also showed some discrepancies between two very similar cities. Particularly, in Calgary, people are willing to pay more for SFD houses with larger lots – a trend that we did not observe until the Pandemic unfolded.

Our findings have several implications that are specifically relevant to Edmonton and Calgary. Particularly, the magnified preference for larger spaces in Calgary could appreciate large lot houses within its city border. Coupled with the trend of WFH, this could hint at a potential increase in urban flight to neighboring municipalities in search of houses with similar lot sizes with cheaper price tags, deteriorating urban sprawl in surrounding Calgary areas (Han, 2019). Therefore, our research will inform post Pandemic regional urban planning to address changing demands for dwelling spaces while protecting prime agricultural lands that surround the regions.

Our results also underscore the importance of being attentive to the complex and potentially heterogeneous impacts of the Pandemic across different geographical regions. Even for similar cities under the homogenous Pandemic policies, the impacts of the Pandemic on amenity values vary across different types of environmental amenities and different housing styles. These differences may be attributed to numerous underlying market structural factors such as consumer characteristics, the local economy, and the endowment of environmental amenities. More generally, our research demonstrated that the results from hedonic studies conducted in seemingly similar cities and time periods may not be easily transferable to inform and support policies in other areas. This highlights the need to consider the unique context of each region when designing and implementing policies (Klaiber & Phaneuf, 2010).

Chapter 5 Conclusion

5.1 Thesis Overview

Following the onset of COVID-19 Pandemic, it has been widely reported that the related health measures such as lockdowns and work-from-home (WFH) have significantly changed people's preferences for environmental amenities and housing styles, adding complexity to urban planning challenges, particularly rapidly growing Western Canadian Metropolitan areas including Metro Vancouver, Edmonton and Calgary. To empirically verify these highly publicized anecdotes and provide a timely analysis that underpins evidence-based policymaking, this thesis studies shifts in the values of open spaces and housing attributes post-Pandemic using a hedonic model to data from Western Canadian Metropolitan areas. Chapter 2 presents the results of the Metro Vancouver case, while Chapter 3 presents a comparative analysis between Edmonton and Calgary.

5.2 Summary of Findings

The concerns about using DiD approach that the previous literatures have used to estimate the effects of the Pandemic on amenity values necessitated implementing an alternative specification. The comparison between the results obtained from the DiD method and our preferred model reveals a striking discrepancy in the changes in amenity values. Our preferred method's findings suggest that there are significant variations in estimated changes in amenity values across different types of amenities, housing styles, and regions. Overall, compared to pre-Pandemic periods, the value of dwelling space has appreciated across all study regions and housing styles studied. This indicates that people have come to value larger dwelling space more after experiencing confinement during the lockdowns and facing the need to accommodate all daily activities within their houses. However, we did not find any changes in willingness-to-pay (WTP) for proximity to the central business district (CBD) in any of the study regions. This finding counters with widely publicized anecdotes and earlier Urban Economics studies that found the WFH diminished amenity values associated with living near CBD (Van Nieuwerburgh, 2022; van Vuuren, 2022).

In Metro Vancouver, the amenity values of Blue Spaces and tree canopy have increased after the Pandemic. This implies that houses with superior environmental endowments have become more costly post-Pandemic. Our findings were reinforced by various robustness checks. Additionally, we found that these intensified green premiums were much larger for houses falling within the bottom 25% of the housing price range. In contrast, there were no significant changes in the values of environmental amenities in Edmonton and Calgary,

5.3 Limitation

There are several limitations that must be considered when interpreting our findings. One limitation is the short time frame of our data, which only covers the first year of the Pandemic (until March 2021). This means that we only capture the immediate shocks ensued by the COVID-19 outbreaks, and not any longer-term changes. Whether these preference changes we have observed will persist over the longer term or return to the pre-Pandemic levels is still unclear and is a critical question for future research to investigate.

It is also important to note that our data on environmental amenities only reflects their state at a specific point in the past (e.g., for Tree coverage data in Metro Vancouver is from 2014). Although geographical topologies and tree canopy do not typically change significantly over short periods, some areas might have experienced unobservable changes in amenity levels that were not captured by our data. Any amenity shocks that potentially occurred after 2014 may result in measurement error, leading to the attenuation bias which translates into the underestimations of changes in amenity values (Greene, 2003; Lemieux, 2012). While we cannot quantify the degree of this bias, we do note that for tree canopy at least, Metro Vancouver has not suffered any major tree infestations, unlike Toronto as noted in Han et al. (2021). Furthermore, our categorization of open spaces can be further divided, for instance, Blue Spaces, which is a broad term encompassing a wide range of aquatic environments such as beaches and rivers. Although this classification is designed to function effectively across different jurisdictions with varying data availability and categorizations of open spaces, it is important to acknowledge that oceans and rivers may bear different amenity values (Anderson & West, 2006). Thus, future research should undertake a more detailed decomposition to accurately capture these differences.

The limitation related to the empirical strategies used in this study should also be acknowledged. One potential source of model misspecification is, inter alia, spatial autocorrelation which is often observed in the case of housing transaction data as house prices are influenced by the values of neighbouring observations (LeSage & Pace, 2009). While we have accounted for spatial autocorrelation by clustering the standard errors at the neighbourhood levels following the guideline by Bishop et al. (2020), a more effective approach to handling this issue is discussed in Hu et al. (2022). Additionally, the presence of the minimum lot size requirement, just as in the case for Metro Vancouver, could also result in model misspecification. Banzhaf and Mangum (2019) have empirically demonstrated that the failure to account for the effect of land regulation leads to an underestimation of the WTP for housing amenities among houses with fewer amenities, such as smaller houses. This implies that our model may have underestimated the impacts of COVID-19 on cheaper houses, compared to what we have reported.

Overall, the limitations discussed above suggest that our results may be underestimated, rather than inflated. Therefore, our results should be considered as a lower bound on the changes in amenity values after the Pandemic.

5.4 Implication and Conclusion

Since the outbreak of COVID-19, researchers have assessed the Pandemic's effects in various fields. To make a marginal contribution to this ongoing endeavor from the field of Environmental Economics, this thesis examined the unintended consequence of the Pandemic on revealed values for housing attributes and environmental amenities, as outlined in the research agenda for this discipline (Ashworth et al., 2022).

This research provides urban planners and property developers with novel and insightful empirical evidence on the Pandemic-induced preference changes across three regions, which can inform urban planning in the Pandemic era. Specifically, with the increased demand for dwelling space and the resulting rise in housing prices, urban planners may need to consider promoting densification in Metro Vancouver. One approach to achieving densification could involve easing floor area density regulations or promoting mixed land use, which could help alleviate the housing supply crisis by enabling developers to construct more housing units within geographically and regulatory constrained areas. Furthermore, in the metropolitan areas of Alberta, augmenting the supply of housing within urban regions to address population growth and elevated demand for personal spaces could discourage urban sprawl and deter migration from urban centers, consequently mitigating the fragmentation and conversion of neighboring agricultural lands. Revenue generated from taxation on these land use developments could contribute to maintaining and creating open spaces throughout cities while also serving as an investment for future natural disaster preparedness. This would help ensure that communities are better equipped to handle crises like natural disasters and other challenges such as the next Pandemic.

Additionally, our research revealed the ramification of preference shifts on green equity and environmental justice. Specifically, we found only affordable houses in treed neighbourhoods become more expensive compared to the pre-Pandemic era, exacerbating the affordability of access to urban vegetation for those who may already have limited environmental amenities and often bear disproportionate costs of climate change. This calls policymakers to be alert to the special needs of those for whom the impacts of the Pandemic on environmental inequity is the last straw in an already heavy burden of disproportionate impacts of the COVID policies on various socio-economic outcomes (Statistics Canada, 2021).

Our research provides several insights for future research. Firstly, it highlights the implications for the distributional aspect of benefit and cost analysis of COVID-19 measures, such as studies by Thunström et al. (2020). Our study indicates the costs of the lockdown were potentially regressive in the sense that it has potentially added disproportionate costs on access to urban vegetation post Pandemic. A holistic assessment of the impact of the Pandemic should not ignore the unintended yet considerable effects of preference changes and their potential impacts on green equity.

Moreover, in order to better understand the impacts of lockdowns on amenity values, future research could explore the underlying mechanism behind our results. For instance, understanding the interactions between different housing markets may explain why a decrease in premium in proximity to CBD was not observed across all the regions. An outflow of consumers to more rural housing markets, such as the reported "exodus" from Metro Vancouver to the Abbotsford region, could be a factor. Another avenue for research is to study the reason for inconclusive results on changes in the values of environmental amenities, especially urban parks. One possible explanation is habituation, or the fact that people who already have easy access to amenities may not have experienced a change in their perceptions during the Pandemic, and those who have limited access did not have enough interactions with the nature to change their perceptions. A study has found the proportion of park visits by the repeated users who reside close to parks has increased after the Pandemic (Kim et al., 2023).

Also, it would be interesting to test the convergent validity with other ecosystem evaluation methods that also examine the Pandemic's impacts on the values of environmental amenities, such as stated preference and other revealed preference methods. For example, using travel costs models, Landry et al. (2021) found the Pandemic had negative effects on both trips and the quality of outdoor recreational visits.

In conclusion, we have demonstrated the considerable discrepancies between pre/post Pandemic hedonic functions, at least in the context of Western Canada. Researchers thus should be mindful of a potential hedonic equilibrium shift after 2020, especially when they are handling samples that span across pre- and post-Pandemic periods, although the effects of the Pandemic may be short-lived. A more long-lasting and broader implication of this thesis on the Pandemic is the need for more contextual approaches in hedonics research to study the dynamic relationship between housing prices and shocks to the housing market that alter its underlying characteristics, such as policy interventions. Such an approach will lead to a clearer evaluation of policy interventions and more well-informed policy frameworks for years to come.

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Appendix A

A.1 Supplementary Resources on the Histories of Urban Parks in Response to Epidemics

Historically, the configuration of urban nature has evolved with epidemics (Cranz, 1982; Crompton, 2013; Jones, 2018). For example, during cholera and yellow fever outbreaks in New York City in the 1850's, Frederick Law Olmsted[21], a key figure in establishing Central Park, believed that public parks could alleviate negative health outcomes, as parks can function as "lungs of the city" (Fisher, 2010; Eisenman, 2013; Xing & Brimblecombe, 2020). In fact, researchers postulate that diseases promoted the concept of the "proximate principle" which refers to the price premiums for houses located close to urban green spaces (Crompton, 2013). Therefore, while COVID-19 is a novel disease, the connection between epidemics and green spaces is not new, as green spaces have always been deemed as nature-based solutions to plague well before 2020.

Furthermore, Olmstead strongly believed in the "communicativeness" of parks and the importance of equal access to green spaces, especially for those who cannot afford to pay the house price premiums with the proximate principle (Olmsted Jr & Kimball, 1970; Blodgett, 1976; Kalfus, 1990; Beveridge & Rocheleau, 1995). He believed that public parks were intended to "furnish healthful recreation for the poor and the rich, the young and the old, the vicious and the virtuous "(Martin, 2011).

Moreover, Olmsted had a significant impact on shaping the landscape of Canadian metropolitan areas. Frederick Todd, also known as "Canada's first landscape architect," trained under Olmstead and was involved in critical projects that shaped modern Canadian cities, including the Mont Royal project in Montreal (Gordon, 2002; Pollock-Ellwand, 2019). Todd also played a vital role in planning Alberta provincial legislature grounds in Edmonton and Edmonton's North Saskatchewan River Ravine system, where a lookout named after him is erected (Bower, 2015; Pollock-Ellwand, 2019).

In summary, although our research is broadly categorized as an endeavor by environmental economists to evaluate the pandemic's repercussions on the environment, our research is also pertinent to urban planners, historians, and public health professionals. Will we witness a resurgence of the "proximate principle" in the 21st century?

A.2 A Brief Historical Overview of Urban Planning and Development in Metro Vancouver

Collective regional planning has a long history dating back to 1886 when the Vancouver and Capitulum Waterworks was founded (Metro Vancouver, n.d.). Since then, provincial and local government bodies have made numerous incremental changes to the regional framework to promote coordinated municipal actions (Taylor et al., 2014).

The template for institutional collaboration was born when sewer and water districts were established in 1913 and 1924 (Taylor et al., 2014). Partially motivated by the 1948 Fraser River flood that illuminated the need for coordinated regional response, the Lower Mainland Regional Planning Board (LMRPB) was formed in 1949 (Taylor, 2019). LMRPB's task was to generate a board regional plan to which municipal plans had to abide. Its Official Regional Plan was adopted in 1966.

Their vision was primarily driven by economic reasons, specifically provisioning fiscally sound infrastructure and protecting economic and food security through agriculture (Cameron & Harcourt, 2009;

[21] Olmstead lost one his children due to cholera (Olmsted, 2015)

Taylor, 2019). As an illustration, the 1966 plan already specified areas where development uses were permitted (Taylor et al., 2014). Interestingly, the board is thought to be the first public entity to use the term "urban sprawl" (Taylor, 2019).

In 1967, LMRPB was divided into four regional districts, one of which is Greater Vancouver Regional District (GVRD), partially fueled by the need to collectively address rising environmental problems as a region (Taylor, 2019). Since then, as "*a multi-purpose entity that combined infrastructure planning and operations with regulatory land-use planning*" and a "*cooperative policy-making and service delivery entity designated by provincial legislation*", GVRD has successfully forged common regional development visions, which gained accolades as a model for collaborative reginal planning (Tomlinson & Spiller, 2018). Among its plans are the 1975 "Livable Region 1976/1986", which was later consolidated into the revised version of Official Regional Plan 1980's. In 1996, after some disruptions when all the regional planning bodies and existing plans were abolished by the Social Credit government, "*Livable Region Strategic Plan, 1996-2011*" was adopted. Metro Vancouver, whose name has been modified from GVRD in 2007, revised the 1996 plan and developed Metro 2040 in 2011.

Although most of Metro 2050 is consistent with Metro 2040, there are some differences relevant to this research[22]. First, the revised plan places a greater emphasis on transit-oriented development, including establishment of Major Transit Growth Corridors. Second, the revised plan sets more ambitious climate change related targets and policies, including augmenting green infrastructures as mentioned in *Regional Greenway 2050* plan, upgrading protection targets (50% of lands for nature and 40% of tree canopy coverage in urban areas) from its 2040 base targets (40 % and 32% respectively) (Metro Vancouver, 2022).

The Agricultural Land Reserve (ALR) is a province-wide farmland protection policy and one of Canada's earliest agricultural land preservation policies instrumented through land use designation: it was introduced in 1973 as a response to rapid farm land conversion (Nixon & Newman, 2016). Since its inception, 4.7 million hectares of agricultural lands in the whole of British Columbia and 60,893 hectares in the Metro Vancouver region have been preserved (Nixon & Newman, 2016; Frank & Bigazzi, 2019). However, ALR lands are under continuous threat of conversion to development uses to accommodate the growing population (Condon et al., 2010). While the public support for ALR remains high, some advocate the need for reinforcing the ALR to better protect agricultural lands, while others call for drastic weakening of restraints to ameliorate the housing crisis in the region (Katz, 2009; Eagle et al., 2014; Nixon & Newman, 2016).

Building upon ALR, Metro Vancouver established the Green Zone in 1996, which covers approximately 210,000 hectares and includes ecologically important areas in addition to the ALR (Taylor et al., 2014). Metro Vancouver 2040 plan replaced the Green Zone with three non-urban designations (namely Conservation & Recreation, Agriculture, and Rural) that define boundaries within which future development cannot take place (Taylor et al., 2014; Frank & Bigazzi, 2019).

A.3 A Brief Historical Overview of Urban Planning and Development in Edmonton and Calgary, Alberta

Both Edmonton and Calgary, as well as the corridor area between these two regions, are situated on some of the most highly suitable lands for agriculture in the province of Alberta (Stan & Sanchez-Azofeifa, 2017). The high suitability can be attributed to rainfall, temperatures, and soil quality (Anderson &

[22] Other notable changes include integration of Transport 2050, greater emphasis on climate change, social equity, housing affordability, utilization of industrial lands for other uses such as residential. Setting standard of proportion of affordable housing built.

Cerkowniak, 2010; Kristensen, 2018). The soil is categorized as Black Chernozemic, mostly of glaciolacustrine origin, and is considered as the most fertile soils of the Canadian prairie, with fresher minerals, higher organic matter, greater nutrient content and better structure (Gameda & Dumanski, 1995; Ross et al., 2009; Anderson & Cerkowniak, 2010; Government of Alberta, n.d.-b).

