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

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Abstract

Using individual housing transactions data from Vancouver, this paper estimates the impacts of a recent empty homes tax. Our analysis reveals short-run effects, including sharp declines in both house prices and rents, accompanied by an increase in sales, listings, and time-on-the-market. Interestingly, a reversal of nearly all of these short-run effects follows in the long run, with the exception of the persistent drop in rent. The paper explains these novel facts by developing a model with owner-occupied homes, tenanted rental units, and empty houses. Housing units are constructed by competitive developers and supplied to local households for consumption and to investors as a store of wealth. Empty homes held by investors are classified as *speculative* vacancies. *Frictional* vacancies, on the other hand, are the equilibrium result of search-and-matching frictions in the owner-occupied market. A tax on empty homes can improve housing availability and affordability in the rental market by reducing speculative vacancies, but distort the incentives to supply vacant homes for sale in the owner-occupied market (i.e., frictional vacancies), thereby increasing house prices and lowering homeownership in the long run.

JEL classification: D83, R21, R31, R38
Keywords: empty houses, taxation, housing affordability, search frictions

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1 Introduction

Vacant homes have become increasingly common despite global housing affordability challenges. Residential vacancy rates reached 12.5% in the U.S., 10% in Europe, 20% in Mediterranean countries at the peak of the housing market in 2005–2006, and 22.4% in China in 2014. The fact that these high vacancy rates were accompanied by rising house prices and limited housing availability represents a puzzle in the face of the law of supply: the economic principle that higher house prices result in more houses supplied to the market, not in houses being hoarded and underused. To address this apparent paradox, a set of new policies have been proposed to reduce vacancy rates, ranging from empty homes taxes to eviction bans. We focus on the empty home tax: a policy that has gained popularity and raised substantial revenues in many superstar cities, including London (1993), Paris (1998), Washington D.C. (2003), Jerusalem (2016), Vancouver (2016), Oakland (2018), Taiwan (2022), Sacramento (2022), Toronto (2023), San Francisco (2024) and Japan (2026). These vacant home tax policies were designed to improve housing availability and hence affordability by returning unused houses to the market. This study endeavors to assess the effectiveness of an empty homes tax in achieving these desired outcomes through a combination of empirical analyses and theoretical insights.

Focusing on an Empty Homes Tax (hereinafter, "EHT") recently introduced in the city of Vancouver, this paper makes two contributions to the literature. Empirically, it provides the first casual estimates of the dynamic effects of the EHT on a set of housing market outcomes, including sales, listings, price, time-on-the-market, rents and vacancies. We find that the EHT increases the sales and listings and time-on-the-market, reduces sales price in the short run, but these trends reverse in the long run. On the other hand, the same EHT results in a sustained decrease in rent. Armed with the insights from these novel findings, theoretically, the paper develops a model of housing with a frictional owner-occupied market and a competitive rental market with competitive developers and free entry of investors subject to search frictions. The model is calibrated to match the pre-tax housing market in Vancouver. The quantitative match between the model's predictions of the EHT and those untargeted empirical findings suggests that the model is suitable for quantifying the welfare consequences of the Empty Home Tax.

The Vancouver Empty Homes Tax is a yearly tax applied to any homes or properties in the city of Vancouver that are left unoccupied for more than six months in a given tax year.[1] The initial EHT was announced in 2016 and implemented in 2017. Owners were initially taxed 1 percent of their property's assessed taxable value each year that the home was deemed or declared vacant. The rate was then raised to 1.25 percent in 2020, and 3 percent in 2021. By way of comparison, the Vancouver property tax rate is less than 0.5 percent. Thus, the EHT adds up to a significant holding cost for vacant property owners.

To estimate the causal effects of the EHT on the housing market, we use a transaction-level dataset on housing sales from Multiple Listing Service records for the Greater Vancouver Regional District between 2014 and 2022 and focus on the initial launch of the EHT in 2017. Unlike subsequent tax rate increases, the first wave of the EHT was relatively 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 not long before other housing market policies (see Figure 1), including the foreign buyer tax (FBT) and the speculation and vacancy tax (SVT). The EHT applies to the city of Vancouver, whereas the FBT and the 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. Controlling

[1] All property owners in Vancouver are required to file a property status declaration for the previous calendar year by February 2nd every year. The status of a property can be 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 owners 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.

for a rich set of house attributes and neighborhood demographics, we find support for parallel pre-policy trends for the key outcomes of interest.

To account for housing market momentum (Glaeser et al., 2014), we use monthly neighborhood-level data to estimate the dynamic responses in a set of housing market outcomes – sales, listings, price, time-on-the-market, and rent – to the EHT announcement and implementation using a local projection approach (Jordà, 2005). Our baseline specifications control flexibly for time-varying neighborhood characteristics, local seasonality, city-specific time trends and flexible internal propagation dynamics. In the extended specifications, we further estimate the heterogeneous EHT effects across neighborhoods with different vacancy exposures, with an additional control of a neighborhood-specific impulse function in response to the subsequent metro-wide FBT. Compared with the baseline specification, the identification requirement is even weaker. We effectively consider only variations before and after the EHT across neighborhoods with different vacancy exposure that are "orthogonal" to the FBT's differential impacts across neighborhoods.

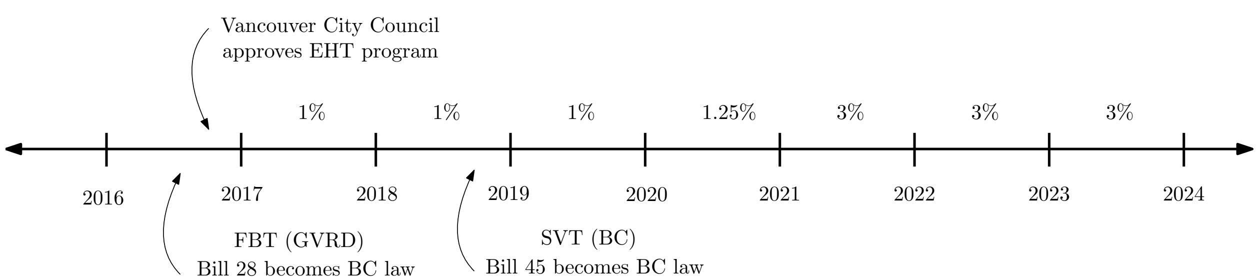


Figure 1: The Timing of Vancouver's EHT.

We find that a 1% EHT led to an increase of 14 monthly sales per neighborhood during the first quarter after the announcement of the policy; this effect declined gradually thereafter, reaching a trough in the fourth quarter after the EHT announcement when the number of monthly sales in an average Vancouver neighborhood reduced by 11 relative to the pre-EHT benchmark. The number of listings followed a similar pattern. Correspondingly, we also observe a sharp increase in the time-on-the-market shortly after the EHT announcement, followed by a decline in the longer run. Turning to the housing cost, the estimation reveals a sharp drop in both prices and rents in the short run, but a reversal in the longer-term for prices but not rents. In particularly, house price growth and rent growth declined by roughly 1% within the first year after the EHT announcement. While price growth subsequently climbed back up to the initial level, the decline in rent was more or less permanent.

These results are robust across samples and specifications, to alternative measurements of vacancy exposures, to excluding neighborhoods immediately adjacent to the border, to excluding 3 months before and after the annoucement of the EHT, as well as to heterogeneous neighborhood-level sensitivity to the subsequent FBT policy.

Together, these results point to a consistent pattern: while the EHT initially appears to achieve the desired objective of improving housing availability and affordability, its cumulative effects diminish over time in the owner-occupied sector but remain stable in the rental sector. The heterogeneous treatment effects of the long run EHT on price versus rents suggest the importance of considering flows of properties between owner-occupied and rental markets. The overshooting response in the short run indicates the presence of speculative investors. The estimated time-on-the-market effects further motivate us to consider for the role of search frictions in understanding how the EHT affects housing markets.

The paper then develops and calibrates a search model that incorporates economic forces highlighted by these new findings with the goal of better understanding empty homes taxes. We argue that a search-theoretic model of housing is most suitable for understanding the effects of the EHT because it rationalizes the simultaneous existence of equilibrium vacancies and excessive housing demand, which is the very issue the EHT seeks to address. More specifically, our theoretical analysis considers two types of vacancies: *frictional vacancies* and *speculative vacancies*. *Frictional vacancies* are a result of uncoordinated churning in a dynamic and diverse housing market (i.e., search-and-matching frictions akin to those modeled by Wheaton (1990). Frictionally vacant homes are temporarily empty either because homeowners are in transition from one housing unit to another, or because newly constructed or newly available homes have yet to be sold and occupied. Many unoccupied homes are in fact available for purchase or lease. In a frictional market, however, it takes time to sell a house, and some vacancies do not sell and are ultimately withdrawn from the market.[2] A certain amount of frictional vacancies are needed to ensure efficient turnover and appropriate pairing of homes with owner-occupiers.

