The Impact of Greenbelts on Housing Markets: Evidence from Toronto*

Alexander Hempel†
University of Toronto

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Abstract

Greenbelts are a common policy tool used to protect natural spaces from urban sprawl. With rising housing costs in many metropolitan areas, questions have been raised about the impact of Greenbelts on housing markets. Despite the intense policy debate, there is little empirical evidence on how Greenbelts affect housing supply and prices across a metropolitan region. In this paper, I contribute a new approach to estimate the impact of Greenbelt policies on housing market outcomes and use it to evaluate the introduction of the world's largest contiguous Greenbelt, which occurred in Toronto in the early-2000s. Using rich project-level data on housing developments, I first show that the Greenbelt did have an impact on housing development patterns, where restricted, developable census tracts saw less housing built relative to unrestricted tracts. Then, to quantify the effects across the metropolitan area, I build and estimate a model of housing supply and demand with heterogeneity at the census tract level. Using the model, I simulate the counterfactual scenario in which no Greenbelt was implemented, finding that the Greenbelt led to a reduction in housing supply of almost 10,000 units and price increases of 4.1% for houses and 6.1% for condominiums in 2010; this corresponds to an increase in condo rent of $675 a year. Finally, I show that had the Greenbelt been paired with a small relaxation of zoning regulations, the effects of the Greenbelt would be minimized, suggesting a viable alternative to developing Greenbelts in the face of rising housing prices.

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†University of Toronto, Department of Economics, Email: alex.hempel@mail.utoronto.ca.

1 Introduction

With cities containing a larger share of the world's population, urban sprawl is becoming an increasingly relevant issue. Urban sprawl, where low-density residential housing expands into the nearby countryside, has several environmental costs ranging from the loss of ecosystems and valuable farmland to pollution from increased car usage (Kahn, 2000). Concern over urban sprawl has led to the creation of greenbelts and other urban growth boundaries, which restrict housing construction on undeveloped land. Examples of greenbelt policies can be found around cities such as London, Amsterdam, Seoul, Portland and Toronto.

While greenbelts are designed to stop sprawl, they may also impose substantial costs. When greenbelts block housing development, they limit the supply of housing and drive up prices, which one can interpret as the "cost" of protecting the greenbelt. With rising housing prices in many major cities, greenbelts have become a contentious policy, where environmental concerns are often pitted against housing affordability objectives. The issue of rising housing prices is not strictly a trade-off between renters and homeowners, but also may impact the broader economy through losses in productivity and labour mobility (Hsieh & Moretti, 2019; Behrens et al., 2014). Despite the intense policy debate, the magnitude of the costs imposed by greenbelts are poorly understood. This is in part because theoretically, greenbelts may lead to either small price effects, if they simply relocate housing elsewhere in the city, or large price effects, if building elsewhere is challenging such as when there are significant land use restrictions (Gyourko & Krimmel, 2021; Glaeser et al., 2006). Empirically, there is little evidence on the magnitude of these costs throughout a region.

In this paper, I develop a new framework for evaluating the housing market impacts of greenbelt policies and their potential interaction with other land use restrictions. I then apply this framework to evaluate the impact of the Ontario Greenbelt, which is located around Toronto, Canada. As the largest contiguous greenbelt in the world, the Ontario Greenbelt serves as a useful setting for evaluating greenbelt policies. Furthermore, the introduction of the policy in the early-2000s allows for a comparison of housing development before and after the policy with high quality panel data, a feature which is not always possible for other greenbelts introduced decades prior.

Exploiting this policy variation, I use an event-study framework to show that the Ontario Greenbelt had a material impact on housing development patterns in the Greater Toronto Area (GTA). I compare housing development trends in census tracts with more Greenbelt coverage to those with less coverage, before and after the policy was implemented, to see if it was binding. I find that while housing development in these census tracts evolved in parallel before the policy, census tracts more restricted by the Greenbelt saw considerably less development relative to the less restricted tracts after. Although these results show that the Greenbelt did affect housing patterns in the region, it is difficult to disentangle the magnitude of the direct effect of greenbelt coverage from spillovers that may have occurred, where the Greenbelt diverted housing construction from restricted to unrestricted areas. To understand these effects in isolation and to expand the analysis to the broader metropolitan area, I develop a model of housing supply and demand for the region.

To estimate the model, I take advantage of granular data on housing construction and transactions from 2000-2010 to recover census tract level housing supply elasticities[1] as well as the housing demand system for the Greater Toronto Area. Information on housing developments comes from Altus Group's Residential New Homes database, which covers the universe of housing projects in the GTA from 2000 to present. Housing transactions data come from Teranet's GeoWarehouse database. The housing supply curves for each census tract are a function of observable tract-level characteristics, and they reveal considerable heterogeneity across locations. I use a discrete, location choice demand model to recover housing demand for each location. With the estimated model, I simulate the effect of the introduction of the Ontario Greenbelt on housing supply and prices.

I find that the Greenbelt had a substantial impact on housing prices just five years after the policy was introduced. By 2010, the Greenbelt led to a reduction of almost 15,000 houses in areas it restricted, which amounts to a reduction in suburban housing construction of 21%. Meanwhile, the Greenbelt also led to the creation of nearly 5,000 additional units in other areas of the city, both as condos (2,850) and other houses (2,000), however this was not enough to offset the decrease in the Greenbelt itself. Taken together, this means that the net effect of the policy was a decrease of almost 10,000 housing units in the region. This housing supply shock translated into an increase in housing prices of 4.1% for single family homes and 6.1% for condominium apartments, which corresponds to an increase in condominium rent of $675 a year. As land becomes more scarce on the urban fringe, one would expect these effects to increase over time.

While these effects are large, I show that land use regulations play a substantial role in driving up prices. One finding in my housing supply model is that census tracts located in an "urban growth center" (UGC) exhibit much larger condominium supply elasticities compared to non-UGC tracts. These UGCs, which are regional subcenters targeted for greater density, were introduced concurrently with the Ontario Greenbelt as part of the *Places to Grow Act* (2005). While the designation does not contain any binding incentives, the targets do enter

[1]These elasticities are at the same geographic level as the ones estimated for the United States in (Baum-Snow & Han, 2023), but in this paper they represent elasticities estimated at one year intervals instead of ten year intervals.

into decisions made by municipal planning officials. If these designations were expanded to more census tracts, this could increase the housing supply response within the city. I simulate a counterfactual of what would have happened if UGC targets were extended to an additional 19 census tracts within 1km of the existing boundaries. I find that this small change to land use regulation could entirely neutralize the housing supply impacts of the Ontario Greenbelt. This would lead to 8% lower prices for condominiums and no change in the price of single family homes (rather than a 4% increase without the land use reform).

These results have important implications for how policymakers approach land use reform. Given the choice between removing greenbelts and reforming land use restrictions, a policymaker could achieve similar price effects based on the results of the counterfactual exercises. However, the two policies differ in how they impact other important outcomes. Namely, greenbelts also provide a number of benefits both directly through open space amenities (Anderson & West, 2006; Koster, 2023) and indirectly through the promotion of density. The benefits of increased density tend to outweigh the costs (Combes et al., 2019) because of agglomeration effects (Ahlfeldt & Pietrostefani, 2019), but also because of other factors such as reduced traffic congestion which leads to less air pollution (Gibson & Carnovale, 2015). As a result, greenbelts would appear to be the preferable policy approach given the two alternatives.

However, my results also highlight one reason why land use reform within cities may not occur. The costs of higher housing prices fall predominantly on renters and first-time home buyers as opposed to incumbent homeowners, who benefit from higher housing prices. The homevoter hypothesis (Fischel, 2004) argues that homeowners have a financial interest in preserving the value of their home and will oppose efforts to build more housing in their neighbourhood. Empirical research has supported this theory in the United States (Dehring et al., 2008) and in Toronto specifically, where city councillors with more homeowners in their ward are shown to oppose more housing construction (Fang et al., 2023). If homeowners also value the benefits of greenbelt policies, then you have the situation that holds in practice: a restrictive greenbelt, restrictive land use policies within cities and higher prices for renters.

This paper primarily contributes to the literature looking at the impact of greenbelt and urban growth boundary policies, where it is the first paper to incorporate panel data into a model of an urban area to understand these impacts. Prior work from Walsh (2007) and Koster (2023) examined the effect of greenbelt style policies across a metropolitan area using a static, model-based estimation approach. Koster (2023) studied the impact of the English Greenbelt, which was introduced in the 1950's and covers 13% of England, using data from the present day and argued that the amenity benefits from the policy made the Greenbelt welfare improving. Due to the more recent introduction of the Ontario Greenbelt, I am able to study how the Ontario Greenbelt actually altered development patterns looking before and after the policy. Other empirical work studying urban growth boundaries that did look before and after a greenbelt policy focused solely on the areas near to the boundary, but not the metropolitan area as a whole (Cunningham, 2007; Deaton & Vyn, 2010). There is also a theoretical literature that looks at the impact of greenbelt policies (Quigley & Swoboda, 2007) and compares urban growth boundaries to alternative policy solutions (Brueckner, 2001, 2007; Anas & Rhee, 2007; Bento et al., 2006).

This paper also contributes to the literature on land use regulation and development frictions by looking at the interaction of land use policies within cities with those on the urban fringe. Land use restrictions within cities have received significant attention in recent years as researchers have sought explanations for rising housing costs (Anagol et al., 2021; Kulka et al., 2022; Glaeser & Gyourko, 2018; Turner et al., 2014; Saiz, 2010; Glaeser & Ward, 2009; Ihlanfeldt, 2007; Mayer & Somerville, 2000). However, much of the land use literature focuses on policies such as minimum lot sizes and maximum built-area ratios, which regulate within city development more than development on the urban fringe. Other development frictions which may be relevant in this paper include land assembly frictions (Brooks & Lutz, 2016) and dynamic considerations from real options (Murphy, 2018; Bulan et al., 2009; Cunningham, 2007). Meanwhile, research such as Koster (2023) that focuses on the impact of greenbelt policies, does not incorporate existing land use restrictions, development frictions or heterogeneity in housing supply responses into their paper. This paper will incorporate frictions and heterogeneity in the supply response within a model with a greenbelt to explore how the impact of a greenbelt policies depends on the stringency of existing regulation.

Finally, this paper contributes to a newer literature examining the vertical structure of cities. Historically, most literature has focused on the horizontal expansion of the urban area, but recent work from Ahlfeldt & Barr (2022) has highlighted the importance of looking at the vertical structure of cities to understand how cities will grow in the future (Ahlfeldt & McMillen, 2018; Helsley & Strange, 2008). This paper separates housing supply into single family housing and condominium apartments, where over 250 apartments were constructed in this period that were over 25 storeys tall. This paper offers a potential explanation for the increase in skyscraper construction, which is that as cities reach either policy induced boundaries like greenbelts or natural boundaries such as the ocean or mountains, skyscraper construction will become more profitable as demand is displaced from the urban fringe into the urban center.

2 Context & Data

2.1 Policy Context

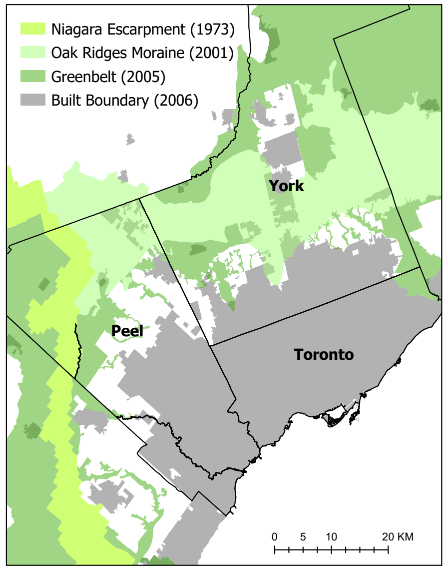
The city of Toronto is a major metropolitan area that has grown significantly in recent decades. Toronto is the largest city in Canada and the sixth largest metropolitan area in North America. From 1991 to 2001, the Toronto area grew by 770,000 residents, from 3.9 million to 4.7 million, or 20% (Statistics Canada, 2016), with much of this coming in the form of immigration. As the city expanded rapidly around the turn of the millennium, there were growing concerns about the destruction of environmentally sensitive land, which prompted protests against large developments and calls for restrictions on sprawl.

In response to political pressure, the Ontario government created the largest contiguous greenbelt in the world around the Greater Toronto Area in the early-2000s (see Figure 1). Greenbelt style protections had already existed in the region starting in 1973 with the Niagara Escarpment, which runs mostly outside of the study area in question in this paper. Then, the Oak Ridges Moraine was protected in 2001, which amounted to nearly 500,000 acres of land. Finally, the *Greenbelt Act (2005)* was introduced which combined the Niagara Escarpment, Oak Ridges Moraine and newly protected land into a single Greenbelt almost 2 million acres in size. The Ontario Greenbelt protects some of the best agricultural land in Canada as well as forests, wetlands and the headwaters that are essential for providing clean water for the region.

