Frictional and Speculative Vacancies: The Effects of an Empty Homes Tax*

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Abstract

Using individual housing transaction data from Vancouver, this paper estimates the impacts of a recent empty homes tax. Our analysis reveals short-term effects, including sharp declines in both house prices and rents, accompanied by increases in sales, listings, and average time-on-the-market. Interestingly, nearly all of these short-term effects reverse in the long run, with the persistent drop in rents being the notable exception. The paper develops a model with owner-occupied homes, tenanted rental units, and empty houses to explain these novel findings. In the model, housing units are supplied by developers to local households for consumption and to investors as a store of wealth. Empty homes held by investors are classified as *speculative* vacancies, while *frictional* vacancies arise from search-and-matching frictions in the owner-occupied market. By discouraging speculative vacancies, a tax on empty homes can improve housing availability in the short term and permanently enhance affordability in the rental market. However, the tax may also discourage the supply of vacant homes for sale in the owner-occupied market (i.e., frictional vacancies), thereby increasing house prices and reducing homeownership in the long run.

JEL classification: D83, R21, R31, R38

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1 Introduction

Despite widespread concerns about housing affordability, residential vacancy rates remain high globally: 10% in the U.S., 14% in Japan, 18% in France, and over 20% in China, Portugal and Spain.[1] The coexistence of high vacancy rates and rising house prices challenges the fundamental economic principle that higher prices should incentivize greater housing supply rather than encourage property hoarding and underutilization. To address this apparent paradox, policymakers have introduced various measures to reduce vacancy rates, including empty homes taxes (EHT) – a policy intended to improve housing availability and affordability by returning underutilized homes to the market. EHTs have gained traction globally, with implementations in London (1993), Paris (1998), Washington D.C. (2003), Jerusalem (2016), Vancouver (2016), Oakland (2018), Taiwan (2022), Sacramento (2022), Toronto (2023), and San Francisco (2024). Despite its growing adoption, the effectiveness of the EHT remains unclear. Does it enhance housing availability and affordability in both owner-occupied and rental markets, or does it generate unintended distortions that ultimately undermine these objectives?

This paper addresses these questions by integrating empirical analysis with theoretical modelling, focusing on the recently introduced EHT in the city of Vancouver. It makes two key contributions. Empirically, it provides the first causal estimates of the EHT's dynamic effects on housing markets. In the owner-occupied market, the EHT initially increases sales and listings, prolongs time-on-market, and reduces prices. However, these effects reverse in the long run. In the rental market, in contrast, the EHT leads to a persistent decline in rents.

[1]Except for Japan and China, these figures represent 2021 residential vacancy rates – including both unoccupied dwellings and seasonal/vacation homes – based the OECD Questionnaire on Affordable and Social Housing (OECD, 2024). Japan's rate, from the same source, is from 2018, whereas China's urban housing vacancy rate is derived from the 2017 China Household Finance Survey (Survey and Research Center for China Household Finance, 2018).

Theoretically, the paper develops a search-based model to rationalize these divergent dynamic patterns across markets. The model features a frictional owner-occupied sector, a competitive rental sector, and real estate investors, distinguishing between *frictional* vacancies (arising from search frictions in housing turnover) and *speculative* vacancies (where properties are deliberately left vacant). While an EHT is designed to reduce speculative vacancies, it may also affect frictional vacancies, with consequences for housing supply and affordability. By replicating the qualitative features of the dynamic patterns estimated from Vancouver's housing markets, the model provides a microfounded interpretation of the EHT's effects, offering insights into both its effectiveness and its unintended consequences.

The Vancouver EHT is an annual tax applied to any home or property in the city of Vancouver that remains unoccupied for more than six months within a given tax year.[2] The initial EHT was announced in 2016 and implemented in 2017. Initially, owners were taxed 1 percent of their property's assessed taxable value each year the home was deemed or declared vacant. The rate was then raised to 1.25 percent in 2020, and to 3 percent in 2021. For comparison, the Vancouver property tax rate is less than 0.5 percent, providing context for the substantial holding costs the EHT imposes on vacant property owners.

To estimate the causal effects of the EHT on housing market outcomes, we use transaction-level data from Multiple Listing Service records for the Greater Vancouver Regional District between 2014 and 2022. Our focus is on the initial launch of the EHT in 2017 because, unlike subsequent tax rate increases, the first wave of the EHT was largely unanticipated and preceded the far-reaching complications of the so-called COVID-19 shock. An empirical challenge for our analysis, however, is that the initial EHT was introduced in close succession

[2]All property owners in Vancouver are required to file a property status declaration for the previous calendar year by February 2nd each year. The property status can be declared as one of the following: principal residence, rented, vacant, or eligible for exemption. According to the bylaw (`https://bylaws.vancouver.ca/11674c.pdf`), valid reasons for tax exemption include (1) death of registered owner; (2) property undergoing redevelopment or major renovations; (3) property of owner in care; (4) rental restriction or prohibition (5) transfer of property; (6) occupancy for full-time work; (7) court order; and (8) limited use residential property.

with other housing market policies, such as the foreign buyer tax (FBT) and the speculation and vacancy tax (SVT) (see Figure 1). The EHT applies to the city of Vancouver, whereas the FBT and SVT apply to the Greater Vancouver Regional District (GVRD) and the province of British Columbia (BC), respectively. This makes it possible to estimate the causal effects of the tax by comparing housing market outcomes before and after the EHT across neighborhoods that are adjacent but on opposite sides of the city border.

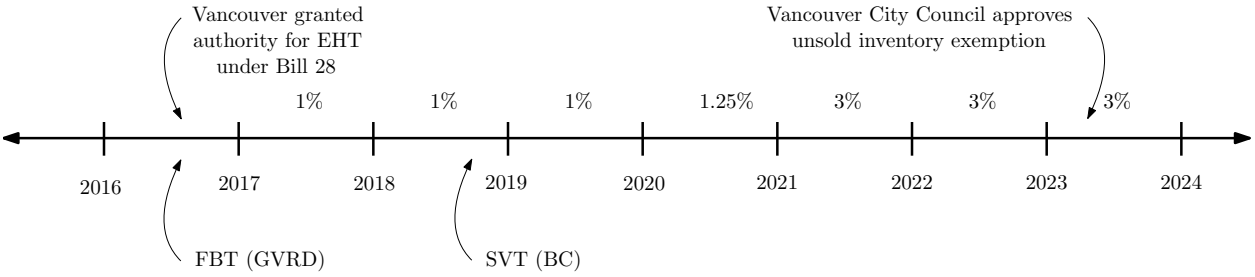


Figure 1: The Timing of Vancouver's EHT.

To account for housing market momentum as highlighted in Glaeser et al. (2014), we use a local projections approach (Jorda 2005) to estimate the dynamic responses of a set of housing market outcomes – sales, listings, time-on-the-market, prices, and rents – to the EHT announcement. Our baseline specifications flexibly control for time-varying neighborhood characteristics, time trends, and internal propagation dynamics. In extended specifications, we implement a shift-share identification strategy to estimate the heterogeneous effects of the EHT across neighborhoods with different exposure shares, while also controlling for the FBT's differential impact across neighborhoods. Compared to the baseline approach, our identification strategy relies on even weaker assumptions, leveraging variation in housing market outcomes before and after the EHT across neighborhoods with different EHT relevance.

We find that a 1% EHT initially increased monthly sales by 14 per neighborhood in the first quarter following the policy announcement. However, this effect gradually declined, and by the fourth quarter, monthly sales in an average Vancouver neighborhood had fallen by

11 compared to the pre-EHT benchmark. A similar pattern emerges for listings, which rise sharply after the announcement but taper off over time. Time-on-market also increases significantly in the short run before declining in the longer term. In terms of housing costs, both prices and rents drop sharply in the short run. However, while prices eventually rebound, rents remain persistently lower.

These results are robust across samples and specifications. Together, these results reveal a clear and consistent pattern: while the EHT initially achieved its intended goal of improving housing availability and affordability, its cumulative effects diminish over time in the owner-occupied market but remain stable in the rental sector. The divergent long-run impacts on prices versus rents highlight the importance of considering how properties are allocated between owner-occupied and rental markets. The transitory short-run response suggests the presence of speculative investors, while the estimated time-on-the-market effects underscore the role of frictions in shaping the EHT's impact on housing market dynamics.

We then develop a dynamic equilibrium model that explicitly incorporates these economic forces. The model features a competitive rental market alongside a frictional owner-occupied market. We argue that a search-theoretic framework is particularly well-suited for analyzing the effects of the EHT because it captures the inherent frictions in the owner-occupied housing market, which give rise to equilibrium vacancies and uncertainty in time-to-sell. Additionally, the model incorporates non-resident investors that hold properties for exogenous financial reasons, rather than for housing consumption. Naturally, these features give rise to two types of vacancies: frictional and speculative. Many unoccupied homes are, in fact, available for purchase, but remain temporarily empty due to ownership transitions or because newly constructed or newly available homes have yet to be sold and occupied. Since it takes time to sell a house in a frictional market, a continuous stock of vacant listings – analogous to the frictional vacancies modeled by Wheaton (1990) – facilitates turnover and helps match homes with suitable owners. On the other hand, even in liquid markets, empty

homes could still arise for speculative reasons. In a market with strong tenant protection laws such as eviction moratoriums or rent controls (Gabriel and Nothaft, 2001), investors may hold homes vacant strategically, either to maintain liquidity (since an empty home is a more liquid asset) or to preserve real option value (Titman, 1985; Cunningham, 2006). Unlike frictional vacancies, speculative vacancies are deliberately kept empty.

An EHT that aims to reduce speculative vacancies may impact frictional vacancies as well, potentially affecting housing availability and affordability in unintended ways. We analyze the housing market effects of a vacancy tax like Vancouver's EHT, deriving comparative statics along an equilibrium balanced growth path to assess long-run impacts. We also undertake a calibration exercise and compute the dynamic equilibrium of the model to explore the housing market's short-run response to the tax. The dynamic patterns that emerge from the calibrated model closely align with those we estimate from the Vancouver markets, indicating that the model's mechanisms offer an economically sound interpretation of the EHT's impact.

The model predicts that an EHT reduces overall vacancies, beginning with speculative vacancies and later constraining frictional vacancies as well. In the short run, housing affordability and availability improve as both the rental and owner-occupied markets absorb speculative vacancies released from investors in response to the EHT. Given that it takes time to fill frictional vacancies, sellers and developers respond to the expected holding costs induced by the tax by demanding higher price premiums and shorter time-to-sell. This reaction stems from their flexibility in choosing whether to supply a home to the rental or frictional owner-occupied market. This shift increases the relative supply of rental units while limiting the stock of available homes for purchase, ultimately reducing homeownership. In terms of housing costs, the tax places downward pressure on rents as dampened investor demand for empty homes reduces the relative stock of housing and hence construction costs. In the long run, the same tax can also drive up house prices by discouraging the supply of

vacancies listed for sale. These insights reveal how the initial improvements in housing availability and affordability following the introduction of an EHT set the stage for unintended longer-term consequences on homeownership and house prices.[3]

Notably, Vancouver's EHT exempts homes that change legal ownership within the reference year. While vacant properties listed for sale – such as those owned by developers – often qualify for this exemption if the listing duration is short, search-and-matching frictions create uncertainty about how long a property will remain unsold and, consequently, whether the tax can ultimately be avoided.[4] Our theoretical analysis accounts for the possibility that a fraction of frictional vacancies may be subject to the EHT exemption, yielding predictions that are consistent with our empirical findings. Further support comes from a recent exemption introduced in 2023 (retroactive to 2022) for "vacant new inventory." Under this exemption, newly constructed residential properties unoccupied for more than six months during the vacancy reference period are no longer subject to Vancouver's EHT if they were listed for sale throughout the reference period (Steacy, 2023). This exemption appears specifically designed to address the unintended disincentives the EHT creates for constructing homes and listing them for sale in a sluggish market. The retroactive nature of the exemption, which led to a $3.8 million tax refund to real estate developers, provides

[3]Our analysis focuses is on the EHT's implications for housing affordability and availability – the stated policy objectives. The normative assessment and optimal policy design, however, depend on the choice of social welfare function, which can, in principle, assign different welfare weights to households and investors. We undertake a welfare analysis in Appendix H that assumes equal weighting of surplus derived from the construction and allocation of housing to households and investors. Specifically, we solve for the constrained efficient allocation of housing in a social planning problem, accounting for search-and-matching frictions and the rising cost of increasing the housing stock. The solution characterizes the optimal EHT rate required to support this allocation and considers a tax exemption for frictional vacancies. Under the equal-weight welfare criterion, the optimal EHT rate is positive due to the rising cost of increasing the housing supply and applies equally to both frictional and speculative vacancies.

[4]Some vacancies remain unsold long enough that they are ultimately withdrawn from the market. Exploiting individual residential listing records in 15 U.S. urban areas between 2004-2013, Carrillo and Williams (2019) find that expired and withdrawn listings are a common feature of real estate markets. In a suburb of Washington DC (Fairfax County, VA), for instance, over half of the properties listed in 2006 were ultimately withdrawn. The high incidence of expired listings suggests that some properties can persist for prolonged periods on the market.

compelling evidence that the initial EHT was indeed affecting frictional vacancies, not just speculative vacancies.

A brief review of the related literature is in order. First, while our analysis focuses on housing markets, the price dynamics induced by speculative holding have been explored in a variety of other markets such as commodities (Hart and Kreps, 1986; Stein, 1987) and financial assets (Tirole, 1985; Shiller, 2014). In these models, consumers engage in immediate consumption, while investors store commodities or assets with the intent of selling them later at a profit. The housing market is especially relevant because housing serves both as a necessary consumption good and service and an investment vehicle for wealth storage. However, unlike the centralized markets for commodities and financial assets, housing markets are characterized by search-and-matching frictions.

Turning to the housing market, our work contributes to the growing literature on the role of speculators and investors in housing markets (Buchak et al., 2020; Favilukis and Van Nieuwerburgh, 2021) by explicitly distinguishing between frictional vacancies, which arise from these frictions, and speculative vacancies, which are linked to investor behavior. Since speculative vacancies are often linked to foreign investors, our research also complements Gorback and Keys (2021), who examine the effects of international capital flows on house prices and housing supply. The distinction between frictional and speculative vacancies is key to understanding how policies targeting vacancies, such as empty homes taxes, may have unintended effects on housing availability and affordability.

There has also been a long-standing interest among economists in vacancies, dating back to the foundational work of Arnott (1989) and Wheaton (1990).[5] A variety of policies have been proposed to reduce vacancy rates, ranging from eviction bans (Collinson et al., 2022;

[5]Recently, Abramson et al. (2022) distinguish between *frictional* and *structural* vacancies, while our analysis differentiates between *frictional* and *speculative* vacancies. In their framework, structural vacancies refer to vacant homes in excess of the number of searchers, whereas speculative vacancies in our model are defined as empty homes held by investors for exogenous financial reasons.

Corbae et al., 2022) and tenant protection laws (Abramson, 2021) to vacant homes taxes. Regarding the latter, the only papers we are aware of are Desgranges and Wasmer (2000), Ménard (2012), and Segú (2020). The first two papers provide theoretical analyses of how a vacant home tax affects rental markets where vacancies arise purely from search frictions. Segú (2020) extends this by incorporating both *voluntary* vacancies by property owners in addition to *involuntary* vacancies resulting from search frictions, which parallels our notions of speculative and frictional vacancies within the rental market context. Notably, their work also provides empirical evidence on how vacancy rates respond to France's *Taxe sur les Logements Vacants* (TLV). We complement this work by providing first estimates of the impact of an EHT on house prices, rents, time-to-sell, listings, and sales, offering direct evidence on its effects on housing affordability and availability.[6]

To analyze the housing market effects of these policies, recent housing search models provide a useful framework, particularly those that account for new construction and the interplay between rental and owner-occupied markets. Our theoretical model draws on the housing search literature, comprehensively surveyed by Han and Strange (2015). While most housing search models have abstracted from the choice between rental and sales markets, recent studies by Halket and di Custoza (2015), Garriga and Hedlund (2020), Head et al. (2023), and Han et al. (2025) explicitly model the coexistence of tenanted and owner-occupied housing. Some elements of our model, including the choice between frictional owner-occupied markets and frictionless rental markets, resemble aspects of the framework developed by Head et al. (2014).

The rest of the paper is organized as follows. Sections 2, 3 and 4 discuss the institutional background, data, empirical strategy and the results. The model environment and equilib-

[6]In commercial real estate markets, Moszkowski and Stackman (2023) examine the consequences of a potential tax on empty storefronts in New York City. They use a search-and-matching model to explore issues like tenant quality and turnover in the retail rental market. While their framework differs from ours in several key ways – such as assuming a fixed number of storefronts and focusing solely on leases – their analysis complements ours by highlighting both the intended and unintended effects of a vacancy tax.

rium are described in Sections 5 and 6. Comparative statics are also derived and discussed in Section 6. Section 7 presents our calibration exercise. Section 8 concludes.

2 Institutional Background

2.1 Vancouver

The Greater Vancouver Regional District (GVRD), also known as Metro Vancouver, is a political subdivision with a population of over 2.5 million. It encompasses 21 municipalities, one electoral area, and one treaty First Nation. The central urban hub is the city of Vancouver, while suburban areas include Richmond, Burnaby, Surrey, Coquitlam, New Westminster, Delta, West Vancouver, Port Coquitlam, North Vancouver (City and District), Port Moody, Langley (Township and City), Pitt Meadows, White Rock, and Maple Ridge. Figure 2 provides a map of Metro Vancouver and its member municipalities. Situated on the western half of the Burrard Peninsula, the city of Vancouver is bordered by the coastline to the west and north, and by city streets to the east and south.

2.2 The Vancouver Empty Home Tax

As previously summarized, the Vancouver Empty Homes Tax (EHT) is an annual tax applied to any non-exempt home or property in the city of Vancouver that remains unoccupied for more than six months in a given tax year. The EHT was introduced as a policy tool to encourage the return of vacant or under-utilized properties to the rental market, addressing the city's housing shortage. Initially approved in July 2016, the tax was first implemented in 2017, with an initial annual rate of 1 percent of a property's assessed taxable value, increasing over time as shown in Figure 1. For example, with the average home price exceeding $1.3 million in 2017, a property left vacant would have incurred an annual tax of $13,000 from

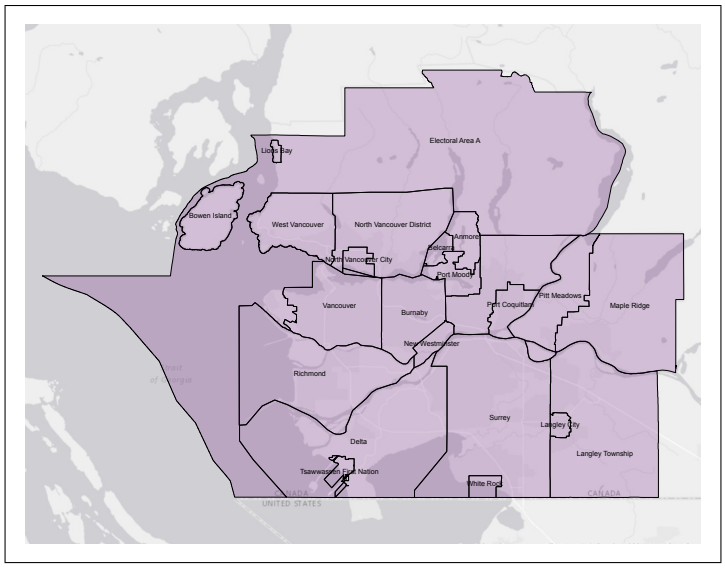


Figure 2: Municipalities of the Greater Vancouver Regional District

2017 to 2019, $16,250 in 2020, and $39,000 from 2022 onward, representing a significant holding cost for owners of vacant properties.

While the EHT in Vancouver is primarily based on self-reporting by property owners, various measures are implemented to enforce the tax. For instance, property owners are required to provide documentation to support their claims of exemption. Additionally, a combination of risk-based and random audits is used to verify compliance. The EHT non-compliance rate based on audit determinations, subsequent complaint process outcomes and external panel reviews is less than 10 percent according to the 2021 Empty Homes Tax Annual Report (City of Vancouver, 2021).

There is also limited scope for EHT circumvention through strategic ownership transfers or short-term rentals. For example, selling an empty house back and forth to a friend each year to gain EHT exemption would not be financially sensible. Transaction costs, including a land transfer tax levied across the province of British Columbia, would have exceeded the amount of the EHT in 2017. Moreover, short-term rentals (i.e., less than 30 days) were not permitted in Vancouver when the EHT was first introduced. In 2017, Vancouver did

not have specific regulations governing short-term rentals through platforms like Airbnb; existing regulations and licensing requirements only allowed short-term rentals by hotels and commercially licensed bed and breakfasts. Declaring a home occupied by short-term Airbnb guests would not have been effective, as these rentals were technically prohibited at the time. In 2018, Vancouver established regulations specifically targeting short-term rentals, requiring hosts to be licensed and restricting rentals to principal residences only. As a result, owners of homes that would otherwise be considered empty are still prevented from using a series of short-term rentals to avoid the EHT.