One contrasting feature between the two regions is their development strategy (Taylor et al., 2014; Qiu et al., 2022). Before comparing the plans of each region, the following section provides a review of the historical evolution of provincial land-use policies, as they have critically shaped both regions' urban development and ultimately caused environmental problems.

Prior to the enactment of Municipal Government Act of 1994, the Alberta provincial government played an active role in urban planning through legislation and regulations. One example is the establishment of Provincial Planning Advisory Board and District Planning Commissions which were renamed as Regional Planning Commissions (RPC) in 1950. RPCs were provincial-municipal authoritative regional planning bodies tasked to conduct research and create regional plans. Notably, the areas surrounding Edmonton and Calgary were subjugated to RPCs to which the province delegated sub-division approval authority, granting the Cities of Edmonton and Calgary control over the development pattern beyond their boundaries (Taylor et al., 2014). Subsequently, the Planning Act of 1963, which was amended in 1977, retained more power to the province over land uses by requiring municipalities to conform to RCP's regional plans (Alberta Land Institute, 2014).

However, those commissions as well as regional plans were abolished when the Municipal Government Act (MGA) became the law in 1995 as part of a series of economic liberalization policies (Benoit et al., 2018). The MGA thus transferred the responsibility for land-use planning to municipal governments (Beckie et al., 2013; Taylor et al., 2014; Benoit et al., 2018). Despite this, the provincial government attempted to maintain control over regional planning by establishing Land Use Polices in 1996. This basically served as a guideline for municipal planning by aligning local initiatives with provincial directions (Alberta Land Institute, 2014). However, while the municipalities are expected to incorporate directives outlined in the policies, including the need to limit fragmentation of agricultural lands, there was "*no mechanism for the province to assess, let alone enforce, municipal compliance*" (Alberta Land Institute, 2014; Taylor et al., 2014).

Pressured to better manage agricultural lands, in 2008 the province developed a policy document called the Land Use Framework (LUF) which was enabled by the Alberta Land Stewardship Act (ALSA) in 2009 (Benoit et al., 2018). Among six other strategies, including schemes for preserving agricultural lands, one strategy of the Land Use Framework is the development of regional plans for seven large watershed-based regions (Taylor et al., 2014; Alberta Land Institute, 2017). Once approved by the provincial government Cabinet, the plan becomes binding to municipal planning, including South Saskatchewan and North Saskatchewan regions where Calgary and Edmonton are respectively located. As of 2022, only two plans have been formally adopted and become legally binding including the South Saskatchewan Regional plan enacted in 2014 and amended in 2017 and 2018 (Government of Alberta, n.d.-a).

In 2017, the MGA was amended (often referred as modernized MGA) to establish growth management boards in respective regions to facilitate inter-municipal collaboration, effectively replacing previous regional frameworks with the Calgary Metropolitan Regional Board and Edmonton Metropolitan Region Board in 2017 (Adebayo, 2022).

A.3.a Comparison of Development Strategies in Edmonton and Calgary in 2010 to 2020

The subsequent section compares the development strategies that have been adopted by Edmonton and Calgary. Our contribution is to update the existing literature by documenting the changes in strategies that have occurred up to the present date. Table A.1 summarizes all of the information into one.

In summary, the main difference between the two regions is that Calgary has adopted high-intensity development strategies since 2010, while Edmonton has long favored low-density development strategies. However, before 2010, both cities expanded their boundaries by annexing and developing neighboring peri-urban lands, resulting in serious urban sprawl and the fragmentation/conversion of farmlands. This was made possible largely due to the absence of policy/physical constraints and provincial support, including the aforementioned RPC (Agrawal et al., 2022).

Calgary is known for its robust regional planning and was the first city to pass a statutory municipal plan in western Canada in 1963, which has since been comprehensively revised numerous times (Taylor et al., 2014). Until 2009, the city growth plans had championed outward expansion to exurban areas. The Calgary Municipal Development Plan (MDP) adopted in 2009 took a drastic turn in direction by encouraging more dense and confined growth patterns. The plan even identifies compact growth as one of overarching goals. The plan even identifies compact growth as one of its overarching goals. Specifically, the plan includes density requirements for new developments and goals for intensification to accommodate future population growth. Similarly, the Calgary Metropolitan Region Board (CMRB), formerly known as the Calgary Regional Partnership, set the overall intensification target for all member municipalities to aim at in their 2012 plan, the "Calgary Metropolitan Plan.". In August 2022, the CMRB revised its 2012 plan and adopted a new Calgary Metropolitan Region Growth Plan which sets detailed densification targets. The CMRB further enunciates its commitment to a compact growth by setting *"policies that address the intensification of existing settlement areas*" and "*concrete actions to be taken by each member to implement the regional plan*" as the minimum content for Growth Plan. Between 2001-2011, the regional growth management strategies were found effective in intensifying growth within the City of Calgary, especially near the light rail transit stations, making Calgary the most densifying city in Canada (Han, 2019). However, as shown earlier, urban sprawl remain to be a growth challenge for the region, necessitating a better regional development management scheme (Taylor et al., 2014; Han, 2019). On top of that, the latest CMRB's plan notes potential Pandemic impacts on the momentum for densification, as demands for single family detached with larger living areas have reportedly intensified (Calgary Metropolitan Region Board, 2022).

Like Calgary, Edmonton's urban development pattern has been categorically outward-suburban expansion oriented. Competition for industrial and residential growth has been the source of conflicts between neighbouring municipalities (Taylor et al., 2014). These inter-municipal conflicts ultimately resulted in the establishment of Capital Regional Board (known as EMRB today) with compulsory membership in 2008 (Taylor et al., 2014). The board has adopted its plan "Growing Forward" in 2009, which designates "priority growth areas" where most of the growth is to occur. However, unlike plans in Calgary, it does not mention fragmentation/conversion of agricultural lands nor the word "compact". The City developed its growth plan "The Way We Grow" in 2010, which encourages densification. especially in downtown areas, but its means and goals were unspecified (Taylor et al., 2014). Edmonton has finally incorporated concrete intensification policies when EMRB updated its growth plan called "Re-imagine" in 2016 and which was revised in 2020. This plan and the latest City of Edmonton's plan "Growth Plan" took a drastic shift in their development approach as both plans aim for compact growth with specific key performance indicators and goals.

Table A.1 Comparison of Growth Strategy between Edmonton and Calgary 2010 – 2021

Jurisdiction	Year Adopted	Plan's Title	Authored by	Key Guiding Principle regarding Land Use	Future Population Growth is to be Absorbed by (Urban Expansion/Intensification Policy)	KPIs for Growth Policies	Is The Word "Compact" Mentioned in the Context of Development? (instances if yes)	Does it Mention Conversion/Fragmentation with regards to Agriculture? (policy statement if yes)	Source
Edmonton									
Regional	2009	Growing Forward	Capital Region Board (CRB)	Protect the environment and Resources and Minimize Regional Footprint	Identifying priority growth areas	Not explicitly mentioned	No only appear as alternative growth scenario	No	https://canadacommons-ca.login.ezproxy.library.ualberta.ca/artifacts/1221147/growing-forward/1774224/
	2021	Edmonton Metropolitan Region Growth Plan (almost identical as Re-imagine (CRB,2016)	Edmonton Metropolitan Regional Board (EMRB)	Achieve compact growth that optimizes infrastructure investment.	Establishing a compact and contiguous development pattern	6 KPIs for Land Use including Intensification target (% of new dwelling units approved in the Built-Up Urban Area)	Yes (compact growth, communities, city core, land use pattern)	Yes (Agricultural viability requires conserving prime agricultural lands for farmland, limiting fragmentation and conversion of the agricultural land base to non-agricultural uses, and fostering growth and diversification through value added productions within the agricultural sector and supportive infrastructure investments.)	https://www.emrb.ca/growth-plan
Municipal	2010	The Way We Grow	City of Edmonton	Sustainability (The Way Ahead: City of Edmonton Strategic Plan 2009-2018) Sustainable Urban Form	An effective development by encouraging 25 % of city-wide housing unit growth to locate in the Downtown and mature neighbourhoods plus completing developing and urban growth areas	Not explicitly mentioned	Yes but mainly mentioned in context of transportation (compact living, compact and transit-oriented)	Yes (3.2.1.6 Prevent premature fragmentation of agricultural lands in the urban growth areas prior to urban expansion.)	https://www.edmonton.ca/public-files/assets/document?path=PDF/MDP_Bylaw_15100.pdf
	2020	The City Plan	City of Edmonton	One of strategic goals is urban form but the plan does not explain what this constitutes	Through the compact development of new and existing neighbourhoods.	Targets of Rebuildable City are 50% of new units added through infill and 600,000 additional residents will be welcomed into the redeveloping area, measures include infill growth, housing growth.	Yes (compact city building, urban form)	Yes (5.3.1.4 Prevent premature fragmentation and conversion of agricultural lands for residential and non-residential uses.)	https://www.edmonton.ca/city_government/city_vision_and_strategic_plan/city-plan
Calgary									
Regional	2014	Calgary Metropolitan Plan	Calgary Regional Partnership (CRP)	Accommodating growth in more compact settlement patterns.	Compact and contiguous development form in priority growth areas, Intensification of existing developed areas to accommodate at least 25%, minimum density etc.	Not explicitly mentioned	Yes (Compact settlement patterns, urban footprint)	Yes (3.c.1 Sustain agricultural lands. Member municipalities will minimize the fragmentation and conversion of better agricultural lands to other land uses.)	https://prism.ucalgary.ca/bitstream/handle/1880/107153/Calgary_Metropolitan_Plan.pdf?sequence=1&isAllowed=y
	2021	Growth Plan	Calgary Metropolitan Regional Board (CMRB)	Encourage efficient growth and strong and sustainable communities.	Designated place types esp. preferred place types (Infill and Redevelopment) where proportion of new planned dwellings are set to be built (e.g., Calgary 90%)	Not explicitly mentioned, to be established.	Yes (development of compact, walkable communities)	Yes (3.1.1.3 All statutory plans shall contain policies that identify and address the following related to agricultural land: (a) impacts of future development on agricultural land, including fragmentation of agricultural land; and (b) strategies to mitigate the identified impacts of development on agricultural land, including any impacts to adjacent agricultural land.)	https://www.calgarymetroregion.ca/growth-and-servicing-plan
Municipal	2009 but revised in 2020	Municipal Development Plan (MDP)	City of Calgary	The Sustainability Principles for Land Use (adopted in 2007)	Accommodate 50% through intensification within boundaries by encouraging infill and redevelopment	Percent of population growth from 2006 accommodated within balanced growth boundary.	Yes (Compact development, urban form)	Yes (4.3.2 b. Prevent the premature fragmentation of agricultural land.)	https://www.calgary.ca/transportation-plan/land-use-mobility.html

Appendix B

B.1 Comprehensive Overview of Treatment Assignment in Difference-in-Differences (DiD)

Regarding distance-based environmental variables, we have four treatment groups that are distinguished by the type of nearest open spaces (Urban Green Spaces, Natural Areas, Blue Spaces and Agricultural Land) that each house has access to, thereby capturing the heterogeneous ecosystem services each offers. Additionally, type-differentiated treatment groups account for the dynamic COVID-19 shocks to distinct preferences for each open space, when interacting with the treatment timing indicator $postCOVID$.

Moreover, these four distance-based treatment groups are further subdivided into two subgroups based on the magnitude of environmental endowment, as indicated by the different proximities to open spaces, namely, the Adjacent and Vicinity groups, following the distinction made by Muehlenbachs et al. (2015). Adjacency effects encompass all the (positive and negative) effect associated with being juxtaposed to or adjacent to each type of open spaces whereas Vicinity effect captures more broader effects of residing close to open spaces.

Having multiple treatment groups differentiated by distance-bands also allows us to investigate heterogeneity within a certain treatment buffer, particularly when both adjacency and vicinity effects are simultaneously included in the estimation. For example, Adjacency may involve some disamenities values or NIMBY (Not-In-My-BackYard) effects of residing too close to some open spaces (e.g., odors for Agriculture and noises for UGS). However, when Adjacency is controlled, the Vicinity effect only captures the effects of residing close to, but not too adjacent to, open spaces (e.g., after controlling for Adjacency, the agriculture Vicinity group may capture the utilities associated with rustic lifestyles while avoiding NIMBY of agricultural activities)[23]. This is also a common practice, especially as insurance against misspecification of treatment bands/ring method in the literatures (Horn et al., 2019).

While there are numerous ways to choose the treatment bands, we set the bands so that approximately 10% of the whole sample belong to the Adjacency group and 25% for the Vicinity group. This allows us to categorize each treatment group as the top decline and top quantile that have prime and sub-prime endowments of environmental amenities, respectively. Taken altogether, the specification of treatment for distance-based variables can be formally expressed as:

$$TREAT_{ij}^{Prime} = \begin{cases} 1, & 0 \le d_{ij} \le d_j^{Adj} \\ 0, & d_{ij} > d_j^{Adj} \end{cases} \qquad TREAT_{ij}^{Subp} = \begin{cases} 1, & 0 \le d_{ij} \le d_j^{Vic} \\ 0, & d_{ij} > d_j^{Adj} \end{cases}$$

where superscript $Prime$ and $Subp$ denote prime and subprime level of environmental endowment respectively and both d_j^{Adj} and d_j^{Vic} are defined as bandwidth or the radii of treatment buffer from the nearest environmental amenity j that $d_j^{Adj} < d_j^{Vic}$.

[23] To facilitate the reader's understanding of the spatial difference-in-differences (DiD) analysis with multiple bandwidths, we offer an analogy using the shape of a donut. Firstly, to create a donut, we must craft a circular dough with a particular radius (e.g. 200 meters), centered around a park. This dough, when considered without a center hole, represents the total effects of proximity, which encompasses both Vicinity effects and Adjacency groups. However, by controlling for Adjacency, we can effectively "carve out" a smaller radius (e.g. 100 meters) from the dough. The resulting crust or "donut" thus reflects the Vicinity effects after accounting for the effects of Adjacency groups.

The distinction between Adjacency and Vicinity groups cannot be applied to the Tree Canopy variable, as it is not measured in terms of distance. Nonetheless, to enable comparisons among groups with varying levels of tree endowments, we applied a similar categorization scheme as outlined above, where a house i is considered to be treated or $TREAT^{Prime}_{i,TreeCanopy} = 1$ and $TREAT^{Subp}_{i,TreeCanopy} = 1$ if it is endowed with the top decile and quantile levels of tree canopy. As will be explained below, this arbitrary treatment specification is source of bias.

To conclude, theses treatment effects are pre-existing differences between groups, which are assumed to be constant under the parallel trend assumption. When these treatment groups are interacted with the treatment timing indicator $postCOVID$, it would allow us to explore the multidimensional impacts of COVID-19 on environmental amenity values, given that the treatment groups differ not only in type, but also in the levels of environmental endowments.

B.2 Proofs that $\beta^* = \Delta\boldsymbol{\beta}$

$\beta^* = \Delta\boldsymbol{\beta}$ where $\Delta\boldsymbol{\beta} = \beta^1 - \beta^0$ given $E[\Delta\varepsilon|g_i, x_i] = 0$ and $\Delta g_i = \Delta\boldsymbol{x}_i = 0$[24]. Assume the true hedonic price functions for pre/post Pandemic periods can modeled as

$$p_i^0 = a^0 + \beta^0 g_i^0 + \gamma^{0'}\boldsymbol{x}_i^0 + \zeta_c + \varepsilon_i^0 \tag{A.1}$$

$$p_i^1 = a^1 + \beta^1 g_i^1 + \gamma^{1'}\boldsymbol{x}_i^1 + \zeta_c + \varepsilon_i^1 \tag{A.2}$$

Using Oaxaca decomposition (Oaxaca, 1973),

$$\Delta p_i \;=\; \Delta a \;+ \Delta\beta g_i^0 \;+ \beta^1 \Delta g_i + \Delta\gamma' \boldsymbol{x}_i^0 + \gamma^{1'}\Delta\boldsymbol{x}_i + \Delta\varepsilon \tag{A.3}$$

Given $\Delta g_i = \Delta\boldsymbol{x}_i = 0,$ (A.3) collapses to

$$\Delta p \;=\; \Delta a \;+ \Delta\beta g_i^0 \;+ \Delta\gamma' \boldsymbol{x}_i^0 + \Delta\varepsilon \tag{A.4}$$

Following Banzhaf (2021), (A.4) can be modeled as below in a case of repeated cross section while suppressing time specific superscript to acknowledge time constancy of g and $\boldsymbol{x}$,

$$p_i^D = a^0 + a^* postCOVID_i + \beta^0 g_i + \beta^* g_i postCOVID_i + \gamma^{0'}\boldsymbol{x_i} + \gamma^{*'}\boldsymbol{x_i} postCOVID_i + \zeta_c + \varepsilon_i^D \tag{A.5}$$

The superscript D denotes post-COVID (1) or otherwise (0), thus the model (A.5) generates

$$p_i^{D=0} = a^0 + \beta^0 g_i + \gamma^{0'}\boldsymbol{x_i} + \zeta_c + \varepsilon_i^0 \tag{A.6}$$

$$p_i^{D=1} = a^0 + a^* + \beta^0 g_i + \beta^* g_i + \gamma^{0'}\boldsymbol{x_i} + \gamma^{*'}\boldsymbol{x_i} + \zeta_c + \varepsilon_i^1 \tag{A.7}$$

Eq.(A.7) is same as eq.(A.2) if and only if

$$\beta^* = \beta^1 - \beta^0 \text{and } \gamma^* = \gamma^1 - \gamma^0 \text{ , QED}$$

---

[24] This is needed to estimate full parameters, but it could be the case where $\Delta\varepsilon$ could be correlated with g e.g., houses near parks appreciate in unobserved ways. A weaker conditional independence assumption ($\Delta\varepsilon \perp g_i|x$) would estimate unbiased estimate of β^*even if $\Delta\gamma'$ is biased as in Banzhaf 2021.