The initial introduction of greenbelt policies by the Ontario government in December 2001 came about as a surprising departure from the government's previous stance on environmental issues. The provincial premier at the time, Mike Harris, had previously extolled the virtues of a "common-sense revolution", where the government reduced its involvement in several policy portfolios including the environment. However, a water contamination scandal in 2001 prompted Harris' resignation and a shift towards more environmental policy engagement including the creation of the Oak Ridges Moraine (Winfield, 2012). This shift was not successful electorally as the government lost the provincial election in 2003 to the Ontario Liberal party. This sudden turnaround however, does make the initially policy shock somewhat unanticipated.

The creation of the complete Greenbelt in 2005 was more anticipated in terms of timing, but there was still uncertainty over the location. The Ontario Liberal party campaigned in 2003 on a promise to further expand the Greenbelt and ultimately won the election. Over the following year and a half, there were several consultations about the plan, but the government did not commit to a specific boundary in order to prevent speculation on land around the boundary. While there was lobbying from several parties including developers,

Figure 1: Map of the Ontario Greenbelt



Greenbelt protections in the Greater Toronto Area were introduced in three phases. There were initial protections on the Niagara Escarpment in 1973, which mostly bypasses the region around Toronto. Then, in 2001, the Oak Ridges Moraine was protected, which runs across the northern portion of the city. Finally, the *Greenbelt Act* (2005) was introduced, which brought the prior two protections under the same umbrella and expanded protections to 600,000 acres of land.

farmers and environmental groups, the ultimate Greenbelt boundary left several unexpected winners and losers, with some developers suing the provincial government for including their parcels of land within the Greenbelt (Bradburn, 2022).

The Ontario Greenbelt has been strictly enforced in the years since. The Greenbelt Act (2005) stopped all changes to official plans and development applications that were not approved as of December 2004. This meant that some building still occurred on the Greenbelt after 2005, but only to applications that were accepted prior to this cutoff. The Greenbelt boundary has not been changed since 2005 other than to *add* a number of urban river valleys in 2017. The only exception was in 2022, when the premier of the province tried to remove 7,200 acres of protection from the Greenbelt, however he reversed the decision in the face of significant political pressure. While there are decennial reviews of the policy, it is meant to be a permanent feature of the planning framework for the region, which differs from some other urban growth boundaries, such as the one in Portland, Oregon, which update fairly regularly to population pressures. The permanent nature of this policy means that the effects on the housing market would only be expected to increase over time.

2.2 Data

2.2.1 Data Sources

To evaluate the impact of the Greenbelt on housing development requires combining several sources of data on housing in the Greater Toronto Area. The focus of this paper will be on the three largest regions in the GTA: the city of Toronto and the regions of Peel and York during the years 2000-2010. The primary data source for this analysis is Altus Group's New Residential Homes database, which contains information on all 11,500 plus housing development projects in the GTA from 2000 to the present day. This dataset includes information on the location of the project, the number of units, the type of unit (apartment, row or single), the size of the units the average price of the units and the developer who built the project as well as detailed information on the timing of the project starting with the date a project first sold an assignment to the occupancy date. This information on the first date sold for the project is useful as it gives a precise time when a project would have "entered" the market. I combine this data with information from the 2001 Canadian Census of Population to construct an annual time series of the number of houses of each type available to be purchased in a census tract in a given year.[2] Census tracts contain between 2,500 and 8,000 people and in total, there are 830 census tracts in the GTA.

I add information on housing sales using transaction-level data from Teranet's GeoWarehouse. This is the official land registry for the province and contains all transfers of land, the prices they were transacted at, the type of unit (freehold or condominium), the date of the transaction and a PIN that can be matched to Teranet's parcel data to geolocate each property. In total there were over 1 million housing transactions between 2000 and 2010. The parcel data has information on lot sizes and I supplement this with publicly available data on housing footprints from Peel and York Region and the City of Toronto. I use this information to create an annual series of housing prices of single family homes and apartments for each census tract. In addition, I create a price index that strips away variation in the characteristics of houses sold across the years to ensure the variation in price is not driven by compositional effects.

Finally, I add information on land use status of each parcel. Agriculture and Agri-Food Canada's (AAFC) Land Use time series is a series of satellite imagery maps at a semi-decadal frequency dating back to 2000. The spatial resolution of the maps is 30x30 meter pixels classified into 7 broad categories including forest, cropland and settlement, with breakdowns at the settlement level into categories including settlement housing, roads, vegetation and

[2] This does not account for any housing that is torn down during this period and not rebuilt in some capacity. This could be an issue if say, an apartment building is replaced by another, larger apartment building. However, there appears to be little evidence of this type of activity during this period.

Table 1: Summary Statistics for Census Tracts in 2010 by Housing Type

	Mean	Min	Median	Max
Single Family Homes				
# Units	1,481	294	1,200	18,472
Δ # Units 2000-2010	239	0	0	15,048
Sale Price ($)	505,902	196,761	451,052	1,798,734
Δ Sale Price 2000-2010 (%)	86	39	82	254
Lot Size (sqft)	18,154	2,065	8,818	627,559
Footprint (sqft)	2,758	918	2,080	21,389
Distance to CBD (km)	18	1	17	82
Census Tract Size (acres)	969	39	223	40,857
Undeveloped Land %	6	0	0	91
Greenbelt %	2	0	0	90
Condominiums				
# Units	1,220	5	815	14,042
Δ # Units 2000-2010	336	0	0	12,242
Sale Price ($)	291,490	65,081	260,528	991,002
Δ Sale Price 2000-2010 (%)	63	-49	56	302
Lot Size (sqft)	.	.	.	.
Footprint (sqft)	.	.	.	.
Distance to CBD (km)	17	0	17	74
Census Tract Size (acres)	523	13	205	22,962
Undeveloped Land %	4	0	0	90
Greenbelt %	1	0	0	70

The following summary statistics are for the year 2010 and for single family homes and condominium apartments separately. There are 681 census tracts with single family homes and transactions and 461 census tracts with condominiums. There is no information on the lot size and footprint for condominium apartments.

high reflectance areas. Based on these designations, I can assign the number of square feet of each land use type to each parcel in 5 year intervals. When I aggregate up to the census tract level, I can compute the share of land that is developable (cropland or forest) and the share that is not developable (the remaining categories). I also use the location of a parcel to determine whether a parcel falls inside the Greenbelt or outside and the distance to the Central Business District (CBD) of the City of Toronto (in this case this is the City Hall). I can use these designations to classify whether a census tract is considered developable or not and the extent to which it falls within the Greenbelt.

I plot basic summary statistics of the dataset in Table 1. For the table I include any census tract by unit type pair for which I observe greater than zero initial units and sales for at least ten of the eleven years. As a result, there are 681 census tracts with single family homes and 461 census tracts with condominium apartments, which do not have any information on lot size and footprint as they fall within a building.[3] The average census tract

[3]It should be noted here that these distinctions are made based on ownership structure and not necessarily building structure. This is relevant only for a subset of cases where some townhouses will be classified as

with each housing type has just over one thousand units, but there is significant dispersion in how much construction occurred over the 2000s. In some census tracts, there were upwards of 12-15 thousand units built, while over half of census tracts saw no housing constructed. Sale prices increased substantially over this period in the Toronto region, rising 86% for single family homes and 63% for condominiums on average.[4] Census tracts with single family homes tend to be twice as large as those with condominiums, which makes sense as they are more dense and smaller boundaries are needed to capture the standard number of people. Finally, most census tracts have no undeveloped land and no Greenbelt land, but those that do have undeveloped and Greenbelt land can have substantial amounts. These statistics show that there is considerable heterogeneity across the region in terms of construction, prices and observable characteristics and therefore capturing the response to a Greenbelt policy through average effects may lead to misleading conclusions.

2.2.2 Descriptive Facts

Housing development in the Toronto region has undergone significant change during the period of study. In this section, I will define housing development as the process of bringing a project to the market and offering units up for sale. I measure this in the data using the date that the first unit in a development project is sold to reflect the fact that the units are up for sale. Typically, the process of selling units occurs concurrently to the acquisition of building permits and start of the construction process so this captures the beginning of a development project generally. One advantage of using the date of the first sale is that unlike building permits, which can be acquired and never acted upon, once units are sold there is pressure from buyers to follow through with the project.[5] Another advantage is that because this date reflects when units are sold, it captures when the project effectively starts competing with other housing units in a neighbourhood. Throughout this paper, talk of housing development or construction timing will be referencing this date.

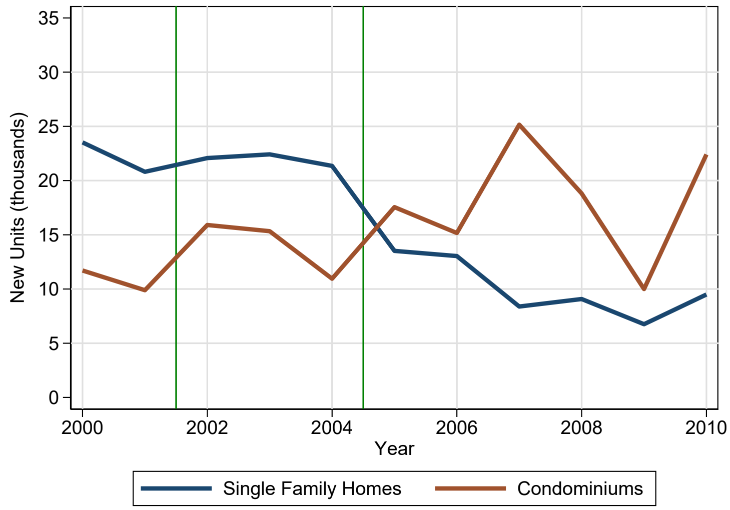
In Figure 2 I show the trends from 2000-2010 in new units brought to the market. For the first half of the decade single family homes were being developed at a rate of between 20 and 25 thousand units a year. However, starting in 2005 this number started declining to below 10 thousand units a year, a reduction by over half. Conversely, the trend for condominiums is increasing during this period, rising from around 10 thousand to as much as 25 thousand

condominiums, while others will be considered single family. There are also some areas with only rental housing, which does not factor into this analysis.

[4] Extreme transaction values were curbed from the sample. Those in the top and bottom percentiles were cut to avoid extreme outliers driving results.

[5] I only include projects that are completed in the analysis. This means that projects that started selling units, but were not completed are not included in the analysis.

Figure 2: New Units Brought to Market Over Time by Type in the GTA



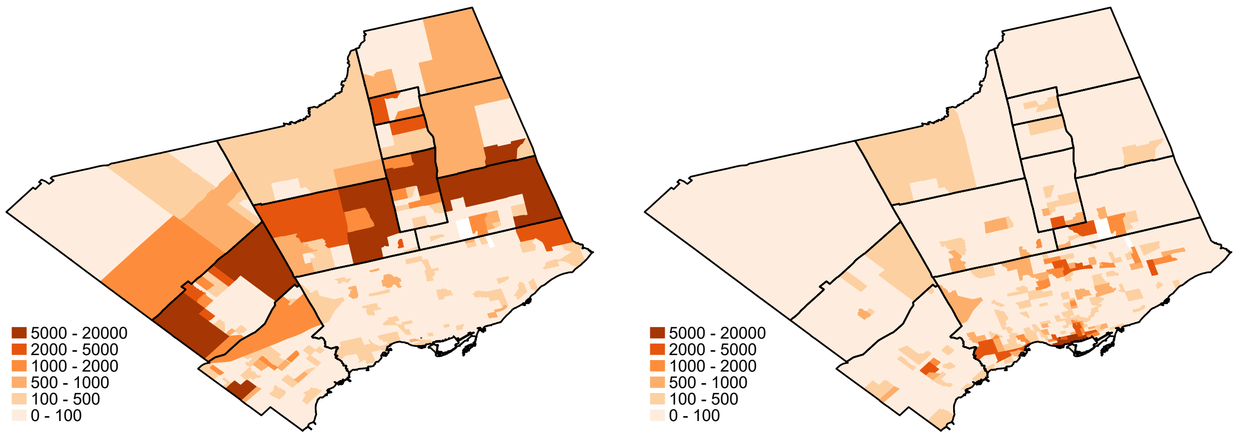
This figure shows the trends in how many units were brought to the market in each year by type. The date used is the date of the first unit sold in a development project. This date usually occurs around the same time that building permits are acquired and that the construction process is getting underway which is a good proxy for developer intentions and behaviour. The dates of the Greenbelt policies are indicated with vertical lines.

in 2007. By 2005, condominium construction became the dominant form of construction in the region. These trends provide suggestive evidence that there was a discernible change in housing development patterns during this time.