According to the 2021 Empty Homes Tax Annual Report (City of Vancouver, 2021), the EHT program levied $38M in tax revenue in 2018 for the 2017 reference year. Despite declines in the number of vacant properties, revenues remained similar in the two subsequent years ($39M and $36M), largely due to late filings from previous years, before declining to $26M for the 2020 reference year.

2.3 Contemporaneous Housing Market Policies

While the introduction of Vancouver's EHT played a significant role in shaping the city's dynamic housing markets, these markets were also influenced by broader economic factors and concurrent government policies. Notably, both the Foreign Buyer Tax (FBT) and the charter amendments granting Vancouver the authority to implement the EHT were announced simultaneously as part of Bill 28 in July 2016 and were enacted into law in BC in August 2016. The FBT is an additional residential property transfer tax that applies when a buyer is a foreign national.[7] Initially set at 15 percent, the FBT has since increased to 20 percent of a residential property's fair market value. In October 2018, the Province of British Columbia further announced the Speculation and Vacancy Tax (SVT), which was implemented in 2019.

[7] A foreign national is an individual who is not a Canadian citizen or a permanent resident.

The SVT, an annual tax of up to 2 percent of a property's assessed value, primarily targets foreign investors in designated large metro areas, including the GVRD.

Unlike the EHT, which applies exclusively to properties within the city of Vancouver, the FBT and SVT apply across the entire Greater Vancouver Regional District, affecting a broader geographic area. Our empirical strategy compares changes in housing market outcomes across the Vancouver city border to disentangle the EHT's effects from concurrent policies like the FBT and SVT, as well as broader macroeconomic forces.

3 Data

3.1 Data

Our primary dataset consists of Multiple Listing Service (MLS) residential real estate transaction records in the GVRD from 2014 to 2022. For each transaction, we observe sales price, listing price, listing date, transaction date, address, and detailed housing characteristics. Using these data, we aggregate transaction-level information to construct key housing market outcome variables at the neighborhood-by-year-by-month level. Neighborhoods are defined at the Forward Sortation Area (FSA) level, a geographical unit based on the first three characters of Canadian postal codes. The primary variables include: (1) number of sales, (2) number of active listings,[8] (3) quality-adjusted sales price, and (4) quality-adjusted time-on-the-market.

To account for heterogeneity across housing units, we utilize rich hedonic information at the transaction level to construct quality-adjusted house price and time-on-the-market

[8]Active listings refer to properties listed for sale within each FSA during a given period. A listing is considered active if it appears on the MLS system at any point during the month. For robustness, we further decompose active listings into new listings and existing listings.

indices for each FSA-by-year-by-month. These indices are derived from the following hedonic regression model:

$$\log y_{i,j,t} = \alpha + \beta_{j,t} + \beta_{zip} + \delta X_{i,j,t} + \epsilon_{i,j,t} \tag{1}$$

where $y_{i,j,t}$ represents either the price or time-on-the-market for house i in neighborhood j at time t, $\beta_{j,t}$ is the FSA-by-year-by-month fixed effect, β_{zip} is the postal code fixed effect, $X_{i,j,t}$ is a vector of control variables, and $\epsilon_{i,j,t}$ is the error term. The control variables include the number of bedrooms, number of bathrooms, log of square footage, property age, property age squared, view, property type, and dwelling type. The exponentiated $\beta_{j,t}$s, adjusted for root mean square error (RMSE), are used to construct the indices at the FSA-by-year-by-month level. Finally, a symmetric 3-month moving average is applied to smooth the indices and reduce noise.

We supplement the MLS data with yearly neighborhood-level average rents from the Canadian Mortgage Housing Corporation (CMHC) Rental Market Survey. Conducted each October, the CMHC survey gathers rental market data through site visits and telephone interviews with owners, property managers, and building superintendents, providing a detailed snapshot of market conditions. CMHC neighborhoods are defined at the census tract level, providing finer geographic granularity than the FSA-level neighborhood definitions in the MLS data. The CMHC defines rent as the monthly amount paid for tenanted units, without adjusting for included services such as utilities or parking. We aggregate the CMHC rent data at the census-tract-by-year level, while maintaining the higher frequency and broader geographic coverage of the MLS data for separate analyses of other housing market outcomes.

Additionally, we enrich our dataset with demographic and housing characteristics from the 2016 Canadian Census, including the proportion of foreign-born residents at both the FSA and census tract levels, providing further context on neighborhood composition.

3.2 Estimation Sample

We restrict our main estimation sample to 2014 – 2018 to avoid complications from later EHT rate increases and disruptions caused by COVID–19. To ensure greater housing stock and neighborhood homogeneity, we further limit our baseline sample to adjacent neighborhoods along the Vancouver-Burnaby and Vancouver-Richmond borders, where the EHT's applicability is determined by geographic boundaries. Figure 3 illustrates the baseline estimation area, with treatment and control regions highlighted.

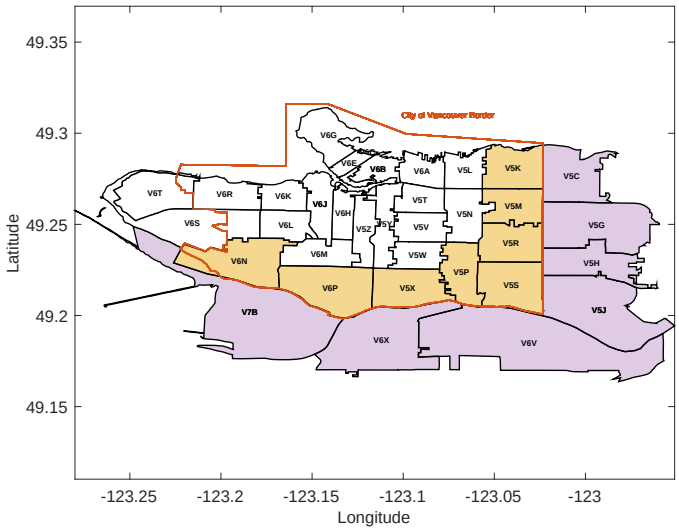


Figure 3: Border Sample

Table 1 presents summary statistics for selected property and neighborhood characteristics in our empirical sample. The *whole sample* columns include all transactions in the GVRD from 2014 to 2018, while the *boundary sample* columns focus on properties just inside or outside the Vancouver city boundary that sold at least once during the same period. As expected, there are some differences between the samples, including average property values, with the average sales price at 808,510 CAD outside Vancouver and 1,151,690 CAD within the city limits. However, as shown in Appendix A, any cross-border differences in

property characteristics remained relatively stable after the EHT was implemented. This stability, along with evidence of smoothly changing neighborhood conditions, helps isolate the EHT's impact on housing market outcomes from other factors.

The final two rows reported in Table 1 are the neighborhood-level averages of the fraction of foreign-born residents and the fraction of foreign-born residents from China, Hong Kong, and Taiwan. Although both are generally higher in the suburban areas, there is significant variation across neighborhoods (at both the FSA and census tract levels) within each group.

4 Empirical Analysis

In this section, we estimate the dynamic effects of the EHT on various housing market outcomes, including the number of sales, number of listings, quality-adjusted sales price, quality-adjusted time-on-the-market, and average rents. It has been well-documented that house price growth exhibits positive autocorrelation in the short run and mean reversion in the long run (e.g., Glaeser et al., 2014). To account for the inherent momentum in the housing market, we employ several variations of the Local Projections (LP) estimator.

4.1 Estimation Strategy

Using the method of local projections (Jordà, 2005), we estimate a set of linear regression models for time horizons $h \in \{0, 1, \cdots, 18\}$. The empirical specification is given by:

$$\Delta_h Y_{j,t+h} = \alpha_j^h + \beta_h \Delta \tau_{j,t}^{EHT} + \sum_{i=2}^{p} \{\gamma_i^h Y_{j,t-i} + \delta_i^h \Delta \tau_{j,t+1-i}^{EHT}\} + \Gamma_h' X_{j,t-1} + \epsilon_{j,t}^h \tag{2}$$

where $\Delta_h Y_{j,t+h} = Y_{j,t+h} - Y_{j,t-1}$ represents the change in the housing outcome of interest (sales, listings, price, time-on-the-market) for neighborhood j between time $t+h$ and $t-1$.

Table 1: Summary statistics Vancouver vs. Suburbs

	Boundary Sample		Whole Sample	
	Suburbs	Vancouver	Suburbs	Vancouver
Transaction level variables				
Price sold	749.60	989.82	808.51	1,151.69
	(489.93)	(586.77)	(576.89)	(1,193.04)
Days on Market	34.99	30.85	36.71	31.14
	(42.49)	(41.02)	(45.30)	(41.80)
Number of Bedrooms	2.57	3.28	2.76	2.39
	(1.49)	(1.86)	(1.52)	(1.64)
Number of Bathrooms	2.23	2.49	2.37	2.10
	(1.21)	(1.38)	(1.30)	(1.32)
Floor Area	1,036.74	1,299.97	1,157.07	1,036.81
	(727.67)	(803.28)	(794.75)	(774.55)
% of properties with view	0.72	0.66	0.63	0.75
	(0.45)	(0.47)	(0.48)	(0.44)
Age of building (years)	18.21	29.05	19.60	23.58
	(18.64)	(29.89)	(18.47)	(24.94)
Observations	10,097	6,699	22,551	32,610
Aggregates variables				
Total Sales	15,476	10,895	37,229	47,517
Total New Listings	15,350	10,828	36,923	46,980
Avg. Monthly Sales per FSA	68.44	29.76	64.44	42.35
	(37.93)	(13.70)	(34.33)	(27.32)
Avg Monthly New Listings per FSA	70.27	30.71	65.86	43.57
	(40.27)	(14.49)	(36.11)	(28.77)
% foreign born in China, HK, TW	0.26	0.16	0.26	0.19
	(0.12)	(0.11)	(0.11)	(0.09)
% foreign born	0.53	0.42	0.54	0.46
	(0.10)	(0.12)	(0.09)	(0.12)

Notes: The top panel provides summary statistics for transaction-level variables used in the baseline estimation, with means reported and standard deviations in parentheses. The bottom panel includes summary statistics for the number of sales, listings, and demographic characteristics at the FSA and census tract levels. The boundary sample refers to transactions in neighborhoods located just inside or just outside the Vancouver border, while the whole sample covers all transactions within the GVRD. Demographic data is sourced from the 2016 Canadian Census, aggregated at the census tract level. The sample period covers 2014 to 2018.

The variable $\Delta\tau_{j,t}^{EHT}$ takes the value of 1 if the EHT was just implemented in neighborhood j at time t, and 0 otherwise. More specifically, if $D_t = 0$ before the EHT announcement and $D_t = 1$ thereafter, and $\text{Van}_j = 1$ for Vancouver city neighborhoods and $\text{Van}_j = 0$ otherwise, then $\tau_{j,t}^{EHT} = D_t \times \text{Van}_j$ and $\Delta\tau_{j,t}^{EHT} = \tau_{j,t}^{EHT} - \tau_{j,t-1}^{EHT}$. The specification includes horizon-specific time-invariant neighborhood fixed effects, α_j^h, as well as time-varying neighborhood-level characteristics observed at time $t-1$, $X_{j,t-1}$. The term $\epsilon_{j,t}^h$ represents the error term. To control for market dynamics and internal propagation effects, we include $p = 12$ lags of both the housing outcome of interest and the policy variable.

The key parameter, β_h, measures the difference in expected changes in the outcome variable $\mathbb{E}[\Delta_h Y_{j,t+h}|\tau_{j,t}^{EHT} = 1] - \mathbb{E}[\Delta_h Y_{j,t+h}|\tau_{j,t}^{EHT} = 0]$ between treatment and control neighborhoods at each horizon h. Therefore, β_h captures the causal effect of the EHT policy on the outcome variable $\Delta_h Y_{j,t+h}$ after h periods. Identification relies on the assumption that, conditional on a rich set of controls and housing market momentum, adjacent neighborhoods on either side of Vancouver's border would experience similar changes in outcomes between month $t-1$ and $t+h$ in the absence of the EHT.

Additionally, we implement a shift-share version of the local projections method, specified as:

$$\Delta_h Y_{j,t+h} = \alpha_j^h + \beta_h \kappa_j \Delta\tau_{j,t}^{EHT} + \sum_{i=2}^{p} \{\gamma_i^h Y_{j,t-i} + \delta_i^h \kappa_j \Delta\tau_{j,t+1-i}^{EHT}\} + \Gamma_h' X_{j,t-1} + \epsilon_{j,t}^h, \qquad (3)$$

where κ_j represents a predetermined exposure measure capturing neighborhood j's sensitivity to the EHT. We measure κ_j using one of the following four variables: the vacancy rate, fraction of immigrants, fraction of immigrants born in China, Hong Kong, or Taiwan, and fraction of non-permanent residents (all based on 2016 data at the FSA level). The vacancy rate serves as a direct measure of local EHT exposure, as the policy targets vacant homes specifically. The remaining exposure variables are motivated by the observation that foreign investors – who are more likely to own vacant homes – tend to cluster in neighborhoods with

higher concentrations of residents from their home countries. Across all measures, higher values of κ_j indicate neighborhoods with greater EHT relevance because they tend to have higher vacancy rates.

By interacting a predetermined local exposure variable, κ_j, with the common policy indicator variable, $\tau_{j,t}^{EHT}$, this specification captures the heterogeneous effects of the EHT across neighborhoods with different exposure levels. Conceptually, this follows a shift-share identification strategy: the policy-induced variation in housing market outcomes comes from a common shock (the EHT) weighted by exogenous local exposure shares. This approach relaxes the identifying assumptions relative to the baseline model. In particular, it allows the implementation of the EHT to be correlated with other non-EHT factors affecting housing markets near the Vancouver city border. However, identification still requires that these other neighborhood-level factors are not systematically correlated with the predetermined exposure measure, κ_j. This shift-share design provides a more flexible identification strategy by isolating the differential impacts of the EHT across exposure levels.

A potential concern is that other policy interventions during the study period may have influenced housing market outcomes in the GVRD, possibly confounding the treatment analysis. For instance, one could argue that differences in β_h effects across κ_j neighborhoods arise not only from the EHT but also from the Foreign Buyer Tax (FBT), which was announced and implemented nearly contemporaneously with the EHT. Note first that, unlike Vancouver's EHT, the FBT applies to the entire GVRD. As a result, its effects should be absorbed by the time trends, thereby mitigating its potential confounding impact. To further account for heterogeneous sensitivity to the FBT across neighborhoods, we estimate an FBT-augmented specification that includes a set of impulse response coefficients for the FBT:

$$\psi_h \Delta \tau_{j,t}^{FBT} + \sum_{i=2}^{p} \phi_i^h \Delta \tau_{j,t+1-i}^{FBT},$$

where $\tau_{j,t}^{FBT}$ equals 1 if the FBT was already implemented by time t and if neighborhood j is likely sensitive to the policy, as proxied by an above-median share of foreign-born homeowners from China, Taiwan, and Hong Kong.[9] Our FBT-augmented specification is therefore

$$\Delta_h Y_{j,t+h} = \alpha_j^h + \beta_h \kappa_j \Delta\tau_{j,t}^{EHT} + \psi_h \Delta\tau_{j,t}^{FBT} + \sum_{i=2}^{p} \{\gamma_i^h Y_{j,t-i} + \delta_i^h \kappa_j \Delta\tau_{j,t+1-i}^{EHT} + \phi_i^h \Delta\tau_{j,t+1-i}^{FBT}\} + \Gamma_h' X_{j,t-1} + \epsilon_{j,t}^h. \tag{4}$$

This specification effectively isolates variations before and after the EHT across neighborhoods with different κ_j values, while controlling for the FBT's differential impacts across neighborhoods.

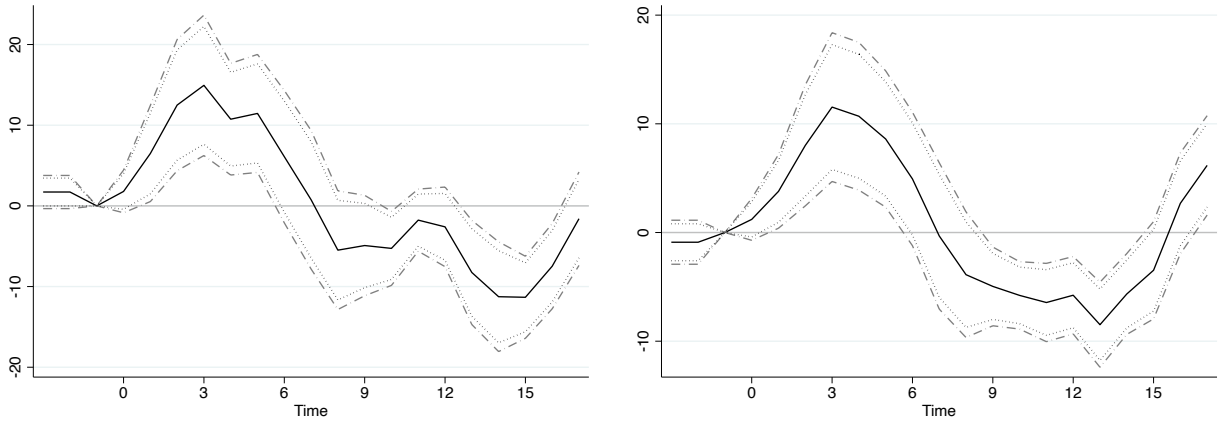
4.2 Results

In this section, we present estimates from the most comprehensive specification given by equation (4), using both the border sample and the Metro Vancouver sample. We begin by setting $\kappa_j = 1$ for all neighborhoods, then explore measures of local exposure to the EHT.

Sales. Figure 4a presents the estimated dynamic coefficients, $\hat{\beta}_h$, for the number of sales as the outcome variable, focusing on neighborhoods adjacent to the city border. The estimates reveal no significant pre-trends in the three months leading up to the EHT announcement, supporting the validity of our identification strategy. Three months after the announcement (October 2016), the difference in monthly sales between an average Vancouver neighborhood and a comparable suburban neighborhood increased by 14 sales relative to the pre-EHT baseline. In other words, the EHT raised monthly sales in Vancouver by 14 per FSA compared to areas just outside the city. Given that average monthly sales were 42

[9]Hartley et al. (2021) and Pavlov et al. (2024) show that the FBT had greater impact on neighborhoods with higher concentrations of immigrants or foreign buyers. The results are robust to alternative definitions.

in Vancouver FSAs and 64 in suburban FSAs, this represents a substantial relative increase. However, this increase was followed by a decline, and by the 5th quarter after the EHT announcement, monthly sales in Vancouver neighborhoods declined by 11 relative to suburban neighborhoods, compared to the pre-EHT difference. Figure 4b extends the analysis to all of Metro Vancouver, revealing similar patterns.[10]



(a) border sample **(b)** whole sample

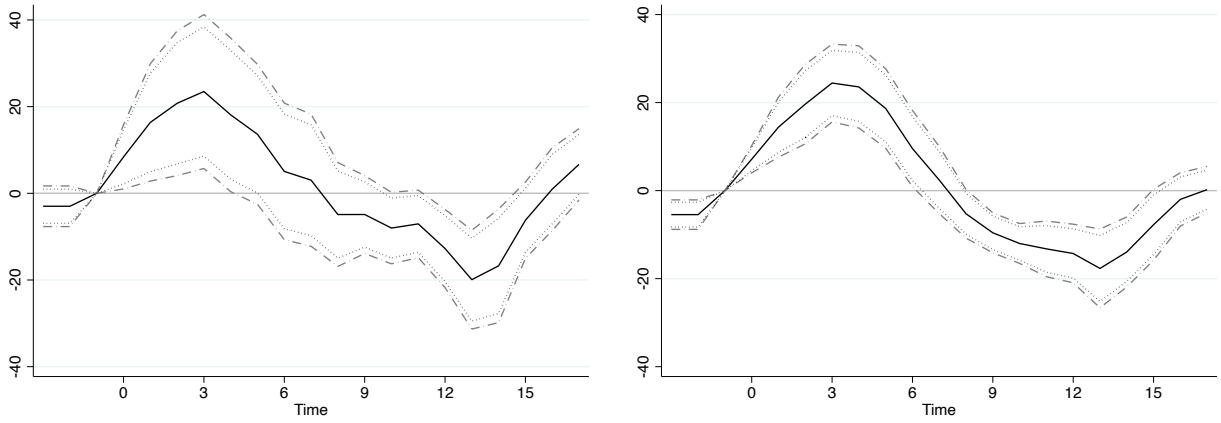
Figure 4: Average causal effects of EHT on number of sales.

Notes: The figure plots the estimated impulse response coefficients at each horizon. All regressions control for average property characteristics, FSA FE and year-month FE. Standard errors are clustered at the year-month level. The dotted and dashed lines represent 90% and 95% confidence intervals, respectively.

Listings. The average number of active listings in Vancouver neighborhoods near the border increased by 21 relative to adjacent suburban neighborhoods within a quarter of the EHT announcement, followed by a gradual decline. Appendix C shows similar patterns for new listings.