Even in a setting without the time-consuming process of search-and-matching, however, empty homes could 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 for liquidity reasons (since a home that is empty is a more liquid asset), or for real option values (Cunningham, 2006). We call such vacancies *speculative vacancies*. Unlike frictional vacancies that are unavoidable due to the search-and-matching frictions in the market, speculative vacancies are deliberately left empty. In this case, by increasing investors' holding costs, an EHT provides an incentive to reallocate vacant homes to either the owner-occupied market or the rental market. This is consistent with what we observe in Vancouver in the short run.

While an EHT aims to reduce speculative vacancies, it may also discourage frictional vacancies. The decline in speculative vacancies in response to the introduction of an EHT represents a one-time increase in the supply of rental and/or owner-occupied housing units, which has the potential to improve housing availability in both rental and owner-occupied markets in the short run. A perpetual reduction in frictional vacancies, one the other hand, has the potential to increase prices and and prolong time-to-buy, thereby exacerbating the housing shortage and reducing affordability in the owner-occupied market in the long run.

[2]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. For instance, in a suburb of Washington DC (Fairfax County, VA), 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.

To formalize these insights, we study the housing market effects of a generic vacant home tax like the EHT in Vancouver by developing a city-level search-theoretic model of housing with the following features: (i) a growing population of households that consume goods and housing services; (ii) houses, constructed by competitive developers, that may be owned or rented; (iii) a competitive rental market and a frictional owner-occupied market; and, finally, (iv) non-resident investors that desire home-ownership for exogenous financial reasons, and not for the consumption of housing services. Empty homes owned by investors correspond to *speculative vacancies*. *Frictional vacancies*, on the other hand, are the equilibrium result of search-and-matching frictions in the owner-occupied market.

We characterize the dynamic equilibrium of the model to explore the housing market's short-run response to the announcement and implementation of an EHT. We also compare equilibrium balanced growth paths (BGPs) with and without an EHT to analyze the long-run effects of the tax. We undertake a calibration exercise that parameterizes the equilibrium BGP using observations of Vancouver's housing markets in the absence of an EHT. We then compute the equilibrium transition path following the introduction of an EHT.

In the long run, the model predicts that an empty homes tax causes a decline in vacancies, including both speculative and frictional vacancies. The decline in vacancies induces an increase in the relative supply of rental units, but a decline in home ownership. In addition, an EHT can simultaneously put downward pressure on rents and upward pressure on house prices.

In the short-run immediately following the introduction of the tax, however, some of these effects can be exactly the opposite of what was just described, as the rental and owner-occupied markets first need to absorb some of the speculative vacancies that are supplied to both markets in response to the EHT. This is policy-relevant because an increase in housing availability and affordability immediately following the introduction of an EHT (or an increase in the tax rate) could obfuscate the longer-term adverse effects of the policy.

These implications are fully consistent with the the causal estimates of the EHT effects on the Vancouver housing market. Interpreting the empirical findings through the lens of the model, we see that the housing market initially needs to absorb some of the speculative vacancies that are supplied back to the market, which improves affordability and availability in the short run. After this initial shock, however, sellers/developers now require a higher price premium and shorter-time-on-the market to offset the expected holding cost induced by the EHT. This follows from their ability to freely choose between supplying a home to the rental market and the owner-occupied market. Given the search-and-matching frictions between the two sides of the owner-occupied market, a shorter time-to-sell implies a longer time-to-buy. This illustrates how an EHT can in fact undermine both housing affordability and availability in the owner-occupied market in the longer run, which explains the subsequent reverse trends in sales, listings and house price from the empirical findings.

The model also spells out two facets of the welfare consequences of the EHT. First, an EHT turns speculative vacancies into more affordable tenanted rentals, which represents an improvement in housing availability and affordability. Second, in a market with frictions, a certain amount of frictional vacancies are needed for the efficient or household-welfare-maximizing level of turnover in the owner-occupied market. By reducing frictional vacancies, an EHT also distorts the incentives to supply homes to the owner-occupied market, which can worsen housing affordability and reduce home ownership. The net welfare impact depends on the amount of frictional vacancies that can be exempted from the EHT.

A brief review of the related literature is in order. There is a long-standing interest among housing economists in vacancies dating back to Arnott (1989). A recent paper by Abramson et al. (2022) distinguishes between *frictional* and *structural* vacancies, whereas the distinction in our analysis is between *frictional* and *speculative* vacancies. Structural vacancies in the aforementioned paper are defined as vacancies in excess of the number of searchers, whereas speculative vacancies in our framework are empty homes owned by investors for exogenous financial reasons.

The policies aimed at reducing vacancies can be broadly classified into two categories: (1) eviction restrictions and tenant protection laws, and (2) vacant home taxes. Policies in the first category have important implications for the well-being of tenants (Collinson et al., 2022), but can also be viewed as vacancy-related policy instruments. Corbae et al. (2022) study the social cost of eviction using a search model of the rental market, and use their framework to assess the positive and normative effects of eviction restrictions on, for example, vacancy creation. Another paper related to tenant protection laws is Abramson (2021), although the focus in that paper is on homelessness rather than vacancy. Turning now to the second category of vacancy-related policies, the only papers on vacant home taxes that we are aware of are Desgranges and Étienne Wasmer (2000), Ménard (2012), and Segú (2020). The former two papers provide theoretical analyses of the rental market effects of a vacant home tax, where vacancies arise from search frictions only. The paper by Segú (2020) incorporates voluntary vacancies by property owners, and presents an empirical analysis of how vacancy rates respond to a vacancy tax.

Our theoretical model draws from the housing search literature. For example, other search-theoretic models of housing markets feature a choice between owning and renting (Halket and di Custoza, 2015; Garriga and Hedlund, 2020; Head et al., 2023; Han et al., 2022). Some of our modelling features, including the choice between a frictional owner-occupied market and a frictionless rental market, are similar to those in Head et al. (2014).

A significant body of theoretical literature explores the economic ramifications of speculative activity. Hart and Kreps (1986) and Stein (1987), for example, explore the price stability consequences of speculation. In their models, consumers engage in transactions for consumption purposes, while speculators buy and hold commodities with the intention of selling them later at a profit. This paradigm mirrors our understanding of the housing market, where households typically acquire housing for the consumption of housing services, while investors buy and hold properties as a means of storing wealth.

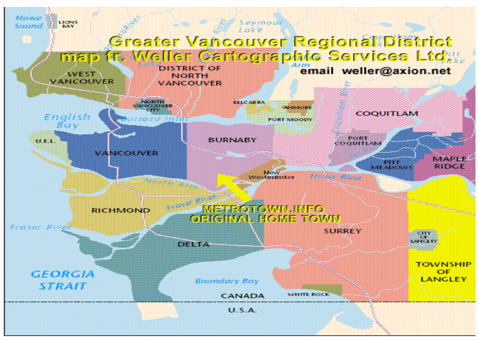
Recent research, such as that conducted by Buchak et al. (2020) and Favilukis and Van Nieuwerburgh (2021), has studied the role of speculators/investors in the housing market specifically. For policy-related questions we seek to answer in our work, it is important to distinguish between frictional vacancies and the empty homes held by investors for reasons unrelated to the time it takes to sell in a frictional housing market. This distinction aids in differentiating our theoretical analysis from studies focusing, for instance, on the role of dealer intermediation as examined by Buchak et al. (2020). Speculative activity, including foreign investment in real estate, shapes local housing markets. Relevant empirical insights into this phenomenon are provided by Gorback and Keys (2021), who estimate the house price and supply-side response to international capital flows.

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 equilibrium are described in Sections 5 and 6. Comparative statics are also derived and discussed in Section 6. Section 7 discusses modeling assumptions. Section 8 presents our calibration and simulation of the model. Section 9 concludes.

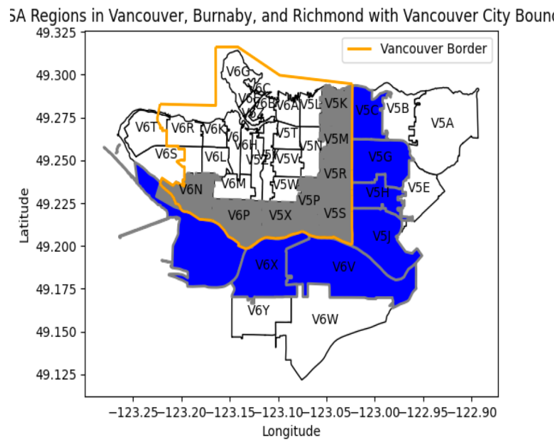
2 Institutional Background

2.1 Vancouver

The Greater Vancouver Regional District, also called Metro Vancouver, is a political subdivision with over 2.5 million people, covering 21 municipalities, one electoral area and one treat First Nation. Its major urban center is the city of Vancouver and its suburban areas include Richmond, Burnaby, Surrey, Coquitlam, New Westminster, Delta, West Vancouver, Port Coquitlam, North Vancouver City, Port Moody, North Vancouver District, Lange Township, Lange City, Pitt Meadows, White Rock, Maple Ridge. Figure 2a provides a map of Metro Vancouver and its local members. Located on the western half of the Burrard Peninsula, the city of Vancouver is bounded by the seashores along the West and North sides, and by street lines along the East and the South.