B.3 Detailed Explanations of Problems Associated with DiD applications in Hedonic Studies

B.3.a SUTVA Violation

One component of SUTVA is non-inference assumption which rules out spillovers and general equilibrium effects. Thus DiD applications in hedonic studies generally assume stable hedonic equilibrium or Palmquist's local non-interference assumption where the change in local amenities does not alter the equilibrium function (Palmquist, 1992; Winke, 2017).

The following briefly shows implication of violation of SUTVA in context of DiD applications in hednic studies. As discussed, most hedonic DiD applications utilize TWFE specification as follows,

$$p_{it} = \beta_0 + \beta_1 TREAT_i + \beta_2 postCOVID_i + \pi TREAT_i * postCOVID_i + \gamma' \boldsymbol{x}_{it} + u_{it}$$

ATT is given as,

$$\hat{\pi} = \mathbb{E}\left[p_1^{a^*} \middle| TREAT = 1, X\right] - \mathbb{E}\left[p_1^{a'} \middle| TREAT = 1, X\right]$$

The identification of ATT hinges on transforming the latter expression on the right hand side to an identifiable one using PTA, SUTVA and No Anticipation (Lechner, 2011). From PTA, the $\mathbb{E}\left[p_1^{a'} \middle| TREAT = 1, X\right]$ can be expressed as

$$\mathbb{E}\left[p_1^{a'} \middle| TREAT = 1, X\right] = \mathbb{E}\left[p_0^{a'} \middle| TREAT = 1, X\right] + \mathbb{E}\left[p_1^{a'} \middle| TREAT = 0, X\right] - \mathbb{E}\left[p_0^{a'} \middle| TREAT = 0, X\right]$$

When no anticipation and SUTVA hold, the first term and the third term on the right hand side can be imputed with $\mathbb{E}[p_0 | TREAT = 1, X]$ and $\mathbb{E}[p_0 | TREAT = 0, X]$, respectively. However, in case of violation of SUTVA such that treatment changing equilibrium hedonic function to $\gamma^{a^*} - \gamma^{a'} \neq 0$, $\mathbb{E}\left[p_1^{a'} \middle| TREAT = 0, X\right]$ is not the same as realized $\mathbb{E}[p_1 | TREAT = 0, X]$.

B.3.b Misspecification of Treatment

Another challenge that arises in this study is the misspecification of the treatment group due to the arbitrary assignment of houses to treatment. For instance, in a post-pandemic scenario, people may prefer proximity to parks but avoid living too close to them to avoid congestion. Consequently, there may not be a premium on houses with prime endowment (e.g., <100m from the nearest parks), but on houses with subprime endowment (e.g., 100m-200m from the nearest parks). Arbitrarily specifying all houses with prime endowment as the treatment group fails to capture the true intensified preference for parks. Although our model specification, which incorporates multiple endowment levels, alleviates this issue, Butts (2021a, 2021b) show incorrect specifications of treatment result in biased ATTs.

Furthermore, dichotomizing continuous variables, such as the distance to the nearest green space, not only causes statistical issues but also fails to capture distance decay (Royston et al., 2006; Fedorov et al., 2009; Schaafsma et al., 2012). Although one can include distance variables in addition to treatment, doing so violates another overlooked but necessary assumption of DiD called positivity.

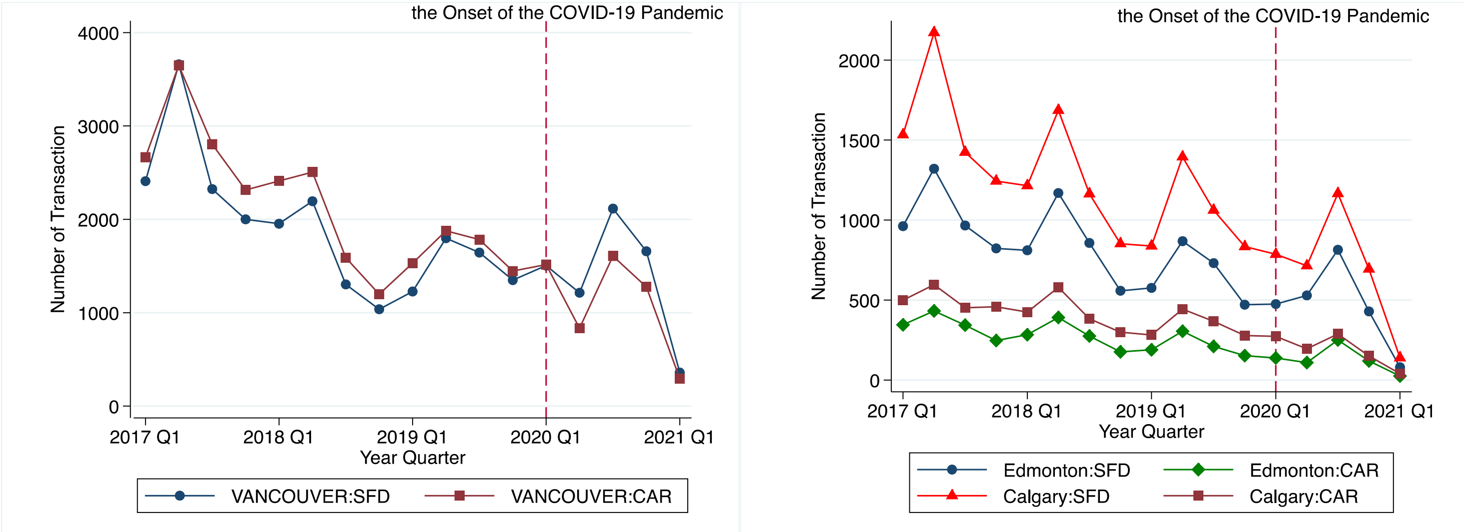
In summary, some of the assumptions in hedonic models conflict with the assumptions of the DiD framework [25] in general and especially with application of potential counterfactual outcome design for policy evaluations during the Pandemic as noted in (Goodman-Bacon & Marcus, 2020; Callaway & Li, 2021; Gauthier, 2021). Therefore, it is not appropriate to apply a potential outcome model in this cas

[25] However, this is not to say that hedonic models and DiD are necessarily incompatible. The burden of proof falls on researchers to justify the use of the DiD framework for hedonic studies. Researchers face a trade-off in choosing a shock that is both local enough to satisfy the TCGA assumption, but also significant enough to cause capitalization or a shift in the price gradient of the variable of interest.

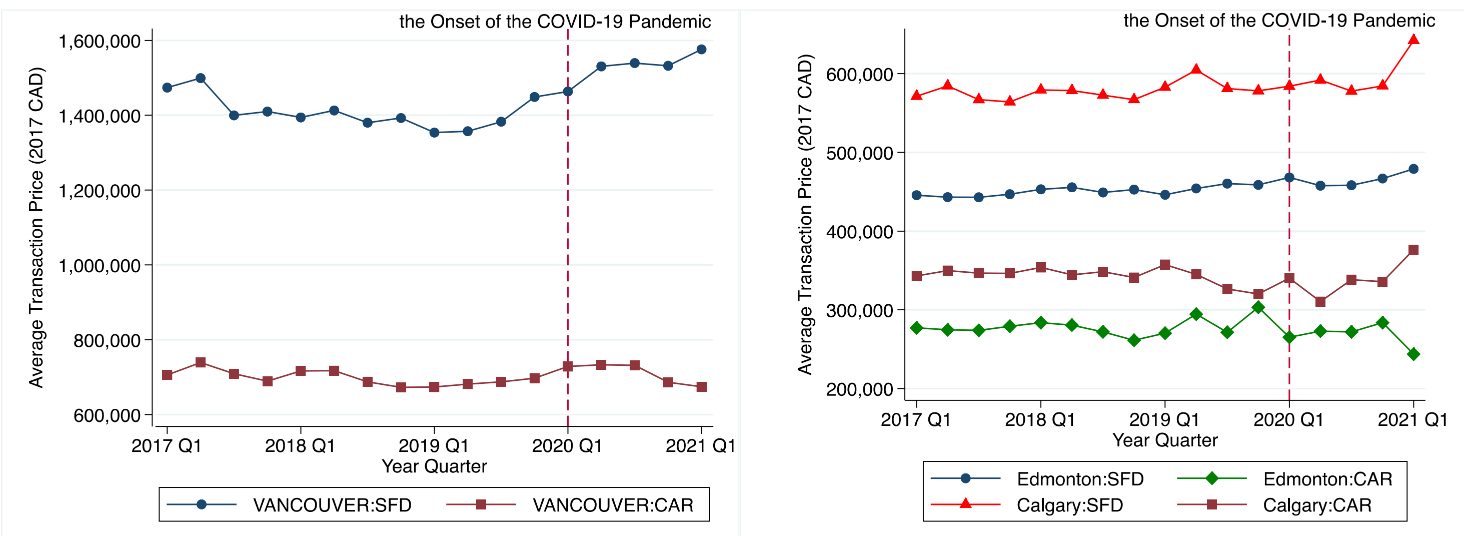
Appendix C

The figures below illustrate the number of transactions per fiscal quarter and mean transaction prices for two distinct housing styles - single-family detached houses (SFD) and condos, apartments, and row houses (CAR) - in both Metro Vancouver and two metropolitan areas in Alberta, namely Edmonton and Calgary.

C.1 The Number of Transactions per Fiscal Quarter by Housing Style in Metro Vancouver (left) and Edmonton and Calgary (right)

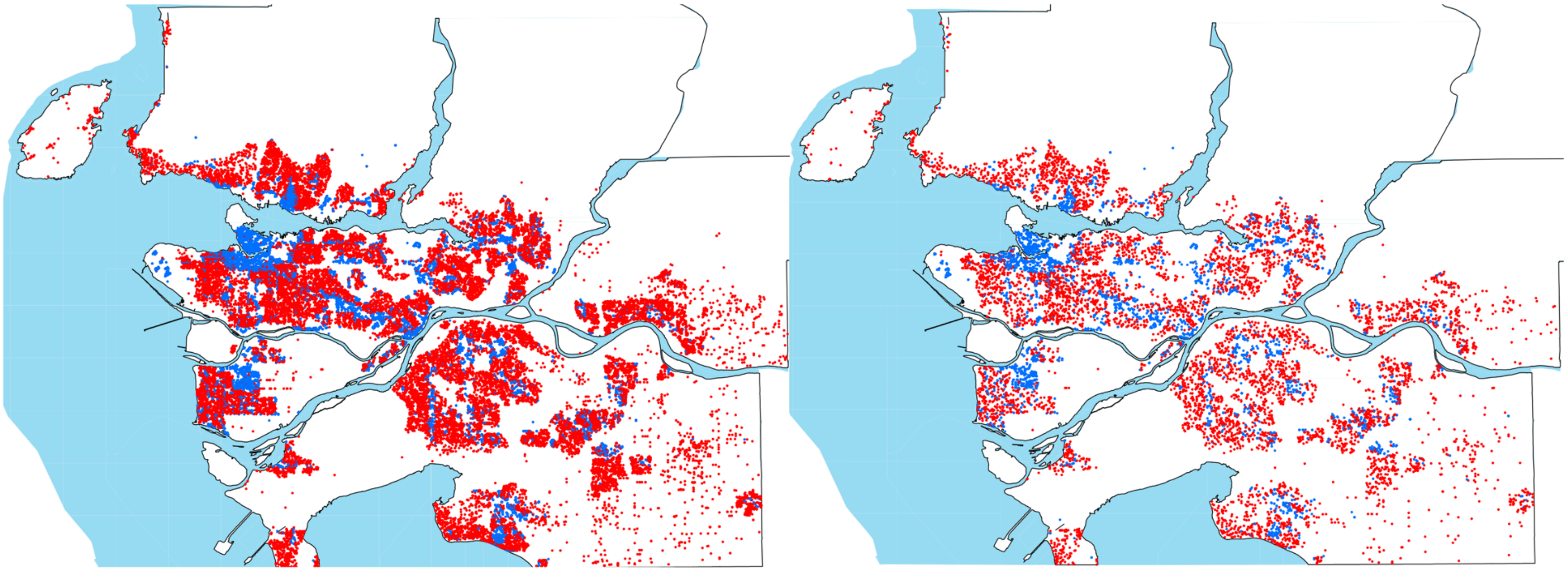


C.2 The Average Transactions Price in 2017 CAD by Housing Style in Metro Vancouver (left) and Edmonton and Calgary (right)

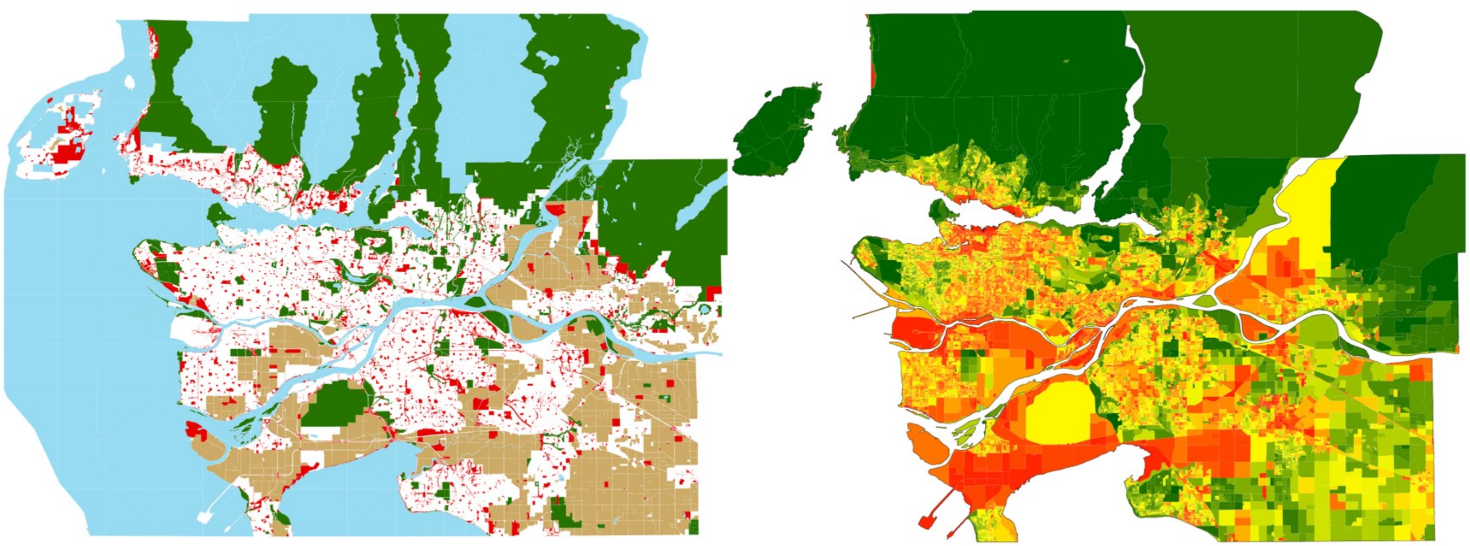


The following figures show the distribution of houses transacted before and after the Pandemic, as well as the geographic representation of environmental amenities in Metro Vancouver, Edmonton, and Calgary. Red areas represent Urban Green Spaces, green areas indicate Natural Areas, Blue areas represent Blue Spaces, and light brown areas represent Agricultural Lands.