Price. To estimate the dynamic effects of the EHT on house prices, we use the change in the log of the neighborhood-level quality-adjusted house price index as the dependent variable. Figure 6 presents the estimated dynamic coefficients, $\hat{\beta}_h$ for both the border and the Metro Vancouver samples. In the border sample (Figure 6a), house prices in Vancouver

[10]Appendix B presents analogous results using a dynamic differences-in-differences method.



(a) border sample **(b)** whole sample

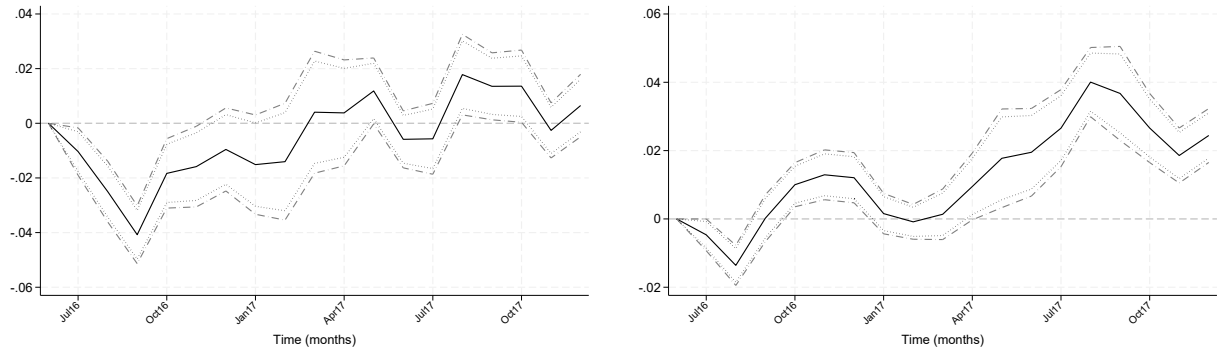
Figure 5: Average causal effects of EHT on number of listings.

Notes: The figure plots the estimated impulse response coefficients at each horizon. All regressions control for average property characteristics, FSA FE and year-month FE. Standard errors are clustered at the year-month level. The dotted and dashed lines represent 90% and 95% confidence intervals, respectively.

neighborhoods initially declined, reaching a maximum drop of 4% within several months of the EHT announcement, before gradually returning to pre-EHT levels. In the broader Metro Vancouver sample (Figure 6b), a similar pattern emerges, but with relative house prices eventually rising above their initial level in the long run.

Time-on-the-Market. To evaluate the effects of the EHT on time-to-sell, we analyze changes in the neighborhood-level quality-adjusted time-on-the-market as the dependent variable. Figure 7 shows that time-on-the-market initially increased following the EHT announcement, then gradually declined. This pattern suggests that an initial surge in listings created market congestion, prolonging listing durations. Over time, time-on-the-market decreased relative to the pre-EHT period, indicating a rebalancing of the market after absorbing the initial surge in listings. Overall, these patterns highlight the interaction between policy intervention and housing market frictions, which we explicitly model in Section 5.

Vacancies. Turning to vacancies, the City of Vancouver reported a decline in homeownership from 70.6% in 2017 to 68.2% in 2020, alongside an increase in rentership from 25.2% to



(a) border sample **(b)** whole sample

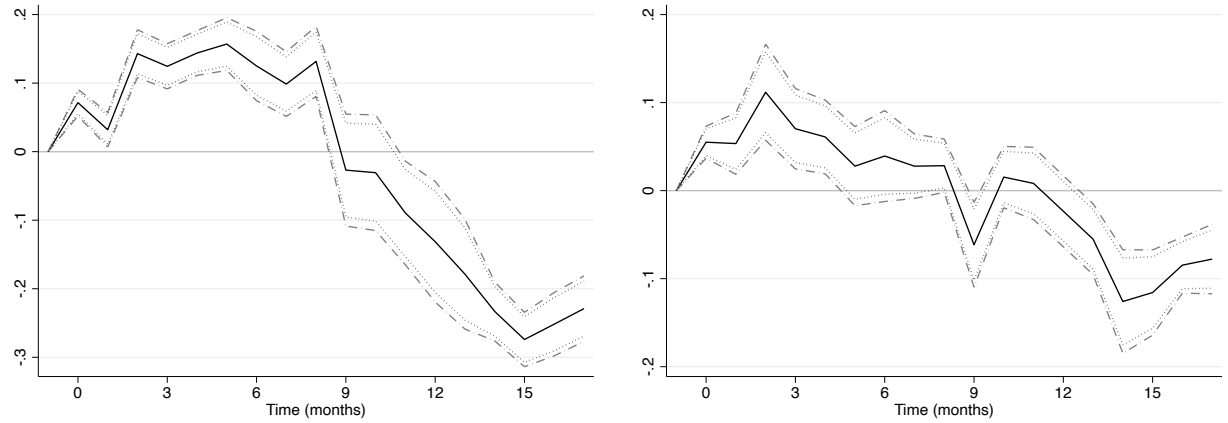
Figure 6: Average causal effects of EHT on prices.

Notes: The figure plots the estimated impulse response coefficients at each horizon. All regressions control for average property characteristics, FSA FE and year-month FE. Standard errors are clustered at the year-month level. The dotted and dashed lines represent 90% and 95% confidence intervals, respectively.

28.8% over the same period. According to the 2021 Empty Homes Tax Annual Report (City of Vancouver, 2021), the share of homes deemed or declared empty has steadily declined since the EHT's introduction, dropping from 4.1% in 2017 to 3.0% in 2020. By comparison, the pre-EHT residential vacancy rate was 4.8% in 2014, as reported in Ecotagious' Analysis of Housing Occupancy in the City of Vancouver Using Electricity Meter Data Analytics.[11] Studies of similar policies find more modest reductions in vacancy rates. For instance, Segú's (2020) study of a tax on vacant homes in France attributes a 13% decrease in municipal vacancy rates between 1997 and 2001 to the tax. In our setting, the Foreign Buyer Tax (FBT) and Speculative Vacancy Tax (SVT) may have also contributed to the observed vacancy rate reductions.

Rents. To further assess the effects of the EHT on the housing market, we examine its impact on the rental market. The CMHC reports average rents for 1-, 2- and 3-bedroom units, but since the data are only available annually, we use a difference-in-differences (DID)

[11] `https://council.vancouver.ca/20160308/documents/rr1EcotagiousReport.pdf`



(a) border sample **(b)** whole sample

Figure 7: Average causal effects of EHT on time-on-the-market.

Notes: The figure plots the estimated impulse response coefficients at each horizon. All regressions control for average property characteristics, FSA FE and year-month FE. Standard errors are clustered at the year-month level. The dotted and dashed lines represent 90% and 95% confidence intervals, respectively.

approach instead of an impulse response method. The following equation is estimated:

$$\log R_{r,j,t} = \alpha_j + \alpha_t + \sum_{h=2014}^{2018} \beta_h D_{t,h} \text{Van}_j + \gamma x_{r,j,t} + e_{r,j,t} \tag{5}$$

where $\log R_{r,j,t}$ is the log of average rent for an r-bedroom rental unit in neighborhood j in year t; $D_{t=h}$ is a set of year dummies that equal 1 if $t = h$ and zero otherwise; Van_j is an indicator variable that equals 1 for neighborhoods within the city of Vancouver and 0 otherwise; $x_{r,j,t}$ includes time-varying average characteristics of transacted properties in neighborhood j in year t, as well as fixed effects including census tract $\times$ bedroom type and year $\times$ bedroom type; and $e_{r,j,t}$ is the error term. The interaction terms $\beta_h D_{t,h} \text{Van}_j$ capture the differential change in rents in Vancouver neighborhoods relative to suburban neighborhoods over time.

The results are presented in Table 2. Columns 1 and 2 report the main estimates based on equation 5. The coefficient on $D_{t=2014} \times \text{Van}_j$ is small and statistically insignificant,

confirming the absence of significant pre-trends in the rental market before the EHT implementation. The coefficients on the interactions between post-EHT year dummies and Vancouver are consistently negative. Specifically, the EHT reduced rents in Vancouver by 1.6% in the year of its announcement and design. This decline persisted in subsequent years, suggesting that the policy had a lasting impact on rents. In Columns 3 and 4, we additionally include interactions between year fixed effects and the previously defined dummy variable τ_j^{FBT}. The estimates remain virtually unchanged, consistent with the interpretation that most of the FBT effects are already absorbed by the year fixed effects.

Table 2: EHT effects on rents

	(1)	(2)	(3)	(4)
Van=1 × Year=2014	-0.008	-0.008	-0.009	-0.009
	(0.009)	(0.009)	(0.009)	(0.009)
Van=1 × Year=2015	0.000	0.000	0.000	0.000
	(.)	(.)	(.)	(.)
Van=1 × Year=2016	-0.015*	-0.016*	-0.016*	-0.017*
	(0.009)	(0.009)	(0.009)	(0.009)
Van=1 × Year=2017	-0.018**	-0.018**	-0.017*	-0.017*
	(0.009)	(0.009)	(0.009)	(0.009)
Van=1 × Year=2018	-0.020*	-0.019*	-0.015	-0.015
	(0.011)	(0.011)	(0.011)	(0.011)
Year FE	Yes	Yes	Yes	Yes
Census Tract FE	Yes	Yes	Yes	Yes
Census Tract FE × No. Bedrooms FE	Yes	Yes	Yes	Yes
Year FE × No. Bedrooms FE	No	Yes	No	Yes
Year FE × FBT	No	No	Yes	Yes
Observations	972	972	972	972

Notes: The table reports the estimated coefficients of the interaction between the City of Vancouver and year fixed effects. The sample includes all neighborhoods in the GVRD from 2014 to 2018. The dependent variable is the change in the log of rent. The unit of observation is at the neighborhood/bedroom no./year level. All regressions control for the average characteristics of transacted properties, and columns 3 and 4 additionally include FBT controls. The omitted category corresponds to year 2015. Standard errors are clustered at the segment-by-year level. The stars indicate the significance level of the coefficients: * p<0.1, ** p<0.05, *** p<0.01.

4.3 Robustness Checks

Here, we present a set of robustness checks to further validate our main empirical findings.

We start with the first set of robustness checks by relaxing the assumption that $\kappa_j = 1$ and incorporating an interaction between κ_j and the EHT dummy in the estimation of Equation (4). Here, κ_j represents one of the vacancy variables observed in 2016. This more flexible identification strategy accommodates correlation between the EHT and other contemporaneous policies or housing market trends, as long as they do not differentially affect neighborhoods based on κ_j. However, it is plausible that neighborhoods with higher κ_j are more sensitive to both the EHT and the FBT. To address this concern, we include κ_j in the construction of $\tau_{j,t}^{FBT}$ in (4) to isolate the variation before and after the EHT across neighborhoods with different κ_j values, while controlling for the FBT's differential impacts. Figures in Appendix D plot the estimated impulse coefficients, where κ_j is measured by one of the four variables from Section 4: vacancy rate, fraction of immigrants, fraction of immigrants from China, Hong Kong, and Taiwan, and share of non-permanent residents (all at the FSA level in 2016). The post-EHT dynamics for sales, listings, prices, and time-on-market remain consistent with the baseline specifications where $\kappa_j = 1$, though the price and listing estimates lose significance in the border sample. This is not surprising, as the shift-share local projections specification places greater demands on the data, and the border sample is relatively small. When we expand the sample, all estimated dynamic patterns remain robust and statistically significant, further reinforcing our main findings.

Another potential source of bias concerns possible spillover effects into neighborhoods outside the city of Vancouver. While geographic spillovers are difficult to rule out entirely, we believe such spillovers are less concerning for the EHT. Unlike housing taxes imposed on buyers (e.g., transaction taxes), the EHT targets owners of existing homes which cannot be relocated across municipal boundaries. Nevertheless, prospective buyers that would have otherwise purchased a home just inside the border may shift to the Vancouver-adjacent

neighborhoods in response to the EHT. To test for potential spillover effects, we employ a "donut approach" by re-estimating the main empirical specification, excluding neighborhoods that are adjacent to the city border. To further ensure the robustness of our results, we also address the possibility of anticipation effects. Specifically, we exclude the three months leading up to the EHT announcement to alleviate concerns that households may have timed their transactions in anticipation of the Vancouver Charter amendments in Bill 28. The results, presented in Appendix E, remain consistent with the baseline findings, suggesting that neither geographic spillovers nor anticipation effects are likely to bias our estimates.

Finally, as a specification check, we estimate the effects of the EHT on house sales and listings using a dynamic difference-in-differences approach. The specification and results, detailed in Appendix B, confirm that despite differences in estimation methodology, the findings remain highly consistent with our baseline results.

4.4 Summary

In summary, our findings reveal a clear and consistent pattern: the EHT initially improves housing availability and affordability, but its impact diminishes over time in the owner-occupied market, while persisting in the rental sector. The divergence in long-term effects on prices versus rents underscores the importance of property allocation between owner-occupied and rental markets. The sharp spike in listings and sales suggests that non-occupying investors play a significant role in Vancouver's housing market, while the dynamic effects on time-on-the-market indicate that the EHT influences congestion in a frictional owner-occupied market. Building on these insights, we next develop a search model to explain these empirical patterns.

5 Model Environment

In this section, we describe an economic environment in which housing developers, resident households, and non-resident investors interact in owner-occupied and rental housing markets. Time is discrete and indexed by t. There are L_t households residing in the city at time t, and ϕL_t outside investors. The population growth rate is ν, so that $L_{t+1} = (1+\nu)L_t$. An assumption of the model is that households, but not investors, require housing in every period.

Households. Households are infinitely-lived with discount factor $\beta \in (0,1)$. They earn a constant exogenous income y each period.[12] Preferences are given by

$$u(c_t, z_t) = c_t + z_t, \tag{6}$$

where c_t denotes non-housing consumption at time t, and

$$z_t = \begin{cases} z > 0 & \text{if homeowner and } \textit{well-matched} \\ 0 & \text{otherwise} \end{cases} \tag{7}$$

denotes the utility premium associated with homeownership. The utility flow from the housing services of a rental unit is normalized to zero. Parameter z is an additional utility benefit designed to capture the enjoyment experienced by homeowners that have found the *right* house and customized it to their idiosyncratic preferences. With probability δ per period, an owner-occupier experiences a preference shock that results in them losing the utility premium from living in that house. That is, the shock causes z_t to fall to zero as long as the household continues to live in their current house. This preference shock captures a household's evolving preferences arising from changes in age and family status over the life cycle, and generates churning in the owner-occupied market.

[12] Section 5.1 contains a discussion of a model extension involving income heterogeneity.

New households entering the city are assumed to be *long-term renters* that initially do not enjoy the benefits of homeownership (i.e., $z_t = 0$ regardless of housing tenure). The potential to gain a utility premium from homeownership arises stochastically: with probability ψ each period, a long-term renter evolves into a *prospective homebuyer* that rents only temporarily while searching for the right match to prompt a purchase in the owner-occupied market.

Housing. Let H_t denote the city's stock of housing at time t. Housing can either be owned (H_t^n), rented out to long-term renters (H_t^r), rented to prospective buyers (H_t^b), vacant and listed for sale[13] (H_t^f), or vacant and investor-owned (H_t^s):

$$H_t = H_t^n + H_t^r + H_t^b + H_t^f + H_t^s. \tag{8}$$

Empty homes held by investors are termed *speculative vacancies*. *Frictional vacancies*, on the other hand, are the result of search-and-matching frictions in the owner-occupied market.

Housing construction is carried out by a large number of competitive developers. The unit cost of new housing construction, $q(H_t/L_t) > 0$, is assumed to increase with the relative supply of housing, defined as the existing stock of housing relative to the population, which is consistent with balanced growth. We interpret this relationship as the rising cost of increasing the supply of residential land. A natural example for q is

$$q(H_t, L_t) = \zeta_0 \left(\frac{H_t}{L_t} \right)^{\zeta_1}, \tag{9}$$

with $\zeta_0 > 0$ and $\zeta_1 \geq 0$. Depreciation is exactly offset by maintenance: the owner of an occupied home incurs cost m per period.

Markets. Households and developers can borrow and lend in a competitive market at gross interest rate $1/\beta$. As for housing services, there are three relevant markets: a rental market, a wholesale market, and an owner-occupied market. The rental market is perfectly

[13] An assumption is that a home must remain vacant while listed for sale in the owner-occupied market.

competitive, with the rental payment at time t denoted by x_t. For analytical convenience, we also assume that vacant homes can be traded in a competitive wholesale market, with V_t denoting the wholesale market value of a house at time t. If a household were to buy a house in the wholesale market, it would serve only as a financial asset.[14] In other words, it would not be the *right* house that delivers the utility premium, z. In order to buy a home from which to derive the additional utility benefit from the housing services enjoyed when living in a home that they own, they must engage in a time-consuming process of search-and-matching in order to find the *right* house in the owner-occupied market.

We model these frictions in the owner-occupied market with a matching function. In addition, search is *directed* by list prices. Within a *submarket* characterized by price, P, bilateral matches are formed between the measures of buyers and sellers participating in that submarket (i.e., the buyers searching for homes at a given price point and the sellers listing vacant homes at that same price). The measure of bilateral matches is governed by a constant returns to scale matching function, so that matching probabilities can be expressed as functions of the buyer-seller ratio, $\theta_t(P)$, termed *submarket tightness*. The matching probability for a buyer participating in submarket P at time t is denoted $\lambda(\theta_t(P))$, and the matching probability for a seller is $\gamma(\theta_t(P))$. The matching probabilities satisfy $\lambda(\theta) \in [0,1]$, $\gamma(\theta) \in [0,1]$, $\lambda'(\theta) < 0$, $\gamma'(\theta) > 0$ and $\gamma(\theta) = \theta\lambda(\theta)$.

Following a preference shock, we assume for simplicity that households sell their house back to a developer in the wholesale market. The developer can then supply it to the competitive rental market or frictional sales market.

Empty-homes-tax. Owners of homes determined to be *vacant* are subject to an empty-homes-tax (EHT). If applicable, the tax is calculated as a percentage, τ, of the value of a vacant home, totaling τV_t for period t. The EHT does not apply to principal residences and tenanted rentals. Importantly, there may also be an EHT exemption when a house

[14] Because of the interest rate and the absence of financial market frictions, households will not have any incentive in equilibrium to buy a home as a financial asset.

changes ownership.[15] Owners on the supply side of the frictional market (i.e., developers) can therefore mitigate their vacancy tax obligations or even avoid it altogether by making strategic listing and rent-or-sell decisions. Nevertheless, there may be some uncertainty about how long it will take to sell and therefore whether the tax will ultimately be avoided when listing a home for sale in a frictional market. Rather than explicitly modeling these strategies, we will assume that developers pay only a fraction, $1 - \omega$, of the EHT, with $\omega \in [0, 1]$. Setting $\omega = 0$ corresponds to an environment where every vacant home, including those listed for sale, is subject to the full EHT, similar to the treatment of vacancies in Desgranges and Wasmer (2000) and Ménard (2012). Conversely, with $\omega = 1$, frictional vacancies are exempt from the tax, aligning with the approach in Segú (2020) for vacant apartments offered for rent.

Investors. Investors, like households, are long-lived with discount factor β. The measure of potential investors at time t grows at the same rate ν as the city's population of households so that the ratio of investors to households, denoted ϕ, remains constant over time. One could interpret investors as fund managers rather than households, and as such they do not need to or want to live in a house. They may nonetheless receive an exogenous flow value from property ownership, denoted π_t at time t. Each individual investor's π_t follows a Markov process:

$$\pi_{t+1} = \begin{cases} \pi_t & \text{with prob. } 1 - \rho \\ \pi' \sim F & \text{with prob. } \rho \end{cases} \tag{10}$$

The random variable π' is independent and identically distributed over time and across investors. This heterogeneity is designed to capture the idea that *some* investors may want to own a house as part of their financial portfolio or as a temporary store of wealth. It could be that homeownership provides a hedge against other sources of financial risk and/or the threat of wealth appropriation.[16] Regardless of the interpretation, sufficient heterogeneity in

[15] In Vancouver, for example, the EHT does not apply in the year that a house changes ownership.

[16] It could also be that some investors value homeownership more than others because they derive utility

π_t results in some investors having a higher willingness to pay for a house than households, developers, and other investors.

Since an investor that owns a home does not live in the house, they can either rent it out[17] or be subject to the EHT.[18] Given the stochastic nature of π_t in (10), homeownership duration can be short and investors may want their investment to be liquid. For that reason, they may want to avoid the illiquidity associated with a home that is rented out (e.g., the time and possible legal costs associated with evicting a tenant in order to sell). We model this additional cost of being a landlord as cost of leasing, ε, which is also heterogeneous across investors: each investor's ε is an *iid* draw from distribution G.[19] Heterogeneity in the benefits of property ownership and the costs of leasing out properties leads investors to make distinct participation decisions, resulting in some becoming landlords (owners of rented properties) and others becoming speculators (owners of vacant properties).

