Tighteningthe Belt: The Impact of Greenbelts on Housing Affordability[*]

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October 25th, 2024

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Abstract

Greenbelts are a widespread policy tool used to protect natural spaces from urban sprawl. With rising housing costs in many metropolitan areas, numerous questions have been raised about the impact of greenbelts on housing markets. In this paper, I evaluate the impact that the introduction of the world's largest contiguous greenbelt, which was formed around Toronto in the early-2000s, had on housing prices across the region. To capture the key dynamics of a greenbelt, I develop an estimable model of the housing market with heterogeneous supply elasticities and a nested logit demand system. Using rich transaction and project-level data on housing prices and developments from 2000-2010, I estimate housing supply and demand curves separately, where I address the endogeneity of housing prices with instrumental variables. Using the estimated model, I find that the Greenbelt led to an average increase in housing costs of 2.9% by 2010. Although non-trivial (C$600 a year in rent), this increase accounts for only 4% of the increase in prices during this period, suggesting that the Greenbelt does not explain much of the deterioration in housing affordability. Skyrocketing housing costs can instead be explained by the fact that strong housing demand within the urban footprint is met with highly inelastic housing supply.

[*]I would like to thank Robert McMillan, Stephan Heblich and Jonathan Hall for their continuous support throughout the project. I would also like to thank Arthur Blouin, Michael Baker and Kory Kroft, Hans Koster, Gabriel Ahlfeldt, Alvin Murphy, Patrick Bayer, Ian Herzog, Torsten Jaccard, James Macek and Guangbin Hong for productive discussions.

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1 Introduction

As urbanization proceeds apace in numerous countries across the world, the phenomenon of urban sprawl is becoming an increasingly prominent and contested issue. While the expansion of typically low-density residential housing into the surrounding countryside can help to relieve housing supply constraints, it also generates losses of valuable farmland and natural ecosystems as well as increased pollution from greater car usage (Kahn, 2000). Such concerns have led to the creation of greenbelts and other urban growth boundaries, which restrict housing construction on undeveloped land. Examples of greenbelt policies abound, in diverse cities that include Amsterdam, London, Portland, Seoul and Toronto.

Although greenbelts are designed to stop sprawl, they have become an increasingly contentious policy option as the environmental benefits are weighed against housing costs. With escalating housing prices in many cities that have greenbelts, concerns are being raised about whether greenbelts are exacerbating the problem by limiting housing supply. Rising housing prices are a concern as they have important distributional consequences and have been shown to affect the broader economy through losses in productivity and labour mobility as workers cannot afford to move to the most desirable cities (Olney & Thompson, 2024; Hsieh & Moretti, 2019; Behrens et al., 2014). Despite the intense policy debate, there exists little evidence on how much greenbelts actually increase housing prices and contribute to worsening housing affordability.[1]

In this paper, I evaluate the impact of the Ontario Greenbelt, which surrounds Toronto, on housing prices in the region. The Ontario Greenbelt is a useful context to explore for two reasons. First, the Ontario Greenbelt is the largest contiguous greenbelt in the world, restricting development on nearly 2 million acres of land. Second, the Ontario Greenbelt was introduced in two phases in the early-2000s, which allows for the analysis of trends before and after the policy introduction using high-quality panel data. This is helpful because many of the most well known greenbelts were introduced decades earlier when data was scarce.

In a first step, I establish that the Ontario Greenbelt was a binding policy constraint on housing development using an event-study. Exploiting the introduction of the policy, I compare restricted, developable census tracts to unrestricted ones, before and after the policy. I find suggestive evidence that the Greenbelt does lead to a decrease in the housing stock in restricted tracts following the policy's introduction. While this result suggests the Greenbelt has an impact on housing quantity, it does not speak to housing affordability across the region, which requires a model.

To capture the broad effects of a greenbelt, I develop a flexible, quantitative model of the

[1] The one notable exception being Koster (2023), who studies the Greenbelt in the UK.

housing market in a large metropolitan area. In the model, a greenbelt affects the housing market both directly and indirectly. The direct effect of the greenbelt is the impact on housing development within the restricted areas. When a greenbelt is implemented, these areas will see less development and an increase in prices, which pushes households who would have lived there to other parts of the city. The indirect effect of the policy is the increase in housing development and prices that occurs in non-greenbelt areas as a result of the increased demand from displaced households. The amount prices rise in non-greenbelt areas will critically depend on how easily developers can meet this increase in demand.

The quantitative model involves granular geographies and significant heterogeneity across space. The unit of observation is the census tract-by-housing type pair. Census tracts roughly correspond to neighbourhoods and housing types in this paper are single family units and condominium apartments. Each tract-by-type pair has its own housing supply curve and supply elasticity that depends on local characteristics, such as the share of developable land and land use regulations. Amenity values are also heterogeneous across space and households choose where to live according to a nested, location-choice model of housing demand.

The heterogeneity in the model is important because it allows the model to capture more realistic patterns of housing development. For housing supply, I include heterogeneous supply elasticities because recent research suggests that developer responses vary significantly both across metropolitan areas (Saiz, 2010) and neighbourhoods (Baum-Snow & Han, 2023). If supply elasticities on the urban fringe are elastic, while those within cities are inelastic, as might be expected, this could lead to a larger impact of the policy than a world where the elasticities are all the same. For housing demand, I use a nested location-choice model to capture the idea that households may not substitute equally between locations. If households do not see a condominium in the city center as a substitute for a house in the greenbelt, the policy will not have a large effect in non-greenbelt areas. Ultimately, the impact of the Ontario Greenbelt is an empirical question that will depend on credible estimates of these supply and demand parameters.

I estimate the model in two separate steps. First, the housing supply curves are estimated at the neighbourhood level using a recently developed instrumental variables approach. Estimating housing supply elasticities at a fine geographic level has been a long running challenge in the literature despite being crucial for understanding the impact of place-based policies, such as the greenbelt. To address this, I use an instrument proposed by Baum-Snow & Han (2023) - the change in *simulated* residential market access (RMA), which is a proxy for the distance-discounted availability of job opportunities in a given location. The reason this is simulated is because RMA, which can be computed using data on population and employment, is not a good instrument on its own due to its correlation with features of a census tract such as population, which is connected to housing supply. Instead, employment in a location is simulated using a Bartik-style product of aggregate labour demand shocks and the initial shares of different jobs across space. The simulated RMA instrument then exploits only variation in labour demand shocks that are driven by aggregate trends which are uncorrelated with census-tract level characteristics.

To estimate the housing supply model, I take advantage of granular data on housing construction and transactions from 2000-2010 to recover census tract level housing supply elasticities. Information about 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, while housing transaction data comes from Teranet's GeoWarehouse. Using the simulated RMA instrument, I find that the housing supply elasticities[2] vary substantially across the region, where locations with the most undeveloped land have the most elastic predicted supply elasticities (around 1) while locations with no developable land are considerably more inelastic (effectively 0).

In the second estimation step, I estimate the nested housing demand system using a new heritage designation instrument for prices. Heritage designations prevent buildings from being demolished for new developments and therefore act as a supply shifter that can be used to identify the demand curve. I collect data on all the heritage designations in the Toronto area and the time they were enacted and compute a heritage designation exposure measure. Conditional on a number of control variables, identification comes from comparing similar census tracts exposed to different degrees of heritage restriction. I find that the average annual price elasticity of demand is around -1.67 and that the nesting parameter, ρ, is 0.23, which reflects some level of within-group preferences, but that consumers are still willing to substitute across regions and housing types.

Using these estimates for housing supply and demand, I find that the Greenbelt had a meaningful impact on the housing market just five years after the policy was introduced. The Greenbelt led to an average reduction in housing construction of 20% by 2010 in areas affected by the Greenbelt while boosting housing construction by around 1% outside the Greenbelt compared to a world without the policy. This housing supply shock translated into an increase in housing prices of 2.9% on average across the region by 2010 with higher effects in the Greenbelt (8.2%) and lower effects for condos (3.6%) and houses outside the Greenbelt (2%). This increase in prices translates to a significant annual increase in rents of C$600 or almost 1% of the annual income of an average renter.

These results, however, are not large enough to suggest the Ontario Greenbelt plays a

[2] It should be noted that these will be year-over-year elasticities as I have annual data, which differs Baum-Snow & Han (2023) who use a ten-year interval.

significant role in Toronto's rapidly deteriorating housing affordability crisis. With average housing prices rising 72% between 2001-2010, the Greenbelt only accounts for 4% of the growth in prices. This context is important not only to grasp the magnitude of Toronto's housing affordability crisis, but also because the impact of a Greenbelt is partially a function of demand shocks. This means that the effect is naturally larger in cities with greater demand and over long time periods and should be normalized to these factors to get a more accurate picture of the role played by the Greenbelt.

The small contribution to rising housing prices can be attributed to a couple factors. First, the construction restricted by the Greenbelt only accounts for 5% of the total 250,000 units built in the region from 2001-2010 or 0.6% of the total housing stock. Therefore, although the policy does seem to distort housing development patterns, it does not do so on a large enough scale to have a bigger impact. Second, housing demand for non-Greenbelt regions that is independent of the policy is very strong as prices would have risen 75% even without the policy. This suggests that as long as people value living within the city, prices will rise there with or without the Greenbelt.

One concern one might have with this conclusion is that perhaps the Ontario Greenbelt policy was not consequential enough to have a large impact. I explore this in a second counterfactual, where I imagine that the Greenbelt restricted all developable land on the urban fringe. I find that this would almost double the reduction in units constructed, up to around 22,000, but that this would still only increase prices by 5%, which accounts for only 7% of the overall increase. This finding suggests that the muted effect of the policy is not a result of the policy being too lenient.

These results provide an important lesson about the relative importance of land use regulations and where they are placed. The findings suggest that land use regulations on the urban fringe, even stringent ones, play a relatively small role in driving up prices. However, the housing market model provides evidence that land use regulations within cities may be more impactful. In my model, I include a land use policy called Urban Growth Centers (UGCs), which are areas that are targeted for greater density by the province. I find that housing supply elasticities in UGCs are around 0.66, which is much more elastic than downtown, non-UGC areas that are around 0.10 on average. I conduct a counterfactual where I expand UGC boundaries by 1 km to see how this would affect the impact of a greenbelt. I find that pairing the implementation of the Greenbelt with this reform to UGCs would actually reduce housing prices by 1.5%. This result suggests that land use regulations within cities, where housing demand is highest, play a far greater role in driving up prices than those on the urban fringe.

This paper is related to two strands of the literature. First, I contribute to the literature on the impact of greenbelts, urban growth boundaries and open space policies. For many years, analysis of greenbelt-style policies was either purely theoretical (Quigley & Swoboda, 2007; Brueckner, 2001, 2007; Anas & Rhee, 2007; Bento et al., 2006) or reduced-form (Cunningham, 2007; Kahn et al., 2010; Deaton & Vyn, 2010). Walsh (2007) represents the first attempt to estimate a structural model to analyze open-space policies, where he studied the effect of a theoretical policy in North Carolina. More recent work by Koster (2023) studies the effect of the UK Greenbelt (introduced in the 1950s-70s) on current welfare using a variation of the quantitative spatial model from Ahlfeldt et al. (2015). He finds that the welfare effects of the UK Greenbelt are positive as the amenity benefits outweigh the housing costs, which went up 7.3% overall.[3] My paper contributes to the literature by developing a model that explores the impact of greenbelts in the shorter-term with more realistic dynamics of housing supply.[4] Specifically, I allow for heterogeneous supply elasticities across space that are estimated based on year-over-year changes in the housing stock. While I show that this feature does lead to much larger price impacts than if homogeneous elasticities are used, I find that the overall price effect of the policy is still limited, which is in line with the findings of Koster (2023) for the UK.

This paper also contributes to the growing literature on land use regulation and its impact on economic outcomes. The general consensus is that land use regulations, often measured using the Wharton Residential Land Use Regulation Index (Gyourko et al., 2021), reduce the housing supply elasticity and drive up prices in more restrictive cities (Glaeser & Gyourko, 2018; Song, 2022; Turner et al., 2014; Kok et al., 2014; Glaeser & Ward, 2009; Ihlanfeldt, 2007; Mayer & Somerville, 2000). While this research documents cross-city effects, more recent research has focused on how zoning affects outcomes within cities. Anagol et al. (2021) studies the effect of maximum height restrictions on construction and prices in Sao Paolo, while Kulka et al. (2023) studies how different land use regulations interact with one another in Greater Boston. My paper contributes to the literature by studying how a greenbelt affects the internal structure of a city and its relative importance compared to policies within urban areas.

The paper is structured as follows. Section 2 introduces the Ontario Greenbelt and the datasets used for the paper. Section 3 presents an event-study that motivates the need for a model. Section 4 presents the conceptual framework and model of the housing market. Section 5 details the estimation of the housing supply and demand curves and presents the results. Finally, Section 6 presents the main results and counterfactuals.

[3] Koster (2023) does not report this change relative to the change in overall prices since implementation, but it is likely a small share as prices rose dramatically in the UK over the last half-century.

[4] The importance of considering these dynamics is well-articulated in Glaeser et al. (2006).

2 Context & Data

2.1 Policy Context

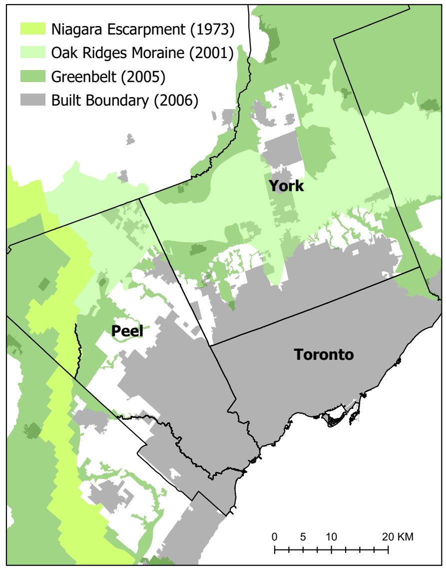
The city of Toronto is a major metropolitan area that has grown significantly in recent decades. Toronto is the largest city in Canada and the sixth largest metropolitan area in North America. From 1991 to 2001, the Toronto area grew by 770,000 residents, from 3.9 million to 4.7 million, or 20% (Statistics Canada, 2016), with much of this growth 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 the early 2000s and in response to political pressure, the Ontario government created the largest contiguous greenbelt in the world around the Greater Toronto Area (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 area studied in this paper. Then, the 500,000 acre Oak Ridges Moraine was protected in 2001. 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 initial policy shock somewhat unanticipated.

After the protection of the Oak Ridges Moraine, the completion of the Greenbelt in 2005 was more anticipated, 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, farmers and environmental groups, the ultimate Greenbelt boundary left several

Figure 1: Map of the Ontario Greenbelt



Note: 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. Black lines represent census divisions.

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 in the protected region that were not approved as of December 2004. This meant that some building still occurred on the Greenbelt after 2005, but only through 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. In 2022, the premier of Ontario 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 is updated fairly regularly in response to population pressure. The permanent nature of the Ontario Greenbelt means that the effects of the greenbelt on housing supply and prices would only be expected to increase over time.

2.2 Data

This paper focuses 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 main dataset used in this paper is an annual panel of census tracts in these three regions with information on the housing stock, price and other observable characteristics. The main challenge is that information from the census is not available on an annual basis, while aggregate annual statistics are not available at a fine enough geography to compare across space within the Greater Toronto Area. Therefore, the dataset is created from a variety of sources that are detailed in this section.

The primary data source for housing developments 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. The 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 the Altus data, which is a flow, with the stock of housing from the 2001 Canadian Census of Population to construct an annual time series of the number of houses of each type in a census tract in a given year.[5] Census tracts contain between 2,500 and 8,000 people and there are 832 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 contain information on lot sizes, which I supplement with publicly available data on housing footprints from Peel and York regions 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.[6]

I add information on land use using Agriculture and Agri-Food Canada's (AAFC) Land Use time series, which is a series of satellite maps at a semi-decadal frequency dating back

[5] For more details on the creation of the annual time series of housing see Appendix Chapter B.1.

[6] For more details on the creation of the price index see Appendix Chapter B.2

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

	Mean	Min	Median	Max
Condominiums				
# Units	1,175	5	797	14,042
Δ # Units 2001-2010	303	0	0	12,242
Sale Price ($)	285,865	63,642	265,275	1,039,340
Δ Sale Price 2001-2010 (%)	56	-47	50	452
Lot Size (sqft)	.	.	.	.
Footprint (sqft)	.	.	.	.
Distance to CBD (km)	17	0	17	74
Census Tract Size (acres)	554	13	202	22,962
Undeveloped Land %	4	0	0	90
Greenbelt %	1	0	0	71
Single Family Homes				
# Units	1,437	120	1,185	18,472
Δ # Units 2001-2010	237	0	0	15,048
Sale Price ($)	498,464	213,926	458,921	1,177,189
Δ Sale Price 2001-2010 (%)	78	5	74	528
Lot Size (sqft)	20,068	2,065	8,931	1,130,959
Footprint (sqft)	2,918	918	2,117	29,353
Distance to CBD (km)	18	1	17	82
Census Tract Size (acres)	992	30	218	40,857
Undeveloped Land %	6	0	0	94
Greenbelt %	2	0	0	92

Note: The following summary statistics are for the year 2010 and for single family homes and condominium apartments separately. There are 714 census tracts with single family homes and transactions and 477 census tracts with condominiums. There is no information on the lot size and footprint for condominium apartments as they fall within a building.

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 high reflectance areas. I then compute the share of developable land, which I define as cropland, forest or wetlands, and developed land (the remaining categories) at the census tract level in five-year intervals. I compute the share of developable land for the intervening years by calculating a land conversion ratio for each census tract based on the number of developments and the amount of converted land over the five-year period. I can then approximate when land was converted based on the development activity in that census tract.

Lastly, I add information on land use regulations including the Greenbelt. I use maps of the Greenbelt from the Ontario Government to determine how much land in a census tract is within those boundaries. One concern is that the Greenbelt grandfathered in some areas of official plans that already made space for development. I address this using maps from the Neptis Foundation, which document exactly where these areas are and I count these as being exempt from the Greenbelt. I consider the share of a census tract covered by the Greenbelt as the share of the entire land area that is considered apart of it. I also add information on whether a census tract centroid is within an Urban Growth Center (UGC), which is a zone designated for greater density, which is used when estimating housing supply functions.