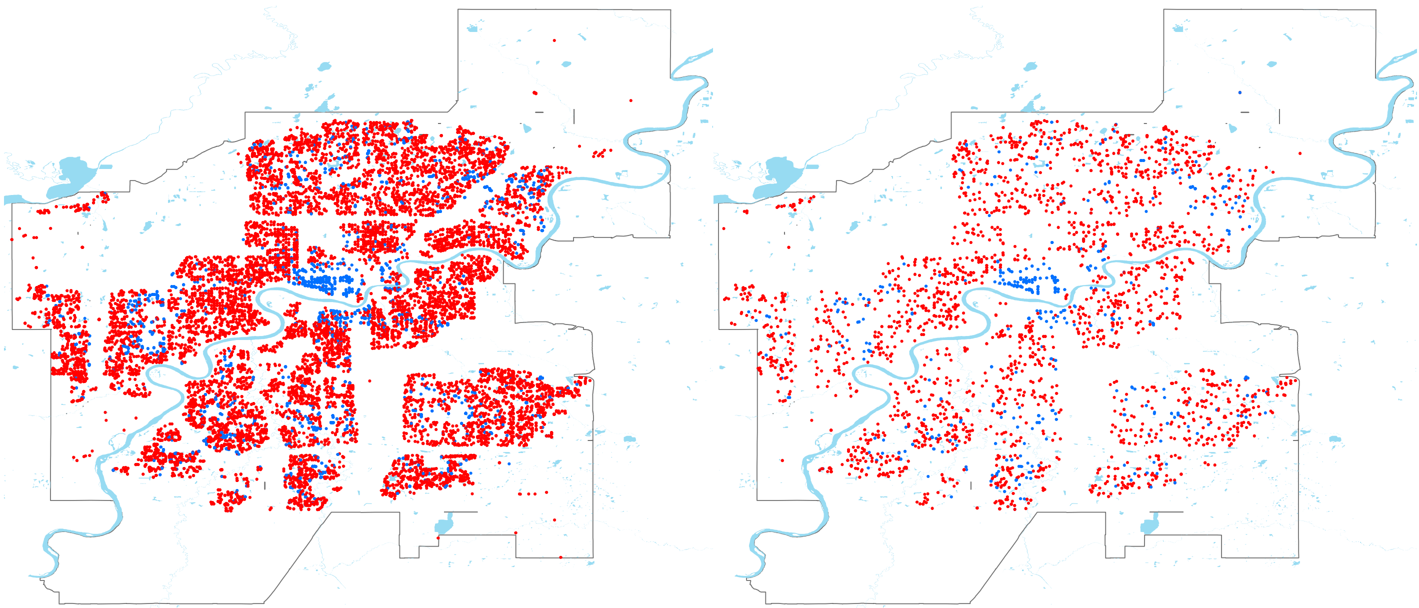
C.3 Distribution of Houses Sold before (left) and after (right) the Pandemic in Metro Vancouver by Housing Style: Single-Family Detached (red) and Condos, Apartments, and Row Houses (blue)



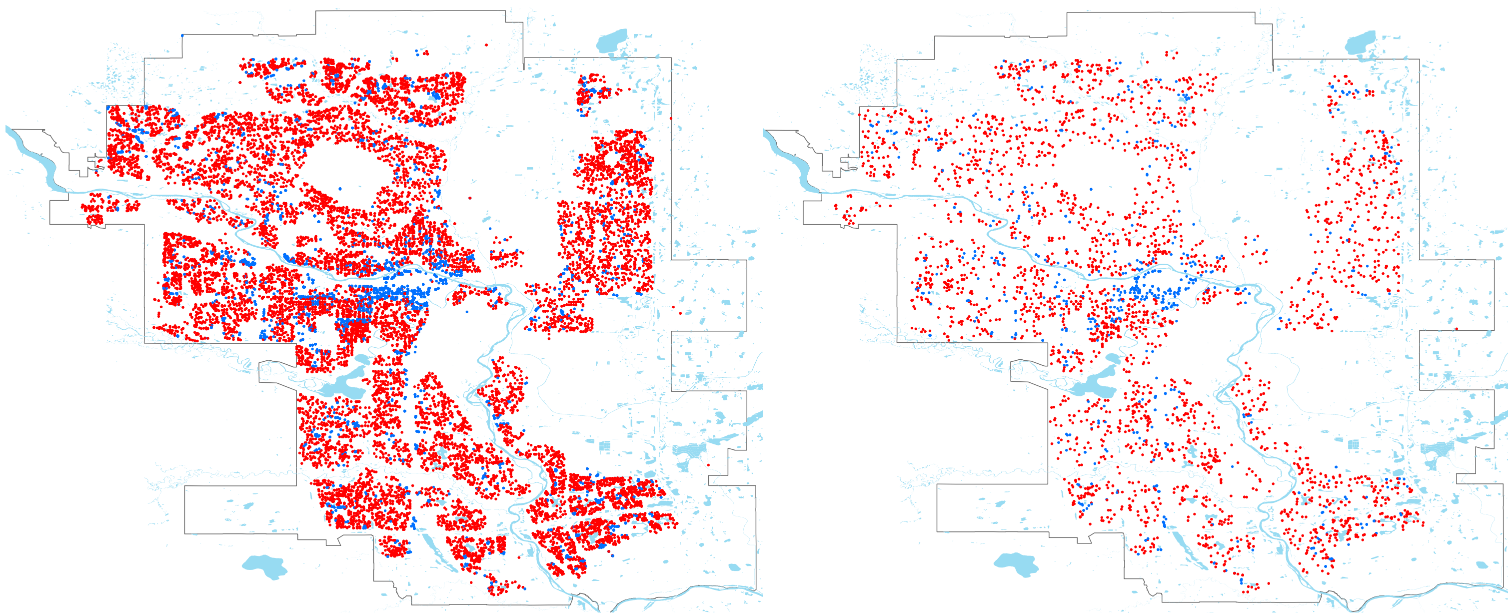
C.4 Geographic Representation of Environmental Amenities (left) and Tree Canopy (right) in Metro Vancouver: with Darker Green indicating Higher Tree Coverage



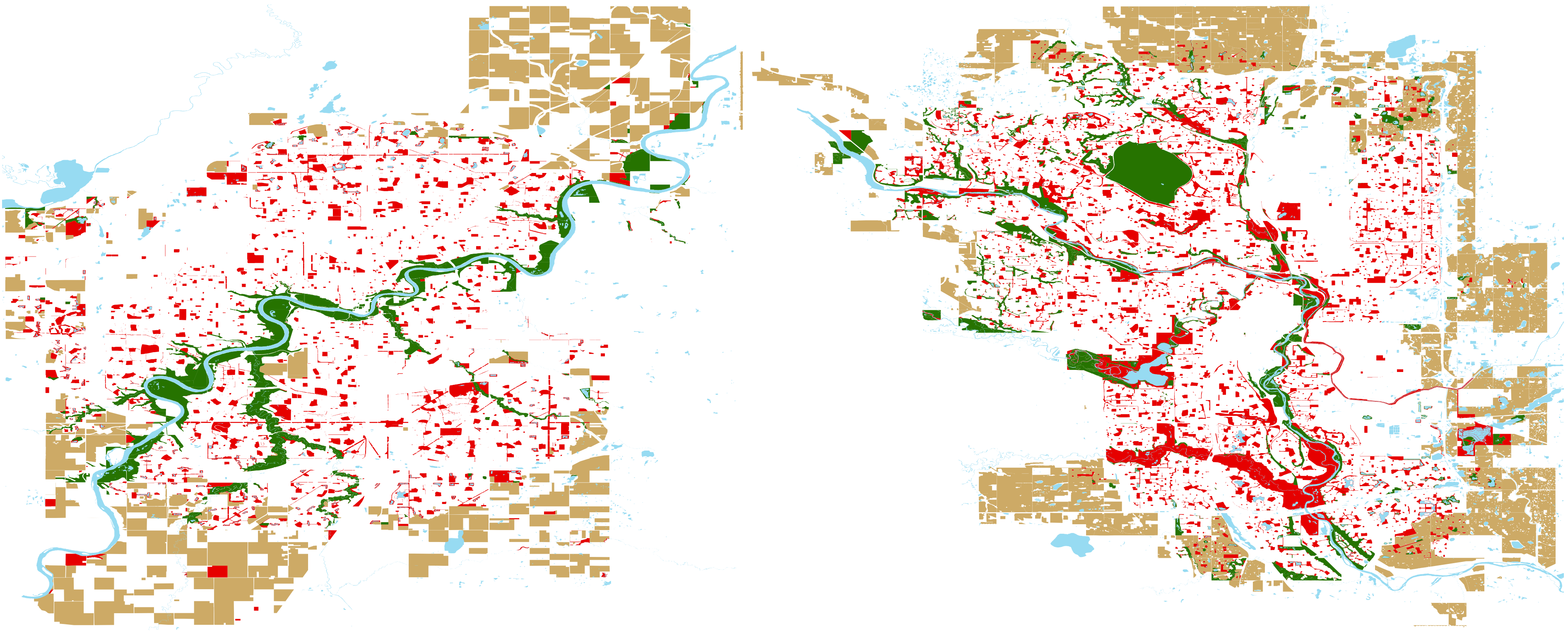
C.5 Distribution of Houses Sold before (left) and after (right) the Pandemic in Edmonton by Housing Style: Single-Family Detached (red) and Condos, Apartments, and Row Houses (blue)



C.6 Distribution of Houses Sold before (left) and after (right) the Pandemic in Calgary by Housing Style: Single-Family Detached (red) and Condos, Apartments, and Row Houses (blue)



C.7 Geographic Representation of Environmental Amenities in Edmonton (left) and Calgary (right)



Appendix D

D.1 Robustness Check: Metro Vancouver

The robustness of the main findings (higher amenity values of blue space, tree canopy, and living space) was tested through various modifications in model specifications. The results of these tests demonstrate that the findings are robust to modifications in a) the timing of the post-Pandemic period, b) functional forms, c) scales of spatial fixed effects and clustering of errors, d) the measurement of variable of interest, e) controlling variables, f) price indices used to adjust housing prices, and g) the data timeframe. In all robustness and sensitivity tests, higher amenity values of tree canopy, proximity to blue space, and larger living space have consistently been observed. Furthermore, these changes were not observed prior to the Pandemic or in the placebo Pandemic scenario, which strengthens the claim that the Pandemic caused the changes in amenity values.

D.1.a Different Timing of the Pandemic Treatment

For all analyses, we set March 18 as the start of the treatment period, which corresponds to the date when the BC government declared a state of emergency due to the COVID-19 pandemic. Although the date on our data is the possession date, it may take some time for consumers and suppliers to assess the impact of COVID-19 and update their preferences. Thus, there may be some time-lags for housing markets to reflect changes in consumer preferences, as suggested by (Goodman-Bacon & Marcus, 2020). To address this potential impact of time-lags, we explored different treatment timings (30 and 50 days after the state of emergency), similar to the approach taken by Irwin and Livy (2021). Table D.1.a presents the results. Overall, the result indicates changing the treatment timing does not significantly alter the findings from the previous results. Therefore, our findings are robust to the timing of treatment.

D.1.a Different Timing of the Pandemic Treatment: 30day and 50day Lags

Different Timing of the Pandemic Treatment: 30day and 50day Lags

	(1)	(2)	(3)	(4)
	SFD		CAR	
	Days After the State of Emergency			
Variables	30 Days	50 Days	30 Days	50 Days
postCOVID	.0559	.0732	-.3105*	-.2947*
	(.1272)	(.1282)	(.1705)	(.1725)
Baseline:				
lnLivingArea	.2643***	.2649***	.6805***	.6813***
	(.0088)	(.0087)	(.0249)	(.0249)
lnLotSize	.2183***	.2179***		
	(.0111)	(.0111)		
lnDistCBD	-.1485**	-.1485**	-.0568***	-.0566***
	(.0623)	(.0624)	(.0212)	(.0211)
lnDistUGS	-6.6e-04	-6.1e-04	-.005*	-.005**
	(.0015)	(.0015)	(.0026)	(.0025)
lnDistNaturalArea	-.0052*	-.0052*	-.0025	-.0026
	(.0028)	(.0028)	(.0036)	(.0037)
lnDistBlueSpace	-.0154**	-.0156**	-.0213***	-.0212***
	(.0076)	(.0076)	(.0063)	(.0063)
lnDistAgriculture	.0104**	.0106**	.0038	.0039
	(.0046)	(.0046)	(.0071)	(.0071)
TreeCanopy	-4.4e-04***	-4.3e-04***	-.0014***	-.0014***
	(1.5e-04)	(1.6e-04)	(2.8e-04)	(2.8e-04)
Change from Baseline:				
postCOVID × lnLivingArea	.0418***	.0387***	.0437*	.0415*
	(.012)	(.012)	(.0235)	(.0235)
postCOVID × lnLotSize	-.0207**	-.0191**		
	(.0081)	(.0082)		
postCOVID × lnDistCBD	.0047	.0041	.0059	.0053
	(.0074)	(.0075)	(.0069)	(.007)
postCOVID × lnDistUGS	.0059*	.0059*	-2.9e-04	-3.4e-04
	(.0031)	(.0032)	(.0018)	(.0019)
postCOVID × lnDistNaturalArea	.0059*	.0059*	.0053*	.006**
	(.0035)	(.0034)	(.0028)	(.0029)
postCOVID × lnDistBlueSpace	-.0107**	-.0103**	.0038	.0034
	(.0048)	(.0049)	(.0037)	(.0037)
postCOVID × lnDistAgriculture	.0067**	.006**	.004	.0032
	(.0028)	(.0029)	(.0038)	(.0039)
postCOVID × TreeCanopy	6.2e-04**	5.9e-04**	9.2e-05	1.2e-04
	(2.6e-04)	(2.6e-04)	(2.4e-04)	(2.2e-04)
Constant	11.4***	11.4***	8.768***	8.763***
	(.7265)	(.7276)	(.3307)	(.3292)
Controls:				
Spatial Fixed Effect	✓	✓	✓	✓
Temporal Fixed Effect	✓	✓	✓	✓
COVID Period Fixed Effect	✓	✓	✓	✓
COVID Policy Effect	✓	✓	✓	✓
Observations	27389	27389	30662	30662
R^2	0.885	0.885	0.862	0.862
Adjusted R^2	0.883	0.883	0.860	0.859
AIC	-32266.7	-32246.0	-31359.3	-31323.3
BIC	-31781.8	-31761.2	-30926.1	-30856.8

Note: Robust standard errors in parentheses are clustered at Census Tract level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Each column represents a separate regression. SFD and CAR refer to Single Family Detached and Condos, Apartments, and Row Houses respectively.
Spatial Fixed Effects at Census Tract as well as municipality level.
Temporal Fixed Effects at year as well as quarter level.

D.1.b Different Functional Forms: Incorporating Pandemic Period Specific Spatial Fixed Effect

To account for time-invariant unobservable factors at neighbourhood levels, such as average air pollution levels, we stack two price controls using a spatial fixed effect across pre- and post-Pandemic periods, as opposed to estimating two separate hedonic price functions for the pre-Pandemic period. However, the Pandemic may have caused changes in unobservable factors that are specific to the post Pandemic period, such as changes in air pollution or preferences to relocate to regions with more hospitals and fewer reported cases. To address this potential influence of time-variant confounders on our results, we also estimated a modified model eq.(A.8) that includes Pandemic-period specific spatial fixed effects at the municipality level, following the approach taken by Kuminoff and Pope (2014) with two sets of spatial fixed effects for the pre- and post-policy periods. By using two sets of spatial fixed effects for the pre and post-Pandemic periods, we were able to isolate the effect of the Pandemic from other time-variant confounders.

$$p_{ict} = a + a^{*} postCOVID_i + \beta\, g_{ict} + \beta^{*} g_{ict} postCOVID_i + \gamma' \boldsymbol{x}_i + \gamma^{*'} \boldsymbol{x}_i postCOVID_i + \zeta_c + \zeta_m postCOVID_i + \eta_t + \varepsilon_{ict} \qquad (A.8)$$

The results are reported below in Table D.1.b.