While this approach to modeling the participation decisions of investors is reminiscent of the rental market participation decision of apartment owners in Segú (2020), it also captures the initial decision to become a property owner. Note that an investor purchasing a house need not undergo the search-and-matching process in the owner-occupied market since they are not shopping for the *right* house to live in and derive utility from. Instead, they buy from a developer in the competitive wholesale market. When an investor decides they no longer want to own the house, they could sell it back to a developer (or to another investor) in the wholesale market, or try to sell to an owner-occupier in the frictional market.

from it as a vacation property.

[17]We maintain the assumption that ϕ is small in the sense that there are fewer investor-landlords than there are renters. A suitable condition along a balanced growth path is $\phi \leq \nu/(\nu + \psi)$.

[18]Importantly, there are no vacancy tax exemptions for investors. For instance, speculators cannot simply transfer the ownership of their Vancouver properties amongst themselves every year to circumvent the EHT. We view this assumption as reasonable given the (unmodeled) transaction costs associated with the transfer of homeownership. Note that exemption from Vancouver's EHT for the legal transfer of ownership requires proof of payment of the property transfer tax.

[19]Additional property management costs that an investor incurs as a landlord is another possible interpretation of ε since some investors may be non-local.

5.1 Discussion of the Modeling Assumptions

Effects of the empty-homes-tax. The model yields predictions about how prices, rents, listings, sales, vacancies, time-on-the-market, homeownership, and new construction respond to an EHT. Specifically, we define and characterize the model's equilibrium balanced growth path (BGP), and derive and discuss comparative statics with respect to the EHT rate, τ. These results, presented in Section 6.4, provide theoretical insights about the *long-run* effects of the EHT. Before imposing stationarity, however, we characterize and define the dynamic equilibrium more generally in Sections 6.1, 6.2 and 6.3. The off-BGP implications of τ are important here because equilibrium outcomes like prices, sales, listings, time-on-the-market, rents, and vacancies may respond differently to the introduction of an EHT in the short term than in the long term. In Section 7, we parameterize the model and compute the transitional dynamics to a long-run BGP following the introduction of the EHT, starting from an initial BGP with $\tau = 0$.

EHT exemption when there is a change in ownership. The model environment assumes that every vacant home is subject to the EHT, but that developers only pay a fraction, $1 - \omega$, of the tax. In Vancouver, the EHT does not apply in the year that a house changes ownership. Developers and households on the supply side of the market can therefore avoid or mitigate their vacancy tax obligations by making strategic listing and rent-vs-sell decisions. If developers in the model were completely exempt from the vacancy tax (i.e., if $\omega = 1$), parameter τ can still affect owner-occupied and rental markets because construction costs depend on the existing housing stock, which includes empty investor-owned homes.[20]

Selling while occupying. An assumption of the model is that a house must be vacant to be listed for sale in the owner-occupied market. Alternatively, we could consider that mismatched owners continue to live in their homes while trying to sell them, thereby avoiding

[20]When construction costs are constant (i.e., $\zeta_1 = 0$) and developers are tax-exempt (i.e., $\omega = 1$), parameter τ does not affect the BGP at all except for the set of homes owned by investors. Of course, other equilibrium outcomes like prices, listings, and sales could be affected by τ off the BGP.

rental costs and the EHT. Similarly, mismatched homeowners and developers might rent out their houses while they are listed for sale. However, practical issues such as staging difficulties, the need to provide advance notice to tenants, and the challenge of coordinating move-in and move-out dates between buyers and sellers generally lead to periods of vacancy between owner-occupiers. Moreover, it is uncommon for newly constructed homes to be rented out temporarily while being listed for sale by developers. Therefore, the assumption that a house must be vacant while listed for sale ensures that search-and-matching frictions generate frictional vacancies in equilibrium. Nevertheless, some sellers may minimize the duration of a frictional vacancy and reduce their expected EHT obligation by renting out or occupying the property while selling. This scenario is effectively equivalent to having better matching efficiency and a higher rate of EHT exemption.

Rental market frictions. While we could model trading frictions in both rental and owner-occupied markets, a key assumption for our analytical results is that search-and-matching frictions are more pronounced in the owner-occupied market. As a result, the allocation of houses to tenants via the rental market involves fewer frictional vacancies compared to the allocation of homeownership. The simplifying assumption of a frictionless rental market streamlines the analysis, clarifies the economic intuition, and suitably captures the price and homeownership dynamics observed in Vancouver following the introduction of the EHT.

Income and wealth. While the assumption that income is constant over time and across households may seem simplistic, it provides a useful framework for examining housing market dynamics. With linear preferences and the assumption that the interest rate is $1/\beta$, households have no incentive to shift consumption intertemporally or accumulate wealth. These assumptions are particularly convenient given the matching risk and preference shocks households encounter in the frictional owner-occupied market, which would otherwise complicate the consumption/savings decision. In cities like Vancouver, where empty homes are

often high-quality properties owned by wealthy individuals, income and wealth heterogeneity may be less critical for studying the effects of the EHT on the price and availability of high-value properties. However, extending the model to include income heterogeneity, non-linear utility, and an endogenous wealth distribution could provide a more comprehensive analysis of different housing market segments and contribute to discussions of social welfare in diverse urban contexts, such as markets with low-quality, abandoned homes.

6 Equilibrium

6.1 Equilibrium Values and Prices

For a developer, the value of a house in the competitive wholesale market reflects the option of renting it out or supplying it to the owner-occupied market:

$$V_t = \max\{x_t - m + \beta V_{t+1}, -(1-\omega)\tau V_t + \beta \max_P \gamma(\theta_t(P))P + (1-\gamma(\theta_t(P)))V_{t+1}\}, \quad (11)$$

where the first expression in curly brackets is the value of renting the house, and the second expression is the value of holding it vacant and listed for sale in the frictional market. The maximization operator in the second expression reflects the directed nature of search in the owner-occupied market, and the function θ_t captures the perceived trade-off between price and submarket tightness. As the supply side of the market can freely choose between participation in the rental market and any submarket of the owner-occupied market, we must have indifference in equilibrium:

$$V_t = x_t - m + \beta V_{t+1} \quad (12)$$

and

$$V_t = -(1-\omega)\tau V_t + \beta \max_P \left[\gamma(\theta_t(P))P + (1-\gamma(\theta_t(P)))V_{t+1}\right]. \tag{13}$$

Equations (12) and (13) equate the value of a vacant home across rental and all active submarkets of the owner-occupied market.

The free entry of competitive developers into housing construction constrains the value of a vacant home since newly constructed homes can be supplied to rental and owner-occupied markets:

$$q(H_t/L_t) \geq V_t. \tag{14}$$

Let V_t^r, V_t^b and V_t^n denote the present discount expected values associated with renting long-term, renting temporarily while buying, and owning. These values satisfy the following system of Bellman equations:

$$V_t^r = y - x_t + \beta\left[(1-\psi)V_{t+1}^r + \psi V_{t+1}^b\right] \tag{15}$$

$$V_t^b = y - x_t + \beta \max_P \lambda(\theta_t(P))\left[V_{t+1}^n - P\right] + (1-\lambda(\theta_t(P)))V_{t+1}^b \tag{16}$$

$$V_t^n = y - m + z + \beta\left\{(1-\delta)V_{t+1}^n + \delta\left[V_{t+1}^b + V_{t+1}\right]\right\}, \tag{17}$$

where the maximization operator in (16) reflects the directed search problem of a prospective homebuyer, and the function θ_t again captures the perceived trade-off between price and tightness. The value of renting long-term, V_t^r, is just current consumption (income minus rent) plus a discounted expected continuation value reflecting the possible transition from *long-term renter* to *buyer-renter*. The value of owning, V_t^n, on the other hand, takes into account current consumption (income minus maintenance costs), the utility benefit of owning the right house, z, and the discounted expected continuation value. This expected continuation value reflects the possibility of maintaining homeowner status next period, which occurs with probability $1-\delta$, as well as the possibility of being hit with the preference shock, which

occurs with probability δ. When hit by the preference shock, the household's status changes from *owner* to *buyer-renter* because they no longer value the housing services provided by their current house and therefore search for a new house to purchase. When this happens, they also experience a capital gain because they sell their current house in period $t+1$ to a developer for the competitive price of V_{t+1} in the wholesale market.

As discussed above, both buyers and developers perceive a trade-off between the price and the matching probability (i.e., tightness) in the owner-occupied market. In equilibrium, this trade-off is pinned down by a version of the supply side indifference condition (13), even for out-of-equilibrium prices:

$$V_t - \beta V_{t+1} + (1-\omega)\tau V_t = \beta\gamma(\theta_t(P))\left[P - V_{t+1}\right]. \tag{18}$$

When buyers direct their search to the set of homes listed at price P, they anticipate that the relative supply of houses is consistent with a buyer-seller ratio, $\theta_t(P)$, satisfying (18).

The directed search problem of a prospective homebuyer is therefore the maximization problem in (16) subject to the supply side equation (18) to constrain the price-tightness pairs to those that would deliver exactly payoff V_t to participating developers:

$$\max_{\theta,P} \lambda(\theta)\left[V^n_{t+1} - V^b_{t+1} - P\right] \quad \text{s.t.} \quad V_t - \beta V_{t+1} + (1-\omega)\tau V_t = \beta\gamma(\theta)\left[P - V_{t+1}\right].$$

The solution is a pair $\{\theta_t, P_{t+1}\}$ that solves the constraint and the following first-order condition:

$$P_{t+1} = \eta(\theta_t)V_{t+1} + (1-\eta(\theta_t))\left[V^n_{t+1} - V^b_{t+1}\right], \tag{19}$$

where $\eta(\theta) = \theta\gamma'(\theta)/\gamma(\theta) = 1 + \theta\lambda'(\theta)/\lambda(\theta)$. This solution is depicted in Figure 8 by the point of tangency between the buyer's indifference curve and the constraint set (i.e., the turquoise set of pairs, $\{\theta, P\}$, satisfying the seller's indifference curve).

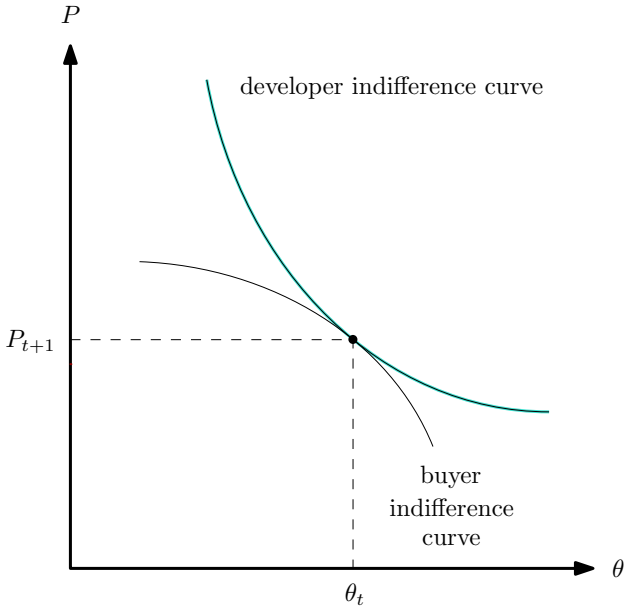


Figure 8: The Solution to the Directed Search Problem.

Each investor, characterized by the current flow value of homeownership, π_t, and the additional cost of being a landlord, ε, decides whether to invest in a property. If they do buy a house, they also decide whether to rent it out or keep it empty. The present discounted expected value of an investor satisfies

$$V_t^i(\pi_t, \varepsilon) = \max \Big\{ \beta \mathbb{E}[V_{t+1}^i(\pi_{t+1}, \varepsilon)], \\ \pi_t - V_t + \max\{x_t - m - \varepsilon, -\tau V_t\} + \beta \mathbb{E}[V_{t+1}^i(\pi_{t+1}, \varepsilon) + V_{t+1}] \Big\}.$$

The first maximization operator reflects the decision of whether or not to buy a house in the wholesale market at a price of V_t from a developer. Conditional on owning a house in period t, the second maximization operator is the investor's choice of whether to rent out the house or keep it vacant. Because the market for vacant homes is competitive, the investor's decision problems are static. Buying/selling vacant homes and renting them out are choices that the investor makes period-by-period as π_t evolves stochastically. To see this more clearly, we can

rewrite their Bellman equation as follows:

$$V_t^i(\pi_t, \varepsilon) = \max\{0, \pi_t - V_t + \max\{x_t - m - \varepsilon, -\tau V_t\} + \beta V_{t+1}\} + \beta \mathbb{E}[V_{t+1}^i(\pi_{t+1}, \varepsilon)].$$

Simplifying further using (12) yields

$$V_t^i(\pi_t, \varepsilon) = \max\{0, \pi_t - \min\{\varepsilon, \kappa_t\}\} + \beta \mathbb{E}[V_{t+1}^i(\pi_{t+1}, \varepsilon)], \tag{20}$$

where

$$\kappa_t = (1 + \tau)V_t - \beta V_{t+1} \tag{21}$$

is the user cost of vacant housing as a capital asset. The investor chooses homeownership if the benefit is sufficiently high: $\pi_t \geq \min\{\varepsilon, \kappa_t\}$. The house is then rented out unless it is too costly (or too inconvenient) for the investor to take on the role of landlord: $\varepsilon < \kappa_t$. Figure 9 plots the optimal decisions of investors for different regions of the parameter space. The kinked orange line represents the locus of marginal investors that achieve the same surplus from owning a house as would any developer. Investors above the orange line find it worthwhile to buy a house. Those in the top right-hand corner own vacant homes because of the additional cost of being a landlord.

6.2 Distributions of Households and Houses

We can characterize the distributions of households and houses to be consistent with the idiosyncratic shocks and search-and-matching frictions in the owner-occupied market. The stocks and flows for households are depicted in Figure 10.

The measure of long-term renters or, equivalently, the measure of houses occupied by

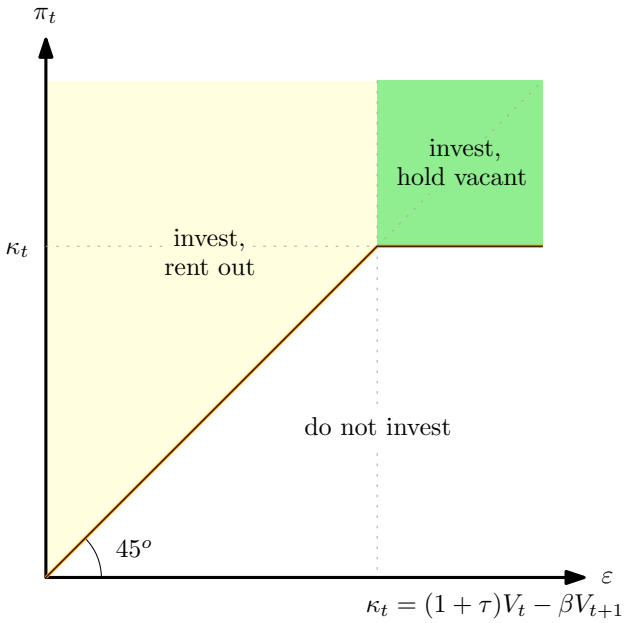


Figure 9: The Equilibrium Decisions of Investors.

long-term renters evolves according to

$$H^r_{t+1} = (1-\psi)H^r_t + \nu L_t.$$

Dividing both sides by L_t and using a lower-case letter to represent the per capita measure yields

$$h^r_{t+1} = \frac{1-\psi}{1+\nu} h^r_t + \frac{\nu}{1+\nu}. \tag{22}$$

The measures of buyer-renters and owners evolve according to

$$\begin{aligned} H^b_{t+1} &= (1-\lambda(\theta_t))H^b_t + \delta H^n_t + \psi H^r_t \\ H^n_{t+1} &= (1-\delta)H^n_t + \lambda(\theta_t)H^b_t, \end{aligned}$$

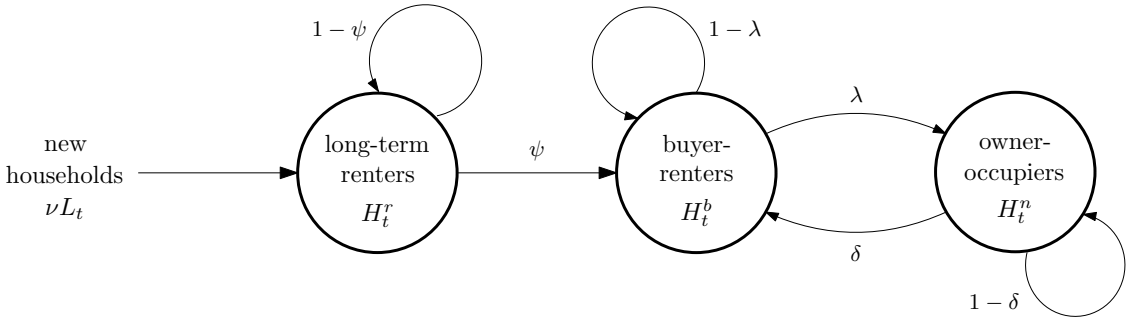


Figure 10: household stocks and flows

and the per-capita versions are

$$h_{t+1}^b = \frac{1-\lambda(\theta_t)}{1+\nu} h_t^b + \frac{\delta}{1+\nu} h_t^n + \frac{\psi}{1+\nu} h_t^r \tag{23}$$

$$h_{t+1}^n = \frac{1-\delta}{1+\nu} h_t^n + \frac{\lambda(\theta_t)}{1+\nu} h_t^b. \tag{24}$$

Housing is supplied to investors via the competitive wholesale market, to renters in the competitive rental market, and to owner-occupiers in the frictional directed search market. Figure 11 depicts the stocks and flows of housing units. Since each household occupies one house, the stock of housing exceeds the population of households because of frictional and speculative vacancies. The time t stock of empty homes owned by investors, termed *speculative vacancies* and denoted H_t^s, is

$$H_t^s = \phi L_t \int_{\kappa_t}^{\infty} \int_{\kappa_t}^{\infty} dF(\pi)\, dG(\varepsilon) = \phi L_t \left[1 - F(\kappa_t)\right] \left[1 - G(\kappa_t)\right].$$

Dividing both sides by L_t yields

$$h_t^s = \phi \left[1 - F(\kappa_t)\right] \left[1 - G(\kappa_t)\right]. \tag{25}$$

The per capita measure of vacant homes available for owner-occupancy must be consistent

with market tightness:

$$h_t^f = \frac{h_t^b}{\theta_t}. \tag{26}$$

The vacancies in (26) are *frictional* vacancies, whereas those in (25) are *speculative* vacancies.

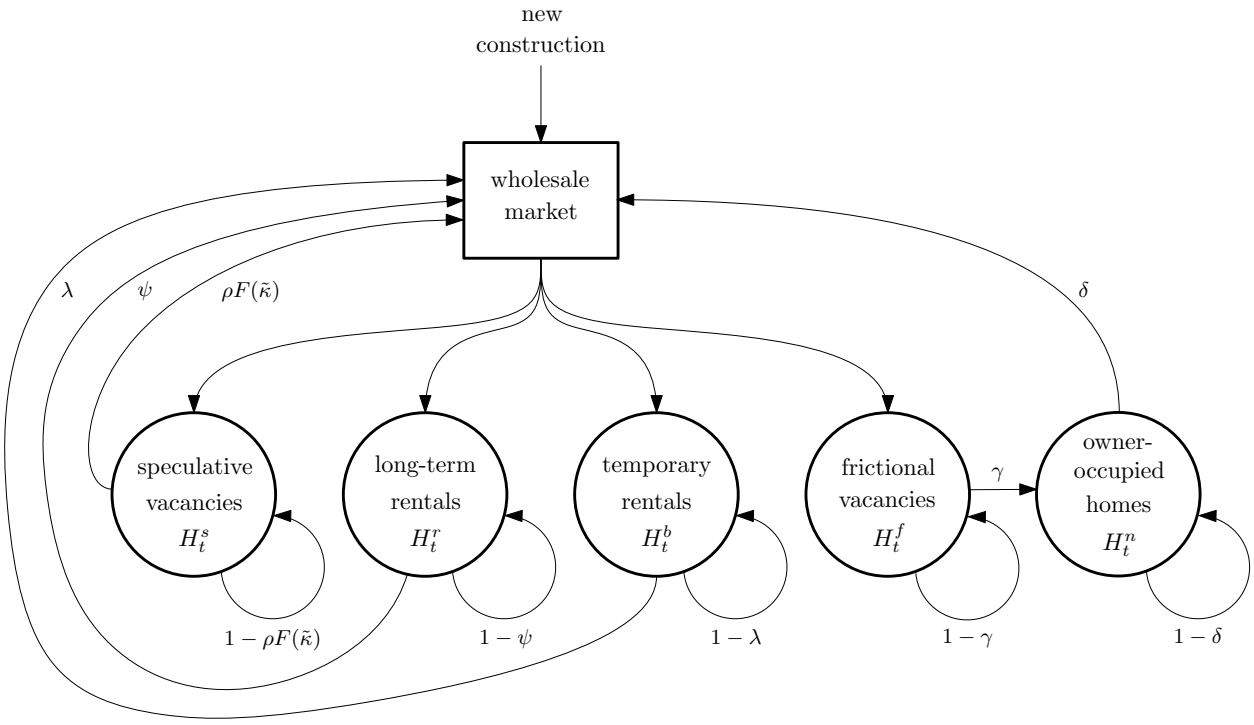


Figure 11: housing stocks and flows

The total supply of housing in the economy at time t is

$$H_t = H_t^n + H_t^r + H_t^b + H_t^f + H_t^s = L_t + H_t^f + H_t^s.$$

Since housing can be constructed but not destroyed in the model, we have $H_t \geq H_{t-1}$ or, equivalently, $h_t(1+\nu) \geq h_{t-1}$, where

$$h_t = h_t^n + h_t^r + h_t^b + h_t^f + h_t^s = 1 + h_t^f + h_t^s \tag{27}$$

is the per capita measure of homes at time t. There is either a growing supply of housing in the economy with a binding free entry condition, or the supply of housing is constant and the free entry condition is slack. More formally, the free entry condition for developers along with housing market clearing can be expressed as

$$q(h_t) \geq V_t \quad \text{and} \quad h_t(1+\nu) \geq h_{t-1} \tag{28}$$

with complementary slackness.