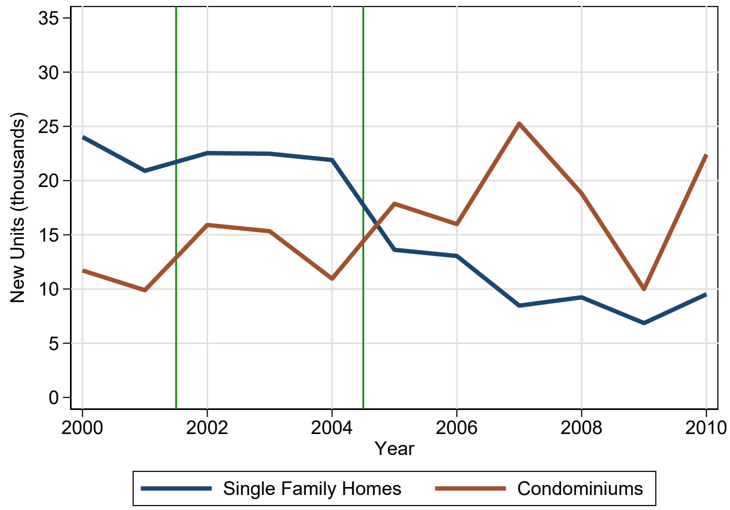
Table 1 presents basic summary statistics of the resulting dataset. For the table, I include any census tract-by-unit type for which I observe greater than zero initial units and sales for more than two years. The resulting dataset includes 714 census tracts with single family homes and 477 census tracts with condominium apartments. The average census tract-by-housing type observation has 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 to 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 78% for single family homes and 56% for condominiums on average. Census tracts which include single family homes tend to be almost twice as large on average as those which include condominiums because census tracts with condominiums 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. Overall, there is considerable heterogeneity across census tracts, which motivates the use of a disaggregated model of the housing market.

3 Motivating Evidence

Although basic economics suggests that a large greenbelt like the Ontario Greenbelt should affect the housing market, it is not certain. One argument is that there is lots of room to build as exhibited by the undeveloped land that is not blocked by the Greenbelt (see the white areas in Figure 1). Another is that the Greenbelt may not be located where people want to live, meaning there would have been little development in those places anyways. If this is true, then the Greenbelt would not distort housing development patterns at all.

In this section, I will present motivating evidence that the Ontario Greenbelt did appear to restrict where housing was able to be built. First, I will look at the raw trends in development by housing type and across the region. Then, I will compare trends in housing development patterns in census tracts affected by the greenbelt to those less affected using an event-study design. Although the magnitudes of these effects cannot be interpreted causally due to concerns over spillovers, where development shifts from treated areas to control areas, the event-study framework will demonstrate that the Greenbelt did appear to cause a sharp break in development trends. This suggests that the Greenbelt is a binding policy intervention.

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



Note: 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.

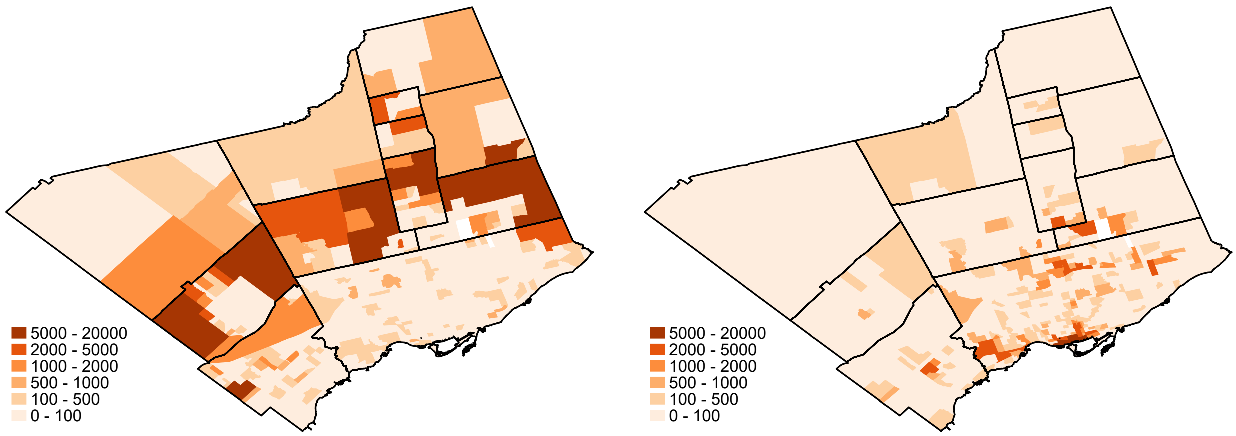
3.1 Descriptive Facts

Housing development in the GTA underwent significant change during the period of study. In Figure 2, I show the trends in new units brought to the market from 2000-2010. For the first half of the decade, single family homes were being developed at a rate of between 20 to 25,000 units a year. However, starting in 2005 this number began declining to below 10,000 units a year, a reduction by over half. Conversely, the trend for condominiums increased during this period, rising from around 10,000 to as much as 25,000 in 2007. By 2005, condominium construction became the dominant form of construction in the region. These trends suggest that there was a discernible change in housing development patterns during this time.

Figure 3 plots development patterns across the region from 2000-2010. I show that the majority of single family home construction occurred on the urban fringe in a handful of census tracts that saw 5 to 15,000 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 to 10,000 units built. 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

Figure 3: Total Units Brought to Market by Census Tract and Type, 2000-2010



(a) Single Family Homes

(b) Condominiums

Note: This figure presents the total number of units brought to the market between 2000-2010 by census tract. The black lines represent census subdivisions (or municipalities). 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.

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 examine these trends in an event-study framework.

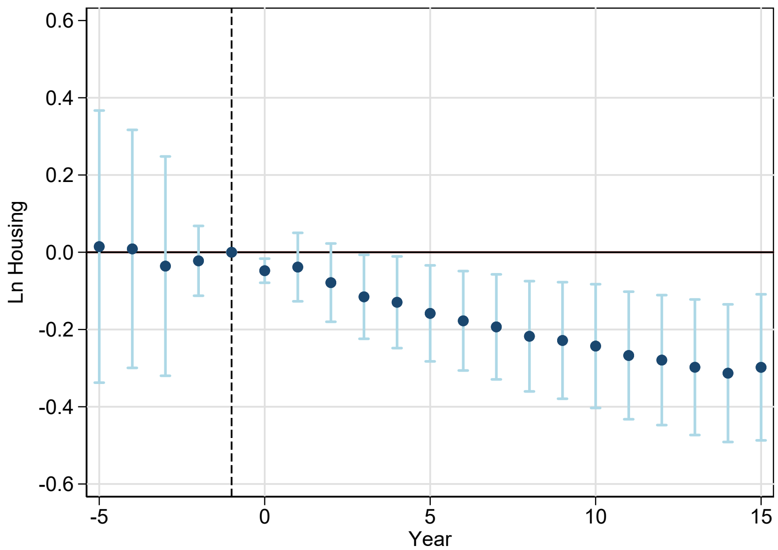
3.2 Event-Study of Greenbelt on Housing Construction

In order to determine whether the declines in single family housing construction within the restricted area are driven by the Greenbelt or some other factor, I employ an event-study framework where I compare census tracts that were more or less exposed to the Greenbelt policy. In this way I can see whether locations that became highly restricted by the policy saw declines in construction relative to those that were less restricted. Because the Greenbelt protects undeveloped land and not developed land, the focus in this section is on single family homes and not on condominiums, which tend to be built within existing urban areas.

I estimate the following regression equation of the housing stock, H.

$$\ln H_{jt} = \sum_{g=-G}^{-2} \alpha^g D_{jt}^g + \sum_{k=0}^{K} \alpha^k D_{jt}^k + \nu_j + \eta_t + \varepsilon_{jt} \tag{1}$$

Figure 4: Housing Development in Greenbelt Tracts Versus Non-Greenbelt



Note: 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.

The variable of interest is the log of housing stock in a census tract j at time t for the years 2000-2020.[7] 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 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 is chosen to represent the point at which one considers a census tract to be treated. The choice of threshold weighs the fact that no census tract is completely covered by the Greenbelt, while census tracts that are only fractionally covered may not be affected at all. Partial treatment of a census tract can still affect construction patterns through higher land costs, the loss of desirable parcels or by reducing the number of parcels available for land assembly (Brooks & Lutz, 2016). I use 50% as the threshold and show that the results are robust to some alternate choices. Treatment is staggered in this empirical setting as some census tracts receive treatment due to the *Oak Ridges Moraine*

[7] The Altus New Residential Homes database extends to the present day, which means I can run this analysis until 2020. This differs from the broader dataset because I only have transactions data up to 2010.

Protection Act in December 2001, while others are only treated after the introduction of the *Greenbelt Act* in February 2005. A tract that is partially protected in 2001, but less than 50%, that crosses the 50% threshold in 2005 is considered to be treated in 2001.

The control group is the set of census tracts that are not covered by the Greenbelt where at least 25% of the land is deemed developable in the initial period of 2000. Census tracts with no developable land are not a valid control group because they have ostensibly been "treated" already. This is because the lack of developable land effectively serves as a restriction like the Greenbelt that prevents future development of houses in those places. These tracts see hardly any development in either the pre-period or the post-period. Appendix Figures 1 and 2 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.

Appendix Figure 3 shows which census tracts fall into the treatment, control and undevelopable groups. In the map, the City of Toronto and the main suburb, Mississauga (which is west of Toronto), are mostly developed already in 2000, leaving most of the analysis to be elsewhere 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.

Figure 4 presents the results of the event-study regression. Prior to the implementation of the policy the treatment and control group follow parallel trends in terms of housing development. However, after the policy was introduced there was 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 reached over 20% and fifteen years after, the difference surpassed 30%. The effects are statistically significant starting four years after the policy, suggesting that it took time for the effects to emerge, which is consistent with the fact that the housing stock does not change significantly year-over-year.[8] Overall, these results show that treated and untreated census tracts followed a similar pattern prior to the Greenbelt's introduction, but untreated tracts saw much more rapid development afterwards.

I show that these results are robust to several alternative approaches. First, I address the recent concerns raised surrounding staggered difference-in-differences with heterogeneous and dynamic treatment effects (Callaway & Sant'Anna, 2021; Sun & Abraham, 2021; Goodman-Bacon, 2021) by implementing the approach from Callaway & Sant'Anna (2021). I show in

[8]These magnitudes make sense in comparison to results found in Koster (2023) for the UK Greenbelt. Although using a different methodology, Koster (2023) finds that the UK Greenbelt reduces housing supply by 37-70%, but over a 40-50 year time period.

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

	Undeveloped Land Share				
	20%	25%	30%	35%	40%
Greenbelt % × Treated = 1	-0.164	-0.177	-0.279**	-0.348**	-0.398***
	(0.116)	(0.117)	(0.124)	(0.132)	(0.139)
N	1617	1365	1197	1071	987
R^2	0.938	0.940	0.938	0.934	0.931

Standard Errors Clustered at the Census Tract Level

Note: 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.

Appendix Figure 4 that the results are very similar to the main event-study. Second, I show that the results are not driven by the choice of greenbelt threshold or development share threshold in Appendix Figures 5 & 6.

Finally, 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 that determine the sample of census tracts. In Table 2, I show that regardless of the sample used, more intense Greenbelt treatment leads to less housing supplied after treatment. These results suggest that a 100% increase in Greenbelt coverage at the census tract level is associated with a 16-40% decrease in housing supply over the post period, which is similar to the discrete case.[9] These results suggest that the effect of the Greenbelt on housing supply patterns holds up whether one looks at treatment as discrete or continuous.

The main concern with this approach is that construction spills over from the treatment to the control group, which violates the stable unit treatment values assumption (SUTVA). This would bias the results upwards (more negative) as the control group would see more construction as a result of the policy. I present some evidence that spillovers do appear to be present, but that they do not invalidate the results. In Appendix Figure 7, I show that census tracts that are 10-50% covered by the Greenbelt, and are therefore considered in the control group, see an increasing trend of housing relative to tracts with less than 10%

[9]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.

Greenbelt coverage. Since the Greenbelt is spatially correlated, this suggests that places with only a little Greenbelt may be growing faster as a result of the policy pushing development from more restricted Greenbelt areas to less restricted ones. However, if I compare the more restricted census tracts to those with less than 10% coverage, effectively removing the closest substitutes from the control group, I find in Appendix Figure 8 that the negative effects of the Greenbelt on housing supply remain. These results suggest that spillovers are a potential threat to identification although they do not completely nullify the overall impact of the policy. Overall, this exercise motivates the need for a model to disentangle the true effects of the Greenbelt and to analyze the broader impact of the policy across the region.

4 Model of the Housing Market

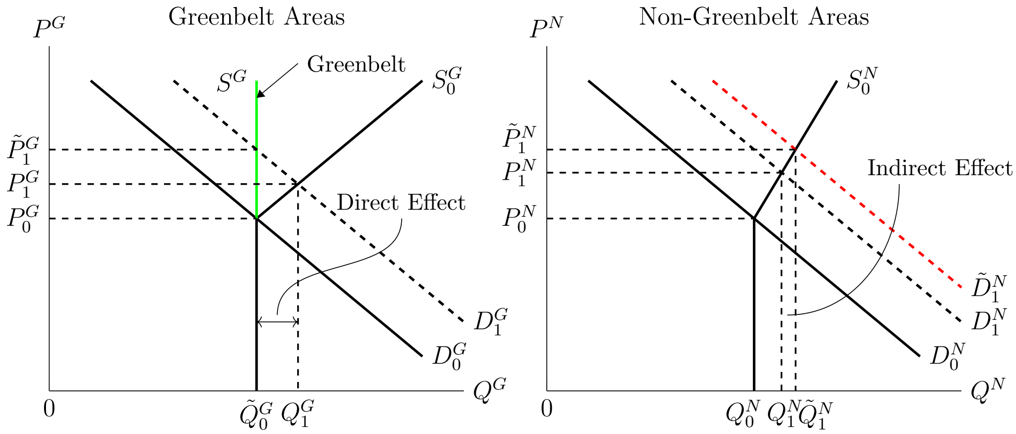
To accurately evaluate the impact of a greenbelt policy on housing affordability, a general equilibrium model of the housing market is required. This is due to the presence of spillovers, where housing development that would have occurred in the greenbelt is moved to other areas of the city, which affects housing supply and prices across the entire region. Spillovers present a challenge to traditional, reduced-form policy evaluation methods, such as the event-study in Section 3, because they are hard to measure and affect the control group. As a result, more structure is required for the analysis of greenbelt policies. In this section, I propose a model of the housing market that incorporates a greenbelt and can be estimated empirically.

4.1 Conceptual Framework

This section formalizes a conceptual framework of greenbelt policies that will motivate the rest of the paper. For the conceptual framework, one can imagine a metropolitan area that is growing over time either due to internal migration, immigration or increased demand for space. A growing city is a prerequisite for a greenbelt to have any effect because otherwise the policy would not restrict any housing demand. I assume that households have preferences over different locations in the city and can choose to move out of the city if prices increase too much. Housing will be supplied by competitive developers who face different costs of building depending on the location and availability of land. Housing is assumed to be an irreversible investment, where a negative supply or demand shock does not result in a reduction in housing quantity supplied. This is reasonable when focusing on short-run outcomes.

The impact of a greenbelt in this conceptual framework can be visualized in Figure 5, which plots the supply and demand curves for areas within the greenbelt and areas outside the greenbelt within the same region. I assume that a housing demand shock (for example,

Figure 5: A Conceptual Model of Greenbelt Implementation

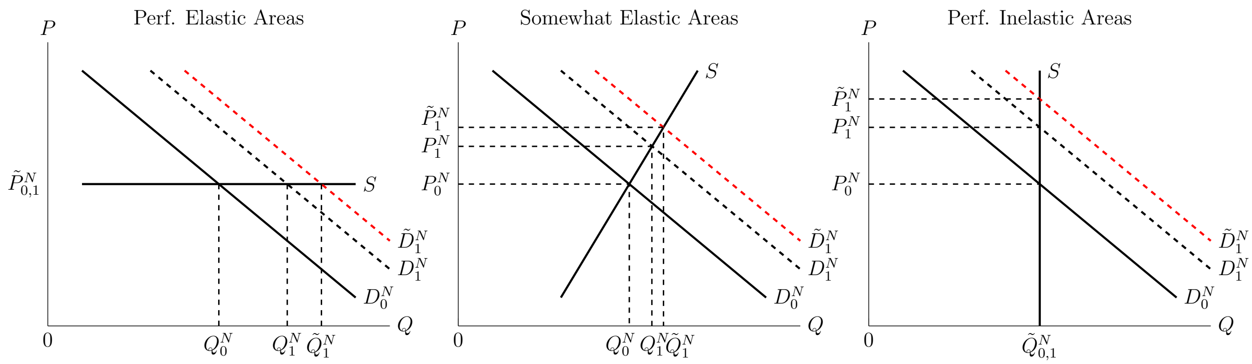


Note: This figure plots a conceptual model for the implementation of a greenbelt policy and the impacts on census tracts restricted by the greenbelt to those unrestricted by the policy. The model assumes a positive demand shock, such as from immigration, that incentivizes a city to grow.

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, Q_1, and a higher price, P_1, in both areas. However, if a greenbelt is introduced and is completely binding, it renders the supply curve perfectly inelastic in greenbelt areas, where no more housing can be built regardless of the price. Because the quantity of housing is less under the greenbelt than it would have been, $\tilde{Q}_1^G < Q_1^G$, prices must rise to $\tilde{P}_1^G$ in equilibrium. The households who are effectively pushed out of greenbelt areas due to this price increase will seek options elsewhere in the region, which increases demand in non-greenbelt areas, $\tilde{D}_1^N > D_1^N$. This will lead to higher prices, $\tilde{P}_1^N$, and quantities, $\tilde{Q}_1^N$, in non-greenbelt areas. To simplify terminology, I refer to the effect the greenbelt has on housing construction within the greenbelt as the *direct* effect of the policy and the spillover of housing demand to non-greenbelt areas as the *indirect* effect.

The conceptual framework can be used to highlight the conditions under which a greenbelt leads to different impacts on prices in absolute terms. Starting with the direct effect within greenbelt areas, one key factor is the size of the demand shock, ΔD_1^G. The more demand there is to live in greenbelt areas after the policy is imposed the larger an effect there will be on prices. This logic extends to thinking about more extended periods of time as the accumulation of demand shocks should result in a larger impact of the policy as well. The other important factor is the supply elasticity of the supply curve, S_0^G. If the supply elasticity in greenbelt areas is highly elastic, then the impact of the policy will be greater because the

Figure 6: Impact of Greenbelt in Non-Greenbelt Areas by Supply Elasticity



Note: This figure plots the impact on prices that a greenbelt has in non-greenbelt areas depending on the supply elasticity in those areas. The left panel depicts perfectly elastic supply, the middle depicts some level of elasticity and the right panel depicts a perfectly inelastic supply curve.

area would have been able to build a lot of housing without the greenbelt restrictions.[10]

The question that is of greater interest in this paper is how the impact on prices in *non*-greenbelt areas is affected by different features of the supply and demand system. First, the impact in non-greenbelt areas increases with the size of the indirect effect, $\Delta\tilde{D}^N_1$. The indirect effect is a function of both the direct effect, the number of households looking for housing elsewhere, and the willingness to substitute to non-greenbelt areas. If households are unwilling to substitute a single family home for a condominium, then the indirect effect will be small. Second, the price effect increases the more inelastic the supply curve, S^N_0, is in the non-greenbelt areas. In Figure 6, I show how the price effect changes with different degrees of housing supply elasticity. If the non-greenbelt areas in a city are low density and suburban with more land available for development, then housing supply is likely to be more elastic and the price effects would be small. On the other hand, if the non-greenbelt areas are highly developed urban centers with little available land and strict land use regulations, then housing supply is likely to be inelastic and the price effects would be larger.