(a) Greater Vancouver Regional District



(b) Border Sample

Figure 2: Greater Vancouver Regional District Map

2.2 The Vancouver Empty Home Tax

The Vancouver Empty Homes Tax (EHT) is a yearly tax applied to any non-exempt home or property in the *city of Vancouver* that is left unoccupied for more than six months in a given tax year. The EHT was initially proposed to help return empty or under-utilized properties to people who live and work in Vancouver. The tax was approved in July 2016 and its first reference year for implementation was 2017. The initial EHT rate applied to owners of properties deemed or declared vacant was 1% of the property's assessed taxable value. The rate was then raised to 1.25% in 2020, 3% in 2021. By way of comparison, the property tax rate in Vancouver is less than half of a percent. The timeline of the announcement and implementation of the EHT is shown in Figure 1.

In 2017, the average home price in Vancouver is over $1.3 million. For a vacant home of that value, the owner would need to pay $13,000 each year from 2017 to 2019, $16,250 in 2020, and $39,000 annually from 2022 onward. Thus, the EHT imposes significant holding costs on the owners of empty homes.

2.3 Contemporaneous Housing Market Policies

Isolating the effects of the EHT in Vancouver's dynamic housing market is challenging due to the simultaneous influence of broader economic factors alongside corresponding government actions. For instance, the Foreign Buyer Tax (FBT) was introduced in Metro Vancouver in August 2016, immediately following the first announcement of the EHT. The foreign buyer tax was initially set to 15 percent of the "fair market value" of the home and implemented on purchases where one of the buyers was a "non-Canadian person." The FBT applies to residential property transactions throughout the Greater Vancouver Regional District (GVRD). In October 2018, the Province of British Columbia further announced the Speculation and Vacancy Tax (SVT) which was then implemented in 2019. The SVT is an annual tax of up to two percent of a property's "assessed value," and applies primarily to foreign investors in designated large metro areas in the province of British Columbia.

One key difference that sets the EHT apart from the others is that the EHT applies only to properties within the city of Vancouver while the FBT and SVT apply to the entire Vancouver metro. Our empirical strategy thus compares changes in housing market outcomes across the Vancouver city border to disentangle the EHT effects from other contemporaneous macro forces and accompanying interventions by the provincial government, such as the FBT and the SVT. Our empirical analysis focuses on the initial wave of the EHT. Unlike the subsequent EHT rate increases, the initial implementation of the EHT was much less anticipated or complicated by the so-called *COVID shock*. That is, the first introduction of the EHT provides a relatively clean cut-off date for policy analysis.

3 Data

3.1 Data

Our primary data are based on the Multiple Listing Service (MLS) residential real estate transaction records in the Greater Vancouver Regional District (GVRD) from 2014 to 2022. For each transaction, we observe sales price, listing price, listing date, transaction date, address, and detailed housing characteristics. We aggregate the transaction-level information to obtain the following key housing market outcome variables at the neighborhood × year × month level: (1) the number of sales; (2) the number of listings; (3) quality-adjusted sales price; (4) quality-adjusted time-on-the-market. Neighborhoods are defined at the Forward-Sortation-Area (FSA) level, where FSA is a designated geographical unit based on the first three characters in a Canadian postal code. Below we describe how we construct these market-level variables.

The number of sales refers to the number of houses sold within each FSA for each year and month, while the number of listings refers to the number of active properties listed within each MSA during each year and month. A listing is considered active if it is available for sale on the MLS system at some point during the month. For robustness, we further decompose the total active listings into the number of new listings and the number of existing listings.

To account for heterogenous housing stock composition, we leverage rich hedonic information at the transaction level and construct quality-adjusted house price and time-on-market indices for each FSA × year × month:

$$\log y_{i(j)t} = \alpha + \beta_{tj} + \beta_{zip} + \delta X_{it} + \epsilon_{it} \tag{1}$$

where y_{it} is the price or time-on-market for house i in the local market j at time t, β_{tj} is the FSA × year × month fixed effect, β_{zip} is the postal code fixed effect, X_h is a set of control variables, and ϵ_{it} is the error term. The controls included are the number of bedrooms, number of bathrooms, log of square footage, age of the property, age squared, view, type of the property, and dwelling type. The β_{tj}s are exponentiated and adjusted by RSME to construct the indices at the FSA $\times$ year $\times$ month level. Lastly, a symmetric moving average of 3 months is applied to the indices to smooth out the noise.

We supplement the MLS data with yearly-varying neigobrhood-level average rents, vacancies and construction permits from the Canadian Mortgage Housing Corporation (CMHC) annual surveys. Each October, CMHC conducts a survey that blends telephone interviews and on-site visits, providing a snapshot of the market during that month. The CMHC neighborhoods are measured at the census tract level, which is more granular than the Forward-Sortation-Area (FSA) level.

In CMHC, vacancy rate is defined as units that were unoccupied yet, and rent is the amount tenants pay for their units. We aggregate rents and vacancies to the census tract $\times$ year level. Construction permit data come from a survey on the number of construction permits issued, which is one of the first steps in the construction process.[3] Construction permits are given by different structure types, which include "single-detached" dwellings, "semi-detached" dwellings, "row" dwellings (attached units in a row), and "apartment and other" dwellings. We aggregate construction permits to the structure type $\times$ census tract $\times$ year level.

We further obtain the social demographic and housing characteristics from the quinquennial 2016 Canadian Census, including the fraction of foreign-born residents at both the FSA and the census tract level.

[3] See more on construction permits on the CMHC & SCHL website.

3.2 Estimation Sample

We restrict the main estimation sample to 2014-2018 to to avoid the complications introduced by subsequent EHT rate increases and the COVID shock. To ensure the housing stock and neighborhoods are relatively homogeneous, we further restrict the baseline sample is to adjacent neighborhoods on opposite sides of the Vancouver-Burnaby and Vancouver-Richmond borders: the geographic lines determining the applicability of the EHT. The geography of the sample used for the baseline estimation is depicted in Figure 2b, with our treatment and control regions indicated by color.

Table 1 presents summary statistics for selected attributes of properties and neighborhood conditions in our empirical sample. The *whole sample* columns include all transactions in the sample. The *boundary sample* columns, in contrast, include only transactions of properties that are just inside or just outside the Vancouver border that sold at least once during 2014–2018. The average prices are 808,510 CAD outside Vancouver and 1,151,690 CAD inside the city limits. Appendix A provides evidence supporting the notion that most property characteristics do not vary significantly across the border and that cross-border differences, if any, do not change significantly after the introduction of the EHT. Importantly, the possibility that housing-market outcome variables might make a discrete jump at the border right after the ETH while housing characteristics and neighborhood conditionsl continue to change smoothly allows for the isolation of the relationship between the EHT and housing market outcomes. The final two variables in Table 1 are the fraction of foreign-born residents in the neighborhood and the fraction of foreign-born residents from China, Hong Kong, and Taiwan. Overall, both are higher in the Suburbs, however there are significant variations across neighborhoods (both FSA and census tract) within each group.

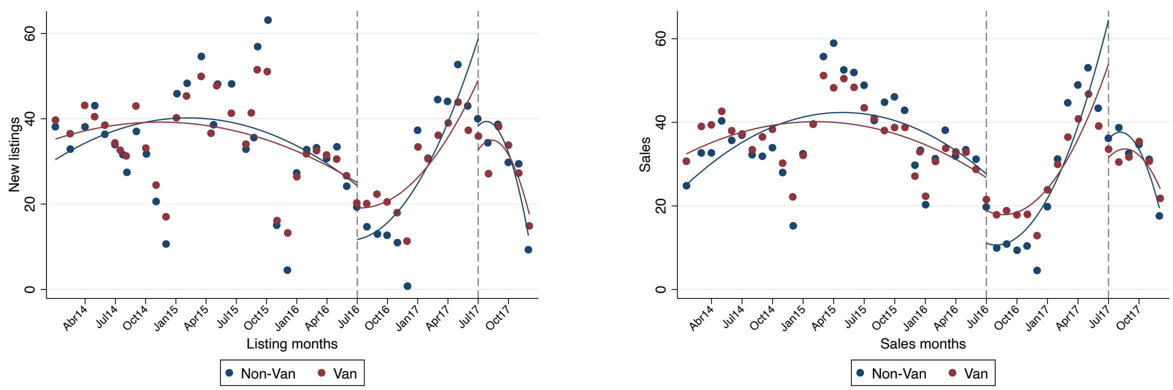
Table 1: Summary statistics Vancouver vs. Suburbs

	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	10097	6699	22551	32610
Aggregates variables				
Total Sales	15476.00	10895.00	37229.00	47517.00
Total New Listings	15350.00	10828.00	36923.00	46980.00
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 presents summary statistics for the sample of transactions used in the baseline estimation. The numbers presented for transaction-level variables represent means. The bottom panel presents summary statistics for the number of sales and listings by FSA and relevant Census demographics. Standard deviations are in parentheses. The boundary sample includes transactions in neighborhoods that are just inside or just outside the Vancouver border. The whole sample includes all transactions in the GVRD. The numbers in parentheses are standard deviations. The demographics from the 2016 Canadian Census are obtained at the CT level. The sample period is 2014-2018.