6.3 Equilibrium Definition

We are now ready to define an equilibrium of the model. To facilitate comparative statics and derive the long-run implications of an EHT, we restrict our attention to an equilibrium balanced growth path (BBG) in some analyses. The derivations and a formal definition of an equilibrium BGP are provided in Appendix G. However, since our focus also includes short-term dynamics, we define the equilibrium here in a more general form.

Definition 1 *Given an initial distribution* $\{h_0^r, h_0^b, h_0^n, h_0^f\}$*, an equilibrium is a sequence of values,* $\{V_t^r, V_t^b, V_t^n\}$*; a sequence of value functions,* $\{V_t^i(\pi, \varepsilon)\}$*; a sequence of house values, rents, and user costs,* $\{V_t, x_t, \kappa_t\}$*; a sequence of prices and functions for market tightness,* $\{P_t, \theta_t(P)\}$*; a sequence of housing stocks,* $\{h_t\}$*; and a sequence of distributions of houses/households,* $\{h_t^r, h_t^b, h_t^n, h_t^f, h_t^s\}$*; such that*

(i) household and investor values: $\{V_t^r, V_t^b, V_t^n\}$ *and* $\{V^i(\pi, \varepsilon)\}$ *satisfy* (15), (16), (17) *and* (20)*, taking house values* $\{V_t\}$*, rents* $\{x_t\}$*, user costs,* $\{\kappa_t\}$*, and market tightness* $\{\theta_t(P)\}$ *as given;*

(ii) free entry in the rental and wholesale markets: $\{x_t\}$ *and* $\{\kappa_t\}$ *satisfy* (12) *and* (21)*;*

(iii) directed search in the sales market: $\{\theta_t(P)\}$ *satisfies* (18)*, and* $\{P_t\}$ *satisfies* (19) *given* $\{\theta_t = \theta_t(P_{t+1})\}$*;*

(iv) aggregation: $\{h_t, h_t^r, h_t^b, h_t^n, h_t^f, h_t^s\}$ *satisfy* (22), (23), (24), (26), *and* (25)*;*

(vi) free entry into housing development: $\{V_t, h_t\}$ *satisfy the inequalities in* (28) *with complementary slackness, given aggregation conditions* (27)*.*

6.4 Analytical Results

Along an equilibrium BGP with population growth and corresponding new housing construction, house values and rental costs remain constant. A formal definition of an equilibrium BGP, including the characterization of the stationary distribution of houses/households, as well as stationary versions of the price equation and free entry condition, can be found in Appendix G. This setup allows us to examine the long-term implications of an increase in the EHT rate, τ.

There are two offsetting effects: First, an increase in the EHT rate, τ, reduces *speculative* vacancies, h^s. Using (G.14), this effect is most straightforward to show under the assumptions that $\zeta_1 = 0$ (i.e, construction costs do not depend on the relative supply of housing) and $\omega = 1$ (i.e., frictional vacancies are fully exempt from the EHT):

$$\frac{\partial h^s}{\partial \tau} = -\phi\Big\{ \left[1 - F(\kappa)\right] g(\kappa) + \left[1 - G(\kappa)\right] g(\kappa) \Big\} q < 0. \tag{29}$$

Figure 12 depicts how an increase in τ reduces the set of investors that own empty homes. By discouraging the ownership of speculative vacancies, an increase in τ causes some investors to instead rent them out,[21] while others abstain from acquiring them altogether.

The second effect is a reduction in *frictional* vacancies when there is imperfect tax exemption ($\omega < 1$). This effect is again relatively straightforward to establish if we maintain

[21] This is akin to the effect of a vacancy tax on *voluntary* vacancies in Segú (2020).

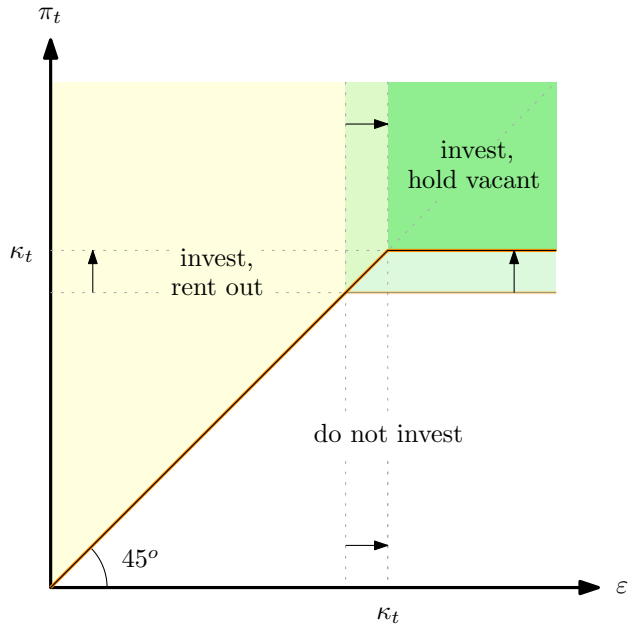


Figure 12: The Effect of τ on the Equilibrium BGP Decisions of Investors.

the assumption that $\zeta_1 = 0$. From (G.9), we have

$$\frac{\partial \theta}{\partial \tau} = \frac{(1-\omega)q}{\beta z} \frac{\left[1-\beta(1-\delta-\eta(\theta)\lambda(\theta))\right]^2}{\alpha(\theta)\eta(\theta)\lambda(\theta)\left[1-\beta(1-\delta-\lambda(\theta)\right]} > 0, \tag{30}$$

where

$$\alpha(\theta) \equiv 1 - \eta(\theta) - \frac{\theta\eta'(\theta)}{\eta(\theta)} = -\frac{\theta\gamma''(\theta)}{\gamma'(\theta)} > 0.$$

Equation (G.11) then yields

$$\frac{\partial h^b}{\partial \tau} = -\frac{\lambda'(\theta)h^b}{\nu+\delta+\lambda(\theta)} \frac{\partial \theta}{\partial \tau} > 0, \tag{31}$$

and equation (G.13) yields

$$\frac{dh^f}{d\tau} = -\frac{h^f}{\theta}\left[\frac{\nu+\delta+\eta(\theta)\lambda(\theta)}{\nu+\delta+\lambda(\theta)}\right]\frac{d\theta}{d\tau} < 0. \tag{32}$$

The reduction in both speculative and frictional vacancies lowers the relative supply of housing, h. When $\zeta_1 > 0$, this lowers the cost of housing development, since $q'(h) > 0$. Increasing the EHT therefore makes it cheaper to build houses that can then be supplied to the rental market, making rental units more affordable.

The reduction in construction costs also affects housing affordability in the owner-occupied market for the same reason. An increase in τ, however, can also drive up the price of owner-occupied homes and reduce the availability of homes for sale. Since developers can freely choose between supplying a home to the rental market and the owner-occupied market, an increase in the EHT applied to frictional vacancies means that vacant homes listed for sale command a higher price premium and a shorter expected time-to-sell, *ceteris paribus*. Given the matching technology, a shorter time-to-sell implies a longer time-to-buy. By altering the incentives to supply homes to the owner-occupied market, the EHT shifts the equilibrium BGP composition of housing from owner-occupied to rental:

$$\frac{dh^n}{d\tau} = -\frac{dh^b}{d\tau} < 0. \tag{33}$$

In other words, the EHT can worsen both the affordability and availability of owner-occupied homes,[22] despite lowering rents and increasing the supply of rental units.

These effects on owner-occupied homes are depicted in Figure 13 under the assumption once again that $\zeta_1 = 0$. As can be seen in the Figure, an increase in τ shifts and stretches a developer's indifference curve upward. Because a house can always be supplied to the more liquid rental market which circumvents the EHT, the tax on vacant homes means that the owners of frictional vacancies need to be appropriately compensated. In the directed search framework, this compensation comes in two forms: a higher price and a higher tightness (i.e., shorter expected time-to-sell).[23]

The overall effect on the equilibrium BGP price of owner-occupied housing is ambiguous.

[22] These effects on frictional vacancies in the owner-occupied market are similar to those derived by Ménard

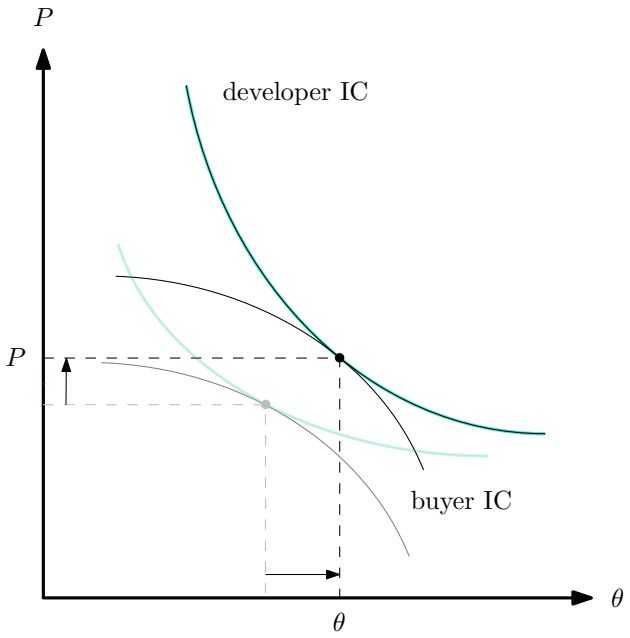


Figure 13: The Effect of τ on Equilibrium BGP Outcomes in the Owner-Occupied Market.

The lower construction cost that results from an increase in τ when $\zeta_1 > 0$ means that the equilibrium wholesale market value of a house is lower, which passes through to the price in the owner-occupied market. As discussed above and illustrated in Figure 13, however, an increase in τ can also put upward pressure on the price of frictional vacancies when $\omega < 1$ because it curbs the incentive to supply them. These two effects thus have opposing forces on the affordability of owner-occupancy.

7 Calibration and Numerical Analysis

The equilibrium BGP implications of the EHT derived in Section 6.4 do not account for the initial effects of converting speculative vacancies into tenanted and owner-occupied homes.

(2012) in the context of a frictional rental market with free entry.

[23]If the housing supply were fixed and there were only frictional markets, as in Desgranges and Wasmer (2000), a vacancy tax could increase affordability by prompting sellers or landlords to list at lower prices or accept less rent to fill their vacant units.

To address this, we extend our analysis by examining the short-run effects of the EHT. Specifically, we parameterize the model to match characteristics of Vancouver's housing markets and numerically compute the equilibrium transition from an initial equilibrium BGP with $\tau = 0$ to a new equilibrium BGP with $\tau > 0$.

7.1 Distributional and Functional Form Assumptions

With a quarterly interpretation of the model's time periods, suppose the matching probabilities take the following form:

$$\lambda(\theta) = \frac{\chi}{1+\theta} \quad \text{and} \quad \gamma(\theta) = \frac{\chi\theta}{1+\theta}.$$

These correspond to a constant-elasticity-of-substitution matching function with matching efficiency parameter $\chi > 0$. Matching efficiency affects how easily a household can find the *right* house in the owner-occupied market from which they derive the homeownership utility premium.

Recall that the flow value of homeownership to an investor remains the same from one period to the next with probability $1 - \rho$, but otherwise is drawn anew from stationary distribution

$$F = \mathcal{N}(\mu, \sigma) = G.$$

Note that by setting F and G equal, both the stock of speculative vacancies and its sensitivity to an EHT are determined by just two parameters, μ and σ.

7.2 Model Calibration

Here we present an illustrative parameterization to demonstrate that the model can replicate some of the observed dynamic patterns. The parameter values and calibration targets are

reported in Table 3.

Table 3: Model Parameters

calibration target	target value	model parameter	parameter value
annual population growth rate (%), 2015–16	1.27	ν	0.0032
annual household income (normalization)	1	y	0.2500
annual interest rate (%)	5	β	0.9879
five-year mobility rate of homeowners (%), 2011–16	20	δ	0.0111
ownership rate (%), 2016	63.7	ψ	0.0061
housing flow value implied by optimal maintenance		z	0.0605
average annual rent relative to median income (%), 2015–16	25.6	ζ_0	3.5729
average annual maintenance cost relative to house value (%)	2.25	m	0.0203
vacancy rate (%), 2014	4.8	ϕ	0.1318
share of homes owned by non-residents (%)	7.6	μ	0.0420
five-year turnover rate for non-resident owners (%), 2011–16	40	ρ	0.0640
annual EHT rate, 2017–19	1	τ	0.0025
assumed value		ω	0.2000
long-run EHT effect on price (%)	0.0	χ	0.8543
maximum long-run decline in rents (%)	0.32	ζ_1	0.1872
vacancy rate (%), 2020	3.0	σ	0.0168

The population growth rate, ν, is set to match that of the GVRD population during 2015 and 2016.[24] Household income is normalized, with annual income $4y$ set to unity. The discount factor, β, is chosen to reflect an annual risk-free rate of 5 percent.

The parameter δ is calibrated using the five-year mobility rate of homeowners. This rate is derived from the total number of households that changed residence between 2011 and 2016, adjusted to account for the proportion of movers that are homeowners, based on data provided by the City of Vancouver. To ensure consistency with a stationary quarterly model, the calculated rate is converted into a quarterly mobility shock probability. A similar approach is applied to calibrate ρ, which governs the turnover rate of investors, under the

[24] `https://www.macrotrends.net/cities/20404/vancouver/population`

supposition that the five-year turnover rate of non-residents is double that of residents. The transition probability, ψ, which captures the rate at which long-term renters become prospective homeowners, is calibrated to match the observed homeownership rate in Vancouver in 2016.

Parameter ζ_0, which adjusts the cost of construction and thereby the equilibrium rental cost, is calibrated to align with the ratio of average annual rent to median income. The average annual rent is calculated from CMHC data, while the median income is obtained from the City of Vancouver's 2016 Census Income Data Release. The maintenance cost parameter, m, is calibrated so that annual maintenance expenses represent 2.25 percent of the market value of the house. This is based on average annual maintenance expenditures of \$11,075 for owner-occupied homes in Canada in 2016.[25] The flow value of housing is determined as the solution to an optimal maintenance problem, assuming a depreciation rate of 2.5 percent.[26]

According to equation (G.14), the per capita measure of speculative vacancies depends on parameter ϕ as well as the distributions F and G. To calibrate these components, we shift the distributions with parameter μ to align with Vancouver's pre-EHT vacancy rate while setting parameter ϕ to match the share of residential properties owned by non-residents. We use the 4.8 percent vacancy rate of residential properties derived from Ecotagious' Analysis of Housing Occupancy in the City of Vancouver Using Electricity Meter Data Analytics.[27] The share of residential properties in Vancouver owned by non-residents is reported as 7.6 percent by the Canadian Housing Statistics Program.[28]

[25]Statistics Canada Table 34-10-0095-01

[26]See Head et al. (2014) page 1189 for details. The premise is that the warm glow derived from homeownership increases with house quality, a stock variable subject to depreciation. The homeowner maintains the optimal house quality by incurring maintenance costs to offset depreciation. The warm glow of homeownership can then be inferred from observed average maintenance costs by interpreting them as the solution to this dynamic optimization problem.

[27]`https://council.vancouver.ca/20160308/documents/rr1EcotagiousReport.pdf`

[28]`https://www150.statcan.gc.ca/n1/pub/11-627-m/11-627-m2017045-eng.pdf`

While there is no EHT in the initial equilibrium BGP, we analyze the equilibrium transition path to a final equilibrium BGP following the unexpected introduction of an EHT set at 1 percent of V_t annually. For the baseline calibration, we set ω to reflect a 20 percent EHT exemption for frictional vacancies, acknowledging its arbitrary nature while also exploring alternative values. The remaining parameters are calibrated using post-EHT observations of Vancouver's housing markets and dynamic response estimates obtained from our empirical analysis presented in Section 4.

The standard deviation, σ, of distributions F and G determines the responsiveness of speculative vacancies to the EHT. Its value is chosen so that the post-EHT equilibrium BGP aligns with a residential vacancy rate of 3.0 percent, consistent with the proportion of empty properties in 2020 as reported in the 2021 Empty Homes Tax Annual Report (City of Vancouver, 2021). The matching efficiency parameter, χ, is set to match the longer-term effect of the EHT on housing prices. As detailed in Section 4, prices eventually returned to their pre-EHT levels, while rents experienced a sustained decline of 1.6 percent. However, under the constraint of meeting all other calibration targets, the calibrated model produces a maximum long-term rent decline of 32 basis points. This outcome corresponds to a scenario where 90 percent of speculative vacancies are eliminated by the EHT. To reflect a more plausible scenario, we set ζ_1 such that speculative vacancies decrease by two-thirds, resulting in a 24 basis point long-term reduction in rent.

The net zero long-term effect on prices aligns with the intuition drawn from the comparative statics in Section 6.4: the EHT's upward pressure on the price premium for frictional vacancies counterbalances the reduced cost of new housing development. Importantly, the assumption that frictional vacancies are not fully exempt from the tax underpins the result that house prices recover in the longer-term, even as construction costs (equivalently, wholesale house values) and rents do not. Beyond prices, the EHT distorts other market dimensions, notably market tightness. To incentivize the supply of frictional vacancies that

are potentially subject to the EHT, the market requires dampened price declines – or even price increases depending on the exemption rate – coupled with shorter expected time-to-sell. Consequently, owner-occupied homes become scarcer and relatively more expensive than rental units once housing markets adjust to the EHT policy. Next, we further explore the nuanced dynamic interplay between housing policy and market outcomes by examining the short-run effects.

7.3 Equilibrium Transition Path with EHT

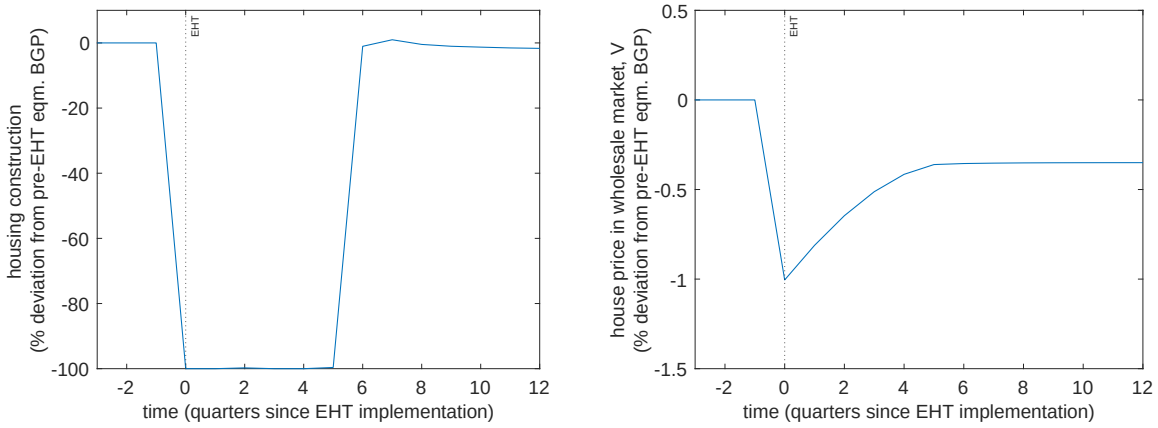
The implementation of the EHT induces some investors with vacant homes to sell them back to the wholesale market. This creates an excess supply of homes, which temporarily halts the construction of new housing and causes the value of a home in the wholesale market to fall below the cost of construction. The immediate fall in V_t coinciding with the introduction of the EHT is depicted in Figure 14b. Figure 14a displays how new construction falls to zero, but resumes a year and a quarter after the introduction of the tax.

In the frictional owner-occupied market, the abundance of homes causes an immediate decline in both prices and market tightness (Figures 15a and 15b). Owing to the tax's discouraging effect on frictional vacancies with less-than-full exemption, prices ultimately rebound and market tightness increases above its pre-tax baseline. These dynamic implications of the calibrated model align with our estimates of the dynamic effects of Vancouver's EHT on prices and time-on-the-market in Figures 6 and 7. Note that the effects of the EHT on price and market tightness depend critically on the tax exemption parameter, ω. When frictional vacancies are fully exempt from the tax ($\omega = 1$), market tightness nearly reverts to its pre-EHT level, and prices decline due to reduced construction costs. In contrast, when frictional vacancies are fully taxed ($\omega = 0$), house prices experience a smaller initial decline and eventually rise above their pre-EHT level.