Although the increase in housing prices in absolute terms is a conventional metric for evaluating the impact of a greenbelt, the *relative* price effect is also important to consider. I define the *relative* price effect as the share of the overall price increase that is explained by the greenbelt in area j, $\frac{\tilde{P}^j_1 - P^j_1}{\tilde{P}^j_1 - P^j_0}$. One benefit of using the relative price effect is that it provides important context for policy evaluation. To illustrate this, one can consider a greenbelt that

[10]This is also assuming that the greenbelt makes the supply curve perfectly inelastic when enforced. If the greenbelt only reduces the elasticity by a fixed amount, the relationship between the supply elasticity and the direct effect is more complex where more elastic supply would result in larger price effects and smaller quantity effects.

is found to raise prices by 5%. This greenbelt would be far more consequential from a policy perspective if overall prices had only risen 10%, than if they had risen 100%. The relative price effect metric captures the amount to which a greenbelt explains the overall increase in prices in a region.

Another benefit of using the relative effect is that it is more useful for comparison across different settings because it normalizes the effect by the demand shock. This is particularly relevant for comparing results across different studies that may use different time horizons since the price effect increases in longer periods of analysis. For example, Koster (2023) finds that housing costs were 7.3% higher in the UK due to the Greenbelt there, but since the UK Greenbelt was implemented several decades prior, housing prices had also grown substantially as well. In this paper, the time horizon will be far shorter, which means that without normalization, a direct comparison makes little sense. The normalization means that we are effectively measuring how much a given greenbelt converts housing demand shocks into higher prices, which is a more fundamental effect of the policy than the absolute price effect, which is a function of a specific setting and analysis.

As with the absolute price changes, it is also worth thinking about which conditions generate large or small relative price effects because some of them change. In greenbelt areas, the relative price effect is governed entirely by the housing supply and demand elasticities of S_0^G and D_1^G, where more elastic supply and inelastic demand lead to the largest direct effects. Housing demand shocks, ΔD_1^G, no longer affect the relative price effect in the greenbelt. In non-greenbelt areas, the relative price effect continues to be increasing in the magnitude of the indirect effect, $\Delta \tilde{D}_1^N$, but now is normalized by the non-greenbelt area demand shock, ΔD_1^N. Since the indirect effect is a function of the demand shock in greenbelt areas, this means that the relative price effect in non-greenbelt areas will effectively be governed by the relative demand for housing in the two areas. The largest relative price effects then arise when demand is very strong in greenbelt areas and is non-existent in non-greenbelt ones. Notably, the relative price effect in non-greenbelt areas does not depend on the supply elasticities, S_0^N, which is a change from the absolute price effect analysis. The housing supply elasticity does govern, however, the extent to which the displaced demand from the greenbelt translates into housing or higher prices in non-greenbelt areas.

The conceptual framework provides a concrete way of thinking about the impact of greenbelt policies on housing prices that provides a roadmap for the analysis in this paper. This section also highlights how the price impact of the policy - both absolute and relative - relies on different parameters of the housing supply and demand system. To quantify the impact of the policy will then require specifying a functional form of housing supply and demand curves that can be estimated, which is the focus of the next sections.

4.2 Model of Housing Supply

To evaluate the impact of a greenbelt it is important to have a model that captures the key mechanisms of how a greenbelt affects the housing market (as discussed in Section 4.1) that can be brought to the data. The challenge is that traditional quantitative spatial models, such as in Ahlfeldt et al. (2015), tend to have overly restrictive assumptions around housing supply that do not make them a good fit for a greenbelt context. In particular, these models are static in nature, which means that they do not capture the short-run frictions associated with changing the urban structure of a city, and they do not allow for the heterogeneity in housing supply elasticites across space, which is inconsistent with recent research that shows how supply responses do depend on features of the local environment (Baum-Snow & Han, 2023). If a model does not include these elements, the main dynamic of a greenbelt, where housing construction is pushed from elastic areas on the urban fringe to inelastic areas in the city center, is not captured, which could lead to an underestimate of the impact of the policy. This section will outline a model of housing supply that accounts for these dynamics and which can be estimated empirically.

Suppose in a metropolitan area there are myopic developers who produce durable housing in a perfectly competitive market of type i in location j at time t, H_{ijt}.[11] Housing types in this paper will be either single family homes or condominium apartments, while locations can be thought of as neighbourhoods or census tracts. These assumptions mean that developers will maximize their *static* profits by choosing the amount of housing that sets their marginal costs equal to the price of a housing unit, which they take as given, subject to the constraint that the level of housing must be greater than or equal to the level from the previous period, $\bar{H}_{ij,t-1}$. This last point captures the fact that, in the short-run, housing is not destroyed if prices fall either over time or across counterfactual scenarios.

To generate heterogeneity over space, developers face different cost functions to produce housing of each type, i, in location, j, at time, t, C_{ijt}. Costs are assumed to be a function of the total stock of a housing type in a location, H_{ijt}, and a set of location-by-type supply parameters, ω_{ijt}, that may vary across time and space. In this paper, I specify a constant elasticity form for the cost function, where $\omega_{ijt} = \{\kappa_{ijt}, \eta_{ijt}\}$:

$$C(H_{ijt}) = \kappa_{ijt} \left(\frac{H_{ijt}}{\eta_{\mathbf{ijt}}} \right)^{\frac{1}{\kappa_{ijt}}}.$$

[11] These assumptions abstract away from concerns around forward looking developers as discussed in Murphy (2018) and market concentration in the development industry as argued in Quintero (2022). Based on the Altus Group data for Toronto, the development industry does not appear to be highly concentrated as there are hundreds of unique developers and none of them take up a significant market share.

Here, $\frac{1}{\kappa_{ijt}}$ is the constant-cost elasticity and η_{ijt} is a building cost shock. Assuming these parameters are known to the developers, the marginal cost is then:

$$\frac{\partial C(H_{ijt})}{\partial H_{ijt}} = \left(\frac{H_{ijt}}{\eta_{\mathbf{ijt}}}\right)^{\frac{1}{\kappa_{ijt}}-1} \frac{1}{\eta_{\mathbf{ijt}}}.$$

Redefining the constant-cost elasticity as $\kappa = \frac{\varphi}{1+\varphi}$ and setting $P_{ijt} = MC_{ijt}$, the housing supply curve can be written as:

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

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

$$\ln H_{ijt} = \underbrace{(1+\varphi_{ijt})\ln\eta_{\mathbf{ijt}}}_{\tilde{\eta}_{ijt}} + \varphi_{ijt}\ln P_{ijt}. \tag{2}$$

The housing supply curve explains how much housing of each type i will be built in location j at a given price P_{ijt}. Since the supply parameters, φ_{ijt} and $\tilde{\eta}_{ijt}$, are allowed to vary across space, there can be different housing supply responses in different locations. Notably, φ_{ijt} captures the location-by-type housing supply elasticity, $\frac{\partial \ln H_{ijt}}{\partial \ln H_{ijt}} = \varphi_{ijt}$. It is reasonable to assume that φ_{ijt} is positive because higher prices should lead to more construction.[12]

In the model, housing supply elasticities will not vary randomly across space. The costs of building will depend on the surrounding natural and built environment, as well as land use regulations that govern what type of housing can be built in a location. I will incorporate this into the model by placing some structure on φ_{ijt} and $\tilde{\eta}_{ijt}$. I assume that both the housing supply elasticity and building cost shocks will depend on observable characteristics of a location, with $\varphi_{ijt} = \gamma_0 + \gamma_1 x_{ijt}$ and $\tilde{\eta}_{ijt} = \upsilon_0 + \upsilon_1 x_{ijt} + \varepsilon_{ijt}$, where ε_{ijt} is an idiosyncratic building cost shock that is revealed to developers prior to making the decision to build.

4.3 Model of Housing Demand

Housing demand is an important consideration in regions surrounded by a greenbelt because greenbelts affect the choice set of households and lead to substitution. Without accounting for substitution in the model, one would not observe a broader greenbelt effect, as the reduction in 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

[12] This also implies that $\kappa_{ijt} < 1$, which means the cost function is convex and that marginal costs are increasing in the amount of housing built.

accounting for substitution across locations that the impact on broader regional outcomes is observed because the substitution to other locations represents a demand shock that induces developers to build more housing. Incorporating substitution patterns into the model poses some modelling challenges as one must account for the entire housing demand *system*, where prices in one location affect demand in every location. I address this challenge in this section, where I present a *nested* location-choice model.

In the model, households choose where to live in two steps as illustrated in Figure 7. First, they choose a housing type and region combination, such as a condominium in the City of Toronto. In the Toronto context there are two housing types, single family home and condominium, and three regions that will be included, York, Peel and the City of Toronto, which gives households six options plus the outside option. The outside option in this model will be the more distant regions in the GTA: Halton and Durham. Then, they choose a specific neighbourhood in that region-by-type combination to live in. This choice structure is reasonable as most households tend to search for either condominium apartments or houses in specific regions. Condominiums tend to be smaller and have a different ownership and maintenance structure compared to houses, which makes them more attractive to certain households. Households also tend to search within particular areas due to their proximity to work, amenity preferences or social connections. Using these three large regions is likely a conservative assumption of the locational preferences of households.

I use a nested approach because it allows for more realistic substitution patterns than non-nested approaches that are feasibly estimated in the data.[13] In the context of the greenbelt, more flexible substitution patterns are critical for understanding the impact of the policy because greenbelts shift the types of units that developers can build and their location. If households treat these units as perfect substitutes, then it does not matter to consumers which kind of housing gets built. However, if households do have strong preferences over housing type and location, then there would be little substitution into urban centers following a greenbelt, which would make the indirect effect of the policy small.

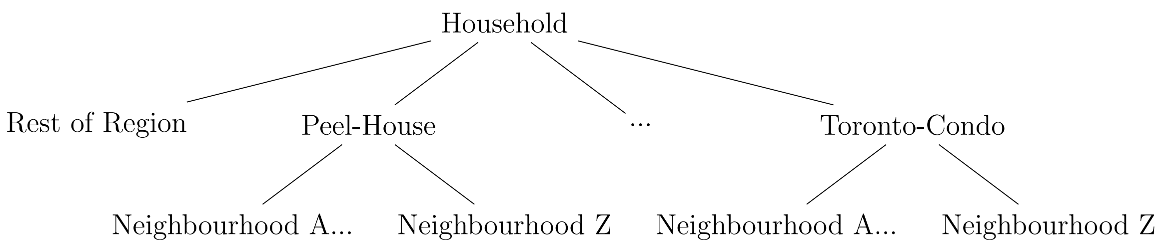
A household's utility can be written as a function of the characteristics of a house of type i in location j in nest B_n at time t:

$$U_{ijt} = \underbrace{\alpha P_{ijt} + x_{ijt}\beta + \xi_{ijt}}_{\delta_{ijt}} + \bar{\epsilon}_{Bt} + (1-\rho)\bar{\epsilon_{ijt}}.$$

In this utility function, α is the price coefficient, x_{ijt} is a set of time-varying observable

[13] In particular, the nested logit is more flexible than a plain logit, which has very restrictive substitution patterns due to the independence of irrelevant alternatives (IIA) property. In plain logit, an increase in price of one good will lead to an increase in demand for all other goods that is proportional to its market share.

Figure 7: Nested Logit Model Tree Diagram



Note: Households are assumed to choose first a location-by-type pair, where the location represents one of the larger regions in the Greater Toronto Area or the outside option. Then, within each location-by-type pair, the household will choose a specific neighbourhood.

characteristics, ξ_{ijt} are the unobserved "product" characteristics, if we think of a house type-location pair as a product, and ρ captures the degree to which households substitute within groups. I assume that the error term $\epsilon_{ijt} = \bar{\epsilon}_{Bt} + (1-\rho)\bar{\epsilon_{ijt}}$ is independent and identically distributed (iid) with the Type I Extreme Value distribution. This means that the share of households in location j of housing type i is written as the product of two probabilities: the probability of choosing option ij within a nest and the probability of choosing nest B_n amongst all nests.

$$s_{ijt} = \frac{\exp\left(\frac{\delta_{ijt}}{(1-\rho)}\right)}{\sum_{k \in B_n} \exp\left(\frac{\delta_{kt}}{(1-\rho_n)}\right)} \frac{\left(\sum_{k \in B_n} \exp\left(\frac{\delta_{kt}}{(1-\rho_n)}\right)\right)^{(1-\rho_n)}}{\sum_{\ell=1}^{L}\left(\sum_{k \in B_\ell} \exp\left(\frac{\delta_{kt}}{(1-\rho_\ell)}\right)\right)^{(1-\rho_\ell)}}. \tag{3}$$

In this specification, if $\rho \to 0$, the shares collapse into a plain logit and there is no within-nest correlation - households would substitute proportionally to market shares. If $\rho \to 1$, then households only choose an option within the chosen group - there would be no substitution across groups.

The housing demand curve can be obtained by multiplying the share of households in a location-by-type pair by the total market size, $H^D_{ijt}(P_{ijt}; M_t, \delta_{ijt}) = M_t \cdot s_{ijt}(P_{ijt}; \delta_{ijt})$. M_t represents the number of people who live in the overall region including the outside option. In this model, the outside option, s_0, will include households who live in the outlying regions surrounding Toronto that are not included in the model.

4.4 Dynamics & Equilibrium

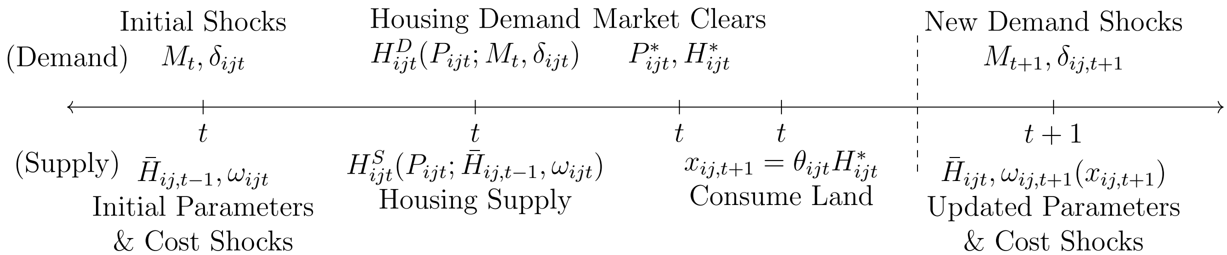
As highlighted in Section 4.1, the impact of a greenbelt is inherently dynamic in nature as the policy only has an effect when demand to live in a greenbelt increases over time. Increases in housing demand in the model come from two sources: increases in market size, M_t, and shifts to preferences, which come through the δ_{ijt} term. In the model, market size, M_t, captures the number of households that live in the entire Greater Toronto Area including the outside option regions. Changes to the market size will arise either through natural population fluctuations, migration flows within the country and immigration flows from outside the country. In Appendix Figure 9, I show that immigration is the dominant source of population change in the GTA followed by the natural increase due to births outpacing deaths. Because immigration levels are set by a binding federal policy cap, it is reasonable to assume that market size fluctuates fairly independently of housing prices within the city and that market size can be treated as exogenous to the housing market.

While a larger market size increases housing demand in all locations proportionally, changes to preferences may occur at a more granular geographic level. Changes to preferences occur through two elements of the indirect utility, δ_{ijt}. I allow for preferences over certain housing and location characteristics to vary over time, β_t. As a result, demand for certain areas may increase systematically such as if households prefer larger lot sizes. The other way preferences shift is through an idiosyncratic shock, ξ_{ijt}, that is visible to households when making their choice of where to live.

Housing supply also has dynamic elements in the model due to the durable nature of housing. The assumption that housing is durable and that developers will not destroy housing that already exists means that the choice of housing in the previous period, $\bar{H}_{ij,t-1}$, affects the housing supply decision in the current period. This is relevant for considering counterfactuals, where housing may not fall below the initial level even if prices in an area fall. The fact that the housing stock carries over to the next period also affects the ease of construction in future periods. This occurs through the location-by-type supply parameters, ω_{ijt}, which are a function of observable characteristics including the share of developable land. As more housing is built in a location, this will reduce the share of developable land and make the housing supply elasticity more inelastic. This is done using a local land conversion factor, θ_{ijt}, that translates an amount of housing construction into a reduction in developable land and consequently, a reduction in the housing supply elasticity.

I summarize the sequence of events in Figure 8. At the beginning of a given period t, there is a market of M_t households, who observe the housing demand shocks in δ_{ijt}, and a set of developers, who observe the existing housing stock, $\bar{H}_{ij,t-1}$, and housing supply parameters, ω_{ijt}. With knowledge of these parameters, rational agents choose the optimal amount of housing supplied and demanded at a given set of prices. Equilibrium in this model is defined as an allocation of housing, H^*_{ijt}, and a set of housing prices, P^*_{ijt}, that solves the household

Figure 8: Timeline of Housing Development in the Model



Note: This figure plots the timeline of housing development used in the model. Each period is characterized by a given market size, M_t, the stock of housing from the previous period, $\bar{H}_{ij,t-1}$, and a set of supply, ω_{ijt}, and demand parameters, δ_{ijt}. There is a unique set of prices that clears the market for housing, which then reduces the amount of developable land and changes the supply elasticity for the subsequent period.

and developer problems and clears the market for housing of type i in location j in time t.

$$H^S_{ijt}(P_{ijt}; \bar{H}_{ij,t-1}, \omega_{ijt}) = H^D_{ijt}(P_{ijt}; M_t, \delta_{ijt})$$

The equilibrium in this model is unique as is shown in a similar housing market setting with a discrete-choice demand specification (Bayer et al., 2004). The transition to the following period then involves updating parameters, $\omega_{ij,t+1}$, that depend on the share of developable land, carrying over the new level of housing stock in each location, observing the new level of market size and drawing new supply and demand shocks.

5 Estimation

5.1 Housing Supply Curves

The conceptual framework noted that one of the key determinants of the impact of a greenbelt is the housing supply elasticity. Ultimately, this is an empirical question that has to be estimated using data. This section will outline how I estimate the housing supply elasticity parameter, φ_{ijt}, and how it varies depending on characteristics of each location. Locations in the empirical work will be census tracts from the 2001 Canadian Census of Population.