3.3 Parallel Trends

Figure 3a provides a graphical representation of the number of listings at the neighborhood level over time for jurisdictions inside and outside the Vancouver city border. The difference between the two markets prior to the introduction of the EHT is small and statistically insignificant. Similar pre-policy patterns emerge for home sales in Figure 3b. This, combined with the descriptive statistics in Table 1, provide compelling support for the parallel trends assumption required for identification.



(a) Listings **(b)** Sales

Figure 3: Time Trends for Sales and Listings

Notes: Each dot represents the average sale price within each group in a given month. The lines best fit linear trend lines within each segment, separated by the two dotted lines." "The first dotted line is the month the right to EHT was announced by the BC government, and the second is when the difference between the two groups reversed. The unit of observation is a market defined as an FSA/year/month. This bin-scatter includes neighborhood fixed effects. The sample comprises all FSA in the greater Vancouver area from January 2014 to December 2017

Strikingly, following the announcement of the EHT in July 2016, the two lines separate. There are more listings and sales just inside Vancouver than just outside. This trend was completely reversed after March 2017, with fewer listings inside Vancouver than just outside Vancouver. The visual evidence here suggests that the housing market over-shoots in the short run but this effect is mitigated in the longer run.

4 Empirical Analysis

In this section, we estimate the dynamic effects of the EHT on a set of housing market outcomes, including number of sales, number of listings, quality-adjusted sales price, quality-adjusted time-on-the-market, average rents, vacancies and construction permits. It is well known that house price growth exhibits positive autocorrelation in the short run and mean reversion in the long run (Glaeser et al., 2014). To control for the internal momentum in the housing market, we employ different variations of the Local Projection (LP) estimator, which is flexible in dealing with non-linearities, state dependence, and a variety of robustness checks.

4.1 Estimation Strategy

As a first step, we estimate a set of linear regression models for time horizons $h \in \{0, 1, \cdots, 18\}$. The empirical specification takes the following form:

$$\Delta Y_{j,t-1,t+h} = \alpha_{j,h} + \beta_h \Delta\tau^{EHT}_{j,t} + \sum_{2\geq i\geq p} \gamma_i \Delta Y_{j,t-1,t-i} + \Gamma'_h X_{j,t-1} + \epsilon_{j,t-1,t+h} \tag{2}$$

where $\Delta Y_{j,t-1,t+h}$ is the change in the local housing outcomes of interest in neighborhood j between month $t-1$ and month $t+h$, measured by sales, listings, price, time-on-the-market, rents and vacancies, respectively; $\Delta\tau^{EHT}_{j,t}$ is the change in the EHT policy between time $t-1$ and t, which is equal 1 is the EHT policy is implemented by time t in the neighborhood j (if neighborhood j is in the city of Vancouver) and 0 otherwise; $\alpha_{j,h}$ is a vector of time-invariant neighborhood fixed effects; $X_{j,t-1}$ is a vector of observed time-varying neighborhood-level characteristics; and $\epsilon_{j,t-1,t+h}$ is a mean-zero error term. We include p lags of the house price index and the main regressor to control for internal propagation dynamics and correlation with prices or the policy events and other variables. This is motivated also by the fact that the EHT might not be implemented randomly but rather in response to the housing market conditions. We estimate equation (2) for separate horizons $h \in \{0, 1, \cdots, 18\}$ by the method of local projection (Jordà, 2005).

The baseline specification includes controls for local seasonality, time and neighborhood-fixed effects, and 12 lags of the house price index and the regressor of interest. The coefficient of interest, β_h, characterize the comparison $\mathbb{E}[\Delta Y_{j,t-1,t+h} | \tau_{j,t}^{EHT} = 1] - \mathbb{E}[\Delta Y_{j,t-1,t+h} | \tau_{j,t}^{EHT} = 0]$ for each horizon h. Therefore, β_h captures the causal effects of the EHT policy on the outcome variable $\Delta Y_{j,t-1,t+h}$ after h periods. Identification requires that conditional on rich controls and housing market momentum, adjacent neighborhoods sitting on opposite sides of the city border do not experience significantly different changes in the outcome of interest between month $t-1$ and t in the absence of the EHT policy. This assumption is supported by evidence in Section 3.3. We will further present a direct test of the assumption along with the main estimation in Section 4.2.

Additionally, we employ an exposure-augmented version of local projections, which takes the following form:

$$\Delta Y_{j,t-1,t+h} = \alpha_{j,h} + \beta_h \kappa_j \Delta \tau_{j,t}^{EHT} + \sum_{2 \geq i \geq p} \{\gamma_i Y_{j,t-i} + \delta_i \Delta \kappa_j \tau_{j,t+1-i}^{EHT}\} + \Gamma'_h X_{j,t-1} + \epsilon_{j,t-1,t+h} \quad (3)$$

where κ_j is the shock exposure to the EHT of local neighborhood j. We measure κ_j by one of the following four variables: vacancy rate, fraction of immigrants, a fraction of China, Hong Kong, and Taiwan-born immigrants, and the non-permanent resident fraction of each FSA in 2016. The vacancy exposure is motivated by the policy mechanism working directly through vacant homes. The remaining exposure variables are motivated by the observation that empty homes in Vancouver are often bought by foreign investors. As foreign investors tend to purchase properties in neighborhoods with more residents from the same ethnic group, neighborhoods with a higher fraction of foreign residents are more likely to be exposed to the EHT. For each of these exposure variables, a higher value of κ is associated with neighborhoods with a higher rate or tendency of vacant homes, which implies a higher relevance of the EHT on the local housing market. Thus we interact the local shock exposure κ_j with the policy dummy $EHT_{j,t}$.

Compared with the baseline specification, the identification requirement here is even weaker. In this case, the changes in the EHT can be correlated with other non-EHT factors that affect the housing market, as long as these other factors do not differentially affect the outcome of interest in adjacent neighborhoods across the city border in a way that depends on the exposure variable κ_j.

One legitimate concern is that that there are other policy interventions over the study period which could have potentially impacted housing market outcomes in and outside the city of Vancouver and thereby confound the treatment analysis. For example, one may argue that different κ_i neighborhoods may show different β_h effects, not because of the EHT, but because of the Foreign Buyer Tax (FBT) that was announced and implemented shortly after the EHT. We take several steps to address this concern. First, unlike the EHT that was implemented only in the city of Vancouver, the FBT was implemented for the entire Vancouver metro. The FBT effect across cities should have already been absorbed by the city-specific time trends. Second, to the extent that Richmond and Burnaby have a higher fraction of Chinese residents than the city of Vancouver as shown in Table 1, we would expect that the FBT would reduce prices outside of the city more than inside the city, which is the opposite of what we would expect from the EHT.[4] Third, to further control for the heterogeneous sensitivity to the FBT across neighborhoods, we estimate an FBT-augmented specification that includes a separate heterogeneous impulse function in response to the FBT, as captured by $\beta'_h \Delta\tau^{FBT}_{j,t} + \sum_{2\geq i\geq p} \phi_i \Delta\tau^{FBT}_{j,t+1-i}$, where the dummy variable $\tau^{FBT}_{j,t}$ equal 1 if

[4] According to the 2021 Census, over half of metro Vancouver residents identify as part of a visible minority, with the largest visible minority being ethnic Chinese who represent 20% of the region. Figure 2 shows the reported percentage of ethnic Chinese residents in metro Vancouver. The maps show that the fraction of Chinese residents is 54.5% in the city of Vancouver, 80% in Richmond, and 67.8% in Burnaby.