In Figure 3, I plot development patterns across space in the region. I show that the majority of single family home construction occurred on the urban fringe in a handful of census tracts that saw 5-15 thousand new units constructed. Within the urban footprint there was very little construction of single family homes during this period. The majority of condominium construction occurred in a very concentrated set of locations in downtown Toronto and some of the regional subcenters, where there were 5-10 thousand units built. Naturally, there were only a few apartments built in the suburban and rural areas.

The Ontario Greenbelt largely affected single family housing development on the urban fringe and therefore the trends and patterns observed are consistent with a story where the Greenbelt slowed urban sprawl. Because there is an uptick in condominium construction, the downward pattern for single family homes cannot solely be explained by aggregate economic effects such as the Great Recession. It does remain possible however that there were secular declines in suburban housing demand or supply shocks to that sector that coincided with the policy and as such, these are merely suggestive figures. To address this in greater detail, I will first discuss a conceptual framework for thinking about greenbelt policies before providing

Figure 3: Total Units Brought to Market by Census Tract and Type



(a) Single Family Homes (b) Condominiums

This figure presents the total number of units brought to the market between 2000-2010 by census tract. For single family homes, the majority of construction occurs at the urban fringe with very little in the urban core. For condominiums, development occurs predominantly in downtown Toronto in very concentrated areas.

reduced-form evidence that the effect of the Greenbelt was in fact a prime factor in this decline.

3 Conceptual Framework

This section will formalize a conceptual model of greenbelt policies that will motivate the rest of the paper. Greenbelts policies affect a substantial amount of land around cities which should serve as a shock not just to the areas directly affected by the policy, but the rest of the metropolitan area as well. The rest of the metropolitan area will be affected primarily through a reallocation of housing development, where developers who would have built in restricted Greenbelt areas now build in unrestricted areas. I formalize this argument and highlight the key nuances in Appendix Figures 1 and 2.

For the conceptual framework, one can imagine a metropolitan area that is growing over time either due to internal migration, immigration or income shocks. This growth over time can be interpreted as a series of housing demand shocks. A city that is not growing will not see any effect from a greenbelt. Within the city, there will be census tracts, which can be thought of as neighbourhoods, which have heterogeneous supply curves. The slope of the supply curves may depend on characteristics of the census tract such as the amount of developable land or the number of land use restrictions on housing construction. Finally, suppose that a government introduces a greenbelt policy that bans housing development within its boundaries. I will not assume that the greenbelt is binding to the entire urban fringe, which allows for the possibility that other suburban areas may continue to expand.

Appendix Figure 1 plots supply and demand curves for a given census tract within the Greenbelt and a given census tract outside the Greenbelt. I assume that a housing demand shock (for example, from immigration) shifts housing demand from D_0 to D_1 over the course of a year. In the absence of a greenbelt, one would move along the supply curve to a higher quantity and a higher price, P_1, in both census tracts. However, if a greenbelt is introduced and is completely binding, it renders the supply curve perfectly inelastic in the greenbelt census tracts, where no more housing can be built regardless of the price. This would increase the price in the greenbelt tracts up to an even higher price, P_G, and would also lead to a lower level of housing provided. The decrease in housing development would mean that some people would no longer have housing and would be forced to substitute towards housing either in non-Greenbelt census tracts within the metropolitan area or cities outside the region entirely. The substitution to other areas within the metropolitan area is represented by D_G in the non-Greenbelt panel. The more restrictive a greenbelt is, meaning the more census tracts it covers, the larger this shift in demand will be.

The extent to which this shift in demand translates into construction within the region and higher prices will depend on the elasticity of housing supply in the other areas of the city. In Appendix Figure 2, I plot different scenarios of how housing demand substitution can translate into construction and prices throughout the rest of the metropolitan area. If housing supply elasticities are more elastic, as they might be around the urban fringe where there is plenty of land to develop, there may be more construction with lower corresponding prices. In this scenario, greenbelts simply relocate housing to other suburban areas, which may lead to smaller impacts on prices and quantities, but would mean the greenbelt does little to curb urban sprawl. A second scenario is where housing supply is somewhat responsive through condominium construction within the urban footprint. In this case, although there is no developable land to build outwards, there could be construction upwards. Depending on how elastic this supply is, the displaced demand from the greenbelt could be met by the supply of denser forms of housing, which means that price effects could be small without leading to more urban sprawl. Finally, there is a scenario where housing supply is unresponsive to demand shocks due to a lack of available land, zoning regulations and local opposition. In this scenario, the displaced demand from the greenbelt leads entirely into higher housing prices and people are pushed out of the region.

This conceptual framework highlights how housing supply responses throughout a metropolitan area play a key role in determining the economic consequences of greenbelt policies. When housing supply elasticities within cities are sufficiently elastic, a city can more easily accommodate a greenbelt policy without causing prices to increase significantly. However, if these elasticities are too inelastic and housing is too hard to build, then price effects are going to be large and lead to emigration from the region.

The rest of this paper will closely follow the steps from the conceptual framework. First, I will test whether the Ontario Greenbelt was sufficiently binding as to create displaced demand to substitute towards other areas of the city. Then, I will estimate a model of supply and demand, with heterogeneous supply curves at the census tract level, and simulate the effect of putting in the Greenbelt in the early-2000s.

4 Supply Effects in Greenbelt Areas

While the Greenbelt is a policy that affects a large area, there are some questions as to how much it actually affected housing development patterns. Looking at Figure 1, we can see that the Ontario Greenbelt does not surround the entirety of the urban fringe in 2006. While it does surround suburbs to the north of the city, it is less restrictive to the east and west. This raises a question of whether the Greenbelt was placed where development was actually going to occur and therefore whether the policy was actually binding. Thinking back to the conceptual framework, this is similar to asking if there was truly a demand shock in the Greenbelt census tracts. I examine this question in this section using a staggered event-study framework comparing developable census tracts that are more exposed to the Greenbelt to those less exposed to the policy. Because the Greenbelt affects undeveloped land and not developed land, the focus in this section will be on single family homes and not on condominiums, which are mostly within existing urban areas.

4.1 Empirical Specification

To determine whether the Ontario Greenbelt had a material effect on housing development patterns, I will estimate the following regression equation.

$$\ln H_{jt} = \sum_{g=-G}^{-2} \alpha^g D_{jt}^g + \sum_{k=0}^{K} \alpha^k D_{jt}^k + \nu_j + \eta_t + \varepsilon_{jt}$$

The variable of interest is the log of housing stock in a census tract j at time t for the years 2000-2020. D_{jt} is a treatment indicator for whether a census tract is exposed to the Greenbelt policy at a lead time of g or lag time of k. I control for census tract (ν_j) and year (η_t) fixed effects, which makes this a two-way fixed effects specification. The parameters of interest are the α's, which as I will discuss shortly, reflect a relative, but not necessarily causal effect of the Greenbelt on housing development patterns due to the presence of spillovers.

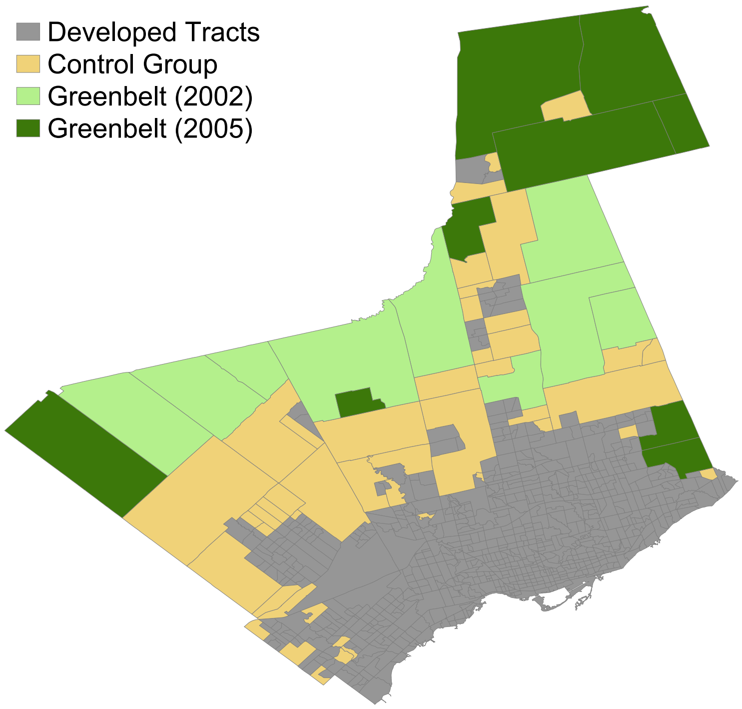
Treatment in this specification is defined as having more than half of the census tract covered by the Ontario Greenbelt. Because the share of land in a census tract covered by the Greenbelt is continuous, a threshold needs to be chosen to represent the point at which one considers a census tract to be treated. The reason this threshold is not set at 100% is that most census tracts are not entirely covered by the Greenbelt, which would leave a very small group of treated tracts. In addition, partial treatment by a greenbelt may still affect housing supply either by increasing competition for land parcels and driving up the cost of land, making desirable parcels for construction undevelopable or by reducing the number of parcels available for land assembly (Brooks & Lutz, 2016). The reason this threshold is not set at anything over 0% is because some locations may only have a small share of land covered by the Greenbelt and therefore may not "behave" like a census tract with restricted land supply. I use 50% then as the threshold and show that the results are robust to some alternative thresholds.

Treatment is staggered in this empirical setting as some census tracts receive treatment due to the *Oak Ridges Moraine Protection Act* in December 2001, while others are only treated after the introduction of the *Greenbelt Act* in February 2005. A tract that receives some exposure to greenbelt protections in 2001, but not enough to eclipse the 50% mark, that crosses the 50% threshold in 2005 is considered to be treated in 2001. Given the recent literature on the problems with staggered difference-in-differences with heterogeneous and dynamic treatment effects (Callaway & Sant'Anna, 2021; Sun & Abraham, 2021; Goodman-Bacon, 2021), which I suspect may be present in this setting, I also estimate the effects of the Greenbelt using the method of Callaway & Sant'Anna (2021). The Callaway & Sant'Anna (2021) estimates average treatment effects for each group-time treatment cohort and compares them only to not yet treated units, which avoids the issue of comparing to already treated units. When I estimate the model using this approach I find the results to be very similar to the original event-study ones.

The control group is the set of census tracts where at least 25% of the land is deemed developable in the initial period of 2000 and where they are not already considered covered by the Greenbelt. The reason the remaining census tracts do not serve as a good control group is because these are places that have ostensibly been "treated" already in the sense that they have restrictions that prevent them from building - namely, a lack of developable land. These tracts see hardly any development in either the pre-period or the post-period. In Appendix Figures 3 and 4, I show that census tracts where undeveloped land is less than 25% of the tract have virtually no Greenbelt exposure and see almost no housing development on average. I also show that results are robust to deviations in this cutoff.

To give a sense of which tracts fall into the treatment, control and undevelopable groups,

Figure 4: Census Tracts Classified into Treatment and Control Groups



This map plots the treatment status of census tracts across the GTA according to whether it is developed, in the control group or in a particular treatment group. Treatment status is defined as having over 50% of a census tract within the Greenbelt.

I plot a map in Figure 4. The map shows that the City of Toronto and the main suburb Mississauga are mostly developed already in 2000, leaving most of the analysis to be around the urban fringe. In general, the treated tracts are farther away from the urban fringe compared to the control group although there is some variation to this along the corridor of suburbs to the north of the city. While the treatment and control groups may not be perfectly balanced in terms of characteristics, I will show that parallel trends holds.

One challenge in interpreting the estimates of this regression is the presence of spillover effects from the treated group into the control group. When the Greenbelt is implemented, some development may shift from the treated areas to the control areas - in fact, this is exactly what the conceptual framework would predict. As a result, the magnitude of the estimates cannot be interpreted as the causal effect of the Greenbelt. This is because the amount of housing built outside the Greenbelt would be larger than the "true" counterfactual leading to an upward bias in the estimate. However, the parameters of interest can still be interpreted as a relative effect between the treated and control groups because the presence of spillovers is dependent on the Greenbelt distorting the housing development behaviour in the region. This limitation also highlights one of the primary reasons why a model is necessary to disentangle these spillovers from the true effect of the policy.