5.1.1 Empirical Specification

To estimate the housing supply elasticity, φ_{ijt}, I take the first-difference of the housing supply curve derived in Equation 2. This yields the following equation that can be estimated using linear regression techniques.

$$\Delta \ln H^S_{ijt} = \Delta\tilde{\eta}_{ijt} + \varphi_{ijt}\Delta \ln P^S_{ijt} + \varepsilon_{ijt} \tag{4}$$

I measure the quantity of housing supplied, H_{ijt}, using the log of housing quantity of type i in census tract j at time t. The main variable of interest is the log of the housing price index, P_{ijt}, of housing type i in census tract j at time t. $\Delta\tilde{\eta}_{ijt}$ captures any time varying observable characteristics.

Since I allow the housing supply parameters to vary according to local characteristics, $\varphi_{ijt} = \gamma_0 + \gamma_1 x_{ijt}$, I interact a number of observable characteristics at the neighbourhood level with the change in price variable. First, I include the share of undeveloped land in a census tract. The share of undeveloped land is an important determinant of census tract level housing supply elasticities because land that is undeveloped should be cheaper and easier to develop than land with existing structures on it. The greater elasticity stems from several factors including 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.[14] I measure the share of developable land using satellite imagery, where cropland and forests are considered developable, while roads and residential areas are considered developed. The Ontario Greenbelt will also affect the share of developable land.

The second key observable characteristic I include is whether a census tract is in an "urban growth centre" (UGC). UGCs are regional subcenters across the GTA that were designated for increased development in 2005 around the time of the Greenbelt's introduction. In Appendix Figure 10, I plot the location of the UGCs that were introduced. The UGCs correspond to centers of business activity across the region, with the largest one in downtown Toronto and were "planned to accommodate significant population and employment growth" (Places to Grow Act, 2005) in cities across Ontario. UGC designations stipulate targets for municipal planners and officials of 400 residents and jobs per hectare in Toronto by 2031 and 200 residents and jobs per hectare 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 compared to nearby locations that did not receive these targets. Estimates of these interaction terms will help form the heterogeneous supply elasticities for the model.

[14] There are reasons to believe however, that the housing supply elasticity on undeveloped land may not be completely elastic either. For example, land assembly is a non-trivial process (Brooks & Lutz, 2016), dynamic behaviour by land owning agents hoping for better future returns can suppress housing supply (Murphy, 2018; Capozza & Li, 1994) and less developed land may also have higher servicing costs.

5.1.2 Identification

Despite first-differencing the housing supply equation, which purges tract-specific, time-invariant unobservables, there are a number of potential concerns that an OLS regression would be biased. The first is omitted variable bias, for which I propose two approaches. In one approach, I include several control variables in the form of census tract characteristics in the initial period of 2001. These include the median income, the share of university graduates, the employment rate, the working age population, the initial price level, the distance to the central business district and the initial share of developable land. In another approach, I use census tract-by-type fixed effects which partial-out the average increase in housing supply by type in each location. While this captures characteristics that cannot be observed, it also absorbs a significant portion of the variation in the data.

The more major concern is the classic simultaneity problem in estimating supply or demand curves where only the equilibrium price and quantity are observed. The problem is that housing demand shocks can be correlated with negative supply shocks, such as the mobilization of local residents against greater development pressure in an area. As noted in Davidoff (2016), highly demanded and productive locations may also be correlated with stricter supply restrictions. If this is the case, OLS estimates of the supply elasticity would be biased towards zero. Positive demand shocks and negative supply shocks would lead to large price increases without the requisite change in quantity.

Addressing this endogeneity requires an instrument that will shift housing demand without shifting housing supply factors like construction costs or zoning policies. In this section, I follow Baum-Snow & Han (2023) in using *simulated* residential market access (RMA) as an instrument for housing prices. RMA is a distance-weighted measure of job accessibility for households living in a given location n (Tsivanidis, 2023). It is computed as the solution to a system of equations setting firm location demand equal to worker location demand.

$$\begin{aligned} FMA_n &= \sum_m \frac{e^{-\kappa\varepsilon\tau_{mn}}\pi_m}{RMA_m} \\ RMA_m &= \sum_n \frac{e^{-\kappa\varepsilon\tau_{mn}}L_n}{FMA_n} \end{aligned} \tag{5}$$

RMA is determined by employment levels, L_n, population in place of residence, π_m, commuting distances, τ_{mn}, and the parameter cluster, $\kappa\varepsilon$, which captures commuting costs. Standard RMA is not in itself a good instrument for housing demand because it depends on factors that could affect housing supply, such as population. For this reason, the instrument used in the paper is the simulated RMA because the actual employment and population levels are replaced by predicted employment levels based on aggregate industry employment growth trends and initial census tract-level industry composition. This shift-share approach means that variation in RMA comes solely from changes to job accessibility due to national employment trends and is orthogonal to local population and housing productivity shocks. This variation in RMA, both across locations and over time, provides the exogenous housing demand shocks required to identify the housing supply curves at the census tract level.

5.1.3 Instrument Construction & First-Stage Results

The simulated RMA instrument is constructed in three steps. First, I estimate the gravity equation of commuting flows, c_{mn}, on commuting distances, τ_{mn}, along the road network to recover the parameter cluster $\kappa\varepsilon$.

$$\ln c_{mn} = \kappa\varepsilon \ln \tau_{mn} + \theta_m + \varsigma_n + \epsilon_{mn}$$

I estimate this equation using a Pseudo-Poisson Maximum Likelihood (PPML) approach because there are many zeros in the commuting flow matrix. I include origin, θ_m, and destination, ς_n, fixed effects and find that the parameter cluster $\kappa\varepsilon = -0.067$. This means a 10% increase in distance is associated with a 0.7% reduction in commuters. This value is larger in magnitude than those found by Tsivanidis (2023) and Baum-Snow & Han (2023) for major congested urban areas, but is within the range of plausible estimates.

Second, I construct the simulated employment levels at the census tract level. I use data from the 2001 Census on employment-by-industry L_{nk}^{01} at the census tract level to get the initial shares.[15] I omit the construction sector to alleviate potential endogeneity concerns that better access to construction employment could be correlated with supply shocks. Then, I compute the change in employment by industry using national employment level trends without the GTA. I can then sum the simulated employment levels across industries to get the simulated employment in each census tract n:

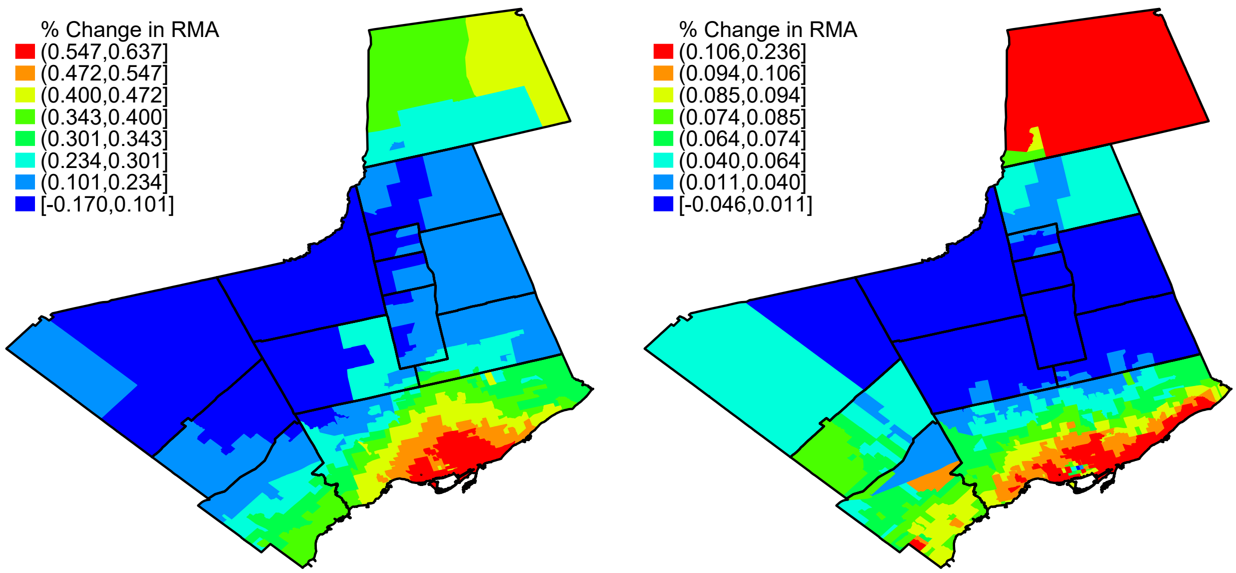
$$\tilde{L}_n^t = \sum_k L_{nk}^{01} \left(\frac{\bar{L}_k^t}{\bar{L}_k^{01}} \right) \tag{6}$$

The population in each census tract, π_n, is inflated in each year to ensure that the total population is equal to the simulated number of workers.

Finally, I plug the simulated values for population, $\tilde{\pi}_n$, and employment, $\tilde{L}_n^t$, into the system of equations for RMA and FMA. I omit employment in census tracts within 2 km of a census tract of residence to avoid concerns that nearby employment could affect the housing

[15] Industries are based on 2 digit NAICS codes and there are 15 industries in the sample

Figure 9: Change in Simulated RMA in Different Years



(a) 2004

(b) 2010

Note: This Figure presents the change in simulated $\ln RMA$ in two separate years, 2004 and 2010 in the Greater Toronto Area. Simulated RMA is calculated using a system of equations for RMA and FMA and data on employment by census tract, population and commuting.

market directly. I solve the system of equations and take first differences to get the change in simulated residential market access, $\Delta \ln \widetilde{RMA}_i$. This captures the change in accessibility to employment that should induce higher housing demand in location i that is independent of unobserved housing productivity factors. I plot the distribution of simulated RMA across space for 2004 in Appendix Figure 11. The map shows how access to employment is highest near the center of Toronto, with a slight westward shift. The farther from the city center, the less access there is to employment.

In Figure 9, I plot the change in simulated RMA in different years. There are two interesting features to note. First, the variation in magnitude differs across years. In 2004, some census tracts saw a decline of 0.17%, while others saw an increase of 0.64%. However, in 2010, the variation is much less, ranging from increases of 0.24% to declines of 0.05%. Second, there is significant variation across space in different years. While the north-western part of the city saw reduced residential market access in 2004, it saw above average growth in RMA in 2010. This variation in housing demand over time and at a fine geographic level will help to identify the supply curves.

One concern may be that the first-stage might be weak and that there is insufficient variation in RMA to be correlated with the endogenous variable - price. In Appendix Table 1, I present the results of the first stage regression of the change in log price, $\Delta \ln P_{ijt}$, on

Table 3: Results for Unified Supply Curve Regression

	No Controls		With Control Vars		CT FEs	
	IV	IV	OLS	IV	OLS	IV
$\Delta \ln P$ - Pre-2005	0.192***	0.124***	0.021	0.112**	0.028*	0.198***
	(0.023)	(0.048)	(0.015)	(0.048)	(0.014)	(0.054)
Post-2005	-0.028	-0.035	-0.024	-0.035	-0.034**	-0.027
	(0.027)	(0.029)	(0.016)	(0.029)	(0.015)	(0.029)
Constant		0.005*	0.220***	0.236***		
		(0.003)	(0.038)	(0.041)		
Controls	X	X	✓	✓	X	X
CT x Unit FE	X	X	X	X	✓	✓
N	10719	10719	10719	10719	10719	10719
Kleibergen-Paap F	742.432	87.137		71.063		63.218

Standard Errors are Clustered at the CT x Unit Type level

Note: This table presents the regression coefficients for the supply curve estimation with no heterogeneity. The first two columns show the results when no controls or fixed effects are used. Columns (3) and (4) show the results when controls are used both in the case of OLS and IV and (5) and (6) do the same, but with census tract by type fixed effects rather than control variables.

the change in log simulated RMA, $\Delta \ln \widetilde{RMA}_{it}$. In all specifications the main coefficient of the instrument is statistically significant and has the correct sign where higher RMA is correlated with higher prices although the effect is weaker post-2005. These results suggest that the simulated RMA instrument is relevant for prices.

5.1.4 Unified Supply Elasticity

Before estimating the complete model, I estimate the "unified" supply elasticity that captures the average supply elasticity across census tracts in the model. This is akin to assuming that $\varphi_{ijt} = \varphi_t$. I present the results in Table 3. In all columns, I include an interaction term for years after 2005, which splits the sample in two and captures how the elasticity changes on average after the Greenbelt's introduction. The first two columns are estimated using no controls or fixed effects, with Column 2 including simply a constant term that captures the average trend over time. I find statistically significant estimates for the unified elasticity of 0.19 and 0.12 in Columns 1 and 2, which means a 10% increase in housing price is associated with between a 1-2% increase in housing supply. I find that the elasticity declines by around 0.03 after 2005, which could indicate broader changes to the regulatory environment or other supply factors, such as input costs, but this result is not statistically significant. The results of the Kleibergen-Paap F-test show that the instrument is strong with a value of 87.1.

In Columns 3 and 4, I control for observable characteristics. This is important because changes in simulated RMA could be correlated with census tract level characteristics such as income, which could affect the quantity of housing supplied. Adding control variables means that identification should be thought of as arising from two census tracts with similar characteristics experiencing different housing demand shocks from simulated RMA. The one experiencing a larger shock should see a larger increase in price and also housing supply. In Column 4, where I use an IV, the elasticity of housing supply is 0.11, going down to 0.08 after 2005. These results are not that different from the version with just a constant, but are far larger than Column 3 where there is no IV.

In Columns 5 and 6, I include census tract-by-housing type fixed effects rather than control variables. This has the added benefit of capturing unobserved features of the census tract or housing type, such as the quality of the housing stock. With this approach, variation comes entirely within a tract-by-type over time, where years with larger price shocks should see larger housing supply responses. In Column 6, I find an elasticity of almost 0.2 pre-2005 that drops to 0.17 after 2005 that is statistically significant. This estimate is slightly larger than those from Columns 2 and 4, but within the same rough magnitude overall. Taken together, I find that the average year-over-year housing supply elasticity is between 0.1-0.2 for the Greater Toronto Area.

5.1.5 Heterogeneous Supply Elasticity

The unified supply elasticity potentially ignores significant heterogeneity across space. To investigate this, I present the results where I interact the change in price term with some observable characteristics in Table 4. I instrument for each price interaction with the corresponding interaction term with the simulated RMA instrument. One interaction term is a location-by-type dummy, which breaks the sample into either a condominium, an urban house or a suburban house, where suburban is defined as having more than 25% of the land still developable. In the table, the coefficients are grouped by the location-by-type dummy, where an urban house is the baseline value. I present the average supply elasticities by period at the bottom of the table, which translates these coefficients into actual elasticities.

The first result looking at the heterogeneous results is that the share of developable land is an important determinant of the housing supply elasticity. Looking at the baseline values for urban houses, we see that the supply elasticities are smaller in these areas compared to the unified elasticities found in the last section. This is to be expected as there is less land that is easily developable in those places. In suburban areas, which by definition have at least 25% of land designated as developable, elasticities are higher than in urban areas. This can be seen in Column 4, where the baseline elasticity in a location with the minimum share of developable land (25%) would be $(0.25 \times 1.176) - 0.139 + 0.048 = 0.203$, which is four times larger than the baseline elasticity for an urban house with no developable land. The elasticity then increases dramatically the more developable land there is. Using the coefficients from Column 4, a 50% increase in developable land share would increase the supply elasticity by 0.588. The coefficient on the share of developable land is statistically significant in all columns except Column 6, which still remains large and positive.

The second result to note is that the urban growth centers are associated with much larger elasticities. A census tract that is designated as a UGC is associated with an elasticity that is around 0.6 larger than a condominium that is not part of a UGC. This result is statistically significant in all columns except Column 6, which has a similar magnitude. As a result, the elasticity for condominiums in a UGC with no developable land is 0.69, while condominiums in a location without the UGC is only 0.081. This suggests that allowing for greater density can lead to housing supply responses that are similar in magnitude to a location with significant amounts of developable land.

The results from Column 4 will be the preferred specification used moving forward in the paper. Although census tract-by-housing type fixed effects may capture some additional unobserved heterogeneity, they also absorb too much variation in the data and lead to a weak instrument problem as exhibited by a Kleibergen-Paap F-statistic of only 1. The variation with controls has a larger F-statistic of 6.6, which is still somewhat small, but makes sense given the number of interactions. The unified elasticity results show that the instrument is quite strong without these interaction terms.

Using the coefficients from Column 4, I can then compute the predicted elasticities in each census tract. I find that the average elasticities across all tracts are 0.145 pre-2005 and 0.07 after, which is in line with the unified elasticity estimates. I plot the distribution of these elasticities across space in Figure 10. 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 (in the west). However, beyond the urban fringe, the elasticities are much larger and surpass 0.8 in a number of locations. For condominiums, housing supply elasticities are largest within urban growth centers and small elsewhere. These results are consistent with the story from the conceptual framework. The Greenbelt is located in the most elastic areas of the city and push housing demand pressure to other, less elastic areas which should raise prices.