the FBT policy was implemented by time t in the neighborhood j and if neighborhood j was more likely affected by the policy, that is, if the number of foreign-born citizens from China, Taiwan, and Hong Kong exceeded the median percentage in the average neighborhood (19.5%) in 2016.[5]

$$\begin{aligned}\Delta Y_{j,t-1,t+h} &= \alpha_{j,h} + \beta_h \kappa_j \Delta\tau^{EHT}_{j,t} + \beta'_h \Delta\tau^{FBT}_{j,t} + \sum_{2\geq i\geq p} \{\gamma_i Y_{j,t-i} + \delta_i \Delta\kappa_j \tau^{EHT}_{j,t+1-i} \\ &\quad + \phi_i \Delta\tau^{FBT}_{j,t+1-i}\} + \Gamma'_h X_{j,t-1} + \epsilon_{j,t-1,t+h} \qquad (4)\end{aligned}$$

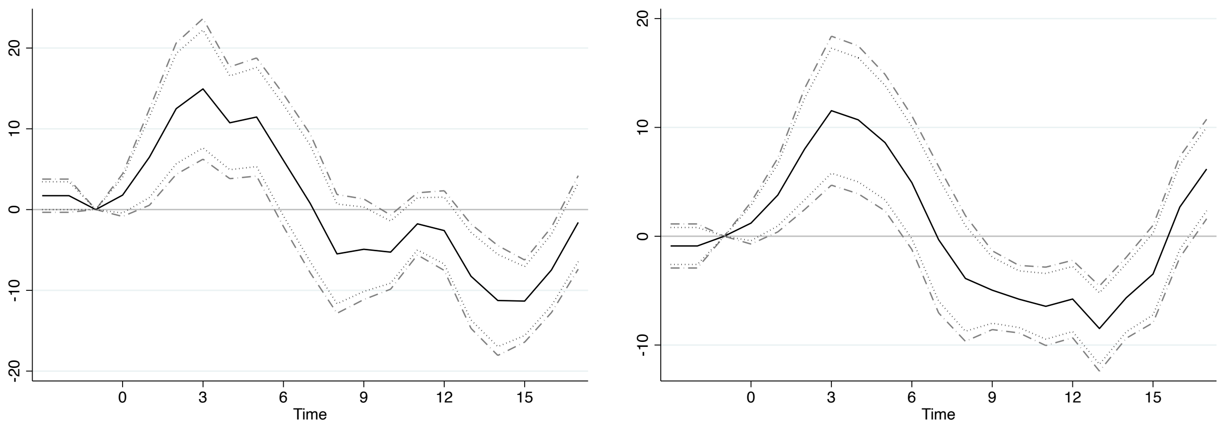
In this FBT-augmented specification, we effectively consider only variations before and after the EHT across neighborhoods with different κ_j that are 'orthogonal" to the FBT's differential impacts across neighborhoods.

4.2 Results

In this section, we present estimates from the most extensive specification (Equation 4) for the border sample and the entire metro sample, respectively. To start, we set $\kappa_j = 1$.

Sales Figure 31a plots the dynamic coefficients of interest, β_h, from the horizon regressions with the number of sales as the outcome variable when the sample is restricted to neighborhoods adjacent to the city border. There were no significant pre-trends during the three months before the EHT, consistent with our identification assumption. Three months after the announcement (September 2016), the difference between the number of sales per month in an average Vancouver neighborhood and the average suburban neighborhood increased by 14 sales per month relative to the mean difference before the announcement. In other words, the EHT increased the average number of monthly sales in Vancouver by 14 per

[5]Studies have shown that the FBT affected more neighborhoods with more foreigners, especially from these countries. The results are robust to alternative definitions.



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

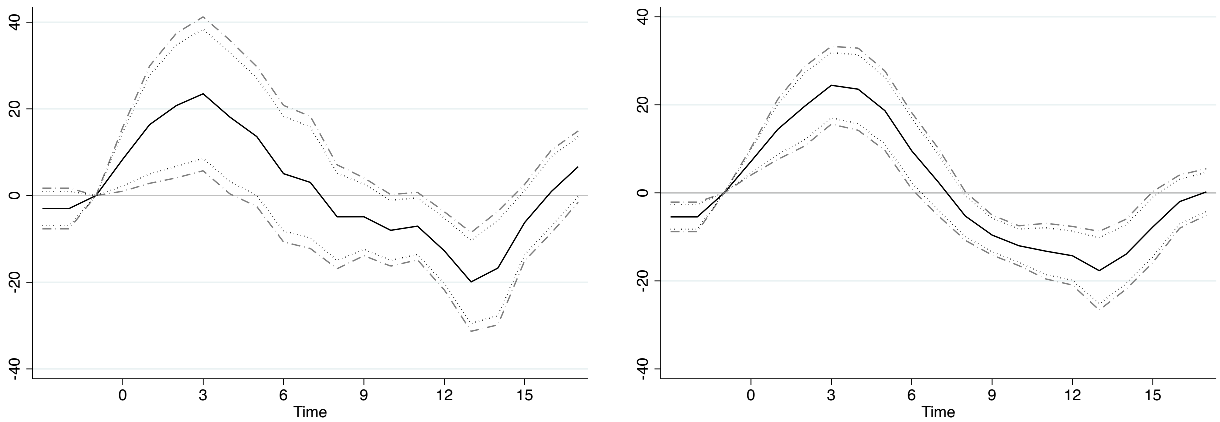
Figure 4: Average causal effects of EHT on number of sales.

Notes: The figure shows the coefficient of estimating the impulse response equation at each horizon. The local exposure κ_i is normalized by its standard deviation. All regressions include property controls, FSA, year/month, vacancy, and local seasonality FE. The standard errors are clustered by year/month periods. The number of lags, p, is 12. The dotted lines are 95% and 90% CI.

neighborhood (defined by FSA) relative to the areas just outside the Vancouver border. An average FSA has approximately 42 sales per month on the Vancouver side and 64 sales per month on the suburban side during the sample period, so the increase in sales per month after the announcement is substantial. This increase, however, was immediately followed by a decline until, in the 5th quarter after the EHT announcement, monthly sales in the average Vancouver neighborhood were 11 less than the average suburban neighborhood relative to the pre-EHT comparison. Figure 31b extends the estimation from the border sample to the entire Vancouver metro. The estimates show that the general patterns persist.[6]

Listings The number of active listings in the average Vancouver neighborhood adjacent to the border increased by 21 per month relative to the average suburban neighborhood in the quarter after the EHT announcement. This increase was followed by a decline in active

[6]For robustness, we include in the Appendix the results of an alternative method: a dynamic differences-in-differences and the results are robust to this method.



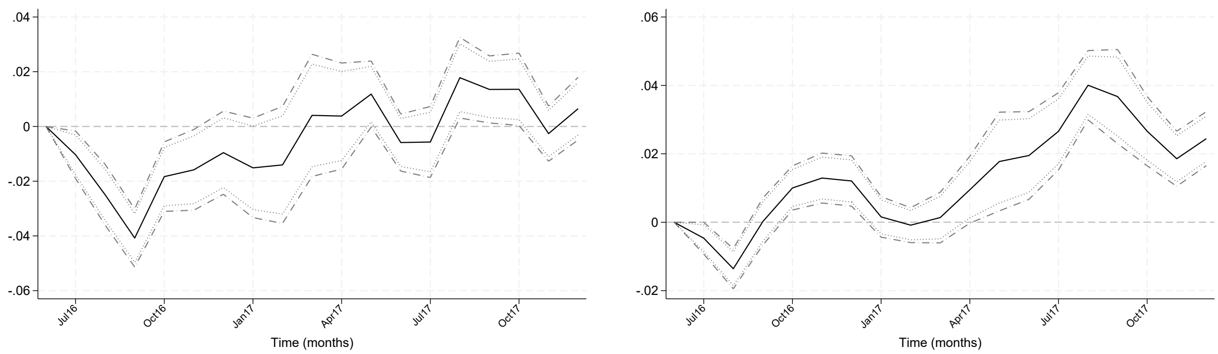
(a) border sample **(b)** whole sample

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

Notes: The figure shows the coefficient of estimating the impulse response equation at each horizon. The local exposure κ_i is normalized by its standard deviation. All regressions include property controls, FSA, year/month, vacancy, and local seasonality FE. The standard errors are clustered by year/month periods. The number of lags, p, is 14. The dotted lines are 95% and 90% CI.

listings that lasted about a year. We propose alternative measures created by decomposing the number of listings into new listings and existing listings. Appendix E shows the results are robust to these alternative measures.