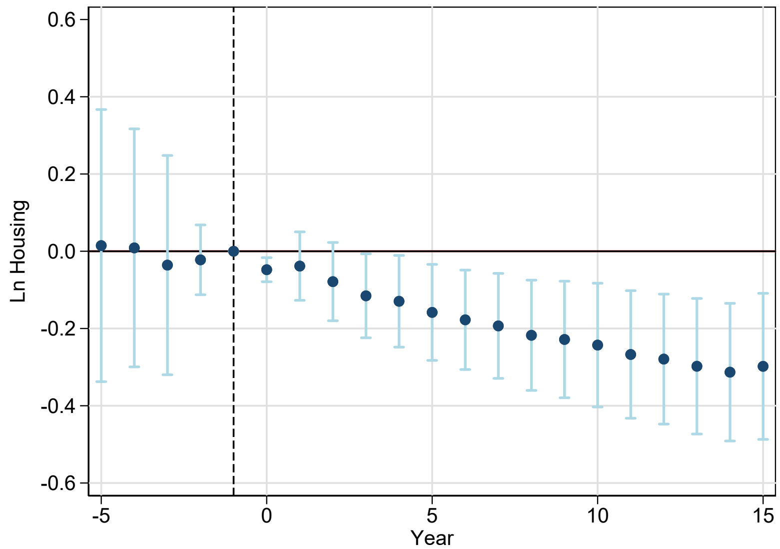
There are two additional threats to identification in this setting. First, there may be concerns that the policy was anticipated leading to developers pushing projects forward in time and leading to an overestimate of the size of the effect. While this may be true for the second phase of the policy, this was unlikely for the first phase. In addition, I show similar trends for each treatment cohort separately and also see that the effects carry on many years into the sample, when it would have been implausible to have brought a project forward from. Second, there may be concerns that the policy boundaries were endogenous to developer interests. If this was the case, then there would be selection concerns that only places unlikely to be developed received the Greenbelt. However, I present a few pieces of evidence to suggest that any selection concerns were orthogonal to development patterns. The first is that several developers were impacted by the policy. I take a sample of 100 large parcels of land that fell within the Greenbelt in 2005 and find that 30 of them were owned by numbered companies or companies with a variation of "Realty" or "Developments" in their name. A second is that developers sued the government after the Greenbelt policy for the lost value of their land (Winfield, 2012). Finally, the government had campaigned on the policy to bolster its environmental credentials and if anything, included more land than was expected initially (Winfield, 2012). Together, this suggests that it is unlikely the ultimate Greenbelt boundaries were subject to developer lobbying in a manner that were bias the results.

4.2 Results

I present the results of the event-study regression in Figure 5. Prior to the implementation of the policy the treatment and control group follow parallel trends in terms of housing development. However, after the policy is introduced there is a steady downward trend in the amount of housing in the Greenbelt tracts relative to the non-Greenbelt tracts. Ten years after the treatment date, the difference between the treated tracts and control tracts reaches over 20% and fifteen years after, the difference surpasses 30%. The effects are statistically significant starting four years after the policy, suggesting that it takes time for the effects to emerge, which is consistent with the longer timelines of housing development projects. Overall, these results show that untreated census tracts followed a similar pattern relative to treated tracts prior to the Greenbelt being introduced, but after the policy, they saw much more rapid development compared to those in the Greenbelt.

The dynamic nature of the effects raises concerns that the results may be biased due to a contaminated treatment group. To address this, I estimate the model again using the

Figure 5: Housing Development in Greenbelt Tracts Versus Non-Greenbelt



This figure depicts the estimates from a linear event-study model with the log of housing in a census tract as the dependent variable and the timing variable the distance to treatment in either 2001 or 2005. Treatment is defined as having more than 50% of the census tract in the Greenbelt. The coefficients can be interpreted as the percentage difference in housing between the treated and control tracts. Standard errors are clustered at the census tract level.

Callaway & Sant'Anna (2021) estimator and plot the treatment effects for each treatment cohort separately in Figure 6. The figure shows that for both treatment groups, the magnitude of the effect is fairly stable, although the standard errors are large, particularly for the 2001 treatment group. In addition, the pre-trends for the 2005 treatment group remain relatively stable. These results suggest that heterogeneous and dynamic treatment effects are not driving the results of the event-study.

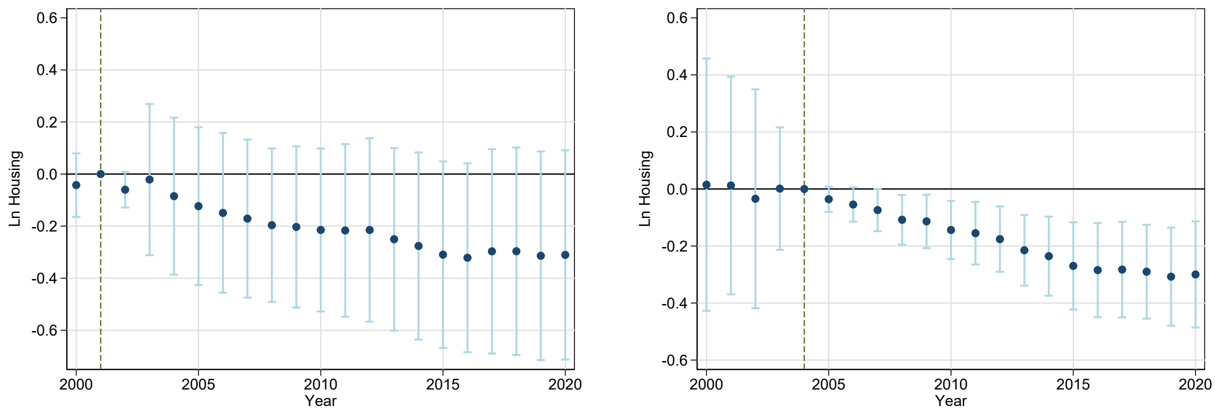
4.3 Robustness

I validate these results using several alternative approaches. First, I investigate if using a continuous treatment variable will also show that the Greenbelt had an effect. To do this, I use the same setup as for the discrete case, but the treatment indicator becomes $D_{jt} = GB\% \times \mathbb{1}(\text{year} >= \text{treat year})$, where the treatment will vary according to treatment intensity. Under this specification, the parameter of interest is identified not only from being treated or not treated, but according to treatment intensity, where more highly treated tracts are compared to less treated tracts.

I estimate this regression using several different thresholds for the undeveloped land share of census tracts to be included in the regression and present the results in Table 2. The results

Figure 6: Callaway & Sant'Anna (2021) Estimator

(a) Treated in 2001 | (b) Treated in 2005



This figure plots the estimates using the Callaway & Sant'Anna (2021) estimator for staggered difference-in-differences. The left panel shows the effects for the group treated in 2001, while the right panel shows the effects for the group treated in 2005. Standard errors are clustered at the census tract level.

suggest that regardless of the sample used, more intense Greenbelt treatment leads to less housing supplied after treatment. These results suggest that a 10% increase in Greenbelt coverage at the census tract level is associated with a 1.6-4% decrease in housing supply over the post period. The effects become stronger as census tracts with more developable land are compared and are only significant at the 30% undeveloped land share threshold. One explanation for this is that the Greenbelt does skew towards more undeveloped tracts and the control group becomes more comparable at those levels. Another explanation is that in places with more elastic housing supply, the level of development in the control group is expected to be higher. These results suggest that the effect of the Greenbelt on housing supply patterns holds up whether one looks at treatment as discrete or continuous.

I also present results where I vary the treatment and control thresholds for the main event-study results. I present these results in Appendix Figures 5 and 6. These results show that choosing different cutoffs for the Greenbelt threshold and the share of developable land need to be in the control group does not change the overall trends between the treatment and control groups. Another comparison I present is where I separate the control group into partially treated Greenbelt tracts and those not treated. That is I compare trends in census tracts that are less than 10% covered by the Greenbelt to those more than 50% covered and those between 10-50% covered by the Greenbelt. I present these results in Appendix Figures 7 and 8. I find that the effects of the Greenbelt are attenuated when comparing just to the census tracts that receive little to no treatment while the census tracts that receive 10-50% treatment actually see an increase in housing supply after the policy relative to the less than

Table 2: Continuous Treatment Regression Results by % of Undeveloped Land Threshold

	Undeveloped Land Share				
	20%	25%	30%	35%	40%
Continuous Treatment	-0.16404	-0.17740	-0.27921**	-0.34771**	-0.39829***
	(0.11591)	(0.11655)	(0.12362)	(0.13241)	(0.13899)
N	1617	1365	1197	1071	987
R^2	0.938	0.940	0.938	0.934	0.931

Standard errors in parentheses

Standard Errors Clustered at the Census Tract Level

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

This table presents the regression coefficient from a continuous treatment regression of the log of housing in a census tract on the share of Greenbelt land. Each column refers to the cutoff of undeveloped land for census tracts included in the sample. Standard errors are clustered at the census tract level.

10% treated group. These results are in fact consistent with the story of spillovers, where the tracts that are between 10-50% treated by the Greenbelt are geographically closer to those more than 50% treated and therefore more likely substitutes in the aftermath of the policy. This is then evidence that the Greenbelt may induce spillovers to nearby areas, but less so to regions farther away.

This section presents compelling evidence that the Greenbelt did have a relative effect on housing construction patterns within the regulated area. Showing this is a critical step for establishing any broader impact from the Greenbelt policy on the metropolitan area as a whole. However, this approach has some important limitations in answering broader questions about the impact of greenbelt policies. First, there is an issue with spillovers, where development may be pushed from the treated areas into the control areas which biases the effect of the policy upwards in an event-study setting. This means that the magnitude of the effects in this section are not interpretable as causal effects of greenbelt policies. Second, the reduced-form approach cannot say anything about the impact of this policy on housing market conditions within the urban footprint, which is crucial in understanding the broader impact of greenbelts overall. To address these shortcomings, I develop a model of housing supply and demand that aims to quantify the effects of Greenbelt policies more broadly by accounting for spillovers into the region as a whole.

5 Model of the Housing Market

Reduced-form analysis of the introduction of the Greenbelt is limited by the fact it can only credibly look at the impacts around the boundary of the Greenbelt. In order to expand the analysis to the broader region, some structure needs to be added using a model. The model needs to be able to account for variation in housing development patterns across space as well as an integrated housing demand system where shocks to the choice set in one part of the region will affect the market elsewhere. Variation in housing development patterns is crucial to account for the existing city structure which means that housing supply does not adjust smoothly across a region. One would expect that housing construction responses would be stronger in places with more developable land and weaker in areas with stringent zoning restrictions and local opposition to construction. An integrated housing demand system is important in order to link the different regions in the case of a Greenbelt shock. When the Greenbelt is implemented, prices within the Greenbelt should rise pushing households to substitute to other areas in the city. The extent of this substitution should be captured in the housing demand system. Without this, the Greenbelt would have no impact on the rest of the metropolitan area. In this section, I propose and estimate a model of housing supply and demand that addresses these needs and can be used for counterfactual analysis.

5.1 Housing Supply

The literature on housing supply has traditionally focused on differences in housing supply elasticities *across* cities (Saiz, 2010), but it is not until recently that greater focused has been paid to differences in housing supply elasticities *within* cities (Baum-Snow & Han, 2023). However, understanding within city differences in housing supply responses is crucial for understanding place-based policies that shift housing demand around within a city. In the context of a Greenbelt, if the housing supply elasticity is assumed to be constant throughout the entire region, then the true effects of the Greenbelt may not be accurately captured.

The conceptual framework presented in Section 3 motivates this clearly. If the housing supply elasticity is uniformly inelastic across a region, then the the amount of displaced demand will be relatively small because little housing would have been built regardless of the Greenbelt. If the housing supply elasticity is uniformly very elastic across a region, then the Greenbelt may reduce housing in the Greenbelt dramatically, but would also be able to build substantial housing elsewhere in the city. This would mean that the Greenbelt would simply shift housing from the Greenbelt to other parts of the city with limited impacts on price. However, if housing supply is more elastic on the urban fringe than in the downtown areas and the Greenbelt is implemented on the urban fringe, the effects will be exacerbated. Imposing the Greenbelt on the elastically supplied parts of the city and pushing people to the inelastic areas, will both displace significant demand, drive up prices and potentially push people outside the market. This thought experiment provides a clear motivation for estimating a model of housing supply with heterogeneous housing supply elasticities. If the estimated housing supply elasticities are significantly different between the urban fringe and the inner city, the effects of the Greenbelt may be relatively large. However, if they are relatively similar, then the effects of the policy may not be significant.

5.1.1 Developer's Problem

In this section, I provide a theoretical foundation for the housing supply curves stemming from a developer's problem. Suppose in each census tract j there is a developer of type $i \in \{C, S\}$ for single family homes and a developer for condominiums. Each developer of type i in location j has a unique cost function, $C_{ij}(H_{ijt})$, that depends on the amount of housing in a census tract in year t, H_{ijt}. These developers operate in a competitive market and take housing prices in their census tract as given.