D.1.b Different Functional Forms: Incorporating Pandemic Period Specific Spatial Fixed Effect

Different Functional Forms: Incorporating Pandemic Period Specific Spatial Fixed Effect

	(1)	(2)	(3)	(4)
	SFD		CAR	
Variables	Base	Included	Base	Included
postCOVID	.0041	.2533	-.2918*	-.2769
	(.1281)	(.2384)	(.1653)	(.1725)
Baseline:				
lnLivingArea	.2644***	.2642***	.6806***	.6804***
	(.0088)	(.0087)	(.025)	(.025)
lnLotSize	.2184***	.2188***		
	(.0111)	(.0112)		
lnDistCBD	-.1464**	-.1428**	-.0563***	-.0567***
	(.0623)	(.0624)	(.0213)	(.0213)
lnDistUGS	-7.3e-04	-8.2e-04	-.005*	-.005*
	(.0015)	(.0015)	(.0026)	(.0026)
lnDistNaturalArea	-.0053*	-.0052*	-.0025	-.0024
	(.0028)	(.0028)	(.0036)	(.0037)
lnDistBlueSpace	-.0156**	-.0151**	-.0215***	-.0213***
	(.0076)	(.0076)	(.0063)	(.0063)
lnDistAgriculture	.0103**	.0109**	.0038	.0032
	(.0045)	(.0046)	(.0071)	(.0071)
TreeCanopy	-4.5e-04***	-4.3e-04***	-.0014***	-.0014***
	(1.5e-04)	(1.5e-04)	(2.8e-04)	(2.8e-04)
Change from Baseline:				
postCOVID × lnLivingArea	.0396***	.0425***	.04*	.0393*
	(.0116)	(.0114)	(.0228)	(.023)
postCOVID × lnLotSize	-.0196**	-.0219**		
	(.0081)	(.0085)		
postCOVID × lnDistCBD	.0054	-.0078	.0053	.0083
	(.0074)	(.0213)	(.0067)	(.0081)
postCOVID × lnDistUGS	.0063**	.0068**	-1.7e-05	-4.6e-04
	(.0029)	(.0029)	(.0018)	(.0018)
postCOVID × lnDistNaturalArea	.0064*	.0054**	.0049*	.0041
	(.0034)	(.0027)	(.0026)	(.0028)
postCOVID × lnDistBlueSpace	-.009*	-.0111***	.0038	.0024
	(.0046)	(.004)	(.0036)	(.0035)
postCOVID × lnDistAgriculture	.0068**	.0028	.0037	.0094**
	(.0028)	(.0035)	(.0037)	(.0048)
postCOVID × TreeCanopy	6.5e-04***	4.9e-04**	1.3e-04	3.3e-04
	(2.5e-04)	(2.0e-04)	(2.4e-04)	(2.4e-04)
Constant	11.38***	11.33***	9***	9.016***
	(.7277)	(.7315)	(.3406)	(.4879)
Controls:				
Spatial Fixed Effect	✓	✓	✓	✓
Temporal Fixed Effect	✓	✓	✓	✓
COVID Period Fixed Effect	✓	✓	✓	✓
COVID Policy Effect	✓	✓	✓	✓
Pandemic Period Spatial Fixed Effect		✓		✓
Observations	27389	27389	30662	30662
R^2	0.885	0.885	0.862	0.862
Adjusted R^2	0.883	0.883	0.860	0.860
AIC	-32216.5	-32252.9	-31365.3	-31405.5
BIC	-31739.8	-31694.1	-30882.1	-30939.0

Note: Robust standard errors in parentheses are clustered at Census Tract level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Each column represents a separate regression. SFD and CAR refers to Single Family Detached and Condos, Apartments, and Row Houses respectively.
Spatial Fixed Effects at Census Tract as well as municipality level.
Temporal Fixed Effects at year as well as quarter level.

The results remain generally consistent with the main results when including Pandemic period-specific spatial fixed effects, with only minor differences observed, indicating the main results are robust to modifications in functional forms. Specifically, the magnitude of the change in tree coverage value is slightly smaller and the significance of proximity to agriculture drops, likely due to some of these effects being subsumed into the Pandemic-period specific spatial fixed effects.

D.1.c Different Scale of Spatial Fixed Effects and Level of Clustering Standard Errors

We conducted an additional robustness check by re-estimating the model by replacing the census tract-level (neighborhood) fixed effects with coarser municipal-level fixed effects and by using a more granular level of clustering standard error at the census dissemination block level. The results show no significant deviation from the main findings, indicating that our results are robust to the choice of scale for the spatial fixed effects, as well as the level of clustering standard errors.

D.1.c Different Scale of Spatial Fixed Effects: Fixed Effect at Municipality Level and Standard Error Clustered at Block Level

Different Scale of Spatial Fixed Effects: Fixed Effect at Municipality Level and Standard Error Clustered at Block Level

	(1)	(2)	(3)	(4)
	SFD		CAR	
Variables				
postCOVID	.0073	.4727**	-.1721	-.2271
	(.1237)	(.2053)	(.1901)	(.2001)
Baseline:				
lnLivingArea	.27***	.2702***	.6667***	.6661***
	(.007)	(.0069)	(.0216)	(.0217)
lnLotSize	.2206***	.2211***		
	(.005)	(.005)		
lnDistCBD	-.1184***	-.1111***	-.037***	-.0382***
	(.0145)	(.0152)	(.009)	(.0091)
lnDistUGS	.0027*	.0026*	-.0024	-.0023
	(.0015)	(.0015)	(.0035)	(.0035)
lnDistNaturalArea	-.0055***	-.0055***	-.0027	-.0028
	(.0019)	(.0018)	(.0035)	(.0035)
lnDistBlueSpace	.0015	.0024	-.0138***	-.0136***
	(.0031)	(.0031)	(.0041)	(.0041)
lnDistAgriculture	.0154***	.0159***	.001	3.8e-04
	(.0021)	(.0022)	(.0044)	(.0045)
TreeCanopy	-.0014***	-.0014***	-.0019***	-.0019***
	(1.6e-04)	(1.5e-04)	(2.5e-04)	(2.5e-04)
Change from Baseline:				
postCOVID × lnLivingArea	.043***	.0439***	.0302	.0326
	(.0128)	(.0128)	(.0245)	(.0247)
postCOVID × lnLotSize	-.0224***	-.024***		
	(.0072)	(.0078)		
postCOVID × lnDistCBD	-7.4e-04	-.0364**	9.5e-04	.0111
	(.007)	(.0184)	(.0065)	(.0089)
postCOVID × lnDistUGS	.0048*	.0054*	3.5e-04	-2.9e-04
	(.0029)	(.0029)	(.0021)	(.0021)
postCOVID × lnDistNaturalArea	.0048**	.004	.0048*	.0051
	(.0024)	(.0024)	(.0028)	(.0031)
postCOVID × lnDistBlueSpace	-.0051	-.0094**	.0026	.0012
	(.0042)	(.0046)	(.0038)	(.0038)
postCOVID × lnDistAgriculture	.0049**	.0026	1.1e-05	.0056
	(.0025)	(.0033)	(.0041)	(.0049)
postCOVID × TreeCanopy	4.5e-04**	3.7e-04*	2.4e-04	4.4e-04*
	(2.2e-04)	(2.0e-04)	(2.5e-04)	(2.5e-04)
Constant	10.26***	10.16***	8.603***	8.612***
	(.1553)	(.1626)	(.1869)	(.1876)
Controls:				
Spatial Fixed Effect	✓	✓	✓	✓
Temporal Fixed Effect	✓	✓	✓	✓
COVID Period Fixed Effect	✓	✓	✓	✓
COVID Policy Effect	✓	✓	✓	✓
Pandemic Period Spatial Fixed Effect		✓		✓
Observations	27389	27389	30662	30662
R^2	0.846	0.846	0.822	0.822
Adjusted R^2	0.846	0.846	0.822	0.822
AIC	-24201.3	-24234.2	-23568.9	-23587.7
BIC	-23593.1	-23543.9	-23002.5	-22937.9

Note: Robust standard errors in parentheses are clustered at Census Dissemination Block level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Each column represents a separate regression. SFD and CAR refers to Single Family Detached and Condos, Apartments, and Row Houses respectively.
Spatial Fixed Effects at municipality level.
Temporal Fixed Effects at year as well as quarter level.

D.1.d Different Measurement of Tree Canopy

We transformed the variable of interest, tree canopy, from its original measurement as a percentage of the areas covered by tree canopy in the census dissemination block to its measurement in absolute areas (square meters) and took the logarithm of it. We then re-estimated the model and found that there were no significant changes in the main findings. This indicates that our results are robust to different measurements of tree canopy.

D.1.d Different Measurement of Tree Canopy: Tree Canopy Percentage Transformed to Tree Canopy Area

Different Measurement of Tree Canopy: Tree Canopy Percentage Transformed to Tree Canopy Area

	(1)	(2)	(3)	(4)
	SFD		CAR	
Variables				
postCOVID	-.0392	.2057	-.3103*	-.3135*
	(.1361)	(.2472)	(.1608)	(.1673)
Baseline:				
lnLivingArea	.2647***	.2644***	.6805***	.6803***
	(.0089)	(.0088)	(.0249)	(.025)
lnLotSize	.2177***	.2183***		
	(.0116)	(.0117)		
lnDistCBD	-.1456**	-.1424**	-.0597**	-.0602**
	(.0625)	(.0626)	(.0234)	(.0234)
lnDistUGS	-6.7e-04	-7.8e-04	-.0052**	-.0052**
	(.0015)	(.0015)	(.0025)	(.0025)
lnDistNaturalArea	-.0048*	-.0047*	-8.1e-04	-6.9e-04
	(.0027)	(.0028)	(.0035)	(.0035)
lnDistBlueSpace	-.0155**	-.0151**	-.0225***	-.0223***
	(.0076)	(.0076)	(.0066)	(.0067)
lnDistAgriculture	.0098**	.0105**	.0035	.0029
	(.0045)	(.0045)	(.0071)	(.0071)
lnTreeCanopyArea	-.0029***	-.0028***	-.0064***	-.0065***
	(9.1e-04)	(8.9e-04)	(.0016)	(.0016)
Change from Baseline:				
postCOVID × lnLivingArea	.0381***	.0419***	.0405*	.0401*
	(.0117)	(.0113)	(.0228)	(.0229)
postCOVID × lnLotSize	-.0182**	-.0215**		
	(.0087)	(.0088)		
postCOVID × lnDistCBD	.0052	-.0059	.0062	.0105
	(.0076)	(.0219)	(.0067)	(.008)
postCOVID × lnDistUGS	.0061**	.0068**	-1.8e-04	-6.5e-04
	(.003)	(.0029)	(.0018)	(.0018)
postCOVID × lnDistNaturalArea	.0059*	.0049*	.0047*	.0034
	(.0033)	(.0027)	(.0026)	(.0027)
postCOVID × lnDistBlueSpace	-.0093**	-.0111***	.0044	.003
	(.0047)	(.004)	(.0037)	(.0036)
postCOVID × lnDistAgriculture	.0084***	.0036	.0043	.0104**
	(.003)	(.0035)	(.0035)	(.0047)
postCOVID × lnTreeCanopyArea	.0045***	.0036**	-7.1e-04	1.0e-04
	(.0016)	(.0014)	(.0013)	(.0013)
Constant	11.42***	11.37***	9.122***	9.138***
	(.7314)	(.7346)	(.3759)	(.4105)
Controls:				
Spatial Fixed Effect	✓	✓	✓	✓
Temporal Fixed Effect	✓	✓	✓	✓
COVID Period Fixed Effect	✓	✓	✓	✓
COVID Policy Effect	✓	✓	✓	✓
Pandemic Period Spatial Fixed Effect		✓		✓
Observations	27389	27389	30662	30662
R^2	0.885	0.885	0.861	0.861
Adjusted R^2	0.883	0.883	0.859	0.859
AIC	-32205.5	-32246.4	-31282.8	-31250.7
BIC	-31728.8	-31687.6	-30949.6	-30642.5

Note: Robust standard errors in parentheses are clustered at Census Tract level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Each column represents a separate regression. SFD and CAR refers to Single Family Detached and Condos, Apartments, and Row Houses respectively.
Spatial Fixed Effects at Census Tract as well as municipality level.
Temporal Fixed Effects at year as well as quarter level.

D.1.e Different Set of Covariates

We omitted the variables School Quality and Crime Rate from our controlling covariates and re-estimated the model. We found that there were no significant changes in the main findings, indicating that our results are insensitive to changes in controlling covariates.

D.1.e Different Set of Covariates: Omitting School Quality and Crime Rate

Different Set of Covariates: Omitting School Quality and Crime Rate

	(1)	(2)	(3)	(4)
	SFD		CAR	
Variables				
postCOVID	-.0153	.2405	-.2631	-.2728
	(.1286)	(.2428)	(.1632)	(.1731)
Baseline:				
lnLivingArea	.2643***	.2642***	.6809***	.6806***
	(.0088)	(.0087)	(.025)	(.025)
lnLotSize	.2183***	.2188***		
	(.0111)	(.0112)		
lnDistCBD	-.1461**	-.1424**	-.0562***	-.0568***
	(.0624)	(.0625)	(.0214)	(.0214)
lnDistUGS	-7.4e-04	-8.3e-04	-.0051**	-.005**
	(.0015)	(.0015)	(.0026)	(.0025)
lnDistNaturalArea	-.0053*	-.0051*	-.0026	-.0026
	(.0028)	(.0028)	(.0037)	(.0037)
lnDistBlueSpace	-.0156**	-.0151**	-.0208***	-.0206***
	(.0076)	(.0076)	(.0062)	(.0062)
lnDistAgriculture	.0103**	.0109**	.0043	.0036
	(.0045)	(.0046)	(.007)	(.007)
TreeCanopy	-4.5e-04***	-4.2e-04***	-.0014***	-.0014***
	(1.6e-04)	(1.5e-04)	(2.8e-04)	(2.8e-04)
Change from Baseline:				
postCOVID × lnLivingArea	.0402***	.0429***	.0402*	.0395*
	(.0116)	(.0114)	(.0228)	(.0231)
postCOVID × lnLotSize	-.0195**	-.022***		
	(.0081)	(.0084)		
postCOVID × lnDistCBD	.0062	-.0077	.0033	.0078
	(.0075)	(.0215)	(.0069)	(.0087)
postCOVID × lnDistUGS	.0064**	.0069**	-1.1e-04	-6.1e-04
	(.003)	(.0029)	(.0019)	(.0018)
postCOVID × lnDistNaturalArea	.0066**	.0055**	.0046*	.004
	(.0033)	(.0027)	(.0027)	(.0028)
postCOVID × lnDistBlueSpace	-.009*	-.0111***	.0038	.0025
	(.0046)	(.004)	(.0035)	(.0035)
postCOVID × lnDistAgriculture	.007**	.003	.0043	.0102**
	(.0029)	(.0035)	(.0037)	(.0048)
postCOVID × TreeCanopy	6.5e-04**	4.8e-04**	7.7e-05	3.2e-04
	(2.5e-04)	(2.0e-04)	(2.3e-04)	(2.3e-04)
Constant	11.33***	11.27***	8.624***	8.64***
	(.7233)	(.7274)	(.3343)	(.3342)
Controls:				
Spatial Fixed Effect	✓	✓	✓	✓
Temporal Fixed Effect	✓	✓	✓	✓
COVID Period Fixed Effect	✓	✓	✓	✓
COVID Policy Effect	✓	✓	✓	✓
Pandemic Period Spatial Fixed Effect		✓		✓
Observations	27389	27389	30662	30662
R^2	0.885	0.885	0.862	0.862
Adjusted R^2	0.883	0.883	0.860	0.860
AIC	-32214.1	-32249.8	-31368.2	-31390.4
BIC	-31762.1	-31715.7	-30951.7	-30890.5

Note: Robust standard errors in parentheses are clustered at Census Tract level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Each column represents a separate regression. SFD and CAR refers to Single Family Detached and Condos, Apartments, and Row Houses respectively.
Spatial Fixed Effects at Census Tract as well as municipality level.
Temporal Fixed Effects at year as well as quarter level.

D.1.f Different Housing Price Index Deflators

We conducted a further test to determine if using different housing price indexes to deflate housing prices would affect the main results; specifically, we adjusted housing prices using Consumer Price Index (Shelter) (CPI) from StatCan[26] and Housing Price Index (HPI) from CREA[27]. We found that the main results were consistent regardless of which housing index was used. Therefore, our results are robust to the choice of housing price index.