Table 4 also highlights how using an instrument is critical for capturing more realistic housing supply elasticities across space. In the OLS specifications, the coefficients are all significantly attenuated, leading to smaller elasticities on average and smaller relationships with key observable characteristics. In Appendix Figure 12, I plot the average elasticity by the distance from the CBD for both the IV results and the OLS results. The IV results show

Table 4: Supply Curve Regression

	No Controls		With Control Vars		CT FEs	
	IV	IV	OLS	IV	OLS	IV
Baseline = Urban House						
$\Delta \ln P$ - Pre-2005	0.078***	0.034	-0.021	0.048	0.014	0.155**
	(0.023)	(0.038)	(0.014)	(0.039)	(0.012)	(0.073)
$\Delta \ln P$ - Post-2005	-0.050	-0.056*	-0.021	-0.058*	-0.031**	-0.051
	(0.031)	(0.032)	(0.016)	(0.032)	(0.015)	(0.038)
Suburban House (> 25% Dev Land)						
$\Delta \ln P$	-0.094	-0.074	0.027	-0.139	-0.015	-0.309
	(0.132)	(0.132)	(0.083)	(0.148)	(0.097)	(0.207)
$\Delta \ln P$ x % Dev Land	1.291***	1.267***	0.444	1.176***	0.225	0.804
	(0.399)	(0.399)	(0.280)	(0.400)	(0.349)	(0.591)
Condominium						
$\Delta \ln P$	0.146***	0.124**	0.025*	0.033	0.013	-0.060
	(0.051)	(0.058)	(0.014)	(0.096)	(0.013)	(0.306)
$\Delta \ln P$ x % Dev Land	0.696	0.748	0.107	0.586	0.079	0.571
	(0.575)	(0.563)	(0.144)	(0.665)	(0.139)	(0.951)
$\Delta \ln P$ x UGC = 1	0.587***	0.607***	0.096**	0.613***	-0.013	0.645
	(0.162)	(0.159)	(0.045)	(0.162)	(0.043)	(0.430)
Constant		0.004	0.191***	0.129*		
		(0.003)	(0.037)	(0.072)		
Controls	X	X	✓	✓	X	X
CT x Unit FE	X	X	X	X	✓	✓
N	10719	10719	10719	10719	10719	10719
Kleibergen-Paap F	37.489	12.372		6.601		1.055
Mean φ (Pre-2005)	0.228	0.177	0.014	0.145	0.027	0.202
Mean φ (Post-2005)	0.161	0.104	-0.012	0.071	-0.007	0.140

Standard Errors are Clustered at the CT x Unit Type level

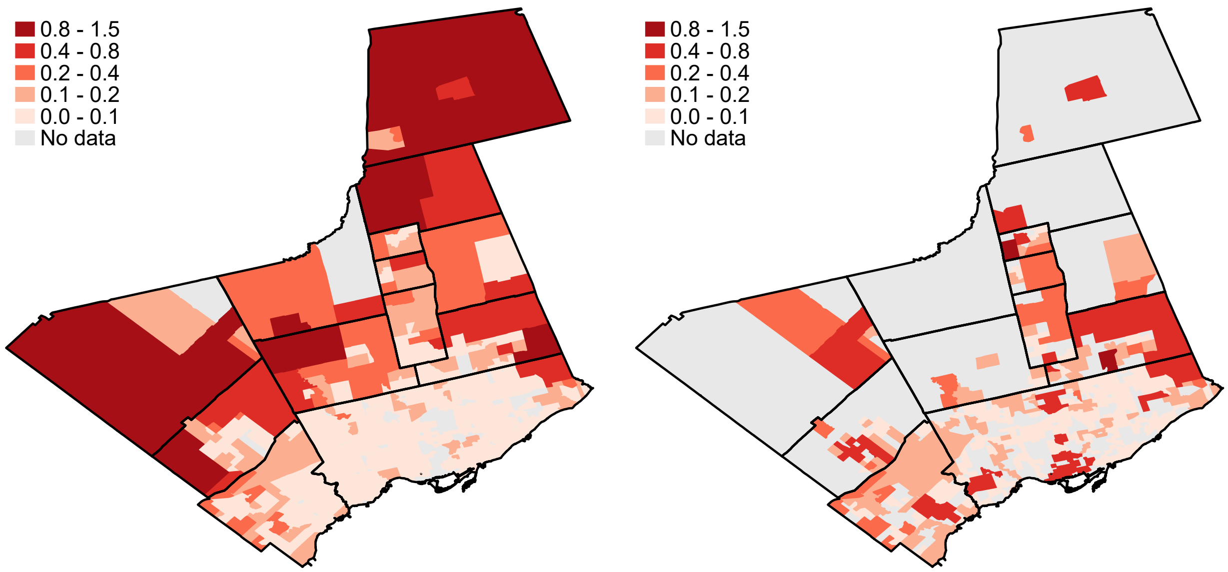
Note: This table plots the results of the supply curve regression where the dependent variable is the log of housing in a census tract of type j. A selection of interaction terms is included in this table, which capture heterogeneity in supply elasticities across census tracts. I group tract-by-type combinations into three types: condominiums, urban houses and suburban houses. I summarize the average elasticities pre- and post-2005 at the bottom.

a larger elasticity that grows more significantly with distance to the CBD, which is highly correlated to the share of developable land.

To put these results in context, I compare them to those in Baum-Snow & Han (2023) in Appendix Figure 13. I find that the average elasticities are within the same range as major American cities such as Boston, New York and Los Angeles although they are slightly

Figure 10: Predicted Supply Elasticities by Housing Type in the GTA, 2004

(a) Single Family Homes (b) Condominiums



Note: 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.

smaller on average. Part of this is due to the elasticities being estimated year-over-year, whereas in Baum-Snow & Han (2023) the elasticities are estimated in a ten-year interval. In the presence of short-run supply frictions, one might expect longer intervals to be more responsive than one-year intervals. Another reason the average elasticities may be smaller in Toronto is that the definition of the metropolitan area may be smaller and include fewer suburban or rural areas, which would raise the overall average. Overall, the supply elasticities estimated for the GTA appear to be reasonable in the context of other research and capture the realistic patterns one would expect across space.

5.2 Housing Demand Curves

The estimation of a housing demand system is critical for understanding the impact of the Greenbelt. As highlighted in the conceptual framework, the amount that households are willing to substitute between locations and housing types is important for determining the extent to which the Greenbelt raises housing prices. This section will outline how I estimate the housing demand elasticity, α, and the within-nest substitution parameter, ρ, which characterize the nested demand system for housing in the Greater Toronto Area.

5.2.1 Empirical Specification

The share of households living in location j in housing type i was given in Equation 3. Following Berry (1994), this expression can be transformed into an equation that is better suited for linear regression purposes:

$$\ln s_{ijt} - \ln s_{0t} = \alpha P_{ijt} + x_{ijt}\beta_t + \xi_{ijt} + \rho \ln\left(\frac{s_{ijt}}{s_{B_n t}}\right) \tag{7}$$

In this equation, the dependent variable is the observed share of households minus the share of the outside option, $\ln s_{ijt} - \ln s_{0t}$. In this model, each year is considered as a market, so each share is the number of housing units of type i in location j in time t divided by the total number of housing units in that year. The total number of housing units includes the outside option, which makes up almost twenty per cent of the total. Housing market shares will increase over time as construction occurs to meet demand and will only shrink when little to no construction occurs and the total market size increases.

The main variables of interest are P_{ijt}, the housing price index, and $\left(\frac{s_{ijt}}{s_{B_n t}}\right)$, the within-nest share of the given tract-by-type. Prices will vary over time and across locations and one would expect places with higher prices to have smaller shares all else equal. The within-nest share parameter, ρ, will be close to one if the within-nest shares closely track the overall shares, but will be close to zero if the chosen nests are irrelevant. While a value of $\rho \to 0$ could mean that nests were poorly chosen, it could also mean that households view all products as similar substitutes.

I include a suite of additional neighbourhood and housing characteristics that could drive a household's location choice. I include demographic characteristics such as the 2001 median income and employment rate from the Census to capture potential preferences over peer groups and as a proxy for school quality. I add housing characteristics such as the average footprint size, lot size, average year built of the building, the share of condominiums or houses in the census tract, the distance to the CBD and the distance to the CBD squared. I also allow for the valuation of certain characteristics, such as income and distance, to vary by year using an interaction between year dummies and the characteristic.

5.2.2 Identification

Identification of the housing demand elasticity, α, comes from variation in housing prices and market shares. I include year and unit type fixed effects, which accounts for the average increase in prices over time, meaning that variation in prices is relative to the annual average price. With these fixed effects and the use of market shares, the main variation in the data that identifies α is within-year and across locations. This means that among similar neighbourhoods in a given year, those that see more growth in the housing stock should have lower housing prices in order to clear the market. The main identification challenge is again the simultaneity problem where housing demand and supply shocks cannot be disentangled. If variation in prices is driven by demand shocks, then we may be recovering the supply curve rather than the demand curve, which may result in positive values of α. Therefore, an instrument that shifts supply while holding demand constant is required.

In this paper, I propose a new housing supply shifter: the proximity to heritage designations. Heritage designations are a legal tool used to prevent houses from being changed in order to preserve its architectural condition. This may be done to preserve an architectural style or to ensure a historically significant building is not destroyed. By preventing the demolition of buildings, heritage designations make new construction more difficult and reduce housing supply. Heritage designations can also serve as a signal to developers that a community is coordinated enough to potentially block other developments. In this case, even if a property is not protected, the proximity to nearby heritage designations could portend a more challenging development process.

For the heritage instrument to be valid, it must satisfy the exclusion restriction. One potential violation is if heritage designations induce housing demand in a location. There are a few reasons this is unlikely to be the case. First, heritage designations do not change anything observable about a property - their purpose is in fact to preserve the building exactly as it is - which means designations should not incite changes in demand based on the change in status of a property. Second, while the age and historic nature of a property may be desirable to some buyers (Ahlfeldt & Holman, 2018), I include controls for the average age of the housing stock to address concerns that older buildings are in demand and drive further demand shocks.

A second potential violation of the exclusion restriction is that people that enact more heritage designations also attract more demand. As pointed out in Ahlfeldt et al. (2017), educated neighbourhoods are more likely to enact heritage designations, which could in turn lead to more demand in a location. To address this I include a set of initial sociodemographic characteristics including education, the employment rate and the median income of a census tract. This would mean that any violations would have to be separate from income and education. While it is possible that some have a greater preference for heritage, it is less likely that this characteristic would attract increased demand distinctly from income and education. Finally, heritage designations may lead to greater demand if the stability they offer neighbourhoods is an amenity to individuals. Another framing however, is that this "stability" is simply the negative supply shock that stability offers. Disentangling a preference for stability from simple inelastic supply is challenging and difficult to address.

Identification of the within-nest parameter, ρ, comes from variation in the within-nest share. As this value is also endogenous, I follow the demand estimation literature and use the number of products in a nest as the instrument for the within-nest share. Nests with more products would be expected to have smaller within-nest shares systematically.

5.2.3 Instrument Construction & First-Stage Results

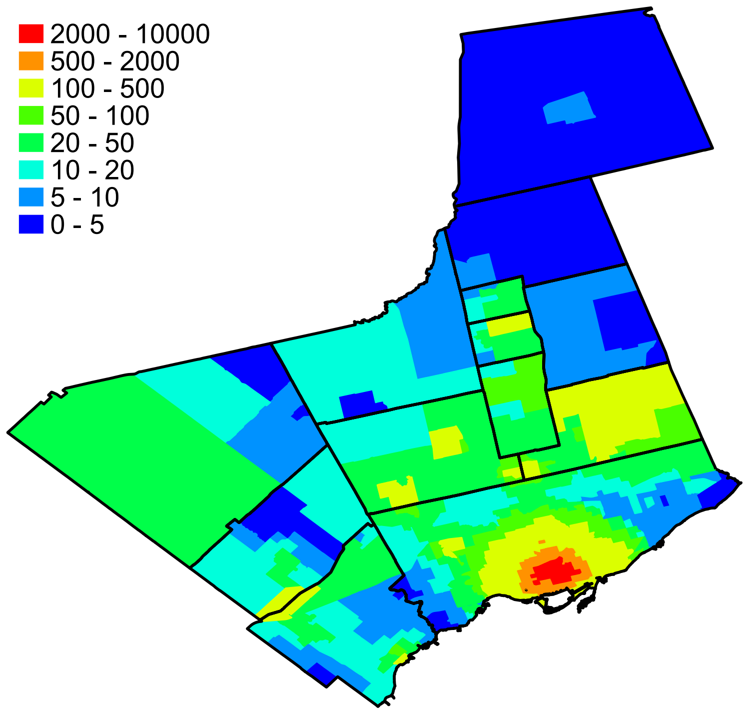
In Ontario, properties can be designated under the Ontario Heritage Act, which means they are protected from renovation and demolition.[16] There are three kinds of heritage designation: Listed, Designated - Part IV and Designated - Part V. Listed properties are simply listed on a register where the city has 60 days to decide whether to designate a property upon receiving a building permit request for the site. Listed properties are often added to the register at the request of local heritage groups and interested residents. Designated - Part IV properties are buildings from the listed register that are formally approved by city council and therefore are officially protected. Designated - Part V properties are properties that fall within a Heritage Conservation District (HCD). HCDs are areas with a distinct architectural style that are deemed important enough that entire blocks of housing are blocked from development - there are 20 such districts in the City of Toronto alone.

I collect information on every heritage designated property (Part IV and V) in the Greater Toronto Area as well as the year of designation. In Figure 11, I show the exposure of each census tract to nearby heritage designations. For each census tract, I calculate heritage exposure as the total number of heritage designations within 10km discounted by $\frac{1}{km^2}$. There is substantial variation in heritage designations across the region even conditional on municipality size and age. There are also significant changes in the number of designations issued each year as shown in Appendix Figure 14. Most heritage designations are enacted during the period of interest from 2000-2010. This variation across time and space is useful as an instrument for price, which also varies along those dimensions.

I present support for the relevancy of the instrument in the first stage regression in Appendix Table 2. I allow the heritage designation instrument to vary by unit type as the effects may differ for condominiums and single family homes. This can be seen where conditional on a set of numerous control variables, heritage designations have a statistically significant, positive impact on housing prices for single family homes, while the effect is positive, but weaker for condominiums. One explanation for this is that single family home neighbourhoods are more likely to be preserved by heritage designations and therefore to

[16] Similar heritage protections can be found in many other countries as well. In the UK, this began in 1953 under the Historic Buildings and Monuments Act.

Figure 11: Heritage Designations Across the Greater Toronto Area, 2010



Note: This map plots the distance-discounted number of heritage designations within a 10km radius of a given census tract. A decay factor of $1/km^2$ is used. Only properties designated under the Ontario Heritage Act are included.

see higher prices as a result of the reduced supply. Condominium areas are less likely to be preserved and more likely to see further development and lower prices overall. This effect is precisely what is meant to be captured by this instrument. The reduced-form regression result shows this as well, where the market share is negatively correlated with the single family homes heritage instrument.

One reason heritage designations in the Greater Toronto Area are more likely to satisfy the exclusion restriction is that they are applied excessively and indiscriminately. The heritage designation process in Toronto is community driven, which has led to over 20,000 designations. This has meant that the marginal designation is not a large, important municipal landmark, but is instead a smaller property with more questionable rationale often with highly local significance. In Appendix Figure 15, I present an image of a proposed heritage designated property, which was recommended for inclusion on the register for being an example of 1880's architecture built by a local bricklayer. The unremarkable nature of most heritage designations suggests there is randomness in the assignment process, at least along the architectural dimension, as many similar properties go unprotected. As a result, it is less likely that people sort into neighbourhoods on the basis of marginal heritage designations

Table 5: Demand Model Regression Results

	OLS		IV - By Radius			IV - With Lags	
	10km	10km	5km	10km	15km	Lag 1-Yr	Lag 2-Yr
Prices (in $10,000)	0.0083***	0.0035**	-0.0376***	-0.0395***	-0.0390***	-0.0385***	-0.0369***
	(0.0017)	(0.0014)	(0.0035)	(0.0038)	(0.0037)	(0.0038)	(0.0036)
ρ			0.2301***	0.2341***	0.2328***	0.2424***	0.2515***
			(0.0289)	(0.0299)	(0.0297)	(0.0316)	(0.0328)
Controls	X	✓	✓	✓	✓	✓	✓
Unit FE	X	✓	✓	✓	✓	✓	✓
Year	X	✓	✓	✓	✓	✓	✓
N	11910	11910	11910	11910	11910	10719	9528
Kleibergen-Paap F			34.08	35	34.03	28.84	29.08
Hansen-J			.9193	.9753	.8314	.9994	.9873

Standard Errors are Clustered at the CSD x Unit Type x Year level

The regression table shows the results of a number of regressions of the log share on price and other attributes. The first two columns show the OLS results with and without controls. The other columns show different radii used for the instrument and the use of lags.

compared to a city where designations were reserved for more significant landmarks.

5.2.4 Housing Demand Curve Results

I present the results of the demand estimation in Table 5. The first two columns present the OLS estimates with no IV or nesting terms, while the remaining columns show the IV results using different radii and lags. Looking at the OLS estimates, the coefficient is positive and the demand curve is upward sloping, which highlights the need for instruments. When using the IV, the results are consistent with downward sloping demand curves and a within-nest parameter between zero and one. In all specifications, the results are significant for both prices and the within-nest term. The Kleibergen-Paap F-test of instrument strength is larger than the conventional thresholds and the null of valid instruments in the Hansen-J test cannot be rejected.

The coefficients for α from the demand regression are not easily interpretable on their own. Instead, the resulting housing demand elasticities are more useful. The average own-price housing demand elasticity using the 10 km radius is -1.68. Unlike for the supply curves, which had a constant elasticity interpretation, the elasticity depends on the price of a housing unit. This means that the elasticity is larger in later years with higher prices and lower in earlier years and for condominiums. The annual averages by housing type range from -0.94 for condominiums in 2001 to -2.56 for single family homes in 2010. The average annual *aggregate* elasticity is much less elastic and ranges from -0.14 in 2001 to -0.25 in 2010. The aggregate elasticity reflects the housing demand response if all housing units went up 1% in value. In effect this captures the substitution to the outside option.

The own-price elasticity estimates are more elastic than those typically found in the literature. Albouy et al. (2016) finds an uncompensated price elasticity around -0.66 and report that most previous 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) find elasticities of -0.64 in Pittsburgh and -0.45 in Phoenix. Baum-Snow & Han (2023) suggest using an estimate of -0.8 in their simulation exercise. Despite this, there are reasons to believe the estimates in this paper are accurate. First of all, many previous estimates do not address price endogeneity using sophisticated instrumental variable approaches, which could bias estimates downward. Second, prices in the GTA are higher than those studied in papers from the somewhat dated literature. Finally, the own-price elasticity is estimated on fairly granular geographies, where housing would be closer substitutes than for larger regions such as cities. The fact that the aggregate elasticity is much smaller would support this point.

The within-nest parameter takes on a value of between 0.23-0.25. As this value is closer to zero than one, it suggests that households see housing across the region as relatively good substitutes for houses within the nest. This is relevant for the study of greenbelts as it means that households would be willing to substitute to downtown areas when the policy is put in place. If ρ was instead found to be closer to one, then the effect of the greenbelt would be restricted to the greenbelt areas.

6 Counterfactuals & Results

With the housing supply and demand curves estimated, I can now solve the housing market model and conduct counterfactuals. I solve the model sequentially starting with the initial values from the first period in 2001 and then for the set of equilibrium prices in each year by finding the vector of prices that sets supply equal to demand in each location-by-type pair subject to the constraint that housing quantities cannot fall below the amount of housing from the previous period. Using these prices, I find the new housing quantities and calculate the amount of land consumed using location specific land conversion values, $\hat{\theta}_{ijt}$. I update the housing supply elasticities for the next period in each location based on the new level of developable land and then move to the next period.

In this paper, I aim to match the observed baseline outcomes by including the error terms from the supply and demand regressions as observable idiosyncratic shocks. For the supply curve, these shocks, ε_{ijt}, are a component of $\tilde{\eta}_{ijt}$, while for the demand curve, these shocks represent the unobserved component of ξ_{ijt}. As a result, I can replicate the baseline results almost perfectly, which will be the scenario that is compared to the counterfactuals. The slight difference between the baseline and observed values stems from two elements of the model. First, I enforce that the housing supply elasticity must be positive, so any values below 0.01 are replaced with that value. Second, the model does not allow for housing supply to fall when prices decline, while the estimated supply curves do not include this kink in the estimation approach.