Both listings and sales increase immediately in response to the EHT (Figures 16a and 16c) as speculative vacancies are supplied to the owner-occupied market, but decline thereafter. These dynamic effects again align qualitatively with our estimated impulse response coefficients plotted in Figures 4 and 5. The initial excess supply of homes caused by the EHT cannot be fully absorbed by newcomers to the city in the rental market and, consequently, the owner-occupied market gets temporarily flooded with frictional vacancies. Both frictional and speculative vacancies, as well as the overall stock of housing, ultimately decline in response to the EHT (Figures 16a, 16b and 16d), as predicted by the theory.

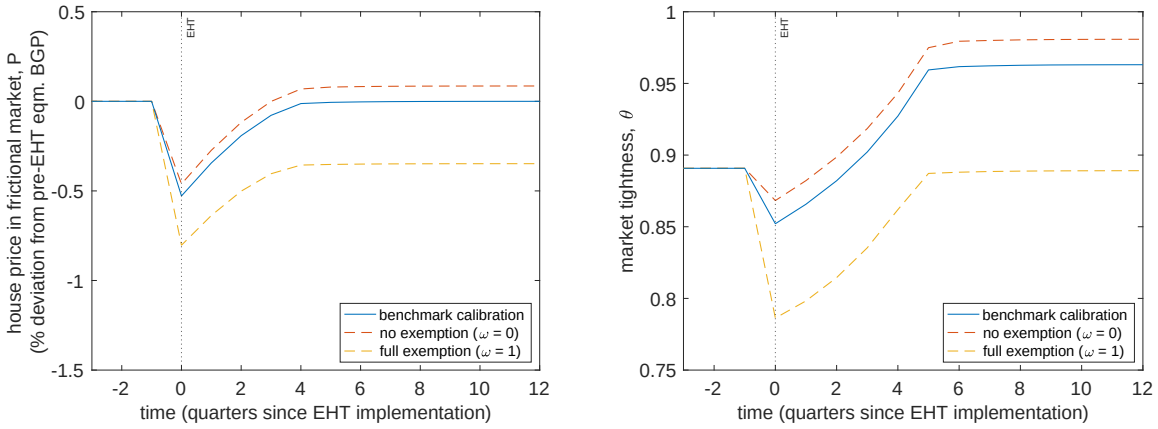
Figure 17 reveals that the relative measure of homeowners increases in the first few months following the implementation of the EHT because it becomes easier to buy a house when they are in abundance. After a modest surge, however, the homeownership rate declines steadily to the new stationary level as frictional vacancies become scarce and it takes longer to find the right home to purchase. This transpires gradually because it takes time for homeowners to experience a preference shock and transition to buyer status. The EHT therefore shifts the composition of housing from owner-occupied to rental because of the distortionary effect on frictional vacancies when there is less-than-full exemption. A compositional shift in the housing stock from owned to rented was also documented in Vancouver, with the rate of principle residence occupancy declining from 70.6% in 2017 to 68.2% in 2020 (City of Vancouver, 2021).

Distinguishing between the short- and long-term effects of the EHT is crucial when considering the policy's overall success. While the tax may lead to a temporary increase in housing availability and affordability immediately after its introduction or a tax rate hike, these initial benefits could obscure more detrimental longer-term outcomes. In the equilibrium transition of the calibrated model, for instance, the distortionary impact on frictional vacancies reduces access to homeownership over time and weakens the affordability gains for owner-occupied housing. In the short run, speculative vacancies are reallocated to households



(a) new housing construction **(b)** house value

Figure 14: Equilibrium construction and house value in response to EHT.

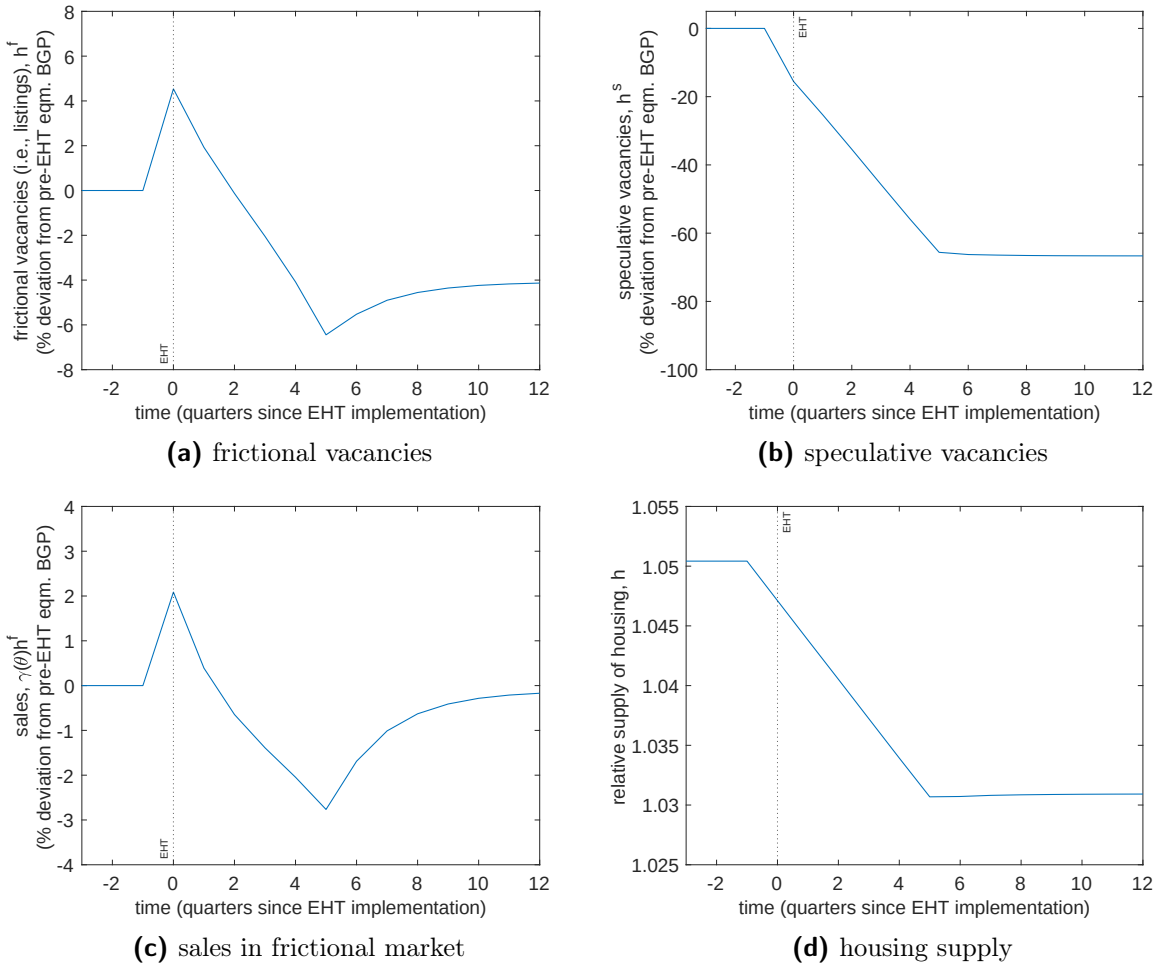


(a) house price **(b)** market tightness

Figure 15: Equilibrium house price and market tightness in response to EHT.

at more affordable rents and prices. However, these positive, temporary effects can be overshadowed by compounding negative impacts in the longer term, as access to owner-occupied housing diminishes and homeownership affordability erodes.

This dynamic analysis highlights the importance of EHT exemption for frictional vacancies. With less-than-full exemption, an EHT reduces frictional vacancies in the long run, which increases the price premium and prolongs time-to-buy, thereby exacerbating the hous-



(a) frictional vacancies **(b)** speculative vacancies

(c) sales in frictional market **(d)** housing supply

Figure 16: Equilibrium vacancies, sales and housing supply in response to EHT.

ing shortage and reducing affordability in the owner-occupied market. These adverse effects on the owner-occupied market rationalize the new exemption established in 2023 (retroactive to 2022) for "vacant new inventory." Residential properties that are unoccupied for more than six months during the vacancy reference period are no longer subject to Vancouver's EHT if the property was either listed for sale throughout the vacancy reference period or newly constructed. This new exemption appears to be specifically designed to address the disincentives created by the EHT to building homes in Vancouver and listing them for sale

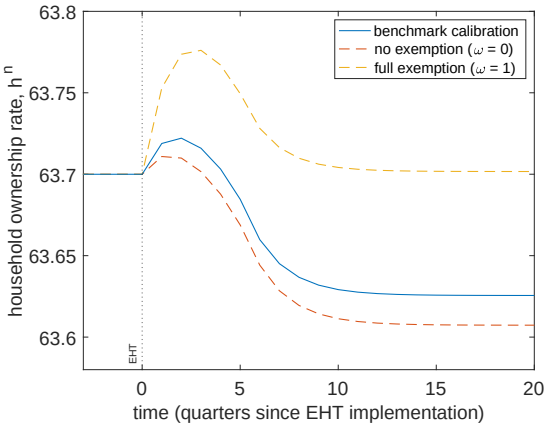


Figure 17: Equilibrium homeownership rate in response to EHT.

(Steacy, 2023).

8 Conclusion

This paper estimates the dynamic responses of Vancouver's housing market to the implementation of an empty homes tax (EHT). Our analysis of transaction-level data reveals a sharp short-run decline in both prices and rents, followed by a longer-term reversal in prices, though not in rents. These dynamics are accompanied by increases in sales, listings, and time-on-the-market in the short run, with a reversal of these trends in the longer run. Therefore, while the EHT initially achieves the desired objective of improving housing availability and affordability, its effects diminish over time in the owner-occupied sector but persist in the rental sector.

To explain these patterns, we develop a model that captures the novel effects of an EHT on the rental market, the owner-occupied market, and new housing construction. The model offers two key insights: first, an EHT converts speculative vacancies into more affordable tenanted rentals, improving housing availability and affordability. Second, the tax can

discourage the supply homes to the owner-occupied market, potentially worsening housing affordability and reducing homeownership.

Our calibrated version of the model qualitatively aligns with the empirical findings. The distinction between speculative and frictional vacancies is key to understanding the patterns observed in the data. The initial increase in listings and sales, along with declines in prices and rents, reflects an excess supply of housing as speculative vacancies return to the market. In contrast, the longer-term reversal of the trends in listings, sales, time-on-the-market, and prices is driven by the EHT's disincentive effects on the supply of frictional vacancies.

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A Housing Characteristics Composition Across Border and After EHT Policy

To test if the composition of housing characteristics is different during the EHT period, we run the following regression:

$$y_{jt} = \alpha + \beta_1 \tau_{jt}^{EHT} + X_{jt}\beta + \mu_{jt} \tag{A.1}$$

The dependent variable is y_{jt}, a characteristic of the property j at time t. The characteristics considered are the number of bedrooms, bathrooms, floor area, age of the property, and view.The main explanatory variable is τ_{jt}^{EHT}, a dummy if the property is in the EHT period in the city of Vancouver. The regressions are at the transaction level. This regression includes year/month fixed effects and neighborhood fixed effects.

The table below shows the results of the above regression in columns (1) and (2) for all outcome characteristics. The majority of the housing characteristics show a nonsignificant or very small coefficient. Only the age of the property shows a significant coefficient, suggesting that the age of the properties sold in the city of Vancouver after June 2016, is 2.6 % lower than the age of the properties sold in the suburbs. Similarly, properties transacted on Vancouver after June 2016, seems to be 3.8 % more likely to have a view than properties in the suburbs. Both of this characteristics are non significant when we extend the sample to more neighborhoods.

Overall, the mostly non-significant differences means that the composition of housing characteristics is not different during the EHT period. The implication is that the way in which characteristics were different between the city and the suburbs (columns 1 and 2) did not change. The regressions serve as evidence that the housing composition in the neighborhoods where the policy was implemented is not different from the housing composition

in the suburbs in the period the policy was implemented.

Table 4: Housing characteristics composition in the neighborhoods affectd by the EHT

	(1)	(2)
Number Bedrooms	0.00459	0.00694
	(0.0190)	(0.0110)
Number Bathrooms	0.00920	-0.0128
	(0.0154)	(0.00951)
Log Floor Area	-0.00526	-0.00258
	(0.00450)	(0.00316)
Log Property Age Sold	-0.0263**	-0.0175
	(0.0101)	(0.0110)
View	0.0382**	-0.000988
	(0.0137)	(0.00724)
Observations	16767	55090
Border threshold	border	ALL
Period EHT	ALL	ALL

Notes: Data comprise all residential property transactions from January 2014 to December 2018. The unit of observation is a transaction. The coefficients are estimates of a property characteristic on the EHT dummy that indicates that the location is Vancouver and occurred posterior to the EHT imposition. All regressions control for the property characteristics (other than the dependent variable), year/ month, and property type fixed effect. Regressions in column (1) includes zip code fixed effects, while regressions with the larger whole sample includes column (2) include neighborhood (FSA) fixed effects, though the results are similar with zip code fixed effects. The border threshold indicates if the property is in the neighborhoods closer to the border. Period EHT denotes whether the transaction occurred prior to or after the imposition of the EHT. Standard errors are in parentheses and *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

B Sales and Listings Dynamic Difference-in-Difference

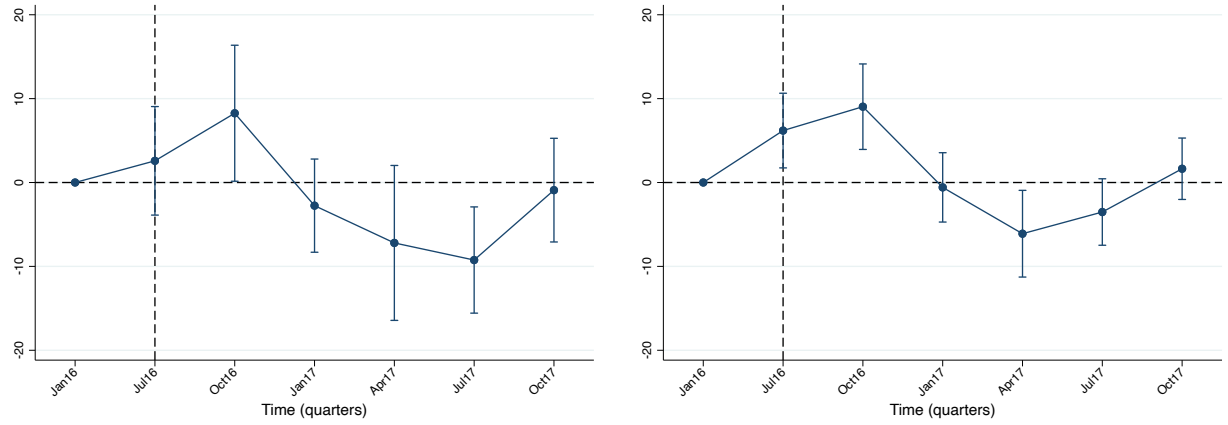
As robustness test, we try for sales and listings an alternative specification. Unlike house price growth, which exhibit positive autocorrelation in the short run and mean reversion in the long run (Glaeser and Gyourko, 2016), sales and listings can be estimated using a more common approach such as difference-in-difference estimation. We estimate the effects of the EHT on the number of sales and listings with the following specification:

$$Y_{jt} = \sum_{h} \beta_h \times \mathrm{D}_{th} \times \mathrm{Van}_j + \gamma x_{jt} + \alpha_j + \beta_t + \epsilon_{jt} \tag{B.1}$$

where the outcome variable, Y_{jt}, is the number of listings or sales in neighbhood j in month t. D_{th} is a dummy variable equaling one if month t is h periods after the period in which the EHT was first introduced (and zero otherwise). The jurisdiction is indicated by Van_j and takes on a value of one for homes within Vancouver city limits (and zero otherwise). x_{jt} are time-varying neighborhood characteristics, α_j is the fixed effect of neighborhood j, and β_t is the year/month fixed effect.We further include neighborhood fixed effects control for the time-invariant neighborhood conditions; property type $\times$ month fixed effects to control for any differences in the listings/sales between cities that are driven by differential trends in preference for a particular type of home; and city $\times$ month fixed effects to account for differential seasonality trends across different cities.

The coefficient of interest, τ_h, reflects the dynamic differences-in-differences in the number of listings and sales inside Vancouver versus outside of the city limits, before versus after the introduction of the EHT. Given the flexible combination of fixed effects and the rich set of controls, the identification of τ_h comes from comparing post-EHT changes in sales and listings for the same type of home on one side of the city border relative to the other side, controlling for differential trends, neighborhood conditions, housing compositions, property-type-specific and city-specific seasonalities.

Figure 18a plots the dynamic coefficients of interest, β_h, from the difference-in-differences regression with the number of sales as the outcome variable when the sample is restricted to neighborhoods adjacent to the city border. In the first quarter following the announcement of the EHT (Oct-Dec 2016), the difference between the number of sales per month in an average Vancouver neighborhood and the average suburban neighborhood increased by 10 sales per month relative to the mean difference before the announcement.



(a) border sample **(b)** whole sample

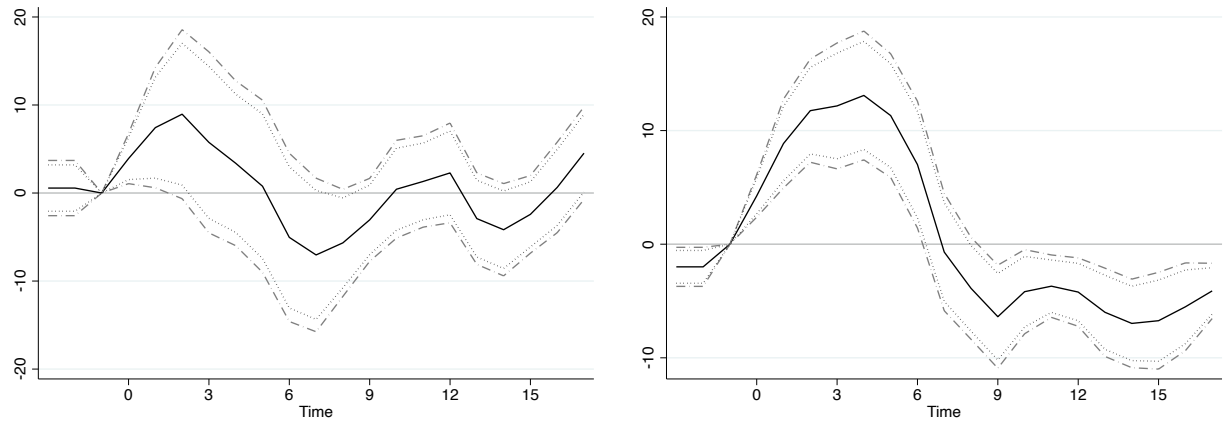
Figure 18: Average causal effects of EHT on number of sales.

Notes: The unit of observation is a market defined as an FSA/year/month. The vertical lines represent the policy-relevant events. The dots represent the coefficients of the average treatment effect at each period. Each regression includes neighborhood, vacancy rate quartiles, and year/month fixed effects. The standard errors are clustered in two ways: by FSA and by month period. The omitted pretrend period is comprised of the two quarters before the announcement.

The number of active listings in the average Vancouver neighborhood adjacent to the border increased by 10 per month relative to the average suburban neighborhood in the quarter after the EHT announcement. This increase was followed by a decline in active listings that lasted about a year.

C Robustness Checks on Definition of Listings

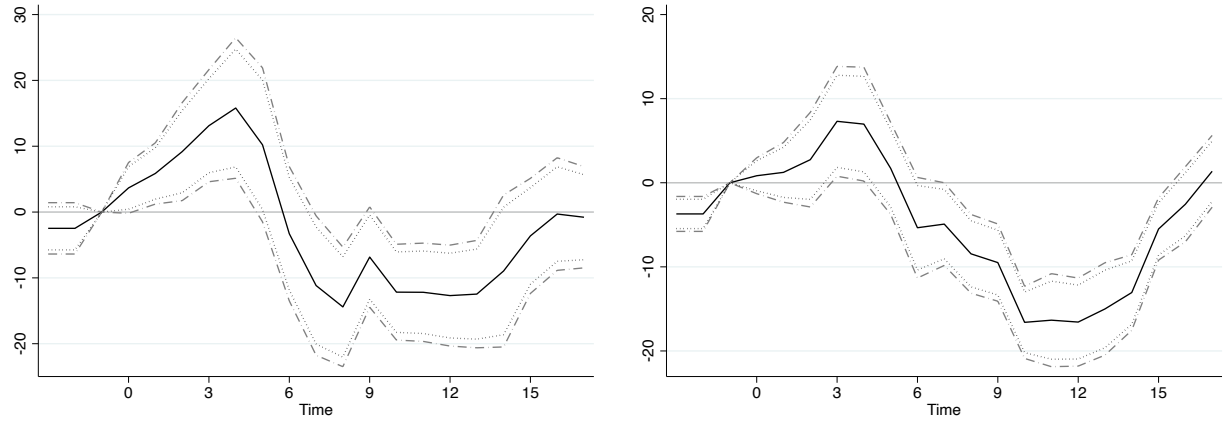
This section performs robustness checks on the definition of listings. We consider two definitions of listings: (1) the total number of listings in the market at a given time (existing listings); and (2) the number of new listings. A listing is counted as existing if it was listed before the beginning of period t and is yet to be sold. The second definition is the number of new listings in the market at a given time. These two definitions sum to the total listings used in the main text. The results are presented in Figure 19 and Figure 20 for the border sample and the whole sample respectively. The results are robust to the definition of listings. The results for the total number of active listings follow the predictions of the model and are consistent with the results in the main text.