Price To estimate the dynamic effects of the EHT on price, we repeat the estimation above except that the main outcome of interest here is the neighborhood-level quality-adjusted house price index, indicated by $\Delta \ln P_{j,t-1,t+h}$, i.e., the log change in the quality-adjusted house price in neighborhood j between month $t-1$ and month $t+h$. Figure 6 shows the estimated $\hat{\beta}_h$ coefficients for the border sample and the whole sample 1 to 18 months into the future. The effects after the announcement of the EHT are immediate and statistically significant. Using the border sample, panel 6a shows that, after the policy was announced, house prices declined initially in Vancouver neighborhoods, with the peak of the decline at roughly 1% occurring in the third month after the announcement, but subsequently climbed back up to the initial level over the following months. Panel 6b extends the estimation



(a) border sample

(b) whole sample

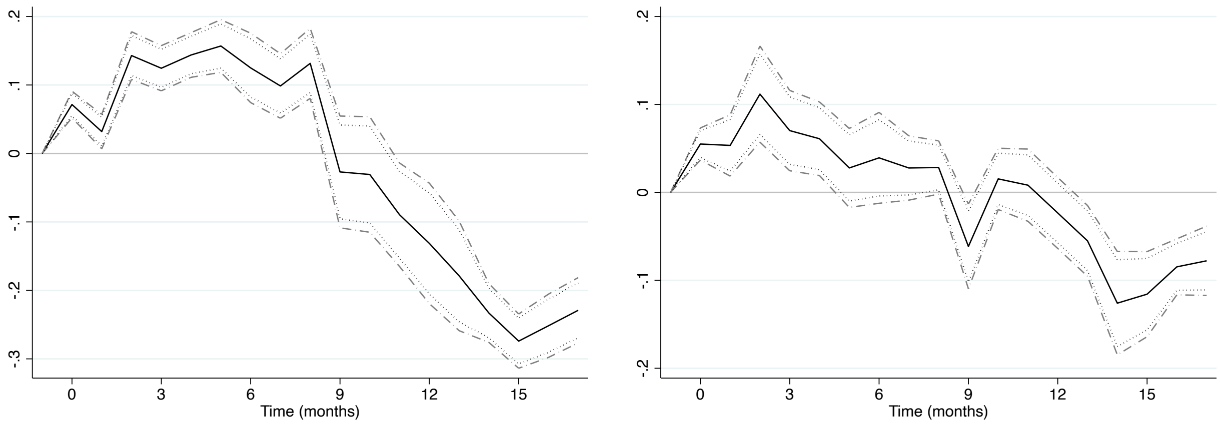
Figure 6: Average causal effects of EHT on prices.

Notes: The figure shows the coefficient of estimating the impulse response equation at each horizon. All regressions include FSA, year/month, vacancy, and local seasonality FE. The number of lags, p, is 10. The standard errors are clustered by year/month periods. The dotted lines are 95% and 90% CI.

sample to the entire Vancouver metro. The pattern is consistent except that house price climbed up to a level above the initial level in the long run.

Time-on-the-Market Figure 7 shows the estimated impulse response coefficients for the neighborhood-level quality-adjusted time-on-the-market for the border sample and the whole sample, based on the dynamic impulse response function in Equation (4). The plots reveal that time-on-the-market increases right after the EHT is announced, followed by a decline. This pattern suggests that the initial oversupply of listings creates competition to sell, which increases time-on-the-market. The subsequent decline points to the existence of search frictions and its interaction with the policy intervention, which we model in Section 5.

Rents and Vacancies To further understand the effects of the EHT on the housing market, we now turn to analyzing rents and vacancies, which are only available at the yearly frequency. The CMHC reports average for 1, 2 and 3 bedroom units, so we use market segment $\times$ year level data. Given the limitations of the reduced sample from the yearly panel and data quality, we cannot employ the impulse response method. Instead, we estimate the



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

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

Notes: The figure shows the coefficient of estimating the impulse response equation at each horizon. All regressions include FSA, year/month, vacancy, and local seasonality FE. The number of lags, p, is 14. The standard errors are clustered by year/month periods. The dotted lines are 95% and 90% CI. We do not include FBT controls in this estimation.

effects of the EHT on rents using a difference-in-differences (DID) approach. We estimate the following equation:

$$Y_{j,t} = \alpha_j + \alpha_t + \sum_h \beta_h \times \mathrm{D}_{t,h} \times \mathrm{Van}_j + \gamma x_{j,t} \tag{5}$$

where $Y_{j,t}$ is the log change of rent in market segment j in year t, $\mathrm{D}_{t,h}$ is a dummy variable equal to 1 if t is the year of the EHT implementation and h is the year after the implementation, and Van_j is a dummy variable equal to 1 if the neighborhood j is in the city of Vancouver.

The results are presented in Table 2. The estimated coefficients of the interaction between the city of Vancouver and year fixed effects show that the EHT decrease rents in Vancouver. Columns 1 and 2 present the results of equation 5. Columns 3 and 4 includes the interaction of years and the dummy variable D_j^{FBT} equal 1 if the Vancouver neighborhood j was most likely affected by the policy, that is if the number of foreign-born citizens from China, Taiwan, and Hong Kong exceeds the median percentage in the average neighborhood. Table 2 shows that there were no significant pre-trends in rental markets before the introduction of the EHT, supporting our identification assumption. Across specifications, we find that the EHT decreased rents in Vancouver by 1.6% in the year the policy was implemented. This effect stayed roughly the same in the following years. Overall the results are consistent with a short and long run decrease in rent prices following the EHT implementation.

Table 2: EHT effects on rent

	(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
No. Bedrooms FE	Yes	Yes	Yes	Yes
Census Tract × No. Bedrooms FE	Yes	Yes	Yes	Yes
Year × No. Bedrooms FE	No	Yes	No	Yes
Observations	972	972	972	972

Notes: The table shows the estimated coefficients of the interaction between the city of Vancouver and year fixed effects. The sample includes all neighborhoods in the GVAR from 2014 to 2018. The dependent variable is the log change of rent. The standard errors are clustered by market segment and year. The unit of observation is the market segment × year level. Columns 3 and 4 includes FBT controls. All regressions include controls for the average transaction characteristics in the neighborhood. The omitted category is the year 2015. The stars indicate the significance level of the coefficients, * p<0.1, ** p<0.05, *** p<0.01.

Turning to vacancies, the City of Vancouver reported a decline in home-ownership from 70.6 percent in 2017 to 68.2 percent in 2020, and an increase in rentership from 25.2 percent in 2017 to 28.8 percent in 2020, in line with the model's longer term predictions. According to the 2021 Empty Homes Tax Annual Report (City of Vancouver, 2021), there has been a declining share of properties deemed or declared empty since the EHT was first launched. The share of empty homes was only 3.0 percent in 2020 compared to 4.1 in 2017. In 2014, before the EHT, the vacancy rate of residential properties was 4.8 percent according to Ecotagious' Analysis of Housing Occupancy in the City of Vancouver Using Electricity Meter Data Analytics.[7,8]

4.3 Robustness Checks

In this section, we present a set of robustness checks to provide additional support for our main empirical findings.

We start with the first set of robustness checks by relaxing $\kappa_j = 1$ and including an interaction between κ_j and the EHT dummy in estimating Equation (4), where κ_j is measured by one of the vacancy variables in 2016. Following Grindaker et al. (2023), the identification assumption now becomes:

$$E\{\tau_{j,t}^{EHT}\kappa_j\epsilon_{j,t-1,t+h}\} = 0 \tag{6}$$

where $\kappa_j\epsilon_{j,t-1,t+h}$ is a weighted-average of the time t, horizon h error terms across local housing markets. Informally, condition (6) requires that when the EHT was announced, housing market outcomes in high-κ_j locations are not systematically different from those in low-κ_j locations for other reasons than the EHT, conditional on a rich set of controls and heterogeneous sensitivity to the FBT; and this does not require exogeneity of κ_j. Compared to the baseline specification, this is a much weaker assumption. It allows the EHT to be correlated with contemperaneous policies and housing market trends as long as they do not impact differentially high- v.s. low-κ_j neighborhoods. For example, if the city neighborhoods

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

[8] Segú (2020) uses the quasi-experimental setting of an introduction of a tax on vacant homes in France in 1999, and finds that the vacancy tax accounted for a 13% decrease in municipal vacancy rates between 1997 and 2001.

experienced a different housing market cycle compared with the suburban neighborhoods at the time of the EHT, that itself is not a problem as long as these variations are not systematic across high- and low-κ_j neighborhoods. The evidence on parallel trends suggests that this is likely the case. However, one might expect that the FBT affects high κ_j neighborhoods more than low-κ_j neighborhoods by its design. To alleviate this concern, we include the interaction between κ_j and the FBT dummy, as well as their lags, as specified in Equation (4). Thus, we effectively consider only variation caused by EHT this is "orthogonal" to the heterogeneous FBT impacts across neighborhoods.

Figures 20-24 in Appendix B plot the estimated impulse function where κ_j is measured by one of the four variables documented above: vacancy rate, fraction of immigrants, a fraction of China, Hong Kong, and Taiwan-born immigrants, and the non-permanent resident fraction of each FSA in 2016. There are no pre-trends in the outcome variables, supporting the assumption that high and low κ_j neighborhoods are on parallel trends prior to the announcement of the EHT. The dynamic patterns for the sales, listings, price and time-on-the-market are consistent with the patterns from the baseline specifications where $\kappa_j = 1$, providing additional support for our main findings.