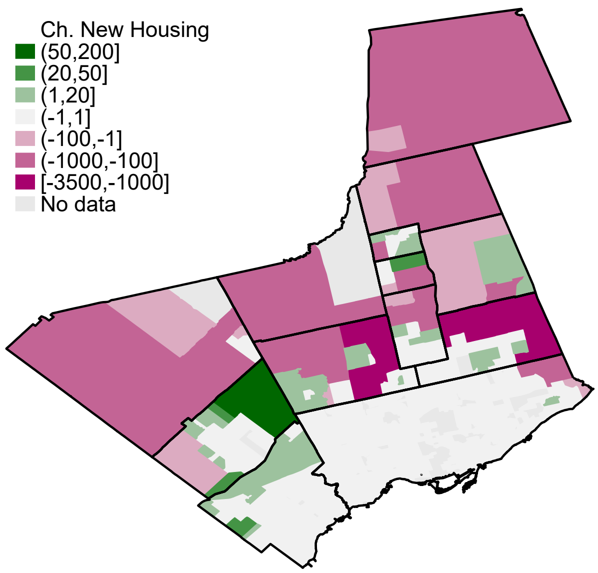
6.1 Counterfactual #1: No Greenbelt

To evaluate the impact of the Greenbelt policy, I compute how housing prices would have evolved had the Greenbelt not been implemented in the early-2000s. The Greenbelt enters the model through the share of developable land and the housing supply elasticity, $\hat{\varphi}_{ijt} = \hat{\gamma}_0 + \hat{\gamma}_1 x_{ijt}$. In this counterfactual, I recompute the share of developable land in a census tract had the Greenbelt not been implemented, which yields a more elastic housing supply elasticity based off the estimated coefficients from Table 4. These changes will occur in 2002 for the Oak Ridges Moraine and 2005 for the remaining Greenbelt. This will then increase the amount of construction in Greenbelt areas all else equal and lead to changes across the region through the housing demand system.

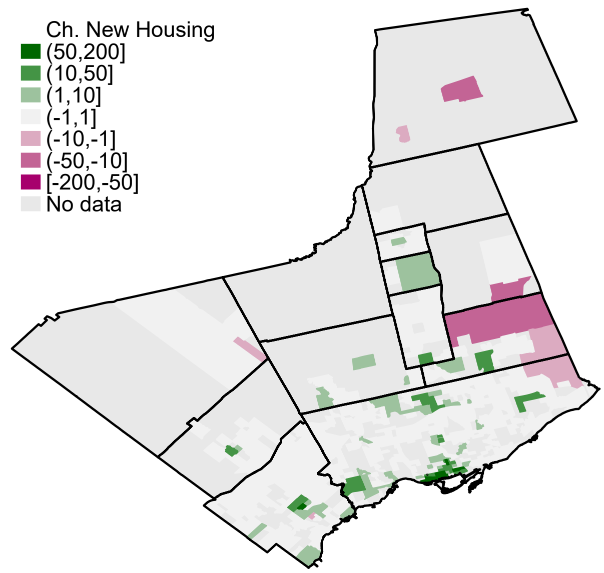
I present the results of the effect of the Greenbelt on housing construction across space in Figure 12. In this figure, I compare the observed baseline quantities when the Greenbelt was implemented to the estimated counterfactual when there was no Greenbelt. As expected the Greenbelt leads to a reduction in housing construction in Greenbelt areas with the strongest effects in locations immediately at the urban fringe, where pressure for urban expansion would be highest. The Greenbelt also pushes development into the existing urban footprint. For single family homes, this is mainly in unrestricted, suburban areas and not in the city center where housing supply elasticities are virtually zero. For condominiums, the increase in housing is mainly in UGCs and the very concentrated area around Toronto's CBD. These results are consistent with the story of the Greenbelt constricting outward expansion and pushing development into a limited set of locations within the existing urban footprint.

In Appendix Figure 16, I plot the cumulative impact on construction by housing type. Within the Greenbelt, housing construction is reduced by almost 14,000 units relative to the scenario with no Greenbelt. This translates to a 20% decrease in the amount of construction within areas affected by the Greenbelt. Connecting this to the event-study results in Section 3, I find that the tracts highly treated by the Greenbelt would see a reduction in the housing *stock* of 10.5%. This estimate is significant, but noticeably smaller than the ones found in the event-study (19.5% by 2010) which suggests that spillovers did lead to an overestimate of

Figure 12: Cumulative Effect of the Greenbelt on Housing Supply in 2010



(a) Single Family Homes



(b) Condominiums

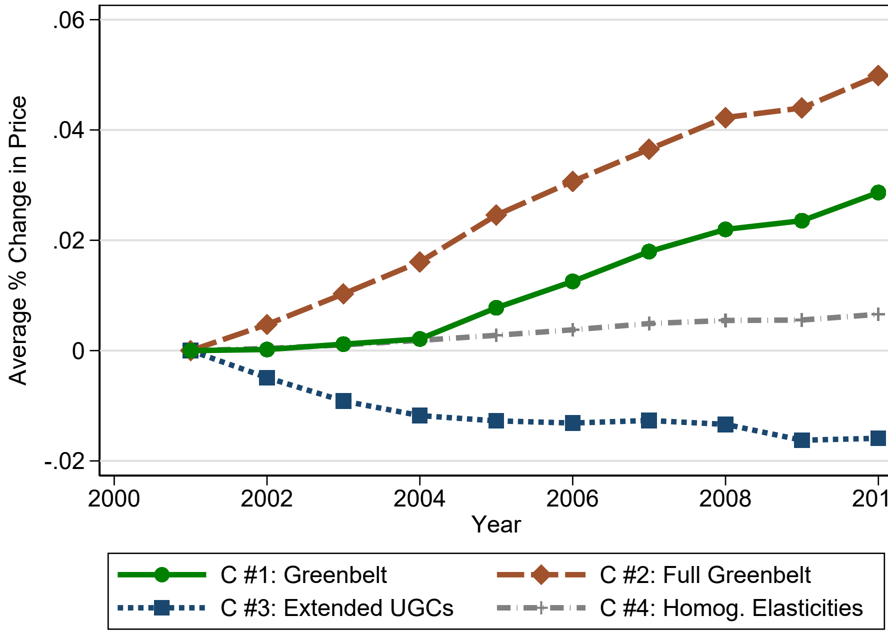
Note: This Figure presents the cumulative change in housing quantity by census tract and unit type in the region from 2001 to 2010. The change reflects the difference between the observed baseline with the Greenbelt and the counterfactual scenario where the Greenbelt is removed. Positive values reflect an increase in housing as a result of the policy while negative values reflect a reduction.

the Greenbelt effect. Outside of the Greenbelt there are modest positive effects on housing construction that amount to a 1% average increase in housing construction. The net effect on construction is a reduction of almost 12,000 units, which is 5% of total construction and 0.6% of the total housing stock in the region.

This negative housing supply shock translates to an increase in average prices across the region that are presented in Figure 13. By 2010, I find that the Greenbelt increased prices on average across all housing types by 2.9% relative to the no Greenbelt scenario. In Appendix Figure 17, I break this down by housing type and find that prices rose 8.2% in the Greenbelt areas, 3.6% for condos and 2% for all other housing types. This makes sense as the sharpest declines in housing supply were found within the Greenbelt.

While this shock is a positive for homeowners, around half the residents of the City of Toronto are renters - for whom this would reflect an increase in housing costs. Using the price-to-rent ratio of 20 for the Toronto area, this increase translates into an increase in annual rent of around C$600 a year for renters. According to the Canadian Survey of Labour and Income Dynamics, in 2010, the average pre-tax income of a renter in the Toronto area was C$61,200, which means this translates to an increase in costs worth almost 1% of pre-tax earnings - a consequential amount.

Figure 13: Price Effects of the Greenbelt Under Different Counterfactuals



Note: This figure plots the price effects of four scenarios relative to the no Greenbelt scenario: the baseline Greenbelt, a completely binding Greenbelt, a 1km extension of Urban Growth Center (UGC) boundaries and the baseline Greenbelt with homogeneous supply elasticities.

Although the effect seems substantial on an individual level, the Greenbelt accounts for only a small share of the overall increase in prices during this period. From 2001-2010, prices rose an average of 72% in the region, which means that the Greenbelt accounts for only 4% of this increase. This can be attributed to the somewhat muted impact on the overall housing stock as well as the fact that living within the urban footprint is highly desirable in Toronto, where prices rose 75% independently of the Greenbelt. This finding suggests that factors other than the Greenbelt are mostly to blame for the rapidly deteriorating housing affordability in the region.

6.2 Counterfactual #2: Full Greenbelt

One concern one might have with the main findings is that the Ontario Greenbelt policy was simply not stringent enough to affect housing prices in a substantial way. As can be seen from the map of the Greenbelt in Figure 1, the Greenbelt does not constrain the urban fringe in all parts of region, which could potentially mitigate its impact. I explore this with a counterfactual where I assume that the Greenbelt restricts all developable land around the urban fringe. This will reduce the housing supply elasticities significantly as developable land is a major source of greater developer responsiveness in the model.

In Figure 13, I plot the result of this counterfactual. I find that prices in this scenario rise 5% by 2010, which is nearly double the impact of the actual Greenbelt. Housing developments also fall by more at almost 22,000 units. Despite this, the increase in housing prices still represents only 7% of the overall increase in prices. This finding suggests that the limited contribution of the Greenbelt to higher housing prices is not because the policy boundary was not stringent enough and must be due to other factors.

6.3 Counterfactual #3: Extended UGCs

An important question in the literature is the relative impact of different types of land use policy on housing prices and the interactions between them. For example, Kulka et al. (2023) find that the most effective policy reform for Boston would be the relaxation of density restrictions, while relaxing height restrictions or allowing multi-family housing are less effective solutions. In this paper, I can also assess the relative importance of different land use regulations through the inclusion of Urban Growth Centers (UGCs) in the housing supply model. UGCs are targets set by government to achieve higher density in certain regional subcenters, which can be thought of as a way of relaxing density restrictions. When estimating the model, I find that these UGCs have housing supply elasticities of 0.66, while the average housing supply elasticity for condominiums not in UGCs is only 0.10.

To assess the relative importance of the Ontario Greenbelt and these UGCs, I conduct a counterfactual exercise where I expand the boundary of UGCs at the same time as the Greenbelt is implemented. In theory, this should mitigate the effect of the Greenbelt policy. I expand the boundary of the UGCs by 1 km in each direction as seen in Appendix Figure 10, which includes an additional 33 census tracts. I find that this additional policy reform actually leads to a decrease in housing prices across the region by 1.5% as seen in Figure 13. While prices still rise in the Greenbelt by 4.6%, prices fall for condos by 2.6% and for other single family homes by 1-1.5%. This tells us that not only does this moderate reform mitigate against the impact of the Greenbelt it actually lowers prices overall.

This is an important finding for policymakers as it suggests that policy reform within cities is far more effective at addressing rising housing prices than reform at the urban fringe. One reason for this is that demand to live in urban centers, close to jobs and amenities, is higher than farther away locales. This also provides a roadmap for thinking about environmental protection. If one wants to protect environmentally sensitive land on the urban fringe, housing price impacts can be mitigated if paired with land use reform within cities.

6.4 Counterfactual #4: Homogeneous Supply Elasticities

A final question is whether the inclusion of heterogeneous housing supply elasticities is worthwhile given the estimation challenges. To explore this, I consider a world where I use homogeneous elasticities instead. I take the average elasticities in a non-Greenbelt world, which is around 0.15 prior to 2005, and then reduce this elasticity in accordance with the amount of Greenbelt in a census tract using the same coefficient as I used in the first counterfactual. In most cases, this moves the elasticity to 0.01 - the minimum value allowed by my model. As a result, every census tract has the same elasticity each year, except when the Greenbelt is implemented, those census tracts see the elasticity reduced.

The use of homogeneous elasticities is expected to lead to smaller greenbelt price impacts. This is because in the actual housing supply model, I find that housing supply is more elastic on the urban fringe where there is more developable land and less elastic in city centers. When the Greenbelt is introduced, it inhibits areas that are more likely to increase supply and pushes demand into locations that are more likely to raise prices. Failing to account for this dynamic should then underestimate the effect of the policy.

I show in Figure 13 that this is the case. The model that uses heterogeneous elasticities finds that the impact of the Greenbelt on prices is three times larger than the one with homogeneous elasticities. Therefore, failing to account for these dynamics would lead to an underestimation of the effect of the policy. Despite this, the overall effect of the policy remains somewhat small.

7 Conclusion

Greenbelts are employed by cities to manage urban sprawl, but their effects on the housing market have not been well understood. This paper shows that although the Ontario Greenbelt increased housing prices somewhat, its impact is relatively small in the context of the rampant price escalation in Toronto. This finding is in line with work by Koster (2023) who finds that the welfare benefits of the UK Greenbelt outweigh the housing price costs. This paper also presents evidence that density restrictions are more meaningful constraints on housing development than greenbelts. The notion that density constraints are a particularly restrictive land use regulation is consistent with findings from Kulka et al. (2023).

Although this paper is focused on a single context, there are some lessons that can generalize to other settings. A key insight in this paper is that demand for housing is strong enough within the City of Toronto such that the Greenbelt only accounts for a small portion of the overall increase. This may not be the case in cities with less desirable urban cores and more desirable communities in the suburbs. In these cities, a greenbelt may contribute a greater share of price increases than was seen in Toronto.

This paper was largely silent on the benefits of greenbelt policy, focusing mainly on properly accounting for the costs. There are a number of potential benefits of greenbelt policies that have been documented in prior work. One benefit is that people value open space, which the greenbelt preserves, as seen in work by Anderson & West (2006) and Koster (2023). Another benefit of greenbelts is larger agglomeration effects that are achieved by pushing development into city centers. Recent research has argued that the benefits of agglomeration likely outweigh the potential costs (Combes et al., 2019; Ahlfeldt & Pietrostefani, 2019). Finally, increased density can also reduce traffic congestion, which could lead to less air pollution (Gibson & Carnovale, 2015) and smoother commutes. More work can be done in the future linking greenbelts to these outcomes to establish a more complete welfare analysis of the policy.

Finally, while this paper argues that the relaxation of density restrictions is a more effective policy approach than the removal of greenbelts, it also showcases why this may not happen from a political economy perspective. The Ontario Greenbelt leads to an increase in housing values for homeowners across the region, which translates to higher housing costs for renters and first time homeowners. As documented by Fischel (2004), self-interested homeowners, who are narrowly focused on the value of their property, are unlikely to support a reform that would bring down prices in their neighbourhood. Fang et al. (2023) show this in Toronto specifically, where councillors from wards with a higher homeownership share tend to be less likely to approve new development. Furthermore, homeowners tend to be higher income and more educated, which is also correlated with preferences for more environmentally conscious policymaking. This means that voters are likely to support banning new housing both in the greenbelt and within their neighbourhoods. This presents a challenge for policymakers that could be an interesting avenue of future work.

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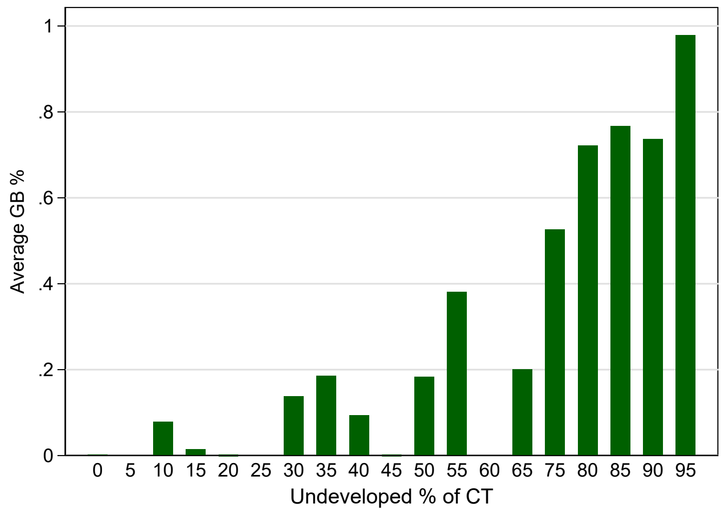
A Figures

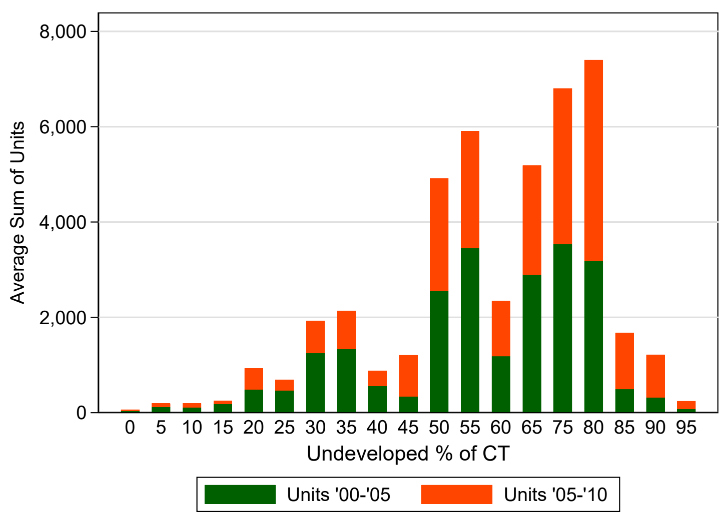
A.1 Event-Study Figures

Figure 1: Average Greenbelt Exposure by Share of Undeveloped Land %



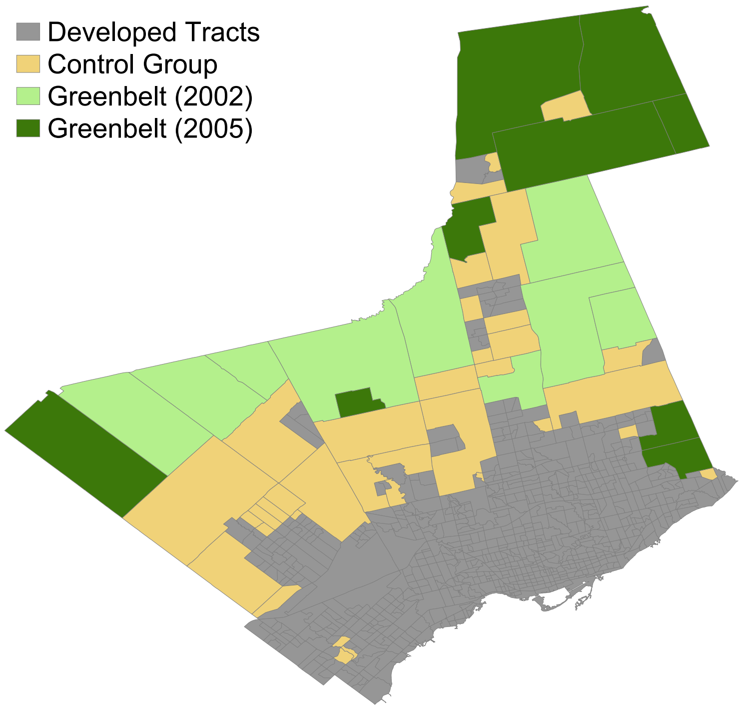
Note: This figure plots the average greenbelt exposure at the census tract level by the share of undeveloped land. Less developed census tracts are more likely to be exposed to the Greenbelt.