The cost function for a developer is assumed to be of constant elasticity form:

$$C(H_{ijt}) = \rho_{ijt} \left(\frac{H_{ijt}}{\alpha_{\mathbf{ijt}}} \right)^{\frac{1}{\rho_{ijt}}}$$

where ρ_{ijt} and α_{ijt} are census tract by type level parameters. If $\rho_{ijt} < 1$, this is a convex function, where the cost is increasing in the amount of housing in a census tract. The marginal cost for a price taking developer is then:

$$\frac{\partial C(H_{ijt})}{\partial H_{ijt}} = \left(\frac{H_{ijt}}{\alpha_{\mathbf{ij}}} \right)^{\frac{1}{\rho_{ijt}} - 1} \frac{1}{\alpha_{\mathbf{ijt}}}$$

Redefining $\rho = \frac{\varphi}{1+\varphi}$ and with profit maximizing developers, who set $P_{ijt} = MC_{ijt}$, the housing supply curve can be written as:

$$H^S_{ijt}(P_{ijt}) = {\alpha_{\mathbf{ijt}}}^{1+\varphi_{ijt}} \left(P_{ijt}\right)^{\varphi_{ijt}}$$

This can also be written in log-linear form, which is useful for the estimation of the model

$$\ln H_{ijt} = (1 + \varphi_{ijt}) \ln \alpha_{\mathbf{ijt}} + \varphi_{ijt} \ln P_{ijt}$$

where φ_{ijt} is the constant elasticity of housing supply. Assuming that φ_{ijt} is positive, this implies that ρ_{ijt} is less than 1 and that the cost function is convex. Finally, I will assume that $\ln \alpha_{ijt}$ and φ_{ijt} are functions of observable tract-level characteristics, x_{ijt}.

$$(1 + \varphi_{ijt}) \ln \alpha_{ijt} = \alpha_0 + \alpha_1 x_{ijt} + \alpha_{it} + \alpha_{ij}, \qquad \varphi_{ijt} = \gamma_0 + \gamma_1 x_{ijt}$$

Plugging these into the supply curve yields the following equation of heterogeneous supply elasticities

$$\ln H_{ijt} = \alpha_0 + \alpha_1 x_{ijt} + \alpha_{it} + \alpha_{ij} + \gamma_0 \ln P_{ijt} + \gamma_1 x_{ijt} \ln P_{ijt} + \varepsilon_{ijt} \tag{1}$$

This supply curve reflects the amount of housing of type i, in census tract j at time t as a function of prices in that census tract and characteristics of the tract.

5.1.2 Supply Curve Estimation

This housing supply curve from Equation 1 is easily estimable in the data using ordinary least squares. The dependent variable is the log of housing of type i in census tract j at time t. The time series of housing quantities is constructed using information from the Canadian Census of Population and development flows from the Altus Group's New Residential Homes database. The date used for housing being added to a census tract is the date of the first sale of a development project as this is when a set of units can be considered to be purchased and competing with other units within the census tract. If there is no housing of that type in a particular location, that type by location is omitted from the analysis. The main variable of interest is the log of the housing price index of type i in census tract j at time t. The housing price index reflects the prices paid for housing in a location after partialling out variation in housing characteristics from year to year. I focus only on census tracts that saw more than five sales for a given house type in a particular location in a year to avoid large small sample concerns. I include census tract and year fixed effects to control for time invariant features of a neighbourhood and region wide shocks to housing supply such as input price shocks.

I include a number of observable characteristics at the neighbourhood level to capture heterogeneity in the housing supply elasticities. First, I include the share of undeveloped land in a census tract. The share of undeveloped land is an important determinant in census tract level housing supply elasticity because land that is undeveloped should be cheaper and easier to develop than land with existing building on it. This is for several reasons including the the fact that acquiring the land is less expensive and that there will be less community opposition to projects that are not in an existing community. However, there are a number of reasons why housing supply elasticities in very undeveloped areas may still be somewhat inelastic. One reason is that land assembly is a non-trivial process and can be very costly (Brooks & Lutz, 2016) as there may be parcels that would be optimal to include in a project that are difficult or impossible to acquire. Another is that dynamic behaviour from parcel owners can mean that housing is not built even when it may appear profitable (Murphy, 2018; Capozza & Li, 1994). Finally, if areas are not serviced with infrastructure such as roads, sewage and water, this becomes costly for a developer to build. One would expect this to be the case farther away from the urban fringe. As a result, the impact of developable land on the housing supply elasticity is an empirical question.

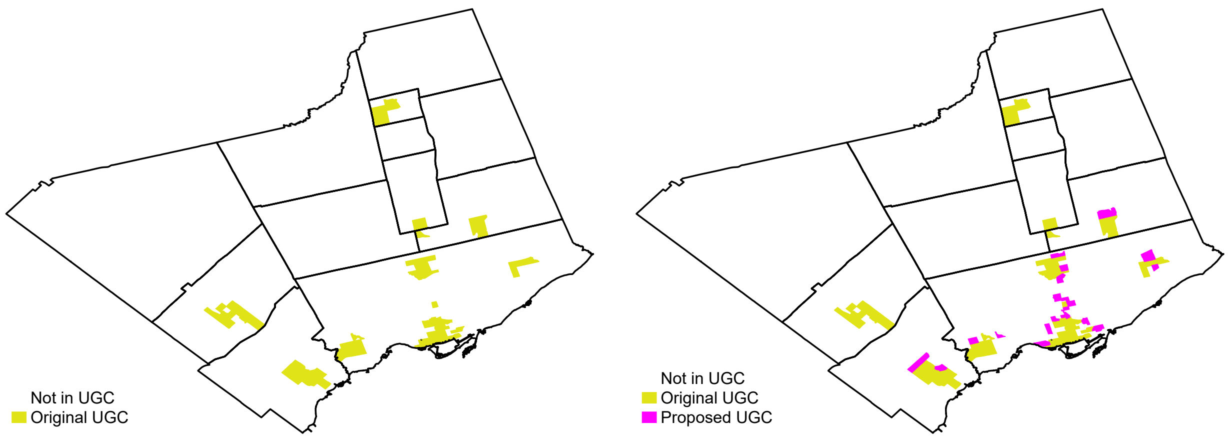
When estimating the model, I observe the share of developable land in 5 year intervals meaning that there is only variation in this variable in a couple stages. The share of developable land is also varied using the shock from the introduction of greenbelt policies in the early-2000s. This means that the share of developable land is the observed share minus the share of this land that is restricted by the Greenbelt. This is an important detail for counterfactual analysis as I can then revert this variable back to the pre-Greenbelt share of developable land to estimate the housing supply elasticity in the absence of the Greenbelt.

The second key observable characteristic I include is the presence of a census tract in an "urban growth centre" (UGC). Urban growth centers are regional subcenters across the GTA that were designated for increased development in 2005 around the time of the Greenbelt's introduction. Urban growth centers were "planned to accommodate significant population and employment growth" in cities across Ontario (Places to Grow Act, 2005). They consisted of targets for municipal planners and officials of 400 residents and jobs in Toronto by 2031 and 200 residents and jobs throughout the rest of the GTA by 2031. As a result of these targets, these locations would be expected to have a more elastic supply of condominiums and high density towers compared to nearby locations that did not receive these targets. In Figure 7, I plot the location of the UGCs that were introduced. The UGCs correspond to centers of business activity across the region, with the largest on in downtown Toronto. Finally, I include the distance to the city center as an observable characteristic as the distance could correspond to other factors that affect housing supply elasticity.

Identification of the housing supply elasticity comes from variation in housing prices across years within a census tract. Heterogeneity in housing supply elasticities comes from variation across census tract characteristics for tracts that receive similar changes to housing prices. One concern with estimating the supply curves using OLS is that price shocks are endogenous, which can arise either from simulataneity concerns or omitted variable bias. To address concerns of simultaneity bias, I use the lag of the housing price index rather than the contemporary price in the regression. This helps address concerns that the introduction of housing onto the market is affecting the price because I am using prices that occur prior to the introduction of the housing to the market. This is more convincing due to the data I have on development timing where I observe the exact moment that a project enters the market using the first sale in a project. The lagged price may also be a more important determinant of a development project being brought to the market than the contemporary price due to the long time frame it takes for a project to be conceived of, permitted for and

Figure 7: Urban Growth Centers in the Greater Toronto Area

(a) Actual UGCs (b) Proposed UGC Expansion



This figure plots the location of "urban growth centers" in the GTA region. In yellow are the actual UGCs that were introduced in 2005 with density targets for the designated areas. In pink are a proposed set of 19 UGCs that fall within 1 km of the existing UGC boundaries to be used in the counterfactual analysis.

ultimately put up for sale. If a project ultimately starts selling in 2005, a developer likely used the price from 2004 as a signal for whether to pursue the project in the first place. To address concerns of omitted variable bias, I use very granular fixed effects at the census tract by unit type level as well as year fixed effects. This means that any bias has to arise in a time varying manner at a fine geographic level and be correlated to housing prices in that location.

5.1.3 Supply Curve Estimation Results

I present the main results from the supply curve estimation in Table 3. The first column presents the results from a regression with just price and a unit type fixed effect, which yields a small statistically insignificant effect. When I add year by type and census tract by type fixed effects in columns (2) and (3), I find estimates that are statistically significant, but not especially large. I start adding observable characteristics in columns (4)-(6) and some interesting trends stick out. First, the share of developable land increases the housing supply elasticity at a rate of just over 0.5. That means that a 10% increase in the share of developable land leads to a 0.05 point increase in the elasticity of housing supply. This effect also does not vary between houses and condominiums, which is somewhat counterintuitive. The coefficient on the uninteracted share of developable land term is negative, which also makes sense because the less developable land over the course of the sample, the more houses there should be. This also is intuitive graphically, where if you increase the slope of the supply curve, a decrease in the intercept implies a rotation of the supply curve. Second, a

Table 3: Supply Curve Regression

	(1)	(2)	(3)	(4)	(5)	(6)
ln P, t-1	0.022	0.147***	0.082***	0.075**	0.074**	0.002
	(0.069)	(0.014)	(0.023)	(0.031)	(0.031)	(0.055)
ln P x House = 1				-0.049	-0.050	0.003
				(0.039)	(0.039)	(0.059)
ln P x % Developable Land				0.520***	0.578***	0.527***
				(0.188)	(0.185)	(0.193)
ln P x % Developable Land x House = 1					-0.022	
					(0.020)	
ln P x Dist. to CBD x House = 1						0.003*
						(0.001)
ln P x Near UGC = 1 x Condo = 1						0.373***
						(0.113)
% Developable Land				-6.561***	-7.039***	-6.616***
				(2.292)	(2.230)	(2.360)
Unit Type FE	✓	X	X	X	X	X
Year x Unit Type FE	X	X	✓	✓	✓	✓
CT x Unit Type FE	X	✓	✓	✓	✓	✓
N	11160	11160	11160	11160	11160	11160
R^2	0.131	0.992	0.993	0.993	0.993	0.993

Standard Errors are Clustered at the CT x Unit Type level

This table plots the results of the supply curve regression where the dependent variable is the log of housing in a census tract of type j. A selection of interaction terms is included in this table, which capture heterogeneity in supply elasticities across census tracts.

census tract's presence in a UGC when it is a condominium leads to a statistically significant increase in the housing supply elasticity of 0.373. This suggests that these targets are at least correlated with more permissive zoning policies. Finally, distance to the Central Business District (CBD) leads to slightly more elastic housing supply, however the effect is mostly dominated by the share of developable land which is highly correlated with distance. Still, some census tracts are upward of 50 km away from the CBD and this would translate into a 0.15 point increase in the housing supply elasticity.

Using these results I predict elasticities for each census tract and by type and plot them in Figure 8. As predicted, there is considerable heterogeneity across locations and housing types. For single family homes housing supply elasticities are close to zero within the existing built up areas of Toronto and the largest suburb of Mississauga. However, beyond the urban fringe, the elasticities are much larger and surpass 0.4 in a number of locations. That said, this is still relatively inelastic which points to the fact that housing supply elasticities may be fairly inelastic in general. For condominiums, many of the elasticities are close to zero both due to low responses and a lack of condominiums in many of the census tracts. Within UGCs, the elasticities are positive and closer to 0.4. I also plot the kernel density plots for the housing supply elasticities with and without the Greenbelt in Appendix Figure 9. I show that for census tracts that have developable land there is a distribution of positive values ranging from 0.3 to 0.8. For condominiums, elasticities are either within UGCs and around 0.4 or they are close to zero. Remaining single family homes have elasticities that are slightly higher than for condominiums, but not significantly so.