D.1.f Different Housing Price Index Deflators

Different Housing Price Index Deflators

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	SFD				CAR			
	Index Used to Adjust Housing Price							
	CPI		HPI		CPI		HPI	
postCOVID	.0039	.2503	-6.7e-04	.2494	-.2872*	-.2647	-.2675	-.2646
	(.127)	(.2371)	(.1268)	(.2393)	(.1652)	(.1723)	(.1668)	(.1738)
Baseline:								
lnLivingArea	.2632***	.263***	.2633***	.2631***	.674***	.6739***	.6807***	.6805***
	(.0087)	(.0086)	(.0088)	(.0087)	(.0251)	(.0251)	(.0251)	(.0252)
lnLotSize	.2192***	.2196***	.218***	.2186***				
	(.0111)	(.0112)	(.0111)	(.0112)				
lnDistCBD	-.1469**	-.1436**	-.1424**	-.1387**	-.0541**	-.0545**	-.0555**	-.0561***
	(.0628)	(.0628)	(.0629)	(.0629)	(.0217)	(.0217)	(.0216)	(.0216)
lnDistUGS	-8.2e-04	-9.2e-04	-6.1e-04	-7.0e-04	-.0049*	-.0048*	-.005*	-.0049*
	(.0015)	(.0015)	(.0015)	(.0015)	(.0027)	(.0027)	(.0026)	(.0026)
lnDistNaturalArea	-.0051*	-.0049*	-.0051*	-.0051*	-.003	-.003	-.0024	-.0023
	(.0028)	(.0028)	(.0028)	(.0028)	(.0037)	(.0037)	(.0036)	(.0036)
lnDistBlueSpace	-.0159**	-.0153**	-.0157**	-.0152*	-.0213***	-.021***	-.0217***	-.0215***
	(.0077)	(.0077)	(.0077)	(.0077)	(.0063)	(.0063)	(.0062)	(.0062)
lnDistAgriculture	.0106**	.0112**	.0103**	.011**	.0039	.0032	.0041	.0034
	(.0045)	(.0046)	(.0045)	(.0046)	(.0072)	(.0072)	(.007)	(.007)
TreeCanopy	-4.7e-04***	-4.4e-04***	-4.8e-04***	-4.5e-04***	-.0014***	-.0014***	-.0014***	-.0014***
	(1.6e-04)	(1.5e-04)	(1.6e-04)	(1.5e-04)	(2.8e-04)	(2.8e-04)	(2.8e-04)	(2.8e-04)
Change from Baseline:								
postCOVID × lnLivingArea	.0427***	.0456***	.0395***	.0425***	.0438*	.0428*	.0419*	.0417*
	(.0117)	(.0114)	(.0117)	(.0115)	(.0228)	(.023)	(.0229)	(.0231)
postCOVID × lnLotSize	-.0205**	-.0226***	-.021**	-.0237***				
	(.0081)	(.0084)	(.0082)	(.0086)				
postCOVID × lnDistCBD	.0046	-.0079	.0069	-.0066	.005	.0076	.005	.0096
	(.0073)	(.0211)	(.0073)	(.0217)	(.0069)	(.0083)	(.0067)	(.0081)
postCOVID × lnDistUGS	.0063**	.0068**	.0061**	.0066**	-4.2e-04	-8.4e-04	-2.6e-04	-7.0e-04
	(.003)	(.0029)	(.0031)	(.003)	(.0019)	(.0018)	(.0019)	(.0018)
postCOVID × lnDistNaturalArea	.0063*	.0053*	.006*	.0053*	.005*	.004	.0048*	.0039
	(.0033)	(.0027)	(.0034)	(.0028)	(.0026)	(.0028)	(.0026)	(.0028)
postCOVID × lnDistBlueSpace	-.0087*	-.0111***	-.0092**	-.0115***	.0037	.0025	.0042	.0028
	(.0046)	(.0041)	(.0046)	(.004)	(.0036)	(.0035)	(.0035)	(.0035)
postCOVID × lnDistAgriculture	.0069**	.003	.0071**	.0026	.0028	.0087*	.0036	.0096**
	(.0029)	(.0035)	(.0028)	(.0034)	(.0038)	(.0048)	(.0038)	(.0049)
postCOVID × TreeCanopy	6.4e-04***	4.8e-04**	6.5e-04***	5.0e-04**	1.3e-04	3.4e-04	1.1e-04	3.1e-04
	(2.5e-04)	(2.0e-04)	(2.5e-04)	(2.0e-04)	(2.4e-04)	(2.4e-04)	(2.4e-04)	(2.4e-04)
Constant	11.35***	11.3***	11.28***	11.22***	8.836***	8.849***	8.642***	8.657***
	(.7359)	(.7397)	(.7328)	(.7365)	(.3358)	(.3364)	(.3347)	(.3352)
Controls:								
Spatial Fixed Effect	✓	✓	✓	✓	✓	✓	✓	✓
Temporal Fixed Effect	✓	✓	✓	✓	✓	✓	✓	✓
COVID Period Fixed Effect	✓	✓	✓	✓	✓	✓	✓	✓
COVID Policy Effect	✓	✓	✓	✓	✓	✓	✓	✓
Pandemic Period Spatial Fixed Effect		✓		✓		✓		✓
Observations	27405	27405	27377	27377	30634	30634	30669	30669
R^2	0.884	0.885	0.887	0.887	0.855	0.855	0.865	0.865
Adjusted R^2	0.882	0.883	0.885	0.885	0.853	0.853	0.862	0.863
AIC	-31885.7	-31923.8	-32456.8	-32494.6	-30529.8	-30545.1	-31674.1	-31691.7
BIC	-31409.0	-31365.0	-31980.1	-31935.8	-30088.3	-30020.4	-31232.5	-31166.8

Note: Robust standard errors in parentheses are clustered at Census Tract level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Each column represents a separate regression. SFD and CAR refers to Single Family Detached and Condos, Apartments, and Row Houses respectively.
Spatial Fixed Effects at Census Tract as well as municipality level.
Temporal Fixed Effects at year as well as quarter level.

[26] https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1810000401
[27] https://www.crea.ca/housing-market-stats/mls-home-price-index/

D.1.g Different Data Sampling Periods

We conducted a robustness check to examine whether using a different sample period for the transaction data (e.g., 2018 instead of 2017) would affect the main findings. We found that no significant changes were observed in the main results, indicating that our findings are robust to the length of the period used to compare the Post-Pandemic hedonic functions.

D.1.g Different Data Sampling Periods: Using Samples from 2018 Onward Only

Different Data Sampling Periods: Different Data Sampling Periods: Using Samples from 2018 Onward Only

	(1)	(2)	(3)	(4)
	SFD		CAR	
Variables				
postCOVID	-4.1e-04	.0158	-.5341***	-.6059***
	(.1204)	(.2062)	(.1922)	(.204)
Baseline:				
lnLivingArea	.2725***	.2723***	.6304***	.6297***
	(.0106)	(.0105)	(.033)	(.0331)
lnLotSize	.2039***	.2044***		
	(.0105)	(.0106)		
lnDistCBD	-.1444**	-.1445**	-.0346**	-.0362**
	(.0663)	(.0665)	(.0163)	(.0164)
lnDistUGS	-.0018	-.0017	-.0074***	-.0072***
	(.0017)	(.0017)	(.0026)	(.0026)
lnDistNatur	-.0062**	-.0067**	-.003	-.003
	(.0028)	(.0029)	(.0048)	(.0049)
lnDistBlue	-.0146*	-.014*	-.0196***	-.0192***
	(.0078)	(.0078)	(.0066)	(.0066)
lnDistAgri	.0149***	.0155***	.007	.0063
	(.0044)	(.0044)	(.0076)	(.0076)
TreeCanopyPer	-7.2e-04***	-7.0e-04***	-.0012***	-.0013***
	(1.8e-04)	(1.7e-04)	(2.8e-04)	(2.8e-04)
Change from Baseline:				
postCOVID $\times$ lnLivingArea	.0328***	.0351***	.0852***	.0891***
	(.0124)	(.0125)	(.0278)	(.0283)
postCOVID $\times$ lnLotSize	-.0071	-.0088		
	(.0086)	(.009)		
postCOVID $\times$ lnDistCBD	2.1e-04	.0024	-.0034	.0041
	(.0069)	(.0183)	(.0064)	(.0086)
postCOVID $\times$ lnDistUGS	.0087***	.0084***	.0024	.0018
	(.0029)	(.0029)	(.0018)	(.0018)
postCOVID $\times$ lnDistNatur	.0049*	.0063**	.0062**	.0064**
	(.0029)	(.0026)	(.0026)	(.0029)
postCOVID $\times$ lnDistBlue	-.0105**	-.0121***	5.6e-05	-.0019
	(.0045)	(.0042)	(.0037)	(.0038)
postCOVID $\times$ lnDistAgri	.0045	.002	-5.3e-04	.0039
	(.0027)	(.0034)	(.0037)	(.0047)
postCOVID $\times$ TreeCanopyPer	7.1e-04***	6.3e-04***	8.0e-05	1.8e-04
	(2.3e-04)	(2.0e-04)	(2.3e-04)	(2.4e-04)
Constant	11.35***	11.34***	8.866***	8.885***
	(.7279)	(.7307)	(.3191)	(.321)
Controls:				
Spatial Fixed Effect	✓	✓	✓	✓
Temporal Fixed Effect	✓	✓	✓	✓
COVID Period Fixed Effect	✓	✓	✓	✓
COVID Policy Effect	✓	✓	✓	✓
Pandemic Period Spatial Fixed Effect		✓		✓
Observations	16088	16088	17415	17415
R^2	0.894	0.894	0.871	0.871
Adjusted R^2	0.891	0.891	0.867	0.867
AIC	-20478.1	-20479.5	-19445.7	-19445.9
BIC	-20040.0	-19964.5	-19041.9	-18964.4

Note: Robust standard errors in parentheses are clustered at Census Tract level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Each column represents a separate regression. SFD and CAR refers to Single Family Detached and Condos, Apartments, and Row Houses respectively.
Spatial Fixed Effects at Census Tract as well as municipality level.
Temporal Fixed Effects at year as well as quarter level.

D.1.h Potential Pre-existing Trend / Falsification Test

Our preferred model tests the time-invariance of the price gradient on the variables of interest across pre- and post-Pandemic periods. Results have shown a significant discontinuity after the Pandemic for the values of blue space and tree canopy as well as living space. However, this change may not necessarily be due to the Pandemic, but rather a pre-existing trend. For example, the higher willingness to pay (WTP) for high tree density in the post-Pandemic period may be due to a recent surge in demand for more treed neighborhoods as part of climate change adaptation strategies.

To eliminate the possibility of spurious causation and strengthen our inference, we conducted a falsification/placebo test based following Boes et al. (2015). In this test, we falsely assumed that the Pandemic had unfolded a year earlier (i.e., $postCOVID = 1$ if transacted between March 2019 to March 2020) and tested if there was a pre-existing trend leading up to the actual onset of the Pandemic (March 2020). To conduct this test, we compared a two-year pre-treatment group (2017 to March 2019) and a false Pandemic treatment group (March 2019 to March 2020) with a two-year pre-treatment window (2018 to March 2020) and an actual Pandemic treatment group (March 2020 to March 2021).

D.1.h Potential Pre-existing Trend / Falsification Test: Metro Vancouver

Potential Pre-existing Trends and Falsification Test
Pandemic (2018 - Mar.2020 vs - Mar.2021) vis-à-vis Placebo (2017 - Mar.2019 vs - Mar.2020)

	(1)	(2)	(3)	(4)
	SFD		CAR	
	Pandemic	Placebo	Pandemic	Placebo
postCOVID	.0571	.3083	-.5461***	.3126
	(.2138)	(.215)	(.1934)	(.2186)
Baseline:				
lnLivingArea	.266***	.2609***	.6402***	.6852***
	(.0101)	(.0091)	(.0318)	(.0266)
lnLotSize	.2104***	.2264***		
	(.0109)	(.0118)		
lnDistCBD	-.1415**	-.1214*	-.0432***	-.0559***
	(.0663)	(.0667)	(.0166)	(.0206)
lnDistUGS	-8.1e-04	-8.2e-04	-.0062**	-.0038
	(.0017)	(.0017)	(.0027)	(.0026)
lnDistNaturalArea	-.0068**	-.0057*	-.0027	-.0028
	(.0029)	(.003)	(.0045)	(.0035)
lnDistBlueSpace	-.0146*	-.0146*	-.0202***	-.0227***
	(.0075)	(.0077)	(.0062)	(.0068)
lnDistAgriculture	.0149***	.0087*	.0037	.0037
	(.0045)	(.0047)	(.0076)	(.0071)
TreeCanopy	-6.6e-04***	-4.3e-04***	-.0013***	-.0015***
	(1.7e-04)	(1.6e-04)	(2.8e-04)	(3.0e-04)
Change from Baseline:				
postCOVID × lnLivingArea	.0413***	.018	.0805***	-.0271
	(.012)	(.0125)	(.0266)	(.0316)
postCOVID × lnLotSize	-.0133	-.0279***		
	(.0087)	(.0077)		
postCOVID × lnDistCBD	-.0012	-.0103	.0048	-.0026
	(.0192)	(.02)	(.0084)	(.0066)
postCOVID × lnDistUGS	.0076***	-9.1e-04	7.1e-04	-.0025
	(.0029)	(.0023)	(.0018)	(.0017)
postCOVID × lnDistNaturalArea	.0063**	.0017	.0062**	-.0014
	(.0026)	(.0028)	(.0029)	(.0024)
postCOVID × lnDistBlueSpace	-.0119***	.002	-.0016	.0067*
	(.0043)	(.005)	(.0037)	(.0035)
postCOVID × lnDistAgriculture	.0016	.0023	.0055	.0041
	(.0035)	(.0035)	(.0049)	(.004)
postCOVID × TreeCanopy	6.0e-04***	2.1e-04	2.2e-04	3.8e-04*
	(2.0e-04)	(1.9e-04)	(2.3e-04)	(2.1e-04)
Constant	11.33***	11.1***	8.891***	8.664***
	(.7373)	(.7819)	(.319)	(.3263)
Controls:				
Spatial Fixed Effect	✓	✓	✓	✓
Temporal Fixed Effect	✓	✓	✓	✓
COVID Period Fixed Effect	✓	✓	✓	✓
COVID Policy Effect	✓	✓	✓	✓
Pandemic Period Spatial Fixed Effect	✓	✓	✓	✓
Observations	17664	22496	19465	26619
R^2	0.893	0.889	0.870	0.863
Adjusted R^2	0.890	0.887	0.867	0.861
AIC	-22390.7	-26985.4	-21668.2	-27525.5
BIC	-21861.7	-26456.0	-21179.8	-27034.2

Note: Robust standard errors in parentheses are clustered at Census Tract level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Each column represents a separate regression. SFD and CAR refer to Single Family Detached and Condos, Apartments, and Row Houses respectively.
Spatial Fixed Effects at Census Tract as well as municipalities level.
Temporal Fixed Effects at year as well as quarter level.

The results of the placebo test are presented in Table D.1.h. The even-numbered columns represent the placebo results that test whether there were significant shifts in the price gradient in the fake Pandemic year (March 2019 to March 2020). The results confirm that, overall, there was no trend (up nor down) in the living areas as well as the environmental amenities variables. This suggests two key points: first, we can trust in time-constant gradient assumption (TCGA) across 2017-2019, solidifying our justification for treating the 2017-2019 period as one unified equilibrium; and second, there is no momentum in shifts in price gradients in neither direction leading up to the onset of the Pandemic. These results enhance the plausibility of our claim that the change in WTP was not due to the pre-existing trend carried over from pre-Pandemic but rather caused by the Pandemic.

Additionally, we conducted a similar placebo test for quantile regression and found that the observed higher appreciation in tree canopy for lower-end houses was not present during the fake Pandemic years. This further supports our claim that the changes in amenity values were caused by the Pandemic, and not a pre-existing trend.