Figure 2: Average Development 2000-2010 by Share of Undeveloped Land %



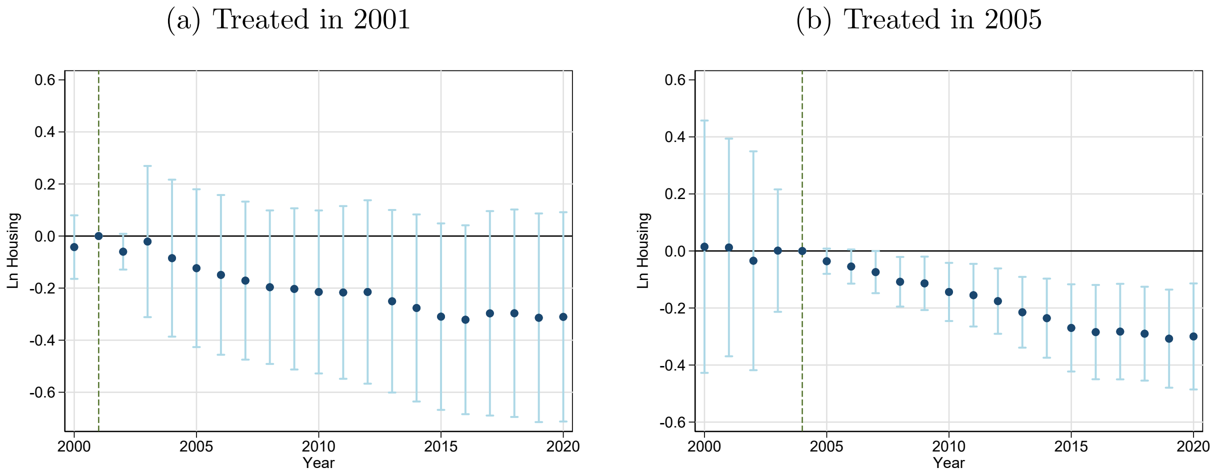
Note: This figure plots the average amount of housing development in the periods before and after the full Greenbelt was implemented. Census tracts that have less than 20% of land undeveloped see virtually no housing construction on average relative to those with more undeveloped land.

Figure 3: Census Tracts Classified into Treatment and Control Groups



Note: 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.

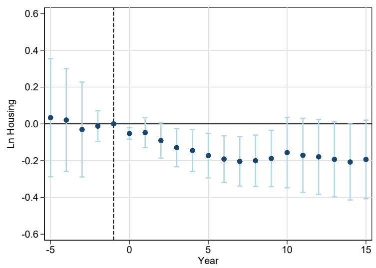
Figure 4: Callaway & Sant'Anna (2021) Estimator



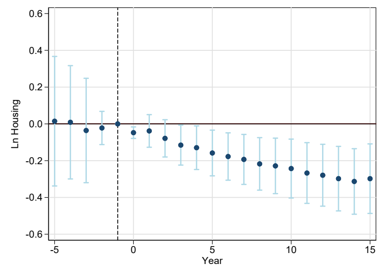
Note: This figure plots the estimates using the Callaway & Sant'Anna (2021) estimator for staggered difference-in-differences. The left panel shows the effects for the group treated in 2001, while the right panel shows the effects for the group treated in 2005. Standard errors are clustered at the census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

Figure 5: Event Study Results by Greenbelt Threshold

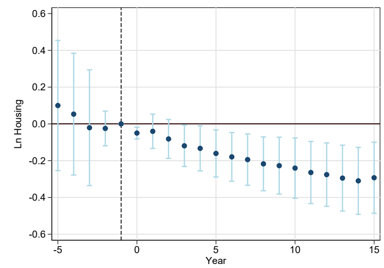
(a) GB Cutoff: 45%



(b) GB Cutoff: 50% (main)



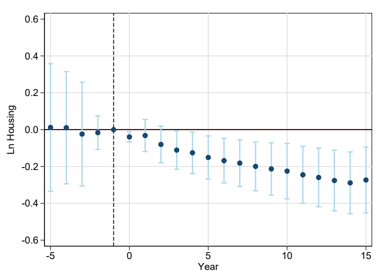
(c) GB Cutoff: 55%



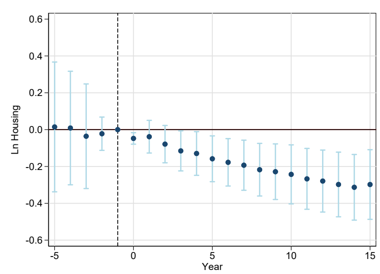
Note: This figure plots the results of the event study regression specification using different thresholds for being treated by the Greenbelt policy. The dependent variable is the log of housing while a census tract is considered treated if there is more than the specified threshold covered by the Greenbelt.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

Figure 6: Event Study Results by Developable Land % Threshold

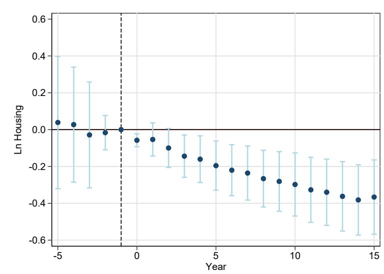
(a) Dev Cutoff: 20%



(b) Dev Cutoff: 25% (main)

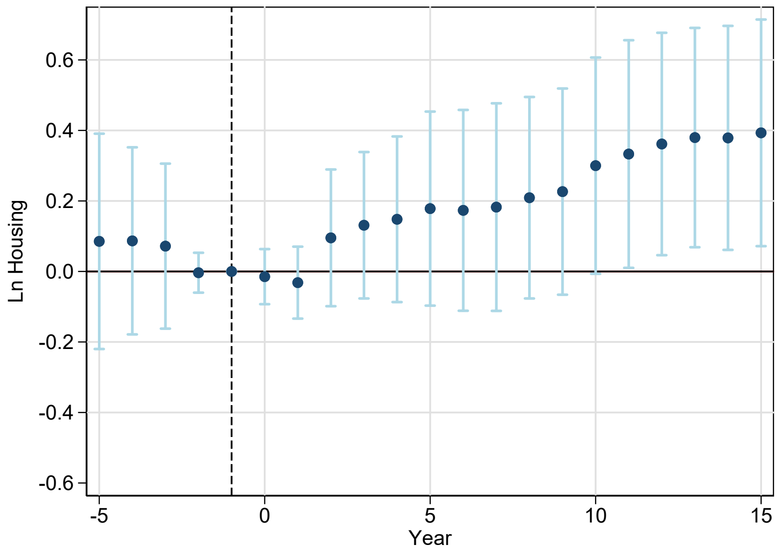


(c) Dev Cutoff: 30%



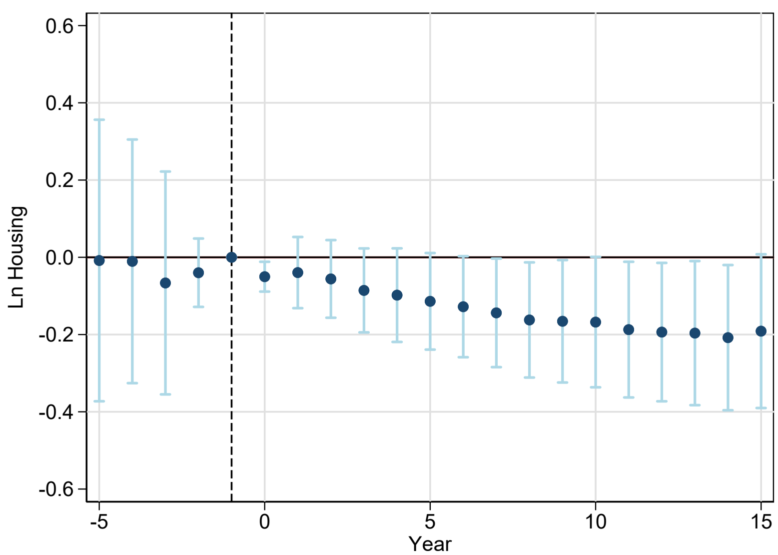
Note: This figure plots the results of the event study regression specification using different thresholds for the amount of developable land available to be included in the control group. The dependent variable is the log of housing while a census tract is considered treated if it is more than 50% covered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

Figure 7: Event Study Results Comparing 10-50% Covered to Those <10% Covered



Note: 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.

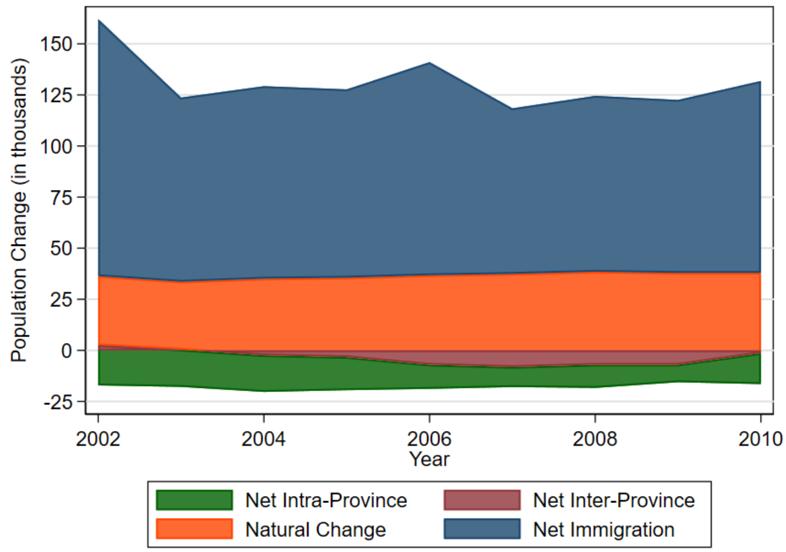
Figure 8: Event Study Results Omitting 10-50% Greenbelt Tracts From Control



Note: 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.

A.2 Model Figures

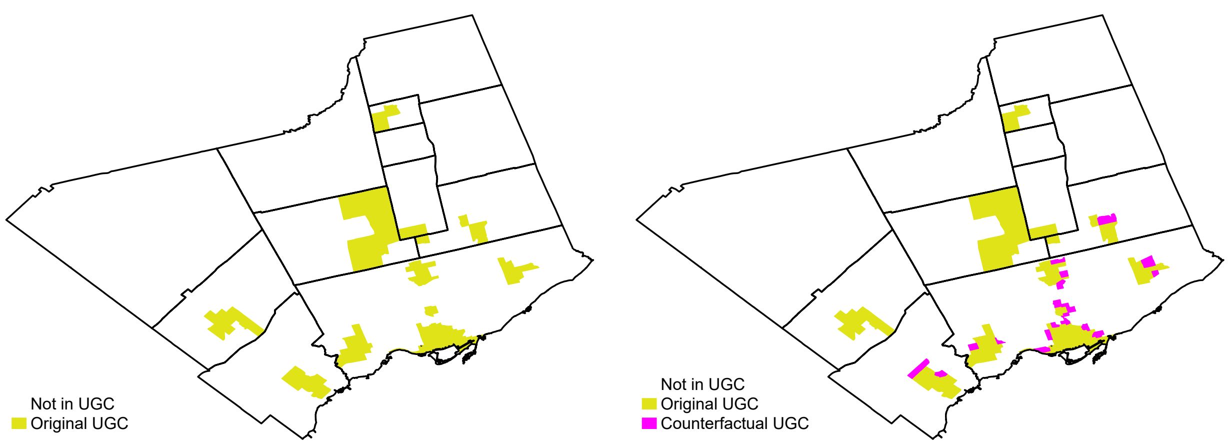
Figure 9: Components of Population Change in the Greater Toronto Area, 2002-2010



Note: This figure plots the makeup of population changes throughout the period of study. Positive values means people are coming into the GTA, while negative values means people are leaving. Immigration is the number of people coming through immigration channels and natural change is the net growth from births minus deaths. Intra- and inter-provincial migration are people moving to other regions in the province of Ontario and other provinces within Canada respectively.

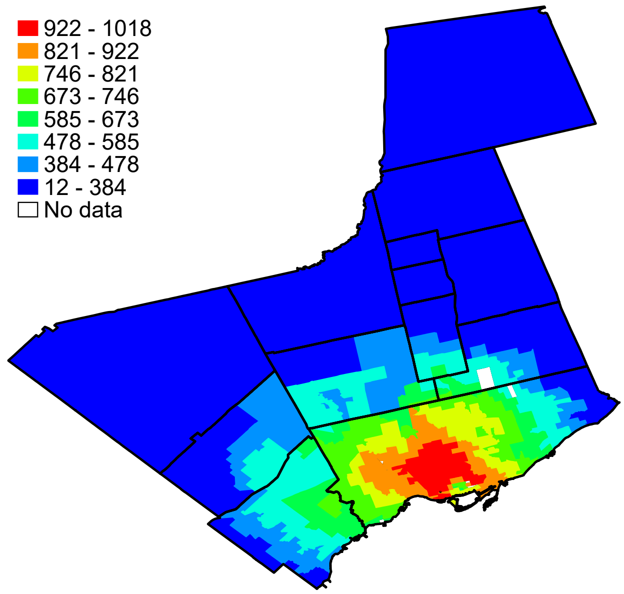
Figure 10: Urban Growth Centers in the Greater Toronto Area

(a) Actual UGCs (b) Proposed UGC Expansion



Note: 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.

Figure 11: Ln Simulated RMA, 2004



Note: This figure shows the distribution of simulated residential market access (RMA) in 2004 in the Greater Toronto Area. Simulated RMA is calculated as the solution to a system of equations setting firm market access equal to RMA in each location, where employment and population values are replace by shift-share simulated values. Areas that are more red have greater access to employment opportunities, while blue areas have less access.

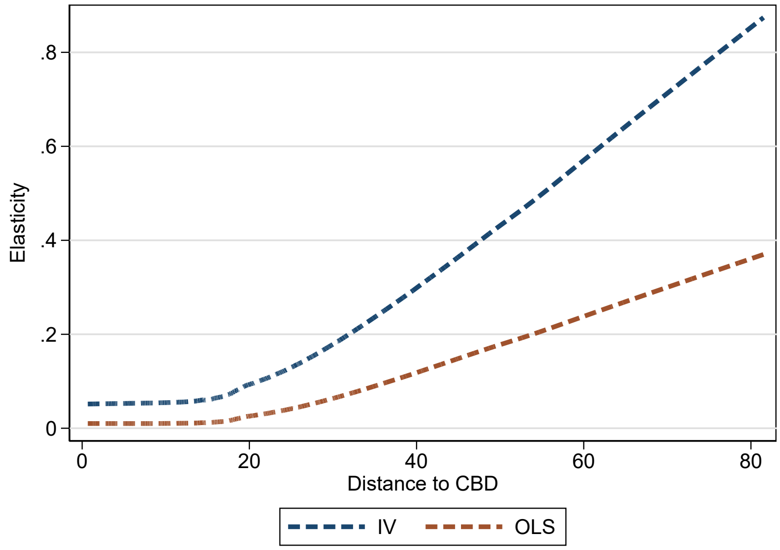
Table 1: First Stage Results of Unified Supply Curve Regression

	No Controls		With Control Vars	CT FEs
	$\Delta \ln P$	$\Delta \ln P$	$\Delta \ln P$	$\Delta \ln P$
$\Delta \ln \widetilde{RMA}_i$ - Pre-2005	13.962***	5.189***	5.035***	4.963***
	(0.260)	(0.312)	(0.316)	(0.319)
Post-2005	-10.946***	-4.244***	-4.130***	-4.075***
	(0.285)	(0.312)	(0.314)	(0.315)
Constant		0.046***	-0.225***	
		(0.001)	(0.032)	
Controls	X	X	✓	X
CT x Unit FE	X	X	X	✓
N	10719	10719	10719	10719

Standard Errors are Clustered at the CT x Unit Type level

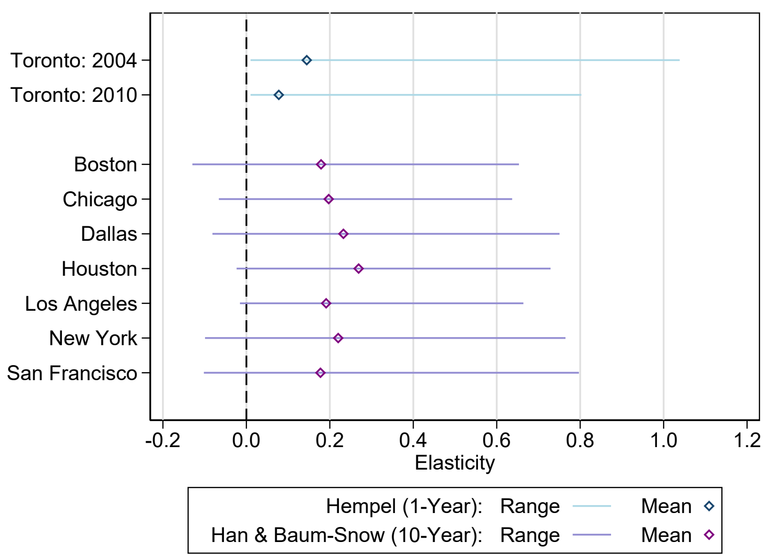
Note: This table presents the regression coefficients from the first stage regression of prices on simulated ln RMA. The first two columns have no controls with one omitting the constant term. I subsequently control for a set of variables including median income, employment rate, university degree share and others. The final column is estimated without controls, but with census tract fixed effects.

Figure 12: Comparing Predicted Elasticities by Distance to CBD and Regression Type



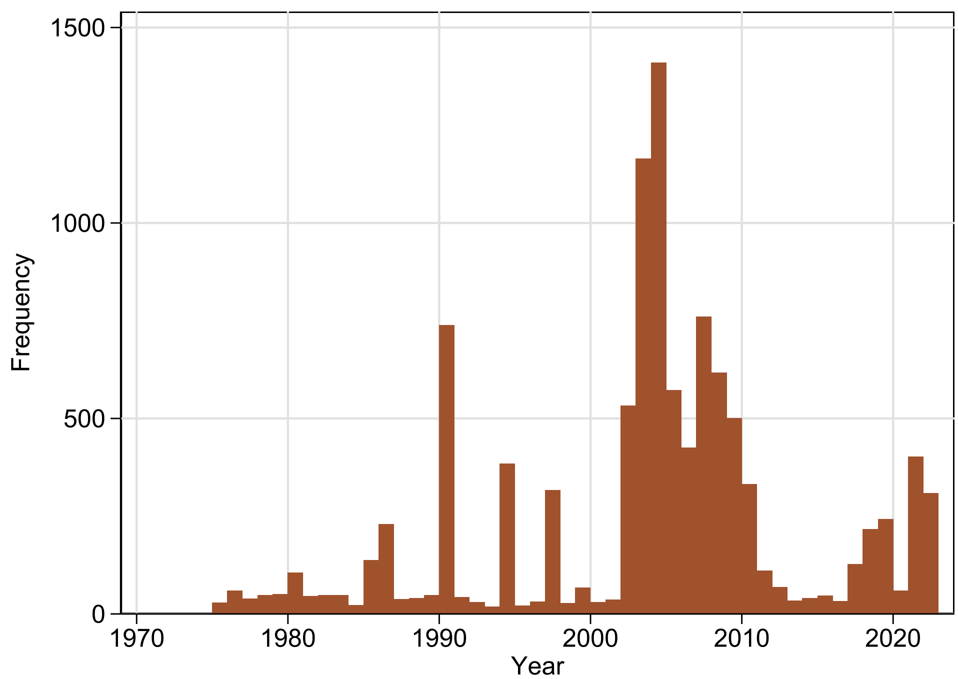
Note: This figure plots lowess regression of elasticity on distance to the central business district (CBD) for both the OLS and IV elasticity estimates. Distance is calculated in kilometers and elasticities are estimated using coefficients in Column 4 of Table 4.