To provide context to these numbers, I compare my results to those in Baum-Snow & Han (2023) for census tracts in the United States. I plot the range and mean of my main estimates together with estimates for some major American cities in Appendix Figure 10. I find that the mean estimates I have for Toronto, which are 0.09 and 0.08 for single family homes and condos respectively, are slightly smaller than those for the American cities, which hover around 0.2.[6] However, the range of estimates is fairly similar as in all cities the maximum elasticities are greater than 0.6 and less than 0.8. One explanation for the lower mean elasticities is that the elasticities estimated for Toronto are one year elasticities, whereas the estimates in Baum-Snow & Han (2023) are ten-year elasticities. Because supply responses should be more elastic in the longer term compared to the shorter term, this could explain the difference. A second explanation is that the set of census tracts attributed to each city may differ from those included in my analysis, which omits some of the more distant suburbs of the Greater Toronto Area, which may be more elastic and raise the average supply elasticity.

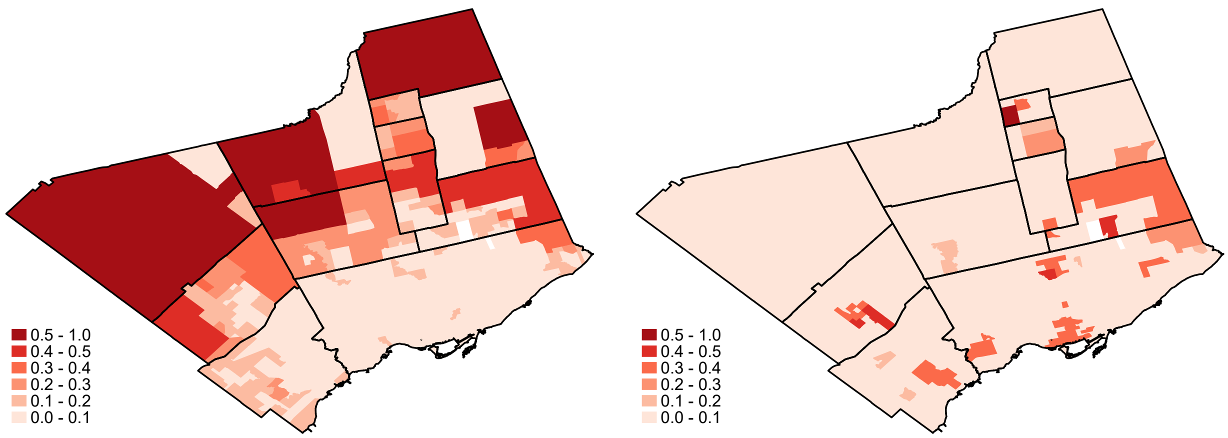
5.2 Housing Demand

Housing demand is an important component of a model with greenbelts because greenbelts affect the choice set of households and lead to substitution. Without accounting for substitution, there would be no broader greenbelt effect, as the loss of development within the greenbelt would simply lead to a decline in housing supply in that area and higher prices with no spillover to the rest of the city. It is only when accounting for substitution across locations that greenbelts have an impact on broader regional outcomes because the substitution to other locations represents a demand shock that induces developers to build more housing. The requirement for a model to incorporate substitution patterns adds some complexity to the type of housing demand model. In particular, it means that I need to estimate a housing demand *system*, where the price of housing in one location enters into the decision making of a household looking at housing anywhere in the region. In this section, I explain how I do

[6] Atlanta stands out as the one notable exception here, which is closer to 0.4, but it is also known as a particularly sprawling city

Figure 8: Predicted Supply Elasticities by Housing Type in the GTA, 2010

(a) Single Family Homes (b) Condominiums



These maps plot the predicted supply elasticities across census tracts in the GTA in 2010. These elasticities capture the percentage change in housing supply resulting from a 1% change in housing prices.

this using a discrete-choice model of location choice where households decide where to live in the region.

5.2.1 Housing Demand Model

A household's utility can be written as a function of the characteristics of a house of type i in location j at time t.

$$U_{ijt} = \alpha P_{ijt} + x_{ijt}\beta + \xi_{ijt} + \epsilon_{ijt}$$

where ϵ_{ijt} is distributed Type I Extreme Value (Gumbel), α is the price coefficient, x_{ijt} is a set of time-varying observable characteristics and ξ_{ijt} are the unobserved "product" characteristics, if we think of a house type-location pair as a product. The market share, s_{ijt} of houses of type i in location j is

$$s_{ijt} = \frac{\exp\left(\delta_{ijt}\right)}{1 + \sum_k \exp\left(\delta_{ikt}\right)} \tag{2}$$

where $\delta_{ijt} = \alpha P_{ijt} + x_{ijt}\beta + \xi_{ijt}$. We can take logs and then rearrange this equation to obtain the following expression

$$\ln s_{ijt} - \ln s_0 = \alpha P_{ijt} + x_{ijt}\beta + \xi_{ijt} \tag{3}$$

Because the housing shares, s_{ijt}, are observed in the data as the share of all housing of each type across the region in each year, this equation can be estimated using regression methods. The outside option, s_0 is defined as the share of housing in adjacent regions Durham and

Halton that are outside of the sample used in the analysis. This choice of the outside option has an important implication for the interpretation of the counterfactual as a decrease in housing supply within the Peel, York and Toronto markets will translate into an increase in housing in more distant markets - typically in the form of more urban sprawl.

This model represents an integrated housing demand system because the location-type shares s_{ijt} depend on the prices of all other locations and unit types. In the case of the Greenbelt, if the price within the Greenbelt rises, this will decrease the share demanded within the Greenbelt and raise demand elsewhere. One limitation of this model is that households will substitute to locations in proportion to their market shares and not as a function of similarity.

I estimate Equation 3 using a 2SLS linear regression approach. To estimate the price coefficient in Equation 3, I need an instrument for price because price is endogenous. I propose using a Hausman style instrument, which in this case means using the average prices of houses of type i more than 5km and less than 20km from a given census tract as the instrument for price in that census tract j. The average price of houses at a distance away meets the exclusion restriction because it does not enter into the utility of a household choosing location j directly. It is unlikely that the characteristics of neighbourhoods several kilometers away is influencing your choice to live somewhere. However, the prices of housing in these places remains a relevant instrument because changes to the pricing structure of competing products can affect each other. This style of instrument is commonly applied in differentiated product settings and has previously been used in the housing literature to estimate price coefficients such as in Bayer et al. (2007). I control for census tract by unit type fixed effects and year by unit type fixed effects to account for time invariant unobserved characteristics and limit the sample to housing sold on the secondary market to avoid the impact of pre-construction sales on results.

I present the results of the demand estimation in Table 4. The first two columns report results without any fixed effects and these results are larger than the ones that do control for fixed effects suggesting that locations with higher prices may be correlated with less housing supply. This is consistent with the established facts that most development in this period came around the urban fringe, where prices are lower. When instrumenting for price, the magnitude of the estimates increases somewhat substantially, which means that the OLS regression is biased downwards. I explore using different distances from the census tract for the instrument and find that the results are robust to the choice of distance. In all cases, the first stage is highly statistically significant.

The coefficients from the demand regression are not easily interpretable on their own, but the resulting housing demand elasticities are more useful. The average annual housing

Table 4: Demand Model Regression Results

	(1) OLS	(2) IV-5km	(3) OLS	(4) IV-5km	(5) IV-8km	(6) IV-10km
Prices (in \$10,000)	-0.13491***	-0.17108***	-0.00139***	-0.01222***	-0.01372***	-0.01507***
	(0.00344)	(0.00274)	(0.00033)	(0.00199)	(0.00237)	(0.00270)
CT x Unit Type FE	X	X	✓	✓	✓	✓
Year FE	X	X	✓	✓	✓	✓
N	9784	9784	9780	9780	9780	9780
Kleibergen-Paap F		5,029.2		248.57	232.96	186.89

Standard Errors are Clustered at the CT x Unit Type level

This table presents the regression results from the 2SLS regression of location-unit type housing shares on housing prices using prices from transactions more than 5km away as an instrument. Columns (1) and (2) are estimated without any fixed effects and columns (2), (4)-(6) instrument for price. Columns (4)-(6) use different thresholds for the distance to include competitor prices.

elasticities range from -0.32 in 2001 to -0.51 in 2010. These numbers are similar in magnitude to those in the somewhat dated literature with housing price elasticities. Albouy et al. (2016) finds an uncompensated price elasticity around -0.66 and reports that most estimates fall between -0.3 and -1. Zabel (2004) summarizes a variety of elasticity estimates ranging from -0.2 to -0.9. Hanushek & Quigley (1980) finds elasticities of -0.64 in Pittsburgh and -0.45 in Phoenix. Given this past research, the estimates I obtain are not unreasonable. With these estimates and the housing supply results in the previous section, I can now solve for equilibrium prices and quantities and conduct counterfactual analysis.

6 Counterfactuals

Up to this point, I have established that the Ontario Greenbelt had an impact on housing development patterns and have estimated a model of housing supply and demand for the Greater Toronto Area. To determine the complete impact of the Greenbelt on the Toronto housing market will require simulating what would have occurred had the Greenbelt not been put into place.

6.1 Equilibrium

Equilibrium in this model simply consists of setting supply in each census tract equal to demand using the supply and demand functions. I rewrite Equation 2 to be in terms of log housing as a function of the total market size, M_t

$$Q^D_{ijt}(P) = \ln M_t + \alpha P_{ijt} + \xi_{ij} + \xi t \tag{4}$$

I write the equation of log housing supply as

$$Q_{ijt}^S(P) = \alpha_0 + \alpha_1 x_{ijt} + \alpha_{it} + \alpha_{ij} + \gamma_0 \ln P_{ijt} + \gamma_1 x_{ijt} \ln P_{ijt} \tag{5}$$

In equilibrium, quantity supplied will equal quantity demanded, $Q_{ijt}^S(P) = Q_{ijt}^D(P)$. Bayer et al. (2004) show in a similar housing market setting with a discrete choice demand specification, that there is a unique vector of prices that clears the market for housing.

Using the estimates from the model I can solve for the equilibrium values in the baseline case where the Greenbelt was implemented. These values will not exactly replicate the observations in the data as the error terms are not included, but there will be variation in the model over time. This variation comes from the estimated aggregate annual shocks to supply and demand, ξ_t and α_{it}, which are assumed to be unaffected by the counterfactual and changes in the share of developable land through x_{ijt}. It is the share of developable land channel through which the Greenbelt will enter the model and affect equilibrium values.

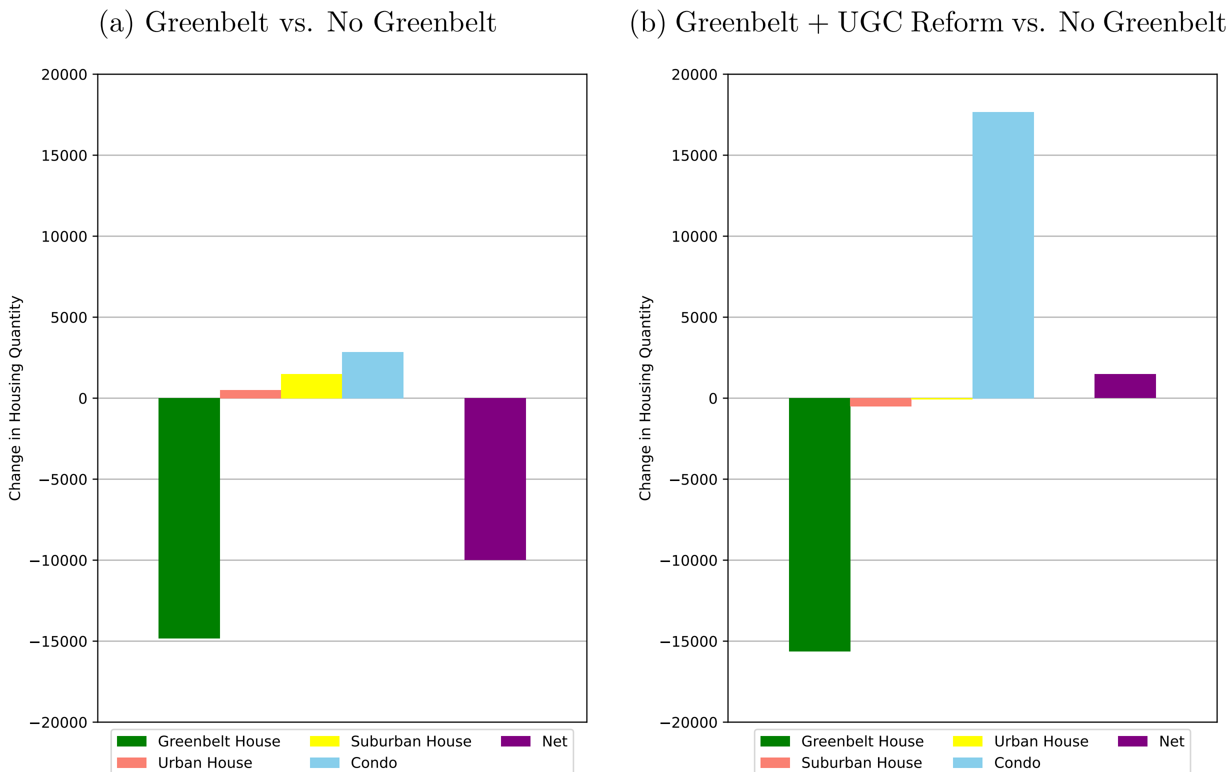
6.2 Counterfactual 1: No Greenbelt

The primary counterfactual exercise I run is to compare the equilibrium with the Greenbelt to the case without the Greenbelt. The difference in prices and quantities in the market and across different parts of the city, will highlight the impact of the Greenbelt not just in the restricted areas, but across the region. To do this, I replace x_{ijt} in Greenbelt census tracts with the share of developable land in those tracts, when the Greenbelt land is considered developable. To illustrate this clearly, imagine a census tract where 40% of its land is developable, but half of this land is in the Greenbelt. In the baseline case only 20% of the land will be considered developable, but in the counterfactual scenario this will be adjusted to 40%. Increasing the share of developable land will increase the housing supply elasticity based on the coefficients from Table 3 and rotate the supply curve clockwise. I then re-estimate the equilibrium given the new $\tilde{Q}_{ijt}^S$.