The second potential bias concerns possible spillover to the neighborhoods outside the city of Vancouver. While it is hard to rule out geographic spillover in general, we believe such spillover is less of a concern for the EHT. Conceptually, unlike many housing taxes (e.g., transaction taxes, foreign buyer taxes) that are imposed on home buyers, the EHT is imposed on owners of existing homes. While homebuyers can flow from one market to another, houses are tied to specific locations, making it infeasible for existing homeowners to transfer housing stock across the border. Empirically, as a robustness check, we apply a 'donut approach' by repeating the main estimation but excluding neighborhoods that are adjacent to the city border. The results in Appendix C are consistent with the findings from the border sample and the metro sample, suggesting the geographic spillover is less likely to bias our estimates.

Third, one might be worried that households may have anticipated the EHT and rushed to sell or rent out their properties even before the EHT was announced. Note that we have already shown that there are no pre-trends in the outcome variables before the EHT was announced. To further alleviate this concern, we remove 3 months before the EHT and repeat the baseline estimation. The results reported in Appendix C again provide assuring support.

Finally, as a specification check, we estimate the effects of the EHT on house sales and listings using a dynamic differences-in-differences approach. We present this specification and the results in Appendix F. Despite the difference in the estimation method, the results are strikingly consistent with our baseline findings.

Summary In sum, we find a remarkably consistent pattern: while the EHT initially appears to achieve the desired objective of improving housing availability and affordability, its cumulative effects diminish over time in the owner-occupied housing sector but remain stable in the rental sector. The heterogeneous treatment effects of the long run EHT effects on price versus rents suggest that a careful evaluation of empty homes taxes must consider flows of properties between owner-occupied and rental markets. The overshooting response in the short run indicates the role of speculative investors. The effects on time-on-the-market and vacancies further suggest that the EHT interacts with search frictions present in the housing market. Armed with these insights, we now propose a search model to explain these empirical findings and to quantify the welfare costs of the EHT.

5 Model Environment

Time is discrete and indexed by t. There are L_t households residing in the city at time t. The population growth rate is ν, so that $L_{t+1} = (1 + \nu)L_t$. An assumption of the model is that households 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.[9] Preferences are given by

$$u(c_t, z_t) = c_t + z_t, \tag{7}$$

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

$$z_t = \begin{cases} z > 0 & \text{if homeowner and } \textit{well-matched} \\ 0 & \text{otherwise} \end{cases} \tag{8}$$

denotes the utility premium associated with home ownership. 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 is hit by 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 continue 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.

There are some households that are simply not inclined to enjoy the benefits of home-ownership (i.e., $z_t = 0$ regardless of housing tenure): an exogenous fraction $\psi \geq 0$ of all new households entering the city are assumed to be *permanent renters*. The remaining $1 - \psi$ of

[9]Section 7 contains a discussion of a model extension involving income heterogeneity.

households rent 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 permanent renters (H_t^r), rented to prospective buyers (H_t^b), vacant and listed for sale[10] (H_t^f), or vacant and investor-owned (H_t^s):

$$H_t = H_t^n + H_t^r + H_t^b + H_t^f + H_t^s. \tag{9}$$

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 construction of a new housing unit costs

$$q(H_t, L_t) = \zeta_0 + \zeta_1(H_t/L_t). \tag{10}$$

We interpret ζ_0 as the cost of building a house, and $\zeta_1(H_t/L_t)$ as the cost of land. The latter is proportional to the existing stock of housing relative to the population of households, which is consistent with balanced growth. 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 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

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

house in the wholesale market, it would serve only as a financial asset.[11] 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 changes ownership.[12] 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

[11] 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.

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

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 in which every vacant home is subject to the full EHT. With $\omega = 1$, on the other hand, frictional vacancies are exempt from the tax.

Investors. Investors, like households, are long-lived with discount factor β. The measure of potential investors at time t, denoted I_t, grows at the same rate ν as the city's population of households so that the ratio of investors to households, $\phi = I_t/L_t$, 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 home ownership, denoted π_t at time t. Each individual investor's π_t follows a Markov process:

$$\pi_{t+1} = \begin{cases} \pi_t & \text{with prob. } 1-\rho \\ \pi' \sim F_\pi & \text{with prob. } \rho \end{cases} \tag{11}$$

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 home ownership provides a hedge against other sources of financial risk and/or the threat of wealth appropriation.[13] Regardless of the interpretation, sufficient heterogeneity in 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

[13]It could also be that some investors value home ownership more than others because they derive utility from it as a vacation property.

out[14] or be subject to the EHT.[15] Given the stochastic nature of π_t in (11), home-ownership 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 an additional cost of leasing, ε, which is also heterogeneous across investors: each investor's ε is an *iid* draw from distribution F_ε.[16]

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. We assume for simplicity that investors supply to the wholesale market.

[14] We maintain the assumption that ϕ is small in the sense that there are fewer investor-landlords than there are renters. A suitable condition is $\phi \leq \nu + \psi$.

[15] Importantly, there is no vacancy tax exemption for investors. This means, for example, that investors cannot simply transfer the ownership of their homes amongst themselves every year in order to to circumvent the EHT. We view this assumption as reasonable given the (unmodeled) transaction costs associated with the transfer of home ownership. In fact, tax exemption because of the legal transfer of ownership requires proof of payment of the property transfer tax.

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

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:

$$V_t = \max\{x_t - m + \beta V_{t+1}, -(1-\omega)\tau V_t + \beta \max_P \gamma(\theta_t(P))P + (1-\gamma(\theta_t(P)))V_{t+1}\}, \quad (12)$$

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 again 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:

$$V_t = x_t - m + \beta V_{t+1} \quad (13)$$

and

$$V_t = -(1-\omega)\tau V_t + \beta \max_P \left[\gamma(\theta_t(P))P + (1-\gamma(\theta_t(P)))V_{t+1}\right]. \quad (14)$$

Equations (13) and (14) 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:

$$q(H_t, L_t) \geq V_t. \quad (15)$$

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

$$V_t^r = y - x_t + \beta V_{t+1}^r \tag{16}$$

$$V_t^b = y - x_t + \beta \max_P \lambda(\theta_t(P)) \left[V_{t+1}^n - P\right] + (1 - \lambda(\theta_t(P)))V_{t+1}^b \tag{17}$$

$$V_t^n = y - m + z + \beta \left\{(1-\delta)V_{t+1}^n + \delta \left[V_{t+1}^b + V_{t+1}\right]\right\}, \tag{18}$$

where the maximization operator in (17) reflects the directed search problem of a prospective buyer, and the function θ_t again captures the perceived trade-off between price and tightness. The value of buying, V_t^b, is just the present discounted value of lifetime consumption (income minus rent). 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 home-ownership 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* 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 (14), even for out-of-equilibrium prices:

$$V_t = -(1-\omega)\tau V_t + \beta \left[\gamma(\theta_t(P))P + (1 - \gamma(\theta_t(P)))V_{t+1}\right]. \tag{19}$$

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 (19).

The directed search problem of a prospective home buyer is therefore the maximization problem in (17) subject to the supply side equation (19) to constrain the price-tightness pairs to those that would deliver exactly payoff V_t to participating developers:

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

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

$$\gamma(\theta_t) = \frac{[1+(1-\omega)\tau]V_t - \beta V_{t+1}}{\beta\left[P_{t+1} - V_{t+1}\right]} \tag{20}$$

$$P_{t+1} = \eta(\theta_t)V_{t+1} + (1-\eta(\theta_t))\left[V_{t+1}^n - V_{t+1}^b\right], \tag{21}$$

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).

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

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

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

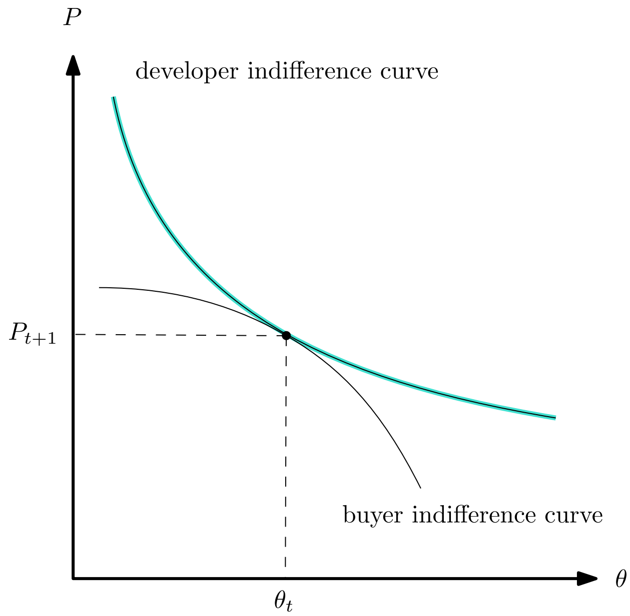


Figure 8: The Solution to the Directed Search Problem.