D.1.i Potential Pre-existing Trend / Falsification Test: Metro Vancouver: Quantile

Potential Pre-existing Trend/ Falsification Test: Metro Vancouver: Quantile

	(1)	(2)	(3)	(4)
	SFD		CAR	
Quantile (τ)	25% Low-end	75% High-end	25% Low-end	75% High-end
postCOVID	.3721	.5479**	.6137***	.2881
	(.2464)	(.2334)	(.2086)	(.1804)
Baseline:				
lnLivingArea	.2395***	.254***	.626***	.7162***
	(.0081)	(.008)	(.0203)	(.0211)
lnLotSize	.1987***	.2646***		
	(.0052)	(.0065)		
lnDistCBD	-.0787***	-.0851***	-.0386***	-.0399***
	(.0124)	(.0134)	(.0101)	(.0118)
lnDistUGS	.0044**	.0019	-2.2e-04	-6.2e-04
	(.0018)	(.0019)	(.0033)	(.0036)
lnDistNaturalArea	-.0021	.0014	2.2e-04	-.0073**
	(.0018)	(.002)	(.0043)	(.0032)
lnDistBlueSpace	.0095***	.0034	-.0116***	-.0107
	(.0031)	(.0035)	(.004)	(.0068)
lnDistAgriculture	.0137***	.0131***	-.0062	.0071
	(.0023)	(.0025)	(.0047)	(.0049)
TreeCanopy	-.0011***	-8.3e-04***	-.0025***	-.0014***
	(1.6e-04)	(1.4e-04)	(3.0e-04)	(2.8e-04)
Change from Baseline:				
postCOVID × lnLivingArea	.0188	.0155	-.049**	-.0258
	(.0147)	(.0135)	(.0233)	(.0216)
postCOVID × lnLotSize	-.0227***	-.0321***		
	(.0074)	(.0088)		
postCOVID × lnDistCBD	-.0364*	-.0228	-.0019	-.003
	(.0203)	(.0196)	(.0091)	(.0097)
postCOVID × lnDistUGS	-.0029	-.0011	.0021	-.0079***
	(.0036)	(.0026)	(.0044)	(.0021)
postCOVID × lnDistNaturalArea	.0035	-1.5e-04	-.0046	.0033
	(.0032)	(.0026)	(.0031)	(.0023)
postCOVID × lnDistBlueSpace	.0041	7.8e-05	.0026	.0042
	(.0046)	(.0052)	(.0054)	(.0047)
postCOVID × lnDistAgriculture	7.0e-04	.003	.0016	.005
	(.0037)	(.004)	(.0058)	(.0043)
postCOVID × TreeCanopy	1.9e-04	1.1e-04	6.8e-04**	1.3e-05
	(2.2e-04)	(1.9e-04)	(3.1e-04)	(2.3e-04)
Constant	10.14***	9.712***	8.783***	8.385***
	(.1577)	(.1615)	(.1921)	(.2032)
Controls:				
Neighbourhood Fixed Effect	✓	✓	✓	✓
Temporal Fixed Effect	✓	✓	✓	✓
COVID Period Fixed Effect	✓	✓	✓	✓
COVID Policy Effect	✓	✓	✓	✓
Time Varying Unobservables Effect	✓	✓	✓	✓
Observations	20654	20654	24417	24417

Note: Robust standard errors in parentheses are clustered at Census Tract level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Each column represents a separate regression. SFD and CAR refers to Single Family Detached and Condos, Apartments, and Row Houses respectively.
Spatial Fixed Effects at municipality level.
Temporal Fixed Effects at year as well as quarter level.

To conclude the robustness check section for Metro Vancouver, we have tested several modifications to model specification and found that our results are robust enough to repel these challenges. Most importantly, the falsification/placebo test confirms our inference that it was the Pandemic that caused the changes in amenity values, and that the accentuated premiums on tree, blue spaces, and living areas for both SFD and CAR are robust.

D.2 Robustness Check: Alberta

D.2.a Different Scale of Spatial Fixed Effect: Edmonton

Additionally, we conducted a DiD analysis with much coarser spatial fixed effects (Ward level) in Edmonton. The results are presented in the following table.

D.2.a Different Spatial Fixed Effect: Ward Level: Edmonton

Different Spatial Fixed Effect: Ward Level: Edmonton

	(1)	(2)	(3)	(4)	(5)	(6)
	SFD			CAR		
Variables	Naïve	Base	COVID Policy	Naïve	Base	COVID Policy
postCOVID		.1729	.1713		-1.613**	-1.619**
		(.4506)	(.451)		(.7781)	(.7893)
lnLivingArea	.5467***	.5477***	.5476***	.6561***	.6441***	.6439***
	(.0296)	(.0295)	(.0295)	(.077)	(.0782)	(.0782)
lnLotSize	.0786***	.0788***	.0788***			
	(.0074)	(.0073)	(.0073)			
lnDistCBD	-.0794***	-.0783***	-.0783***	-.1192***	-.1231***	-.1236***
	(.0275)	(.0277)	(.0277)	(.0253)	(.0243)	(.0243)
lnDistUGS	-.0011	-.0011	-.0011	-.0077	-.0083	-.0083
	(.0017)	(.0017)	(.0017)	(.0056)	(.0056)	(.0056)
lnDistNaturalArea	-.0193***	-.0193***	-.0193***	-.0163	-.0169	-.0169
	(.0043)	(.0044)	(.0044)	(.0116)	(.0117)	(.0117)
lnDistBlueSpace	.0087	.0088	.0088	.0012	3.7e-04	4.6e-04
	(.006)	(.006)	(.006)	(.0146)	(.0145)	(.0145)
lnDistAgriculture	-.0037	-.0036	-.0036	-.0012	-.003	-.003
	(.0039)	(.0038)	(.0038)	(.0076)	(.0076)	(.0076)
TreeCanopy	-.0011	-.0011	-.0011	.0011	.001	.0011
	(.0013)	(.0013)	(.0013)	(.0041)	(.0041)	(.0041)
postCOVID × lnLivingArea	-.0139	-.02	-.0191	.0612	.198*	.1997*
	(.0627)	(.0754)	(.0754)	(.0707)	(.1028)	(.1042)
postCOVID × lnLotSize	.0204	.0191	.0193			
	(.0165)	(.016)	(.0159)			
postCOVID × lnDistCBD	.0051	-.0036	-.0051	.0183	.051	.0496
	(.0251)	(.0182)	(.0185)	(.0334)	(.0407)	(.0415)
postCOVID × lnDistUGS	-.0034	-.0039	-.0039	-.0096	-.0017	-.0028
	(.0035)	(.0038)	(.0038)	(.012)	(.0122)	(.0123)
postCOVID × lnDistNaturalArea	-.0084	-.0088	-.0086	.0117	.0183	.0176
	(.0072)	(.007)	(.007)	(.015)	(.014)	(.0141)
postCOVID × lnDistBlueSpace	.011	.0103	.0102	.0035	.0111	.0115
	(.0087)	(.0088)	(.0089)	(.0247)	(.0236)	(.0234)
postCOVID × lnDistAgriculture	-.0045	-.0057	-.0058	-.0093	-.0017	-.0015
	(.0052)	(.0045)	(.0045)	(.0113)	(.0101)	(.0102)
postCOVID × TreeCanopy	-1.5e-04	-2.6e-04	-3.2e-04	-.0107	-.0086	-.0087
	(.0018)	(.0019)	(.0019)	(.0077)	(.0078)	(.0079)
Constant	8.657***	8.633***	8.633***	8.68***	8.842***	8.848***
	(.3159)	(.316)	(.316)	(.5114)	(.5249)	(.5252)
Controls:						
Spatial Fixed Effect	✓	✓	✓	✓	✓	✓
Temporal Fixed Effect	✓	✓	✓	✓	✓	✓
COVID Period Fixed Effect		✓	✓		✓	✓
COVID Policy Effect			✓			✓
Observations	11928	11928	11928	3913	3913	3913
R^2	0.818	0.818	0.818	0.684	0.684	0.685
Adjusted R^2	0.817	0.817	0.817	0.678	0.679	0.679
AIC	-12812.7	-12811.3	-12808.6	-347.5	-354.1	-353.7
BIC	-12280.9	-12272.1	-12254.6	66.50	66.17	79.05

Note: Robust standard errors in parentheses are clustered at Ward level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Each column represents a separate regression. SFD and CAR refers to Single Family Detached and Condos, Apartments, and Row Houses respectively.
Spatial Fixed Effects at Census Tract as well as municipality level.
Temporal Fixed Effects at year as well as quarter level.

D.2.b Different Scale of Spatial Fixed Effect: Calgary

We also ran a difference-in-differences (DiD) analysis with much coarser spatial fixed effects (Ward level) in Calgary. The results are presented in Table D.2.b.

D.2.b Different Scale of Spatial Fixed Effect: Ward Level: Calgary

Different Scale of Spatial Fixed Effect: Ward Level: Calgary

	(1)	(2)	(3)	(4)	(5)	(6)
	SFD			CAR		
Variables	Naïve	Base	COVID Policy	Naïve	Base	COVID Policy
postCOVID		-.3921	-.3982		.9158	.9397
		(.2528)	(.2532)		(.8115)	(.8146)
lnLivingArea	.5768***	.5747***	.5747***	.6454***	.6527***	.6527***
	(.0192)	(.0193)	(.0193)	(.0487)	(.0461)	(.0461)
lnLotSize	.166***	.1653***	.1653***			
	(.0149)	(.015)	(.015)			
lnDistCBD	-.1814***	-.1837***	-.1837***	-.0987***	-.0941***	-.0941***
	(.0203)	(.0204)	(.0204)	(.0316)	(.0314)	(.0314)
lnDistUGS	-8.3e-04	-8.6e-04	-8.6e-04	-.0036	-.0036	-.0036
	(9.6e-04)	(9.6e-04)	(9.6e-04)	(.0038)	(.0039)	(.0039)
lnDistNaturalArea	-.008**	-.0082**	-.0082**	-.0093	-.0092	-.0092
	(.004)	(.0041)	(.0041)	(.006)	(.006)	(.0061)
lnDistBlueSpace	-.0265***	-.0269***	-.0269***	.0012	.0016	.0016
	(.0052)	(.0052)	(.0052)	(.008)	(.008)	(.008)
lnDistAgriculture	-.0052**	-.0055**	-.0055**	.0163**	.0176**	.0176**
	(.0024)	(.0025)	(.0025)	(.0077)	(.0078)	(.0078)
TreeCanopy	.0023***	.0022***	.0022***	-.0013	-.0013	-.0013
	(4.7e-04)	(4.7e-04)	(4.7e-04)	(.0012)	(.0012)	(.0012)
postCOVID × lnLivingArea	-.0092	.0071	.0071	-.0715	-.1293	-.129
	(.0245)	(.026)	(.026)	(.0771)	(.1171)	(.1178)
postCOVID × lnLotSize	.065**	.0709**	.0707**			
	(.0294)	(.0313)	(.0312)			
postCOVID × lnDistCBD	-.0197*	-.0055	-.0053	-.0051	-.0384*	-.0395*
	(.0116)	(.0123)	(.0123)	(.033)	(.0201)	(.0202)
postCOVID × lnDistUGS	-.0012	-8.8e-04	-9.1e-04	.0096*	.0088*	.0084
	(.0017)	(.0017)	(.0017)	(.0049)	(.0052)	(.0052)
postCOVID × lnDistNaturalArea	.0011	.0022	.0022	-.0044	-.0048	-.0044
	(.0034)	(.0035)	(.0035)	(.0059)	(.0059)	(.0058)
postCOVID × lnDistBlueSpace	-.0045	-.0019	-.0019	-.0034	-.0084	-.0088
	(.0052)	(.0051)	(.0051)	(.0104)	(.0105)	(.0104)
postCOVID × lnDistAgriculture	-.0049**	-.0038*	-.0038*	.004	-.0015	-.0012
	(.0023)	(.002)	(.002)	(.0102)	(.0085)	(.0083)
postCOVID × TreeCanopy	-8.3e-04	-7.3e-04	-7.2e-04	-.0012	-.0012	-.0013
	(6.5e-04)	(6.4e-04)	(6.4e-04)	(.0013)	(.0013)	(.0013)
Constant	9.19***	9.246***	9.247***	8.633***	8.51***	8.508***
	(.2763)	(.2828)	(.2828)	(.5211)	(.4897)	(.4894)
Controls:						
Spatial Fixed Effect	✓	✓	✓	✓	✓	✓
Temporal Fixed Effect	✓	✓	✓	✓	✓	✓
COVID Period Fixed Effect		✓	✓		✓	✓
COVID Policy Effect			✓			✓
Observations	18148	18148	18148	5887	5887	5887
R^2	0.851	0.851	0.851	0.765	0.766	0.766
Adjusted R^2	0.850	0.850	0.850	0.763	0.763	0.763
AIC	-21185.4	-21188.0	-21186.2	-2754.1	-2757.9	-2755.6
BIC	-20599.9	-20594.7	-20577.3	-2293.1	-2290.3	-2274.6

Note: Robust standard errors in parentheses are clustered at Ward level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Each column represents a separate regression. SFD and CAR refers to Single Family Detached and Condos, Apartments, and Row Houses respectively.
Spatial Fixed Effects at Census Tract as well as municipality level.
Temporal Fixed Effects at year as well as quarter level.

D.2.c Potential Pre-existing Trend / Falsification Test: Edmonton

Similar to section D.1.h, we conducted a falsification test in Edmonton. The results of the falsification test are presented below.

D.2.c Potential Pre-existing Trend / Falsification Test: Edmonton

Potential Pre-existing Trend / Falsification Test: Edmonton
Pandemic (2018 - Mar.2020 vs - Mar.2021) vis-à-vis Placebo (2017 - Mar.2019 vs - Mar.2020)

	(1)	(2)	(3)	(4)
	SFD		CAR	
Variables	Pandemic	Placebo	Pandemic	Placebo
postCOVID	-.0516	-.4473	-2.225**	-2.399***
	(.4535)	(.3811)	(.937)	(.741)
Baseline:				
lnLivingArea	.5451***	.5141***	.5496***	.4436***
	(.0383)	(.0489)	(.1021)	(.1103)
lnLotSize	.0689***	.0732***		
	(.0093)	(.0117)		
lnDistCBD	-.1105	-.0908	-.1188*	-.162***
	(.0684)	(.0678)	(.0666)	(.0568)
lnDistUGS	7.1e-04	.0024	-.0042	-.0021
	(.0022)	(.0023)	(.0076)	(.0087)
lnDistNaturalArea	-.0291***	-.0315***	-.0148	-.018
	(.0055)	(.0069)	(.014)	(.0161)
lnDistBlueSpace	-.0049	-.0048	-.036	-.0255
	(.0062)	(.0067)	(.0254)	(.0281)
lnDistAgriculture	.0018	.0026	.0175	.0318**
	(.0042)	(.004)	(.0112)	(.0152)
TreeCanopy	9.5e-04	.0015	-.0041	-.0065
	(.0013)	(.0014)	(.0053)	(.0062)
Change from Baseline:				
postCOVID × lnLivingArea	-.0157	.0746	.2789**	.3554***
	(.0768)	(.0584)	(.121)	(.1006)
postCOVID × lnLotSize	.0257	-.0115		
	(.0164)	(.0191)		
postCOVID × lnDistCBD	.0106	-.0117	.0539	.0665
	(.0241)	(.0296)	(.0337)	(.0577)
postCOVID × lnDistUGS	-.0038	-.0035	-.0067	-.0033
	(.0035)	(.005)	(.0133)	(.0102)
postCOVID × lnDistNaturalArea	-.0071	.0066	.0184	.0198
	(.0069)	(.0065)	(.0152)	(.0171)
postCOVID × lnDistBlueSpace	.0082	-.0014	.0056	-.0322
	(.0076)	(.0068)	(.026)	(.0203)
postCOVID × lnDistAgriculture	-.0035	-.0045	-.0122	-.0247*
	(.0041)	(.0039)	(.0106)	(.0142)
postCOVID × TreeCanopy	-.0023	-9.3e-04	-.0071	.006
	(.0017)	(.0016)	(.0081)	(.0055)
Constant	9.635***	10.83***	7.739***	8.082***
	(.4821)	(.65)	(.8017)	(.8985)
Controls:				
Spatial Fixed Effect	✓	✓	✓	✓
Temporal Fixed Effect	✓	✓	✓	✓
COVID Period Fixed Effect	✓	✓	✓	✓
COVID Policy Effect	✓	✓	✓	✓
Pandemic Period Spatial Fixed Effect	✓	✓	✓	✓
Observations	8016	6172	2567	2055
R^2	0.846	0.846	0.757	0.760
Adjusted R^2	0.841	0.839	0.734	0.732
AIC	-9565.0	-7380.2	-817.2	-689.5
BIC	-9082.8	-6942.9	-454.5	-357.5

Note: Robust standard errors in parentheses are clustered at Census Tract level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Each column represents a separate regression. SFD and CAR refers to Single Family Detached and Condos, Apartments, and Row Houses respectively.
Spatial Fixed Effects at Census Tract as well as municipality level.
Temporal Fixed Effects at year as well as quarter level.