I present the results from this exercise in Figure 9. I find that the Greenbelt led to a substantial decrease of almost 15,000 houses within Greenbelt areas. This decrease displaced demand to other parts of the city, but only led to an increase of around 2,000 houses and 2,850 condominium units, which was not enough to offset the decrease within the Greenbelt. As a result there was a decrease of almost 10,000 units in the housing market relative to the case without the Greenbelt.

This housing demand shock led to an increase in housing prices throughout the region. For single family homes, housing prices rose an average of \$20,000 or 4.1% relative to the baseline without the Greenbelt. For condominiums apartments, prices rose \$13,500 or 6.1%

Figure 9: Model Counterfactuals for 2010



These figures plot the two main counterfactual exercises of this paper. The first shows the effects of the Greenbelt compared to the case where the Greenbelt was not introduced for housing quantities in different parts of the city. The second shows the effects of the Greenbelt when paired with a proposed land use reform (the expansion of UGCs) relative to the case with no Greenbelt.

relative to baseline. These percentages are small relative to the large percentage increases that occurred throughout the region during this period (86% for houses and 63% for condos), suggesting that the Greenbelt is not the main driver of rising housing prices. However, the magnitudes in dollar amounts are still substantial. Toronto has a price-to-rent ratio of around 20 during this period, which means that a $13,500 increase in condominium prices translates to an increase of $675 in annual rent, which is substantial for low income renters.

One reason that prices rose faster for condominiums than for single family homes reflects the fact that condominiums were on average more inelastic compared single family homes. This does not apply to census tracts more exposed to the Greenbelt however, which saw larger price increases due to the Greenbelt as a result of the significant drop in local supply. The small average elasticity for condos reflects the fact that in most census tracts with condominiums, the elasticities are close to zero. This is in many cases a policy choice, where zoning restrictions prevent large buildings from being built in a number of neighbourhoods.

6.3 Counterfactual 2: Add Land Use Reforms

One argument made against removing greenbelts is that there are better ways to address housing affordability than to remove protections from sensitive environmental areas. One proposal is to relax zoning restrictions within cities in order to accommodate any displaced demand from the Greenbelt. I explore this idea in a second counterfactual where I expand the urban growth centre policy discussed in the supply model. I add census tracts that have condominiums within 1 km of an existing growth center boundary to the policy (as seen in Figure 7), which adds 19 tracts. This involves changing the observable characteristics for the supply curves in these regions to be considered part of the UGC. Doing this raises the elasticity of housing supply in those tracts for condominiums substantially.

I solve for the new equilibrium where the Greenbelt exists along with the modified UGCs and compare this to the baseline without a Greenbelt. The results are shown in Figure 9. In this counterfactual, there is a similar decrease in the number of houses in the Greenbelt as in the first counterfactual. However, this effect is now more than entirely offset by the increase in the number of condominiums built during this period, where there is a slight positive net effect on housing supplied. These results also result in changes to the prices of these units as condominium prices fall 8% and housing prices are unchanged.

This exercise highlights how allowing denser housing can help cities meet housing demand while using far less land than urban sprawl. However, these results do omit some important considerations in making this trade-off. First, a condominium unit is smaller than a suburban house and may not house as many people as a house would. Furthermore, if the kind of displaced demand is from individuals seeking suburban housing, it is not obvious that dense apartments are the most likely substitute for these individuals. Despite this, there are several other forms of density that could be encouraged to better match the needs of residents without needing to consume more land.

7 Conclusion

Greenbelts are important policies that cities employ to manage urban sprawl, but their effects on the housing market are not well understood. This paper shows that greenbelt policies can have substantial impacts on housing markets as exhibited by the introduction of the Ontario Greenbelt around the Greater Toronto Area in the early-2000s. One reason for these effects is that greenbelts tend to be placed in locations with elastic housing supply responses while displacing demand to areas with inelastic housing supply responses. This leads to less housing being produced and higher costs. However, this paper also shows that land use reform that allows greater density within cities can be an effective tool for addressing housing affordability without removing protections on sensitive environmental land.

This is an important result because of the myriad of benefits a greenbelt can offer including open space amenities, reduced pollution from car travel, productive local agriculture and the protection of biodiversity. However, we do not have a strong understanding of the magnitude of these benefits because so many of them are diffuse in nature. In particular, while research such as Koster (2023) measures the benefits of living close to a greenbelt through a higher willingness to pay for housing, this represents only one of many possible benefits from greenbelt policies. Other benefits such as the enjoyment a family from within the city has when travelling into nature are more difficult to measure because these public spaces are usually free to consume.

Despite land use reform representing a viable pathway to achieve the many benefits from greenbelts without paying significant costs, there are complex political economy factors which prevent these reforms from taking place. The classic argument is that homeowners are narrowly focused on the value of their property and will oppose any efforts that diminish that value such as increased density (Fischel, 2004). However, with greenbelt policies there is an additional layer, where many strong proponents of greenbelt policies are in fact people who live within cities, while those living within greenbelt boundaries are less supportive. Those living within greenbelts may not be supportive because of the lost real option value of their property, where the value of developing the land disappears (Deaton & Vyn, 2010; Cunningham, 2007). Those within cities may support greenbelts because increased land scarcity simply further increases their home values, they value the benefits of the greenbelt directly or because cities are more liberal and more liberal cities tend to have more restrictive land use policies (Kahn, 2011). A stronger understanding of the political motivations of those in favour and against greenbelt policies could provide important lessons for how to reach a stronger policy consensus in the future.

A final point is that even if zoning reform were to be achieved there are some factors unaccounted for in this model that could affect the ultimate housing market outcomes. First, the type of household that was seeking a house in the Greenbelt may not entertain the possibility of a smaller house in a denser community within the city. Second, dynamic behaviour amongst developers could lead them to withhold construction if they believe that there are higher prices available in the future. In these situations, land use reform may not be the appropriate policy solution and further research is needed to evaluate this possibility.

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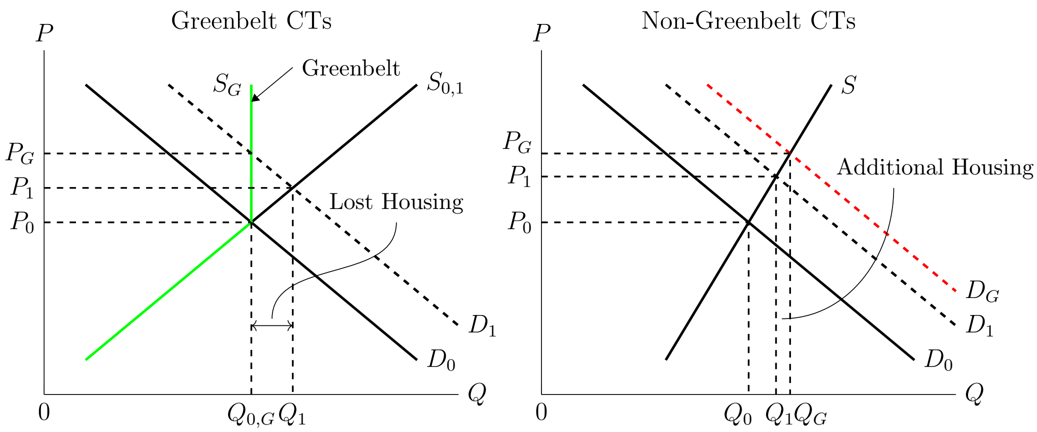
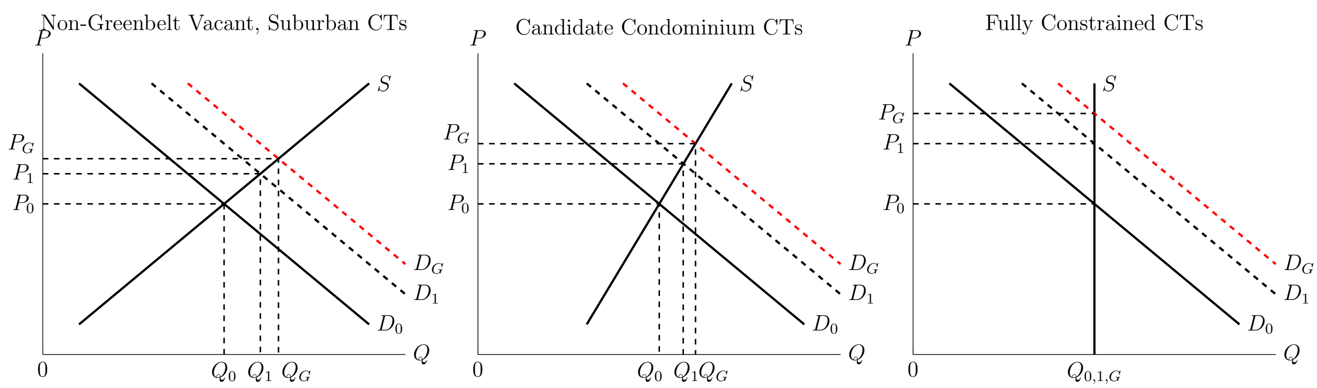
A Figures

Figure 1: A Conceptual Model of Greenbelt Implementation



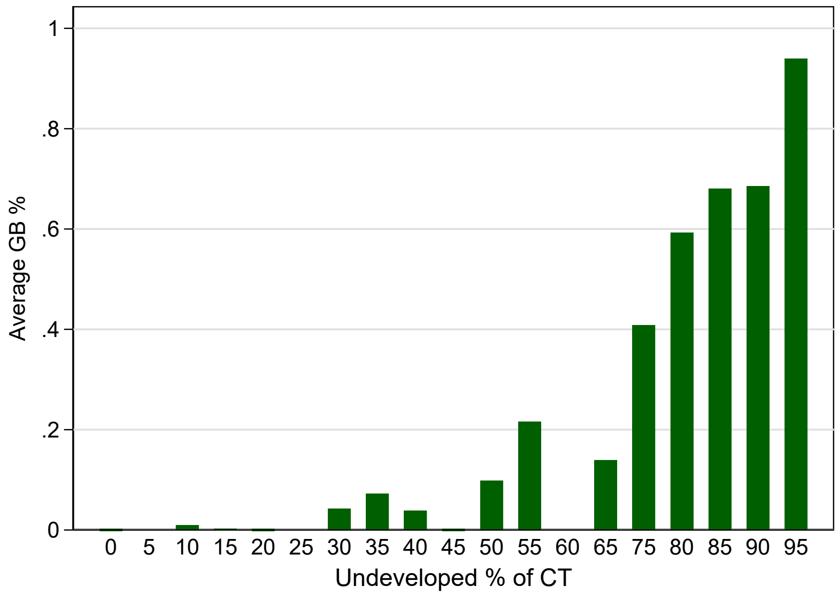
This figure plots a conceptual model for the implementation of a greenbelt policy and the impacts on census tracts restricted by the greenbelt to those unrestricted by the policy. The model assumes a positive demand shock, such as from immigration, that incentivizes a city to grow.