(a) border sample **(b)** whole sample

Figure 19: Average causal effects of EHT on number of existing listings.

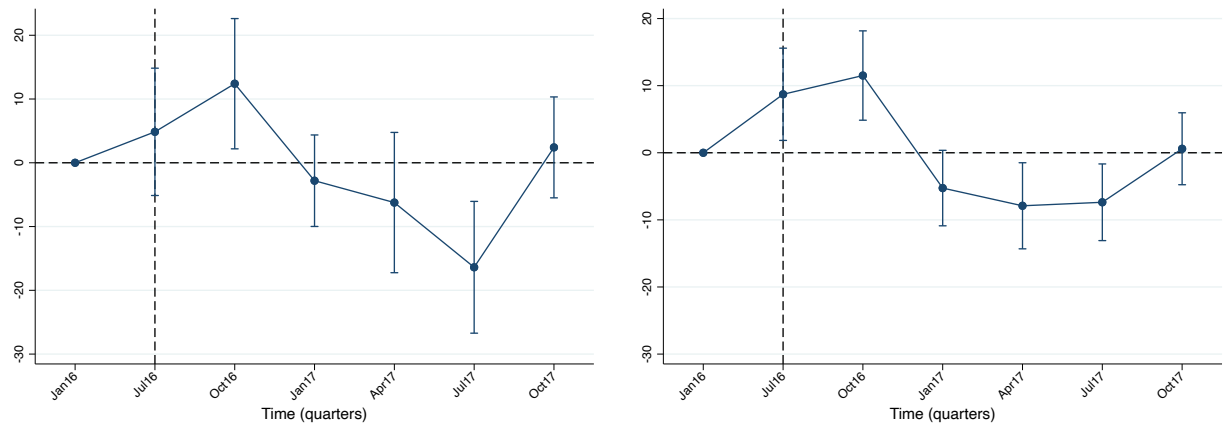
Notes: The figure shows the coefficient of estimating the impulse response equation at each horizon. All regressions control for average property characteristics, FSA FE and year-month FE. The treatment month is June of 2016. The standard errors are clustered by year/month periods. The dotted lines are 95% and 90% CI.



(a) border sample **(b)** whole sample

Figure 20: Average causal effects of EHT on new listings.

Notes: The figure shows the coefficient of estimating the impulse response equation at each horizon. All regressions control for average property characteristics, FSA FE and year-month FE. The treatment month is June of 2016. The standard errors are clustered by year/month periods. The dotted lines are 95% and 90% CI.

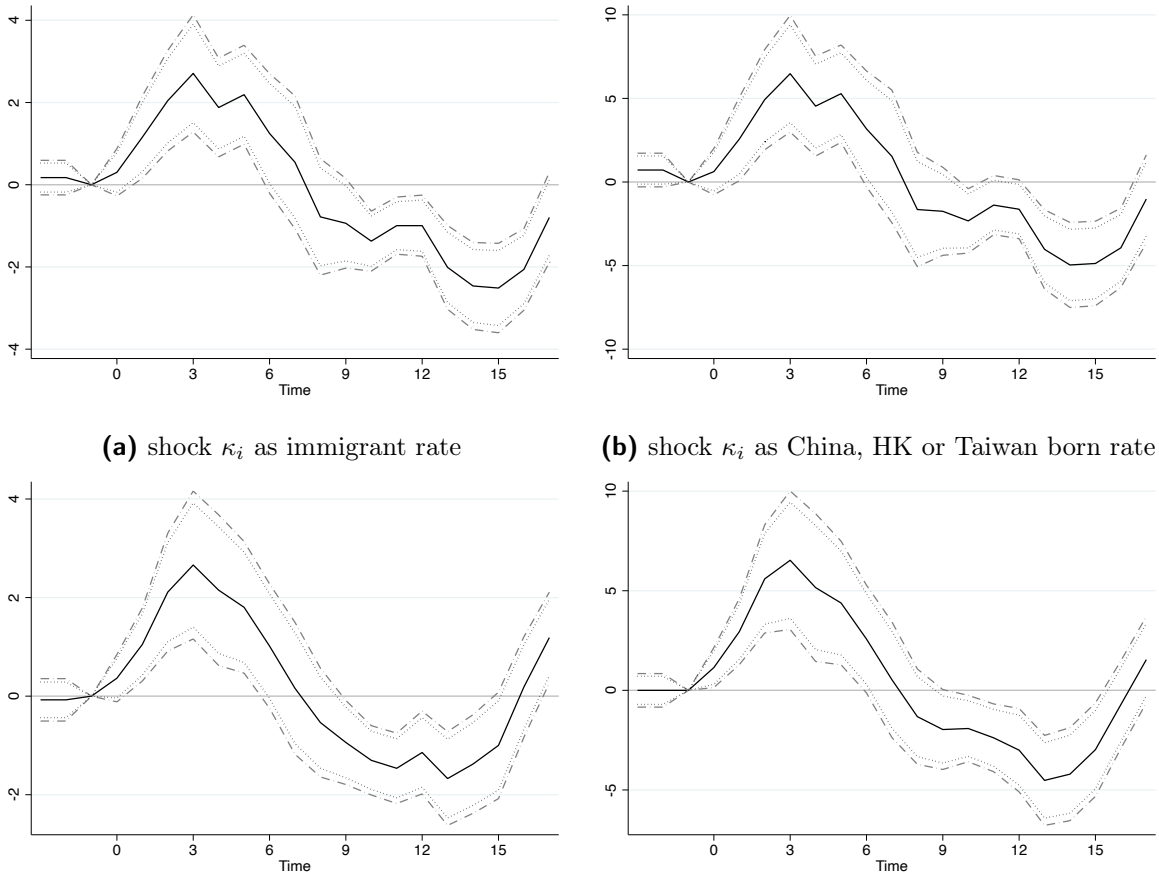


(a) border sample **(b)** whole sample

Figure 21: Average causal effects of EHT on number of listing.

Notes: The unit of observation is a market defined as an FSA/year/month. The vertical lines represent the policy-relevant events. The dots represent the coefficients of the average treatment effect at each period. Each regression includes neighborhood, vacancy rate quartiles, and year/month fixed effects. The standard errors are clustered in two ways: by FSA and by month period. The omitted pretrend period is comprised of the two quarters before the announcement.

D Robustness Checks on Exposure Variables



(a) shock κ_i as immigrant rate

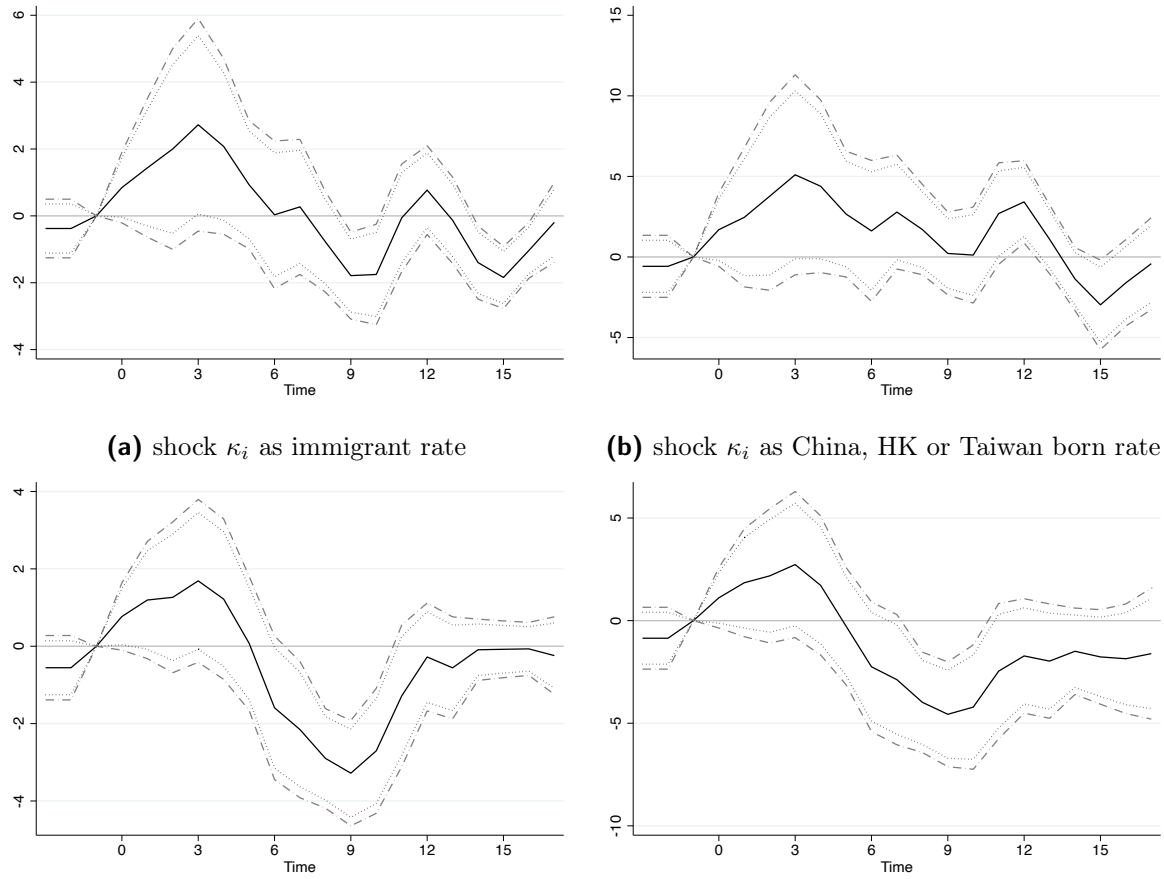
(b) shock κ_i as China, HK or Taiwan born rate

(c) shock κ_i as immigrant rate

(d) shock κ_i as China, HK or Taiwan born rate

Figure 22: Robustness Checks: Average causal effects of EHT on sales

Notes: The figure shows the coefficient of estimating the impulse response equation at each horizon. Panels (a) and (b) correspond to the border sample, while panels (c) and (d) to the whole sample. The local exposure κ_i is normalized by its standard deviation. All regressions control for average property characteristics, FSA FE and year-month FE. The standard errors are clustered by year/month periods. The dotted lines are 95% and 90% CI.



(a) shock κ_i as immigrant rate

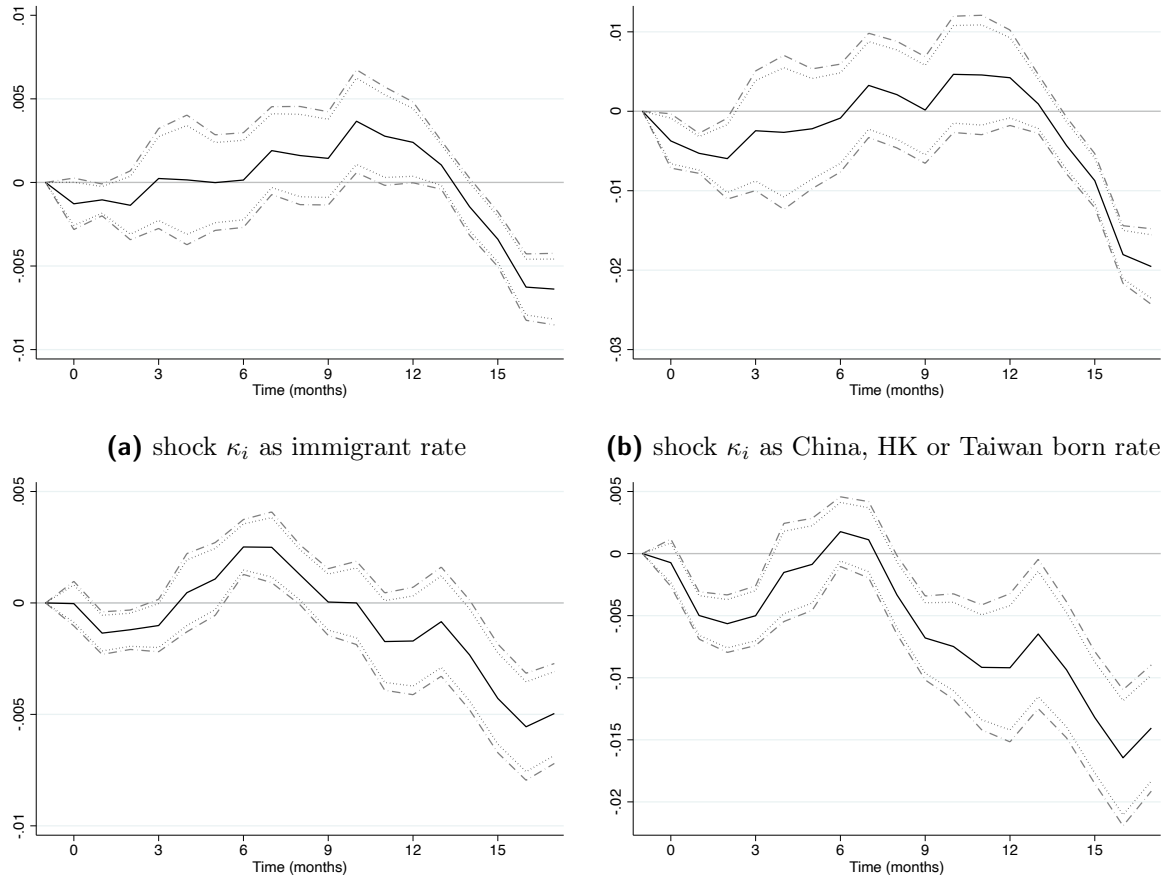
(b) shock κ_i as China, HK or Taiwan born rate

(c) shock κ_i as immigrant rate

(d) shock κ_i as China, HK or Taiwan born rate

Figure 23: Robustness Checks: Average causal effects of EHT on listings

Notes: The figure shows the coefficient of estimating the impulse response equation at each horizon. Panels (a) and (b) correspond to the border sample, while panels (c) and (d) to the whole sample. The local exposure κ_i is normalized by its standard deviation. All regressions control for average property characteristics, FSA FE and year-month FE. The standard errors are clustered by year/month periods. The dotted lines are 95% and 90% CI.



(a) shock κ_i as immigrant rate

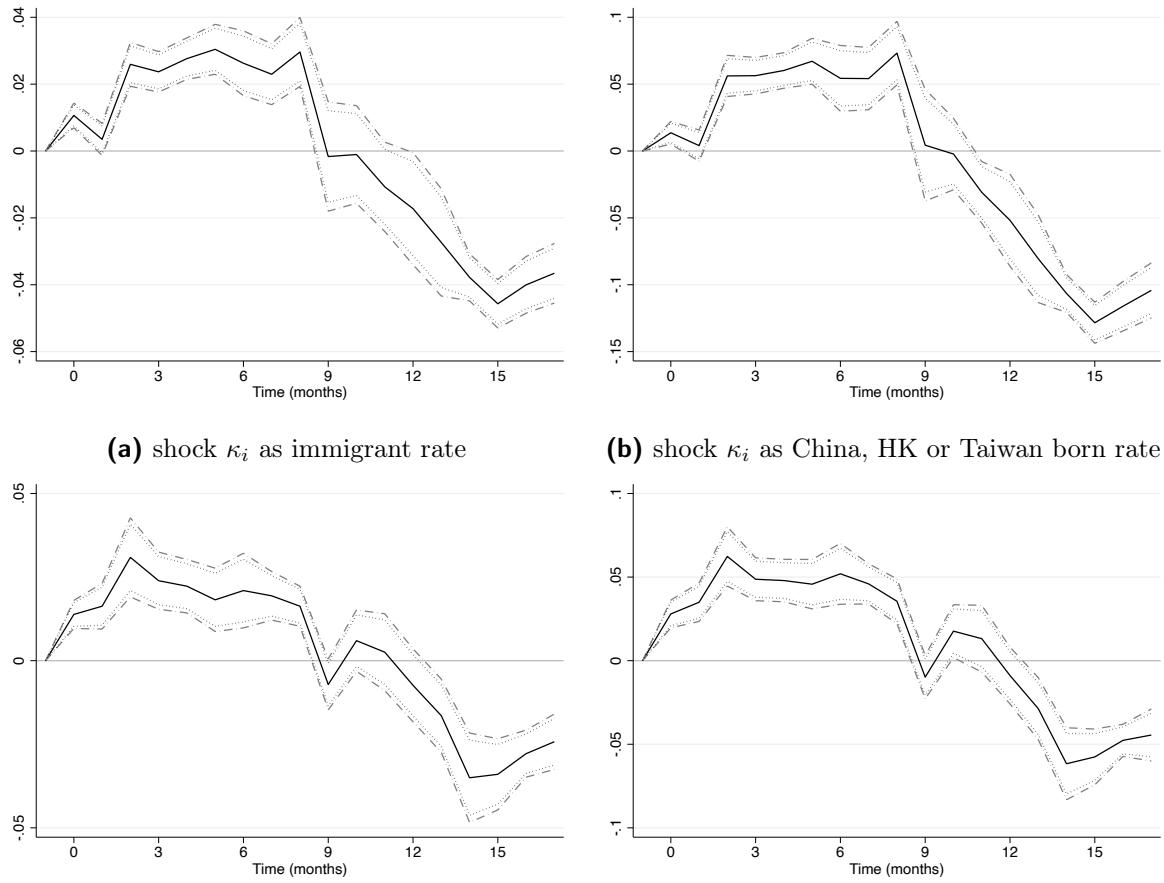
(b) shock κ_i as China, HK or Taiwan born rate

(c) shock κ_i as immigrant rate

(d) shock κ_i as China, HK or Taiwan born rate

Figure 24: Robustness Checks: Average causal effects of EHT on prices

Notes: The figure shows the coefficient of estimating the impulse response equation at each horizon. Panels (a) and (b) correspond to the border sample, while panels (c) and (d) to the whole sample. The local exposure κ_i is normalized by its standard deviation. All regressions control for average property characteristics, FSA FE and year-month FE. The standard errors are clustered by year/month periods.
The dotted lines are 95% and 90% CI.



(a) shock κ_i as immigrant rate

(b) shock κ_i as China, HK or Taiwan born rate

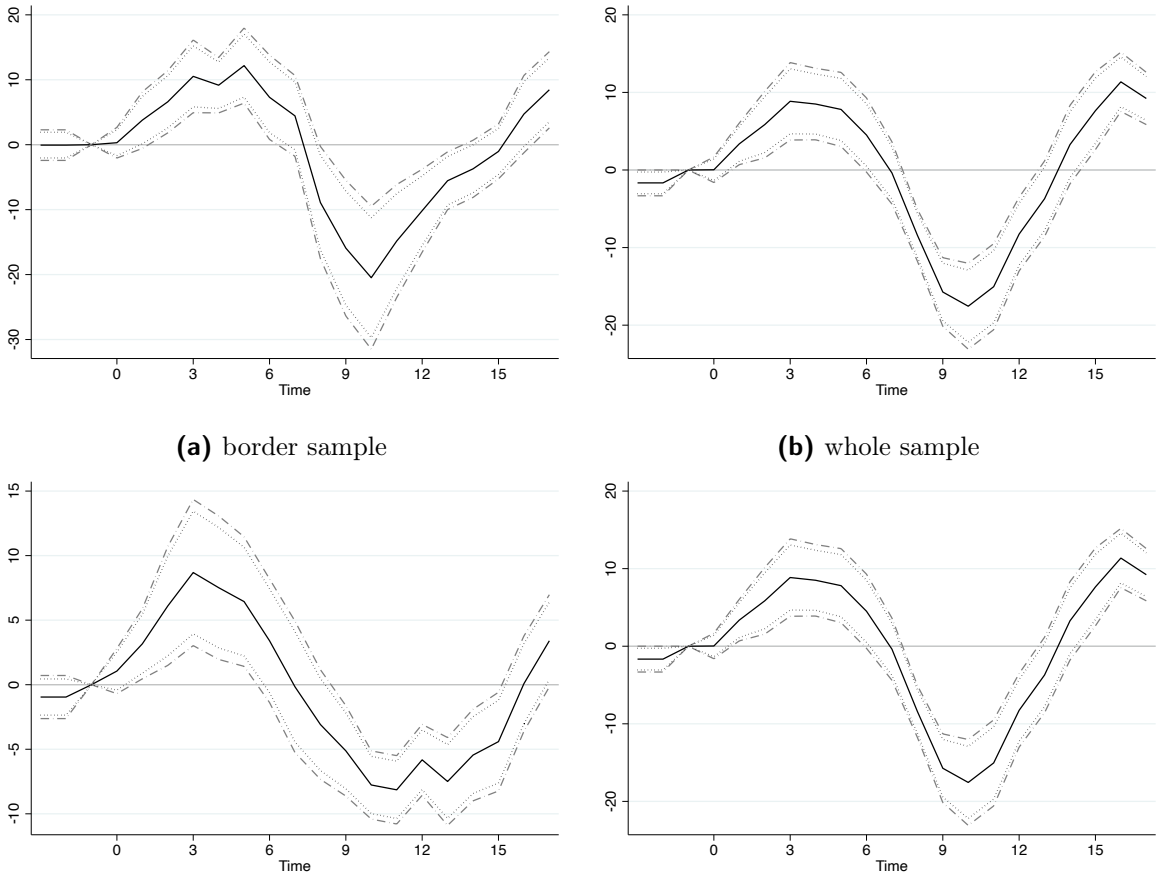
(c) shock κ_i as immigrant rate

(d) shock κ_i as China, HK or Taiwan born rate

Figure 25: Robustness Checks: Average causal effects of EHT on DOM

Notes: The figure shows the coefficient of estimating the impulse response equation at each horizon. Panels (a) and (b) correspond to the border sample, while panels (c) and (d) to the whole sample. The local exposure κ_i is normalized by its standard deviation. All regressions control for average property characteristics, FSA FE and year-month FE. The standard errors are clustered by year/month periods.
The dotted lines are 95% and 90% CI.