D.2.d Potential Pre-existing Trend / Falsification Test: Calgary

Similar to section D.1.h, we conducted a falsification test in Calgary. The results of the falsification test are presented below. In the fake Pandemic year, we did not observe any increase in the value of larger houses, as opposed to the Pandemic period, which strengthens our claim that the change was due to the Pandemic and not a pre-existing trend.

D.2.d Potential Pre-existing Trend / Falsification Test: Calgary

Potential Pre-existing Trend / Falsification Test: Calgary
Pandemic (2018 - Mar.2020 vs - Mar.2021) vis-à-vis Placebo (2017 - Mar.2019 vs - Mar.2020)

	(1)	(2)	(3)	(4)
	SFD		CAR	
Variables	Pandemic	Placebo	Pandemic	Placebo
postCOVID	-.2094	.0373	.6565	1.155
	(.2722)	(.2485)	(.728)	(.7727)
Baseline:				
lnLivingArea	.6074***	.6047***	.6188***	.6444***
	(.0165)	(.0208)	(.0687)	(.0836)
lnLotSize	.1574***	.1491***		
	(.0143)	(.0183)		
lnDistCBD	-.0583	-.0491	-.05	-.0325
	(.0541)	(.0577)	(.0786)	(.0817)
lnDistUGS	-.001	-.0018	-.0066	-.0037
	(.001)	(.0014)	(.0045)	(.0044)
lnDistNaturalArea	-.0103**	-.0107**	-4.7e-04	-.0012
	(.0043)	(.0052)	(.0045)	(.005)
lnDistBlueSpace	-.0323***	-.0349***	-.0026	.0027
	(.0053)	(.0053)	(.0111)	(.0112)
lnDistAgriculture	-.0027*	-.0026	.0047	.0142
	(.0015)	(.0019)	(.0119)	(.0151)
TreeCanopy	.0023***	.002***	-.0033**	-.0031*
	(4.6e-04)	(6.6e-04)	(.0016)	(.0017)
Change from Baseline:				
postCOVID × lnLivingArea	-.0092	.0045	-.1064	-.0763
	(.0224)	(.0223)	(.1122)	(.1196)
postCOVID × lnLotSize	.0494*	.0208		
	(.0269)	(.022)		
postCOVID × lnDistCBD	.0079	-.0144	-.0081	-.0466*
	(.02)	(.0167)	(.0251)	(.0248)
postCOVID × lnDistUGS	-5.3e-04	.0016	.0052	-.0063
	(.0017)	(.0018)	(.0057)	(.0053)
postCOVID × lnDistNaturalArea	-.0033	.0018	-.0119	9.3e-04
	(.0042)	(.0045)	(.0076)	(.0057)
postCOVID × lnDistBlueSpace	-.003	.0031	-.0031	-.0083
	(.0049)	(.0051)	(.0131)	(.0087)
postCOVID × lnDistAgriculture	-.0028*	-.0019	-5.2e-04	-.022*
	(.0016)	(.0017)	(.0127)	(.0117)
postCOVID × TreeCanopy	-4.8e-04	3.4e-04	.0011	-2.3e-05
	(6.4e-04)	(7.5e-04)	(.0015)	(.0014)
Constant	7.696***	7.541***	5.689*	6.648***
	(.8012)	(1.031)	(3.005)	(1.284)
Controls:				
Spatial Fixed Effect	✓	✓	✓	✓
Temporal Fixed Effect	✓	✓	✓	✓
COVID Period Fixed Effect	✓	✓	✓	✓
COVID Policy Effect	✓	✓	✓	✓
Pandemic Period Spatial Fixed Effect	✓	✓	✓	✓
Observations	11979	9330	3920	3219
R^2	0.880	0.880	0.814	0.819
Adjusted R^2	0.877	0.876	0.801	0.804
AIC	-16297.5	-12710.2	-2620.9	-2216.4
BIC	-15780.2	-12231.7	-2219.4	-1845.8

Note: Robust standard errors in parentheses are clustered at Census Tract level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Each column represents a separate regression. SFD and CAR refers to Single Family Detached and Condos, Apartments, and Row Houses respectively.
Spatial Fixed Effects at Census Tract as well as municipality level.
Temporal Fixed Effects at year as well as quarter level.

D.2.e Different Observations: Excluding Transactions in the First Two Months of Pandemic Onset: Edmonton

I re-estimated the models for both Edmonton, and Calgary, excluding the transactions that occurred during the onset of the Pandemic and up to six weeks afterward (i.e., until the beginning of May). I report that there were no significant changes in the results.

D.2.e Different Observations: Excluding Transactions in the First Two Months of Pandemic Onset: Edmonton

Different Observations: Edmonton
Excluding Transactions in the First Two Months of Pandemic Onset (Mar.2020 - May.2020)

	(1)	(2)	(3)	(4)
	SFD		CAR	
Variables				
postCOVID	-.0439	.024	-1.972**	-2.174***
	(.4443)	(.4307)	(.802)	(.8331)
Baseline:				
lnLivingArea	.5397***	.5398***	.5972***	.5972***
	(.031)	(.0312)	(.0785)	(.0787)
lnLotSize	.0751***	.0748***		
	(.0077)	(.0077)		
lnDistCBD	-.1059*	-.1046*	-.086**	-.0865**
	(.0631)	(.0619)	(.0432)	(.0423)
lnDistUGS	6.9e-05	1.5e-04	-.0047	-.0046
	(.0014)	(.0014)	(.0061)	(.0061)
lnDistNaturalArea	-.0276***	-.0276***	-.0153	-.0146
	(.004)	(.004)	(.013)	(.0132)
lnDistBlueSpace	-.004	-.004	-.0398**	-.04**
	(.0054)	(.0054)	(.0188)	(.0193)
lnDistAgriculture	.0039	.004	.0115	.0122
	(.0034)	(.0034)	(.0092)	(.0094)
TreeCanopy	2.4e-04	3.4e-04	-.0063	-.0063
	(.0012)	(.0012)	(.0045)	(.0045)
Change from Baseline:				
postCOVID × lnLivingArea	-.0196	-.0194	.2336**	.244**
	(.0778)	(.0759)	(.1086)	(.109)
postCOVID × lnLotSize	.0207	.0239		
	(.0175)	(.0174)		
postCOVID × lnDistCBD	.0012	-.0015	.0417	.0404
	(.0173)	(.0252)	(.0345)	(.0402)
postCOVID × lnDistUGS	-.0034	-.0044	-5.6e-04	-.004
	(.0037)	(.0035)	(.01)	(.0102)
postCOVID × lnDistNaturalArea	-.0054	-.0056	.0299**	.026*
	(.0064)	(.0068)	(.0132)	(.0135)
postCOVID × lnDistBlueSpace	.0101	.011	-.0013	.0098
	(.0077)	(.0072)	(.0221)	(.0234)
postCOVID × lnDistAgriculture	-.0038	-.0046	-.0041	-.008
	(.0035)	(.0041)	(.0087)	(.0091)
postCOVID × TreeCanopy	-.0014	-.002	-.0054	-.0064
	(.0016)	(.0016)	(.0074)	(.0075)
Constant	10.17***	10.15***	8.389***	8.339***
	(.3704)	(.3962)	(.6831)	(.7234)
Controls:				
Spatial Fixed Effect	✓	✓	✓	✓
Temporal Fixed Effect	✓	✓	✓	✓
COVID Period Fixed Effect	✓	✓	✓	✓
COVID Policy Effect	✓	✓	✓	✓
Pandemic Period Spatial Fixed Effect		✓		✓
Observations	11661	11661	3840	3840
R^2	0.844	0.844	0.753	0.753
Adjusted R^2	0.841	0.841	0.738	0.738
AIC	-14420.5	-14414.1	-1323.7	-1307.9
BIC	-13993.4	-13906.0	-1004.8	-920.2

Note: Robust standard errors in parentheses are clustered at Census Tract level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Each column represents a separate regression. SFD and CAR refers to Single Family Detached and Condos, Apartments, and Row Houses respectively.
Spatial Fixed Effects at Census Tract as well as municipality level.
Temporal Fixed Effects at year as well as quarter level.

D.2.f Different Observations: Excluding Transactions in the First Two Months of Pandemic Onset: Calgary

D.2.f Different Observations: Excluding Transactions in the First Two Months of Pandemic Onset: Calgary

Different Observations: Calgary
Excluding Transactions in the First Two Months of Pandemic Onset (Mar.2020 - May.2020)

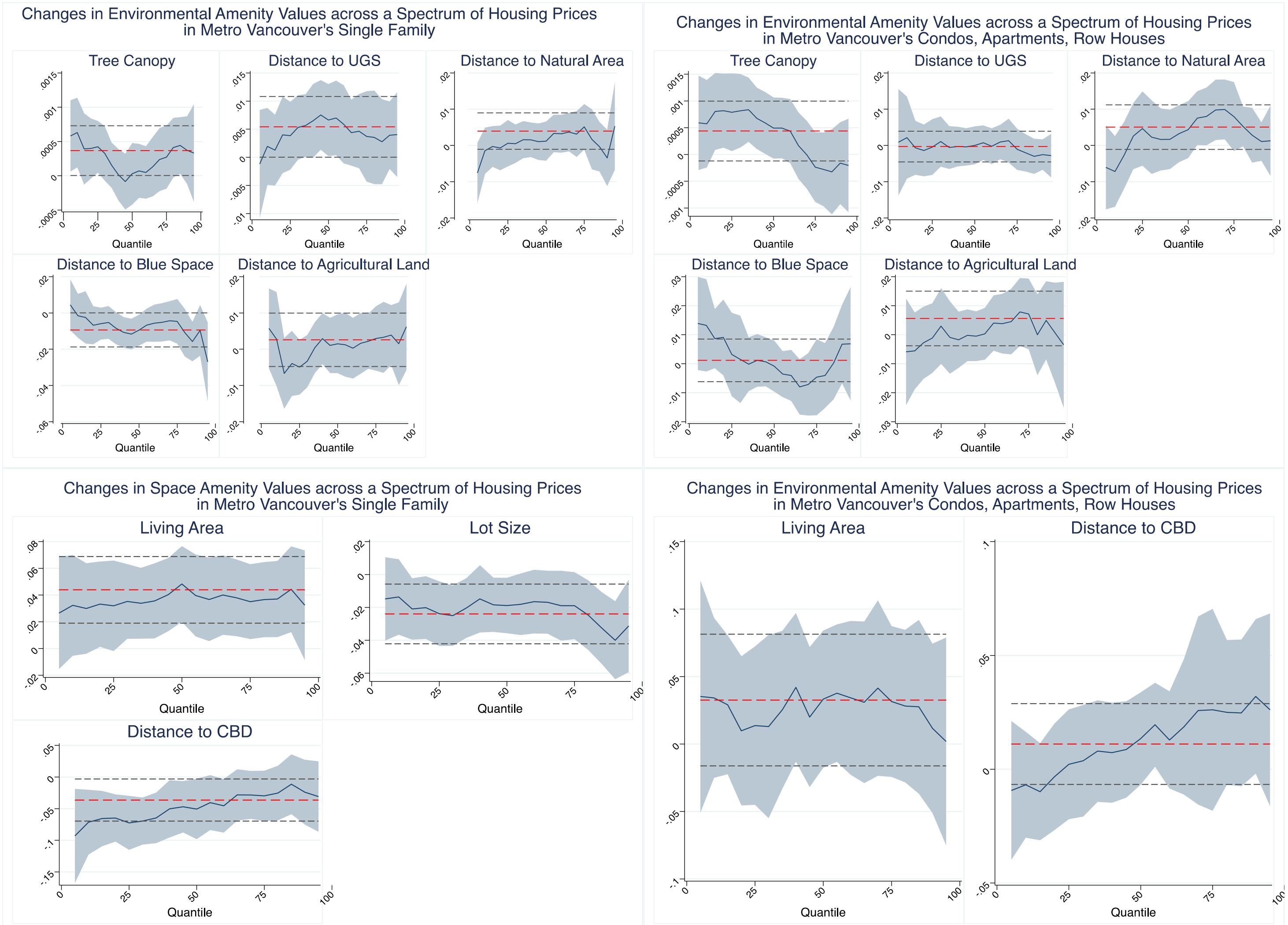
	(1)	(2)	(3)	(4)
	SFD		CAR	
Variables				
postCOVID	-.5068**	-.5742**	1.177	.7885
	(.2501)	(.2814)	(.9255)	(.8307)
Baseline:				
lnLivingArea	.5802***	.5809***	.6345***	.6352***
	(.0195)	(.0197)	(.0502)	(.05)
lnLotSize	.1507***	.1507***		
	(.015)	(.015)		
lnDistCBD	-.0472	-.0493	-.0617	-.0625
	(.0468)	(.0472)	(.0729)	(.0734)
lnDistUGS	-.0011	-.0011	-.0037	-.0037
	(8.7e-04)	(8.7e-04)	(.0038)	(.0038)
lnDistNaturalArea	-.0137***	-.0133***	-.0027	-.0023
	(.0038)	(.0038)	(.0042)	(.0042)
lnDistBlueSpace	-.0292***	-.0294***	.0019	.0015
	(.0046)	(.0046)	(.0097)	(.0096)
lnDistAgriculture	-.0033*	-.0036*	.0086	.008
	(.0019)	(.002)	(.0112)	(.0116)
TreeCanopy	.0019***	.0019***	-.003*	-.0031**
	(3.8e-04)	(3.8e-04)	(.0015)	(.0015)
Change from Baseline:				
postCOVID × lnLivingArea	.024	.0165	-.1252	-.1345
	(.0249)	(.0262)	(.1299)	(.1313)
postCOVID × lnLotSize	.0549*	.0555*		
	(.0292)	(.0298)		
postCOVID × lnDistCBD	.0075	.0182	-.0352	-.0079
	(.0122)	(.0196)	(.0238)	(.0254)
postCOVID × lnDistUGS	-7.4e-04	-6.7e-04	.0045	.0039
	(.0018)	(.0018)	(.005)	(.0052)
postCOVID × lnDistNaturalArea	-4.8e-04	-.0028	-.0091	-.0155*
	(.0034)	(.0039)	(.0074)	(.0088)
postCOVID × lnDistBlueSpace	-.0032	-.0023	-.006	-.005
	(.0048)	(.0049)	(.0115)	(.0132)
postCOVID × lnDistAgriculture	-.0031	-.0019	-.0037	-.003
	(.0019)	(.0019)	(.0124)	(.0129)
postCOVID × TreeCanopy	3.8e-05	7.5e-05	6.1e-04	.0013
	(6.3e-04)	(6.3e-04)	(.0015)	(.0015)
Constant	6.939***	6.953***	8.907***	8.141***
	(.6983)	(.7015)	(2.845)	(3.009)
Controls:				
Spatial Fixed Effect	✓	✓	✓	✓
Temporal Fixed Effect	✓	✓	✓	✓
COVID Period Fixed Effect	✓	✓	✓	✓
COVID Policy Effect	✓	✓	✓	✓
Pandemic Period Spatial Fixed Effect		✓		✓
Observations	17755	17755	5735	5735
R^2	0.874	0.874	0.810	0.811
Adjusted R^2	0.872	0.872	0.801	0.801
AIC	-23771.3	-23767.6	-3910.8	-3908.7
BIC	-23312.0	-23207.1	-3558.1	-3476.2

Note: Robust standard errors in parentheses are clustered at Census Tract level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Each column represents a separate regression. SFD and CAR refers to Single Family Detached and Condos, Apartments, and Row Houses respectively.
Spatial Fixed Effects at Census Tract as well as municipality level.
Temporal Fixed Effects at year as well as quarter level.

D.3 Quantile Regression Plots

These figures plot the changes in the willingness-to-pay (WTP) for amenities, with the y-axis denoting the changes in WTP and the x-axis indicating the quantile of housing prices obtained from Section 3.5.3. The red and black dotted lines represent the coefficient and confidence interval, respectively, obtained from the OLS analysis in Section 3.5.2

D.3 Quantile Regression Plots



D.4 Application of Machine Learning for Variable Selection

Hedonic studies have recently begun to utilize machine learning techniques, including the use of CART (Classification and Regression Tree) for variable selection to assess the relative importance of each attribute in the predicting housing prices (Yoo et al., 2012). For a theoretical background on CART, refer to Chan and Mátyás (2022). In this study, we applied random forest to analyze the importance of variables in our models. The importance was measured in terms of "*partitioning ability*" or how well a particular attribute of interest was able to correctly classify housing prices using covariates (Chan & Mátyás, 2022). The results for both SFD and CAR in Metro Vancouver are shown below, and they generally support our selection of controlling variables.

D.4 Variable Importance Chart Using CART Analysis