Figure 2: A Conceptual Model of Greenbelt Implementation



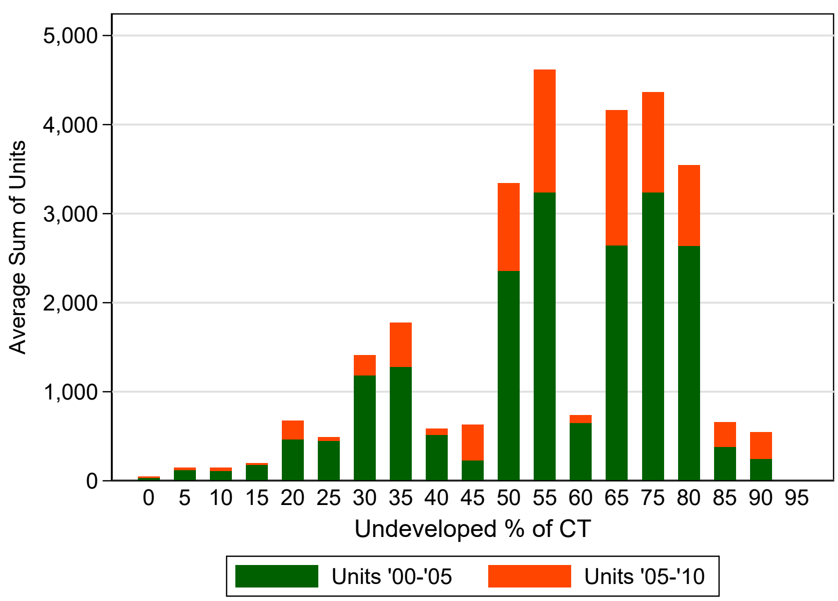
This figure plots a conceptual model for the implementation of a greenbelt policy and the impacts on census tracts of different types within the city. Census tracts with more elastic supply will see larger supply responses and lower price increases compared to those with more inelastic supply curves.

Figure 3: Average Greenbelt Exposure by Share of Undeveloped Land %



This figure plots the average greenbelt exposure at the census tract level by the share of undeveloped land. Less developed census tracts are more likely to be exposed to the Greenbelt.

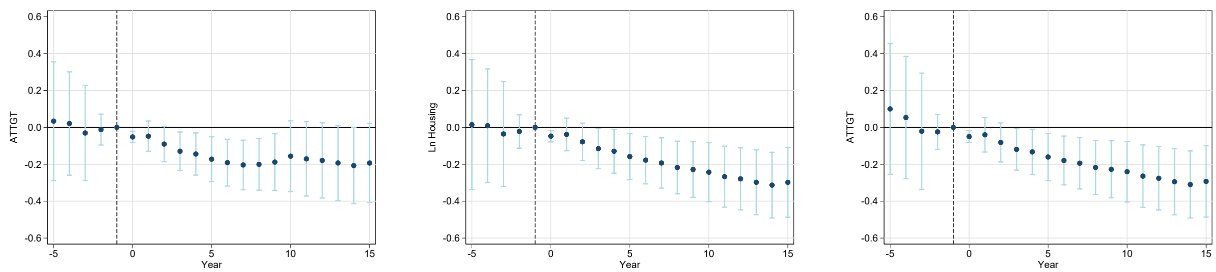
Figure 4: Average Development 2000-2010 by Share of Undeveloped Land %



This figure plots the average amount of housing development in the periods before and after the full Greenbelt was implemented. Census tracts that have less than 20% of land undeveloped see virtually no housing construction on average relative to those with more undeveloped land.

Figure 5: Event Study Results by Greenbelt Threshold

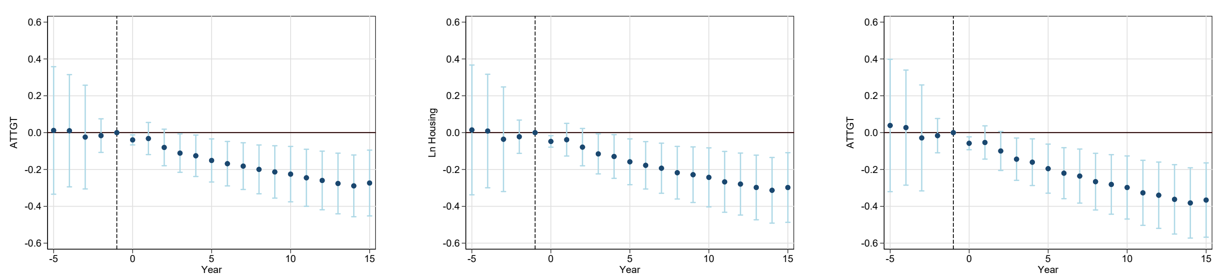
(a) GB Cutoff: 45% (b) GB Cutoff: 50% (main) (c) GB Cutoff: 55%



This figure plots the results of the event study regression specification using different thresholds for being treated by the Greenbelt policy. The dependent variable is the log of housing while a census tract is considered treated if there is more than the specified threshold covered by the Greenbelt. The main result is presented in the center for context.

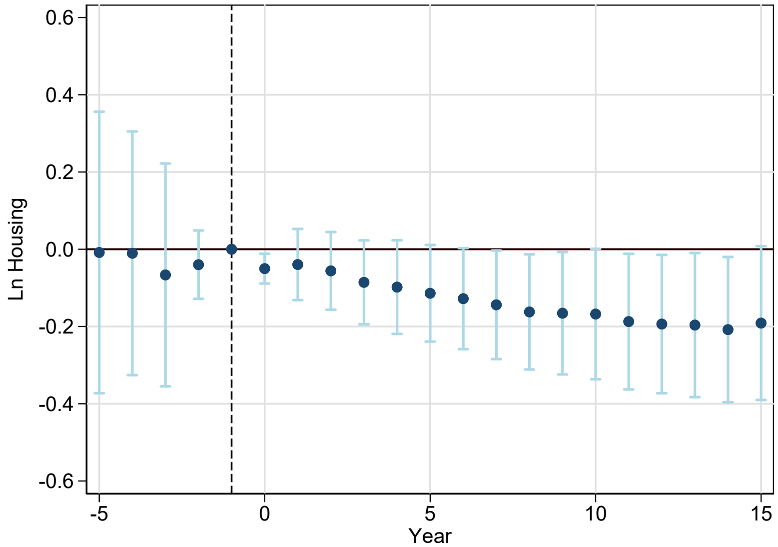
Figure 6: Event Study Results by Developable Land % Threshold

(a) Dev Cutoff: 20% (b) Dev Cutoff: 25% (main) (c) Dev Cutoff: 30%



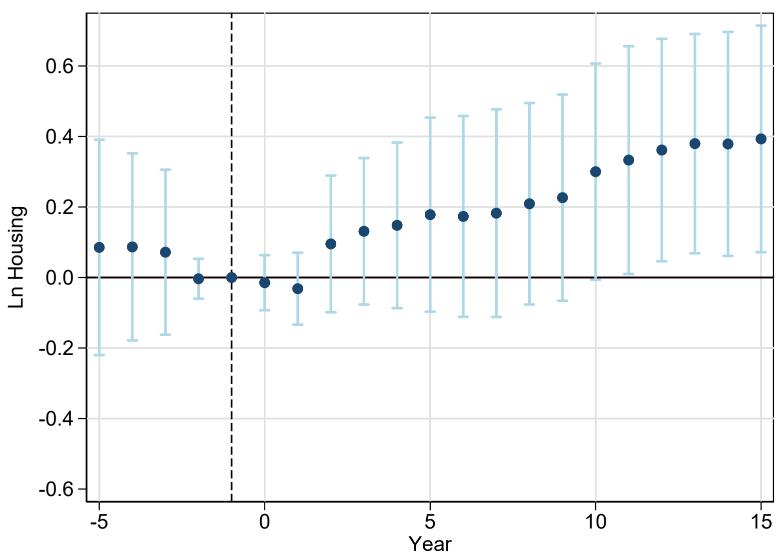
This figure plots the results of the event study regression specification using different thresholds for the amount of developable land available to be included in the control group. The dependent variable is the log of housing while a census tract is considered treated if it is more than 50% covered by the Greenbelt. The main result is presented in the center for context.

Figure 7: Event Study Results Omitting 10-50% Greenbelt Tracts From Control



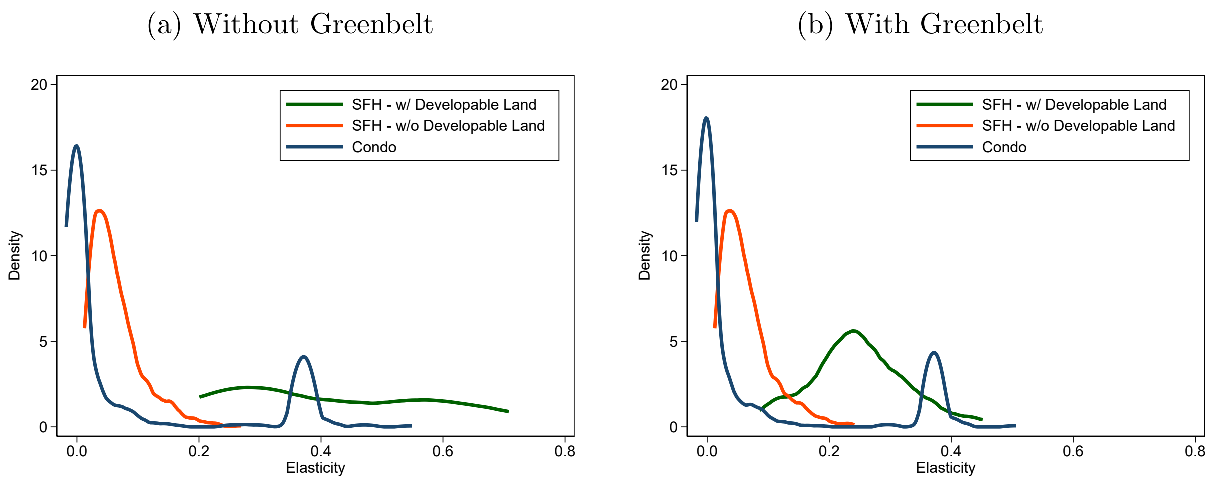
This figure plots the results of the event study regression specification without census tracts treated 10-50% by the Greenbelt included in the control. The dependent variable is the log of housing and a census tract is considered treated if it is more than 50% covered by the Greenbelt. Standard errors are clustered at the census tract level.

Figure 8: Event Study Results Comparing 10-50% Covered to Those <10% Covered



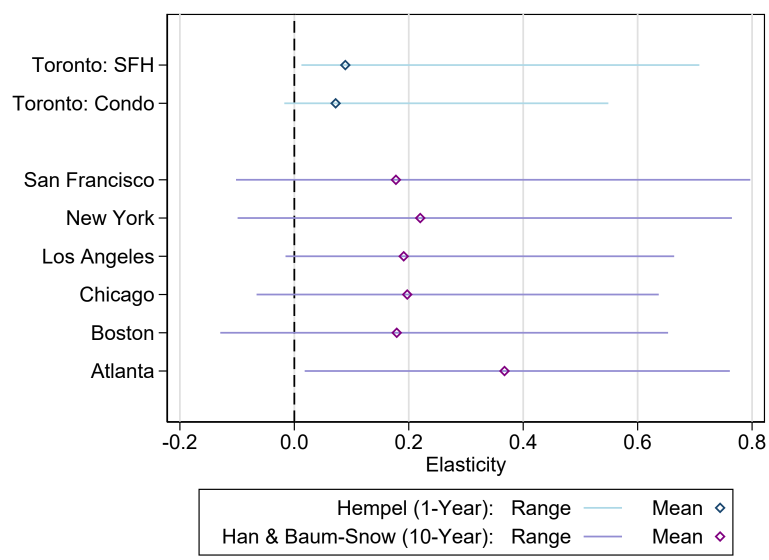
This figure plots the results of the event study regression specification between census tracts treated 10-50% by the Greenbelt and those less than 10% covered. The dependent variable is the log of housing and a census tract is considered treated here if it is between 10-50% covered by the Greenbelt. Standard errors are clustered at the census tract level.

Figure 9: Density of Housing Supply Elasticities, 2010



The kernel density plots depict the distribution of elasticities in the GTA as estimated using my model of housing supply for 2010 across different types of housing. The left panel depicts the distribution assuming there is no Greenbelt, while the right panel depicts the distribution using the Greenbelt influenced share of developable land.

Figure 10: Comparison of Housing Supply Elasticities to US Census Tracts



This figure plots the mean and range for housing supply elasticities in the GTA relative to the estimates for a series of American cities estimated in Baum-Snow & Han (2023). One important difference between these estimates is the American estimates are based on 10-year changes in housing supply and prices, while the ones for Toronto are 1-year changes, which one would expect to be smaller.