Figure 13: Comparing Predicted Elasticities to Han & Baum-Snow (2024)



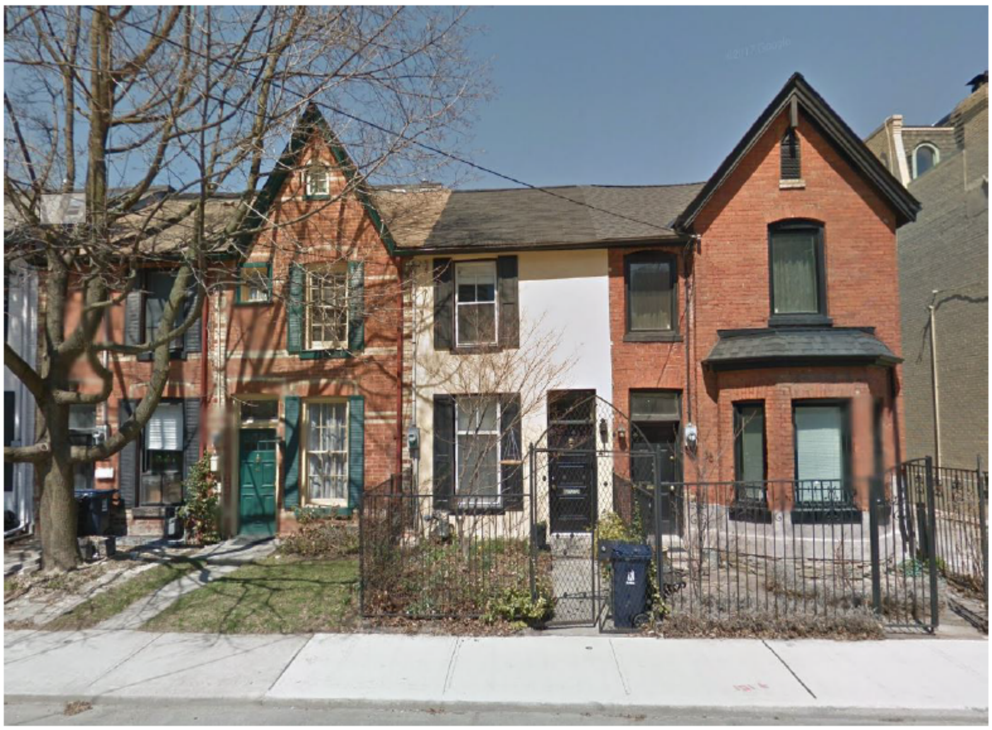
Note: This figure plots the average and range of elasticity estimates in my paper for the years 2004 and 2010 alongside the results for a collection of major American cities as estimated in Baum-Snow & Han (2023). The numbers in this paper are based off year-over-year elasticities, while those for the US are based on 10-year elasticities, which may be more responsive.

Figure 14: Heritage Designations in the Greater Toronto Area Over Time



Note: This map plots number of heritage designations issued each year in the Greater Toronto Area. These are either Designated or part of a Heritage Conservation District (HCD) as Listed properties were never formally protected by law.

Figure 15: Example of a Proposed Heritage Designated Building



Note: This picture is of 38-44 Belmont Ave, Toronto, which was recommended for inclusion on the heritage register for being built from 1881-1886 by local bricklayer.

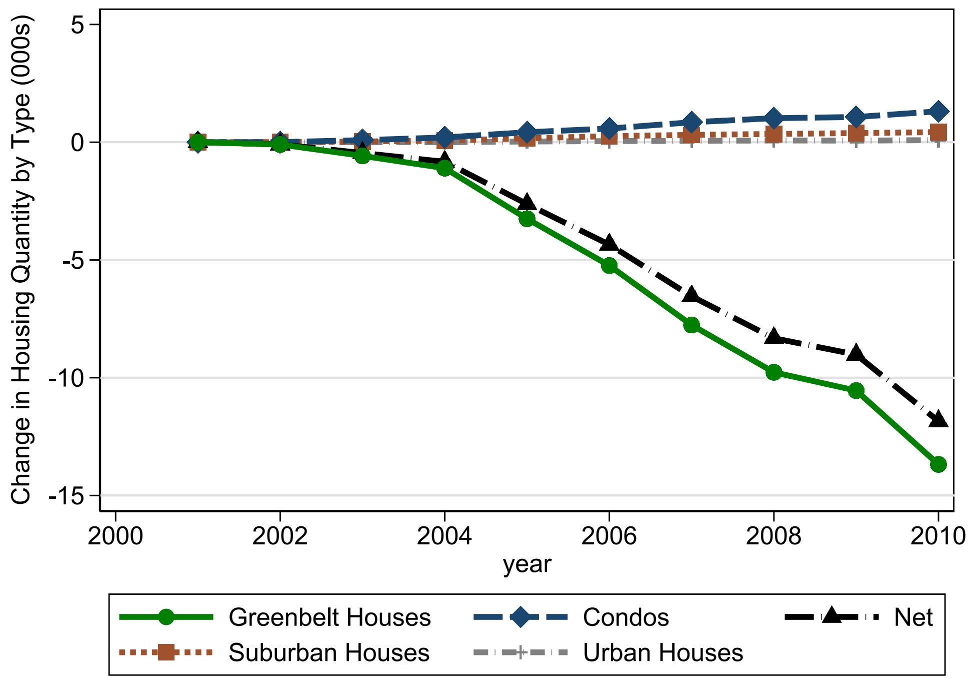
Table 2: First Stage and Reduced Form Results of Demand Regression

	Price (in $10,000$)	log Share
Unit Type=0 × Heritage Exposure	0.0004	-0.0000
	(0.0006)	(0.0000)
Unit Type=1 × Heritage Exposure	0.0053***	-0.0002***
	(0.0008)	(0.0000)
Num. in Nest	-0.0087***	-0.0007***
	(0.0021)	(0.0001)
Initial Share of Unit Type	-4.8007***	2.7382***
	(1.2537)	(0.1348)
Median Income	0.0003***	-0.0000***
	(0.0000)	(0.0000)
Employment Rate	-0.2986***	0.0039**
	(0.0238)	(0.0019)
Average Square Footage	0.0001***	-0.0000*
	(0.0000)	(0.0000)
Average Lot Size	0.0000	-0.0000**
	(0.0000)	(0.0000)
Distance to CBD	-0.5513***	-0.0514***
	(0.0798)	(0.0047)
Distance to CBD × Distance to CBD	0.0053***	0.0006***
	(0.0009)	(0.0001)
Constant	38.3195***	-6.2127***
	(1.7361)	(0.1105)
Unit FE	✓	✓
Year	✓	✓
Observations	11910	11910
R^2	0.693	0.596

Standard Errors are Clustered at the CSD x Unit Type x Year level

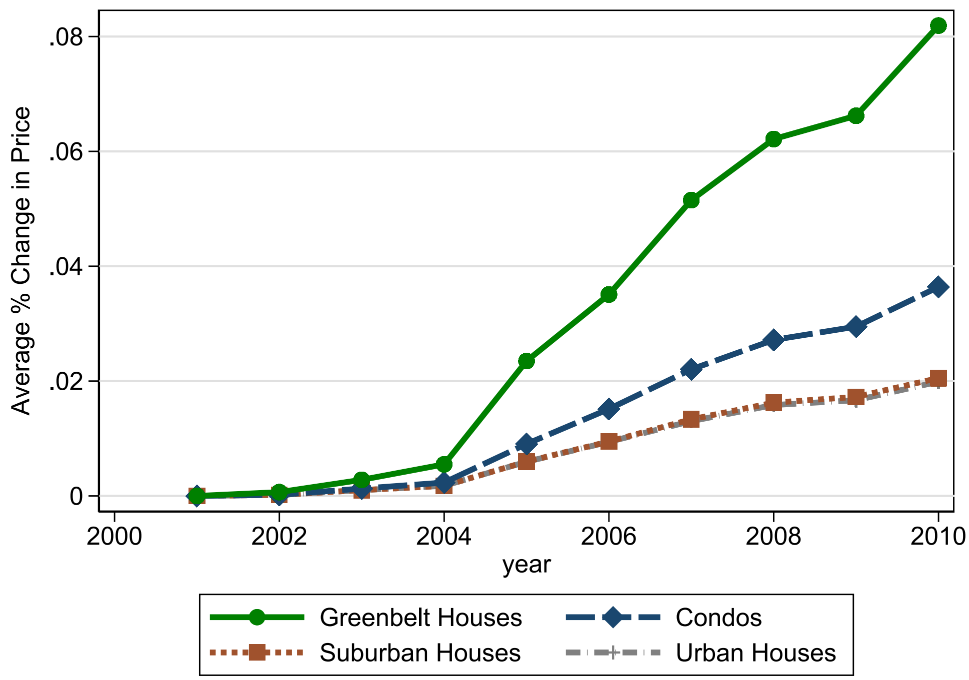
Note: This table presents the regression coefficients from the first stage regression of prices on heritage exposure and a set of control variables. The second column presents a regression of the dependent variable the log share minus the log of the share of the outside option on the instrument and a set of control variables.

Figure 16: Cumulative Quantity Effects of the Greenbelt by Housing Type



Note: This figure shows the cumulative total quantity effect of the Ontario Greenbelt by housing type over time.

Figure 17: Price Effects of the Greenbelt by Housing Type



Note: This figure shows the price effect of the Ontario Greenbelt by housing type over time.

B Data Appendix

This section provides further details on the creation of the main dataset for analysis in this paper. This includes the work done to clean the original microdata sources as well as details on how the microdata is aggregated into the census tract level dataset.

B.1 Housing Supply Series

The analysis in this paper requires information on the evolution of the stock of housing over time in the Greater Toronto Area. To address this, I use data from Altus Group's New Residential Homes database, which captures all development projects that were offered for sale in the GTA from 2000 onwards. It contains useful information on the number of units, average unit size and price sold, date of first sale and approximate location. One limitation of the dataset is that the location refers to the relative positioning of the development to the nearest major intersection. This makes sense as the streets that the houses are currently on did not exist prior to the subdivisions. This means that the development data cannot be matched directly to the parcel data. To get around this, I aggregate the data to the census tract level by assigning each project to its corresponding tract.

Another challenge with the data is determining what date constitutes the date at which a project is considered part of the housing stock. Most of the time, datasets use either building permits data, which is the point at which a building permit is acquired, housing starts data, which is when concrete is first poured, or completions/occupancy data, which is when units are completed and occupied. There is an additional date in the Altus data - the date when the first pre-construction unit is sold - which is the one used in this paper. Typically, the date of the first sold unit coincides with the acquisition of permits and the start of construction, but importantly it signifies the point at which units can be bought in a development project. These units are then at least partial competition to the existing housing stock and could serve to reduce prices in that location. Throughout this paper, references to housing development or construction timing will be referencing this date.

A final challenge is that the Altus data only represents developments, but does not capture the stock of housing itself. To address this, I use housing counts from the 2001 Canadian Census as the baseline for the housing stock. I then match the Altus defined apartment or house flows to the Census defined apartment or house stock to create an annual series at the census tract level. One drawback to this approach is that it does not account for housing that is destroyed or vacated during this period. I present two arguments for why this may not be a major concern. First, housing prices rose rapidly during this time which meant that vacancy rates were low (always below 5% and usually lower). Second, most redevelopment within the urban area took place on reclaimed industrial land, which would not require the destruction of the existing housing stock. There were also no notable, large infrastructure projects during this time that involved the loss of a substantial number of residential units.

B.2 Housing Price Index

The second key component of the dataset is information on housing transactions. Again, microdata is required to achieve the geographic granularity required on an annual basis, but the microdata used in this paper has some issues to resolve first. In this case, aggregation is also somewhat of a challenge as a simple average of prices may introduce bias in the results. Therefore, I create a price *index* using linear regression to remove compositional effects from the changes over time.

B.2.1 Teranet GeoWarehouse - Housing Transactions Data

The housing transactions microdata from Teranet's GeoWarehouse is comprehensive, but also more comprehensive than required for this project. In addition to standard housing transactions reflecting the current market value of housing, Teranet's data includes several other types of transaction that are not useful for the analysis in this paper. However, these additional transaction types are not directly indicated in the data meaning that I have to determine their type according to certain rules, which I will lay out in this section. The complete dataset has 984,419 transactions for single family homes, which will be whittled down to 818,973 (83%) "valid" residential housing transactions.

A first problem is that the data is not restricted to typical houses and it included very large lots such as an amusement park. One approach to addressing this is by defining the parcel and footprint criteria for a house. I define a house as having a lot between 500 and 30,000 sqft with a building footprint of at least 500 sqft on the lot, which drops 52,195 (5%) transactions from the dataset. This does not apply to condominium units, which are identified separately in the data. I validate this method using address points data from Peel region, where I find that I accurately capture 99% of actual residential properties in Mississauga and 98.5% in Brampton. The prediction is slightly less accurate in Caledon (72%), but this is because the land is mostly farmland and many farms are considered residential in the dataset. In this way, large farms are considered developable land in this dataset.

A second problem is the inclusion of consideration prices as part of a parcel's transaction history. When a subdivision is created and the parcels are split up, the value of the land is recorded for tax purposes. However, in the data, this is recorded as a several million dollar valuation for each property it is subdivided into. To disentangle these transactions from valid transactions, I identify transactions that are duplicates of others on the exact same day, for the same price and in the same municipality. Then, I see if at some point in the future, transaction prices are at least 20% below these values, which is likely the true value of the house. I discard the large duplicate transactions in this case. I also drop transactions that are above C$500,000, that are duplicated and which were over double the average price per square foot in that census tract. This is necessary to isolate smaller consideration values. This drops 24,524 (2.5%) observations.

Pre-construction sales represent a third issue to address. Pre-construction sales are ones where the developer sells directly to the buyer. Normally these would be useful to include, but in the data, the transaction is only recorded at the date when a buyer takes possession, which is sometimes multiple years after the pre-construction sale. This would provide misleading information about the contemporary value of properties in that area if included.

To identify transactions that are pre-construction I again group transactions by whether they have duplicates on the same day - at this point the land consideration prices have been excluded. Then for each one of these duplicate groups, I compute the average annualized growth rate in prices between the duplicate sale and the next sale of the property. Houses that are flipped immediately for example should see very high annualized growth rates, while duplicate transactions that are at normal market prices should evolve normally from transaction to transaction. I then tag duplicate groups with an average annualized return of 20% or more as being a pre-construction sale. While this captures many of the obvious pre-construction transactions, it does not capture all of them and I apply two other rules to trim them further. First, I remove all remaining duplicate transactions with 10 or more exact duplicates since these are either pre-construction sales or direct sales to buyers that may not reflect prevailing market prices. Second, I compute the average number of daily sales in a census tract and then delete transactions on days that have more than 30x the daily average number of sales - these likely reflect the land transfer date of a large subdivision and not contemporary open market sales. This exercise trims 78,884 (8%) transactions.

I conduct some final cleanup to drop outlier transactions and behaviour. I drop houses that sell for less than C$50,000, which in many cases is far below the median price in a census tract. This includes dropping private sales and transfers of ownership, which are recorded as $0 or $2 in the data. I exclude sales above $1 million that are more than double the average price per square foot in the census tract and drop transactions that reflect a more than 20% annualized decline in price of a given parcel as these are extreme outliers in the data. This makes up 9,843 (1%) transactions. For condominiums, there were 486,880 initial condominium transactions that was whittled down to 445,995 (92%) where outlier sales values and duplicates on the same day and of the same value were dropped.

B.2.2 Parcel Characteristics

The transactions dataset contains a PIN that matches each transaction to a particular housing parcel. Using the housing parcel data (also from Teranet) and additional datasets, I create a profile for each house that can be merged to the transactions data. The parcel shapefiles themselves have information on the the lot size of the parcel and the exact location. Then I add information on the census tract, municipality and region for each parcel. I compute the distance to the central business district (CBD) using Toronto's City Hall as a proxy, which sits in the middle of the financial district in the middle of Toronto's downtown. I merge in housing footprint data, which each region has separately, that captures the overhead view of structures within a parcel. While this does not capture the full livable square footage typically used by realtors, it does give a good approximation for the size of a house especially since most houses are 2 storeys tall in Toronto.

B.2.3 Creating the Price Index

Rather than just using the average housing price sale, I use a price index which addresses variation in the composition of housing sales in a census tract in a given year. If price increases in a census tract are driven simply by the fact that larger houses are being sold, this does not reflect an increase in the value of that location. To deal with this, I first remove extreme outlier transactions that are either part of a census tract that declines 33% year-over-year, declines 20% year-over-year before returning to previous levels or that are more than \$5 million. Then, I run a regression of log housing price on the observable characteristics in my dataset for houses and condominiums separately.

$$\ln P_{nt} = X_{nt}\beta + \kappa_{ijt} + \varepsilon_{nt}$$

The observable characteristics are the footprint of the house, the lot size of the house and the distance to the city. κ_{ijt} captures the census tract x unit type x year fixed effect, which reflects the value of living in a given census tract that is unexplained by the observable characteristics. I then predict the value of housing if average values of the observable characteristics in the census tract are used, this will purge the year-over-year variation in these observables driving sales. I repeat the same exercise for condominiums, but here I only have distance to the city as an observable.

One problem for the price index is that some census tracts are missing transactions in a given year. Leaving gaps in the dataset poses a problem for the model, where having a balanced panel of data is required to compute the idiosyncratic errors. Rather than dropping census tracts with missing values, which would drop a number of relevant census tracts, especially more rural ones, I linearly interpolate values for years that are missing. I do restrict the sample to census tracts that have sales in at least two years of data. Interpolated values make up only 4% of the census tract-by-year-by-unit-type. Finally, I drop outlier census tracts of average housing prices that are over $1.2 million and below $60,000.