E Spillovers and Anticipation Robustness Checks



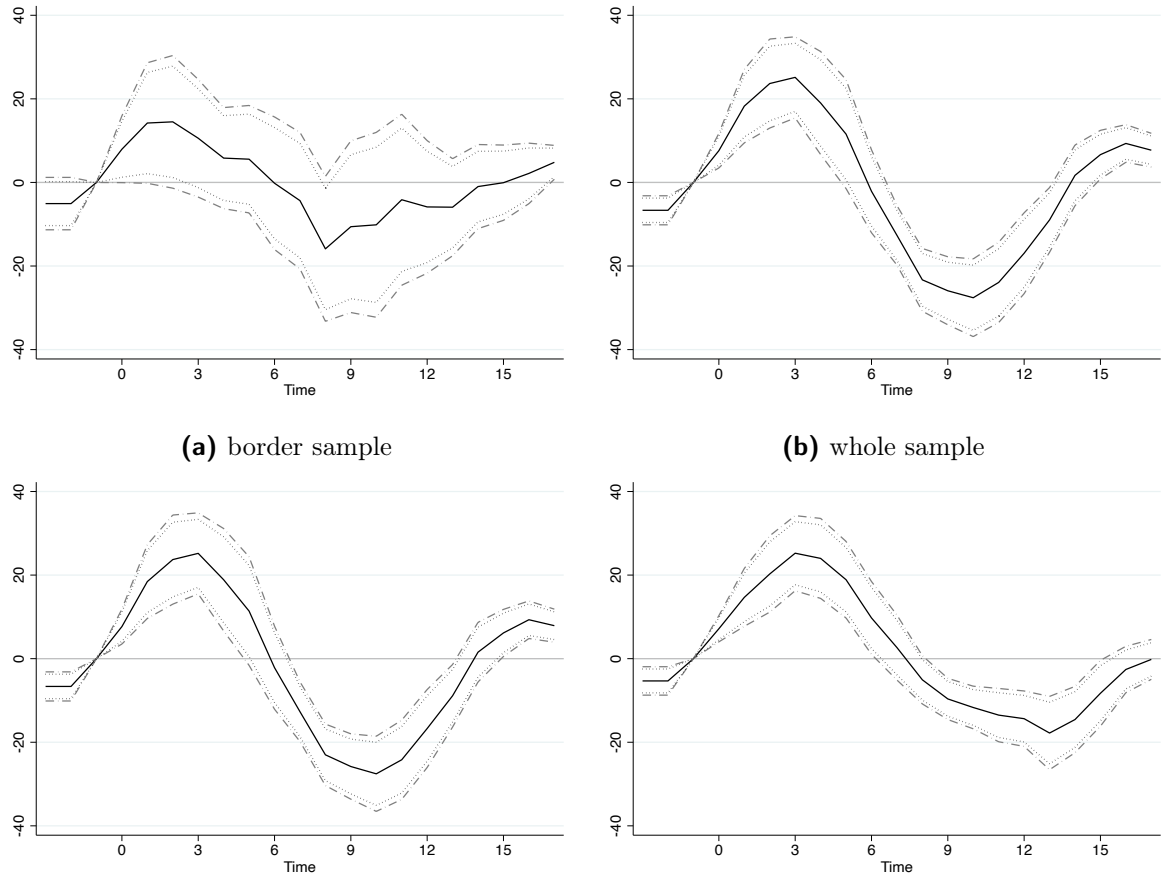
(a) border sample

(b) whole sample

(c) non-border sample and all periods

(d) non-border sample

Figure 26: Anticipation period Jan 2016- May 2016 removed for number of sales.
Notes: The figure shows the coefficient of estimating the impulse response equation at each horizon. All regressions control for average property characteristics, FSA FE and year-month FE. The treatment month is June of 2016. The standard errors are clustered by year/month periods. The dotted lines are 95% and 90% CI.



(a) border sample

(b) whole sample

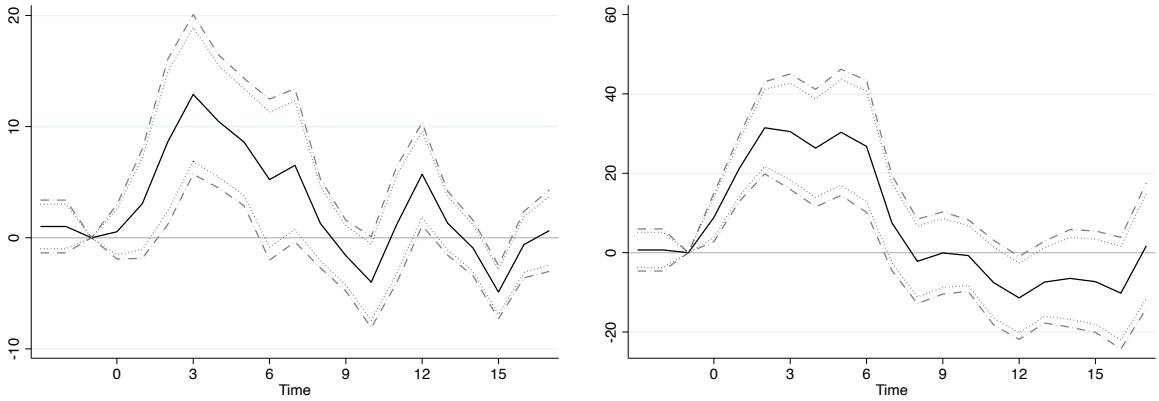
(c) non-border sample and all periods

(d) non-border sample

Figure 27: Anticipation period Jan 2016- May 2016 removed for number of listings.
Notes: The figure shows the coefficient of estimating the impulse response equation at each horizon. All regressions control for average property characteristics, FSA FE and year-month FE. The treatment month is June of 2016. The standard errors are clustered by year/month periods. The dotted lines are 95% and 90% CI.

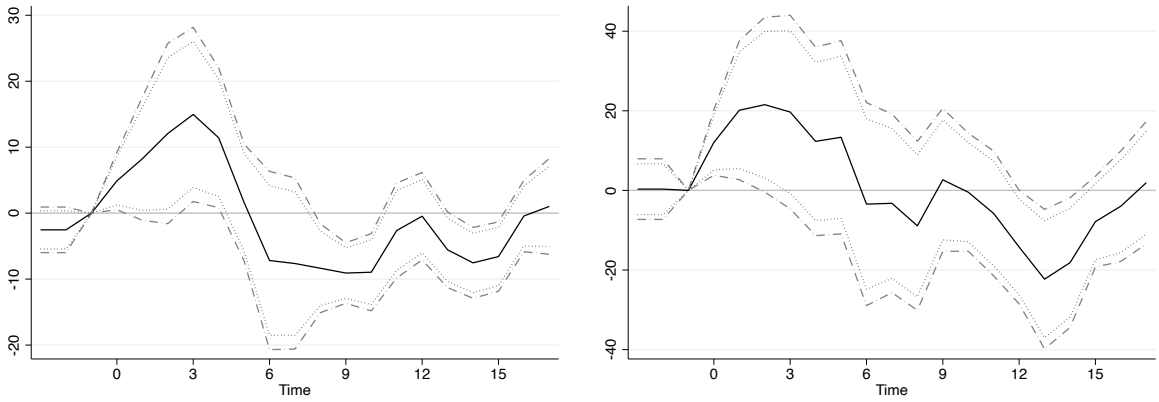
F Robustness Checks on Definition on Border Sample

This section performs robustness checks on the subsample included in the boundary design. We consider two alternative border samples: (1) the FSAs in the Burnaby/Vancouver boundary; and (2) the FSAs in the Richmond/Vancouver boundary. The Burnaby/Vancouver boundary provides a cleaner border, as it is not affected by the presence of a river and industrial areas North-West of Richmond.



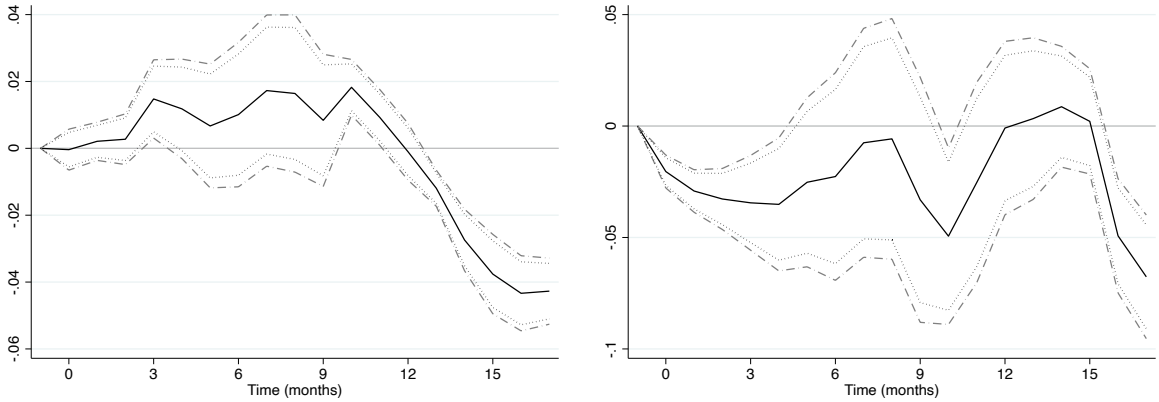
(a) Burnaby/Vancouver **(b)** Richmond/Vancouver

Figure 28: Average causal effects of EHT on sales for alternative border samples



(a) Burnaby/Vancouver **(b)** Richmond/Vancouver

Figure 29: Average causal effects of EHT on listings for alternative border samples



(a) Burnaby/Vancouver **(b)** Richmond/Vancouver

Figure 30: Average causal effects of EHT on prices for alternative border samples

G Equilibrium Balanced Growth Path

Along a balanced growth path (BGP) with population growth and hence new housing construction, house values and rental costs are constant. Conditions (14), (12), and (21) become

$$V = q(h) \tag{G.1}$$

$$x = (1-\beta)q(h) + m \tag{G.2}$$

$$\kappa = (1+\tau-\beta)q(h). \tag{G.3}$$

Equation (G.1) ties the value of a vacant house to the cost of construction. Equations (G.2) and (G.3) then pin down the rental cost of a housing unit, and the user cost of an empty home.

We can write stationary versions of Bellman equations (15), (16), and (17), and of the price equation (19):

$$(1-\beta)V^r = y - x + \beta\psi\left[V^b - V^r\right] \tag{G.4}$$

$$(1-\beta)V^b = y - x + \beta \max_P \lambda(\theta(P))\left[V^n - V^b - P\right] \tag{G.5}$$

$$(1-\beta)V^n = y - m + z - \beta\delta\left[V^n - V^b - V\right], \tag{G.6}$$

$$P = \eta(\theta)V + (1-\eta(\theta))[V^n - V^b]. \tag{G.7}$$

Solving this system yields the following price equation:

$$P = V + \frac{1-\eta(\theta)}{1-\beta(1-\delta-\eta(\theta)\lambda(\theta))}z. \tag{G.8}$$

By combining this price equation with (G.1), (G.3), and the stationary version of (18), we obtain an equilibrium condition that equates the user cost of a frictional vacancy with the

expected discounted equilibrium price premium in the owner-occupied market:

$$[1 + (1 - \omega)\tau - \beta]q(h) = \frac{\beta\gamma(\theta)[1 - \eta(\theta)]}{1 - \beta(1 - \delta - \eta(\theta)\lambda(\theta))}z. \tag{G.9}$$

Imposing stationarity in (22), (23), (24), (26), (25) and yields

$$h^r = \frac{\nu}{\nu + \psi} \tag{G.10}$$

$$h^b = \frac{\psi(\nu + \delta)}{(\nu + \psi)\left[\nu + \delta + \lambda(\theta)\right]} \tag{G.11}$$

$$h^n = \frac{\psi\lambda(\theta)}{(\nu + \psi)\left[\nu + \delta + \lambda(\theta)\right]} \tag{G.12}$$

$$h^f = \frac{h^b}{\theta} \tag{G.13}$$

$$h^s = \phi[1 - F(\kappa)][1 - G(\kappa)]. \tag{G.14}$$

Finally, the stationary version of the aggregation condition (27) is

$$h = h^r + h^b + h^n + h^f + h^s = 1 + h^f + h^s. \tag{G.15}$$

Definition 2 *An equilibrium balanced growth path is a house value, V, rent, x, and user cost, κ; a price P and a market tightness, θ; a housing stock, h; and a distribution of houses/households, $\{h^r, h^b, h^n, h^f, h^s\}$; such that*

(i) free entry in the rental and wholesale markets: x and κ satisfy (G.2) *and* (G.3)*;*

(ii) directed search: P and θ satisfy (G.8) *and* (G.9)*;*

(iii) stationary distribution of houses/households: h^r, h^b, h^n, h^f and h^s satisfy (G.10), (G.11), (G.12), (G.13), *and* (G.14)*;*

(iv) free entry into housing development: V and h satisfy (G.1) *and* (G.15).

H Constrained Efficiency

While the housing affordability and availability implications of the EHT are of interest and policy-relevant, the model also offers valuable insights into welfare implications and optimal EHT policy considerations. In this section, we consider the optimal allocation of a constrained social planner that maximizes the total surplus generated from the construction and allocation of housing to households and investors. The social planner is *constrained* in the sense that they are subject to the same searching-and-matching frictions in the owner-occupied market as households and developers.

From the social planner's perspective, an investor should own a house if it yields positive net financial gain. For example, an investor with $\pi_t - \varepsilon \geq 0$ achieves positive financial surplus in period t as an investor-landlord. The social planner can bestow this surplus by simply allocating the ownership of a rented house to such an investor. Allocating speculative vacancies to investors, in contrast, affects the cost of new housing construction (when $\zeta_1 > 0$) by increasing the total stock of housing. It may be socially desirable to restrict speculative vacancies, except perhaps among investors with a sufficiently high financial gain that it offsets the social cost, net of any forgone surplus as an investor-landlord:

$$\pi_t - \max\{0, \pi_t - \varepsilon\} \geq \hat{\kappa}_t. \tag{H.1}$$

It follows from (H.1) that investors with empty homes at time t are those with $\pi_t \geq \hat{\kappa}_t$ and $\varepsilon \geq \hat{\kappa}_t$, where threshold $\hat{\kappa}_t$ is a choice variable of the social planner reflecting the social cost of a speculative vacancy.

Given threshold $\hat{\kappa}_t$, the average financial gain generated from investment in housing is given by

$$u^i(\hat{\kappa}_t) = \int_{-\infty}^{\hat{\kappa}_t} \int_{\varepsilon}^{\infty} \pi - \varepsilon \, dF(\pi) \, dG(\varepsilon) + [1 - G(\hat{\kappa}_t)] \int_{\hat{\kappa}_t}^{\infty} \pi \, dF(\pi). \tag{H.2}$$

The expression in (H.2) captures the financial surplus of the *representative investor*. The first term reflects the financial gains enjoyed by investor-landlords, and the second term reflects the financial payoffs accruing to speculative investors.

The constrained planner's problem is to choose an allocation of housing across households and investors,

$$\{H_t^r, H_t^b, H_t^n, H_t^f, H_t^s(\hat{\kappa}_t)\}_{t=0}^{\infty},$$

to maximize the present discounted value of the social surplus derived from housing ownership and investment net of construction costs,

$$\sum_{t=0}^{\infty} \beta^t \Big\{ H_t^n z + \phi L_t u^i(\hat{\kappa}_t) - q(H_t(\hat{\kappa}_t)/L_t) \left[H_t(\hat{\kappa}_t) - H_{t-1}(\hat{\kappa}_{t-1}) \right] \Big\},$$

subject to the laws of motion and aggregation conditions that govern distributions of households and housing. The recursive per capita formulation of the constrained social planner's problem is

$$\begin{aligned} W(h_t^b, h_t^n, h_{t-1}^f, \hat{\kappa}_{t-1}) = \max_{h_t^f, \hat{\kappa}_t} \Bigg\{ & h_t^n z + \phi u^i(\hat{\kappa}_t) \\ & - q(1 + h_t^f + h^s(\hat{\kappa}_t)) \left[\frac{(1+\nu)[1 + h_t^f + h^s(\hat{\kappa}_t)] - [1 + h_{t-1}^f + h^s(\hat{\kappa}_{t-1})]}{1+\nu} \right] \\ & + \beta(1+\nu) W(h_{t+1}^b, h_{t+1}^n, h_t^f, \hat{\kappa}_t) \Bigg\} \end{aligned}$$

subject to (23), (24), (25), and (26).

A stationary constrained efficient allocation satisfies the stationary versions of two in-

tertemporal Euler equations derived from the constrained planner's problem,

$$\left[1-\beta+\frac{\nu}{1+\nu}\frac{hq'(h)}{q(h)}\right]q(h)=\frac{\beta\gamma(\theta)[1-\eta(\theta)]}{1-\beta\left[1-\delta-\lambda(\theta)\eta(\theta)\right]}z \tag{H.3}$$

$$\text{and}\quad \left[1-\beta+\frac{\nu}{1+\nu}\frac{hq'(h)}{q(h)}\right]q(h)=\hat{\kappa}, \tag{H.4}$$

along with equations that characterize a stationary distribution of houses/households: (G.10), (G.11), (G.12), (G.13), (G.14), and (G.15). Condition (H.3) equates the social flow cost of constructing an additional frictional vacancy with the expected social flow benefit it will generate through the utility derived from homeownership. The elasticity of the housing construction cost with respect to the relative housing supply times fraction of the new total housing stock attributable to balanced growth appears on the left-hand side. This *construction cost externality* reflects the rising cost of expanding the residential land supply, and can be interpreted as the impact of housing density relative to available land. Meanwhile, the *congestion externality* on the right-hand side of condition (H.3) represents the discounted value of homeownership as a result of the search-and-matching process in a frictional market; it is the extent to which prospective buyers will capture the homeownership utility premium given the relative scarcity of listings. Condition (H.4) then equates the social flow cost of an additional speculative vacancy with that of a frictional vacancy.

Recall that the directed search equilibrium condition along an equilibrium BGP is (G.9), and the optimal cut-off for investor participation as a speculator, κ, satisfies (G.3). An equilibrium allocation along a BGP satisfies these two conditions, along with the equations that characterize a stationary distribution of houses/households: (G.10), (G.11), (G.12), (G.13), (G.14), and (G.15). It follows that the allocation along an equilibrium BGP coincides with the stationary constrained efficient allocation if

$$\tau^*=\frac{\nu}{1+\nu}\frac{hq'(h)}{q(h)}\quad\text{and}\quad\omega^*=0. \tag{H.5}$$

The optimal tax rate equals the elasticity of the housing construction cost with respect to the relative housing supply, multiplied by the fraction of the new total housing stock attributable to balanced growth. For speculative vacancies, this tax rate compels investors to internalize the construction cost externality, aligning their private user cost with the social cost of adding to the housing supply.

The optimal tax applies equally to both frictional and speculative vacancies. This symmetry is efficient because both types of vacancies contribute to the total housing stock, thereby increasing construction costs (when $q'(h) > 0$) that translate into higher prices and rents. In the directed search equilibrium, the congestion externality in the owner-occupied market is already internalized. By imposing an EHT rate of τ^*, policymakers compel developers, sellers, and investors to account for the full social cost of increasing the city's housing supply. Without the EHT, owners of both frictional and speculative vacancies would neglect the broader impact of their decisions on the cost of expanding residential land availability.