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 Bellman equation (22) 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 (13) yields

$$V_t^i(\pi_t, \varepsilon) = \max\{0, \pi_t - \min\{\varepsilon, (1+\tau)V_t - \beta V_{t+1}\}\} + \beta \mathbb{E}[V_{t+1}^i(\pi_{t+1}, \varepsilon)]. \quad (22)$$

The investor chooses home-ownership if the benefit, π_t, is sufficiently high:

$$\pi_t \geq \min\{\varepsilon, (1+\tau)V_t - \beta V_{t+1}\} \equiv \tilde{\pi}_t(\varepsilon).$$

Their house is rented out if the additional cost of being a landlord is sufficiently low:

$$x_t - m - \varepsilon \geq -\tau V_t \quad \Rightarrow \quad \varepsilon \leq -m + \tau V_t + x_t = (1+\tau)V_t - \beta V_{t+1} \equiv \tilde{\varepsilon}_t.$$

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 to the right of the orange line find it worthwhile to buy a house. Those in the top right-hand corner own vacant homes because they would find it too costly to rent them out.

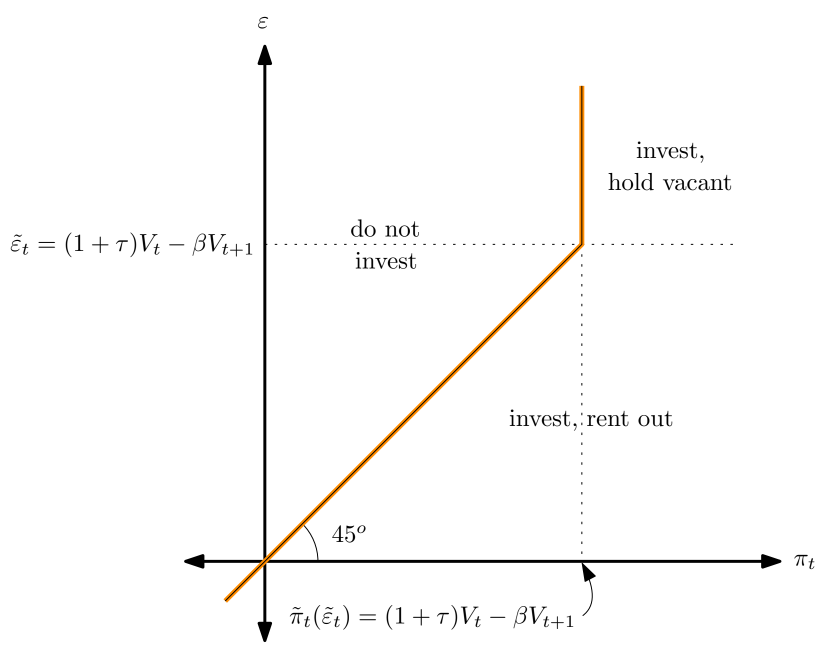


Figure 9: The Equilibrium Decisions of Investors.

6.2 Equilibrium Distributions of Households and Houses

When characterizing the equilibrium distributions of households and houses in period t, we exploit the fact that one household occupies one house, and the assumption that one investor owns at most one house. The stocks and flows for households, investors, and housing units are depicted in Figures 10, 11 and 12.

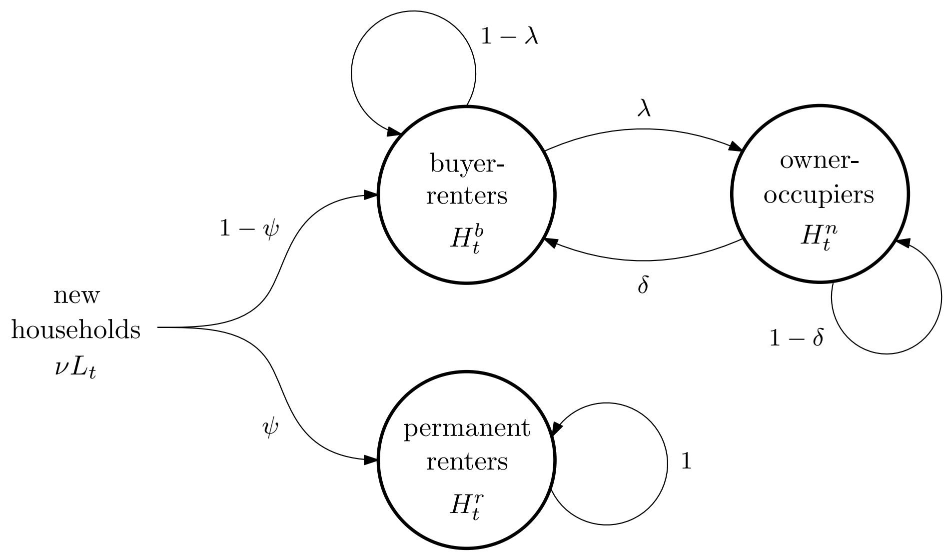


Figure 10: household stocks and flows

The measure of permanent renters or, equivalently, the measure of houses occupied by permanent renters evolves according to

$$H_{t+1}^r = H_t^r + \nu\psi L_t.$$

Dividing all quantities by L_t and using lower-case letters to represent per capita values yields

$$h_{t+1}^r = \frac{1}{1+\nu}h_t^r + \frac{\nu\psi}{1+\nu}. \tag{23}$$

The measures of buyers/renters and owners evolve according to

$$\begin{aligned}
H_{t+1}^b &= (1-\lambda(\theta_t))H_t^b + \delta H_t^n + \nu(1-\psi)L_t \\
H_{t+1}^n &= (1-\delta)H_t^n + \lambda(\theta_t)H_t^b,
\end{aligned}$$

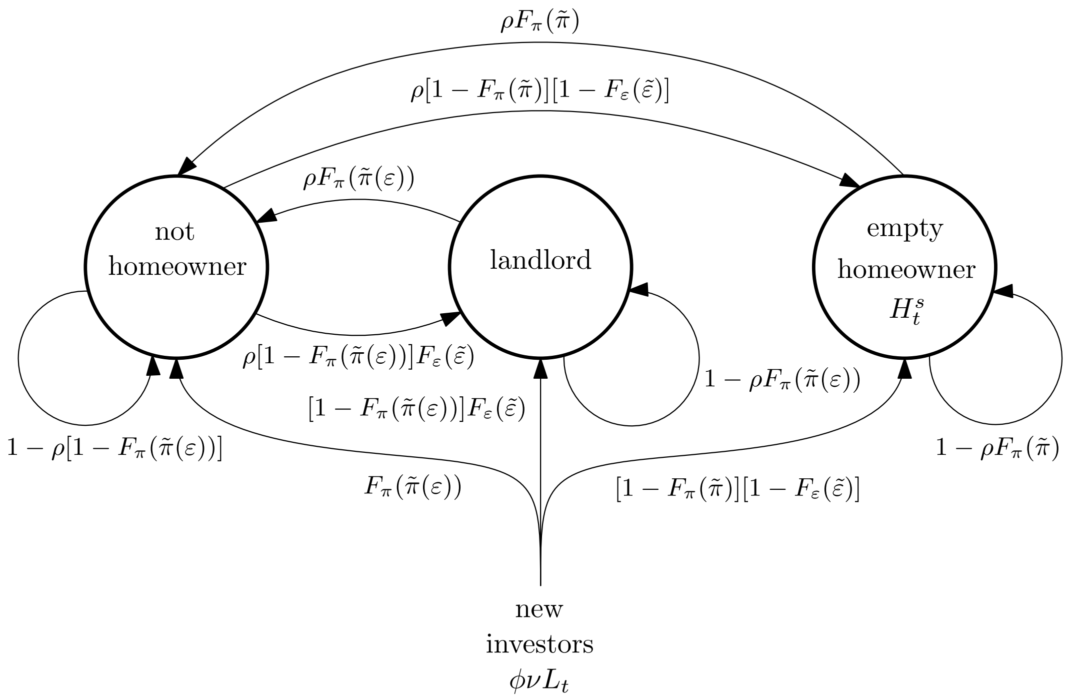


Figure 11: investor stocks and flows

and the per-capita versions are

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

$$h_{t+1}^n = \frac{1 - \delta}{1 + \nu} h_t^n + \frac{\lambda(\theta_t)}{1 + \nu} h_t^b. \tag{25}$$

The per capita measure of homes vacant and for sale in the owner-occupied market is characterized by the directed search equilibrium level of market tightness:

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

Finally, it follows from the analysis surrounding Figure 9 that the per-capita measure of

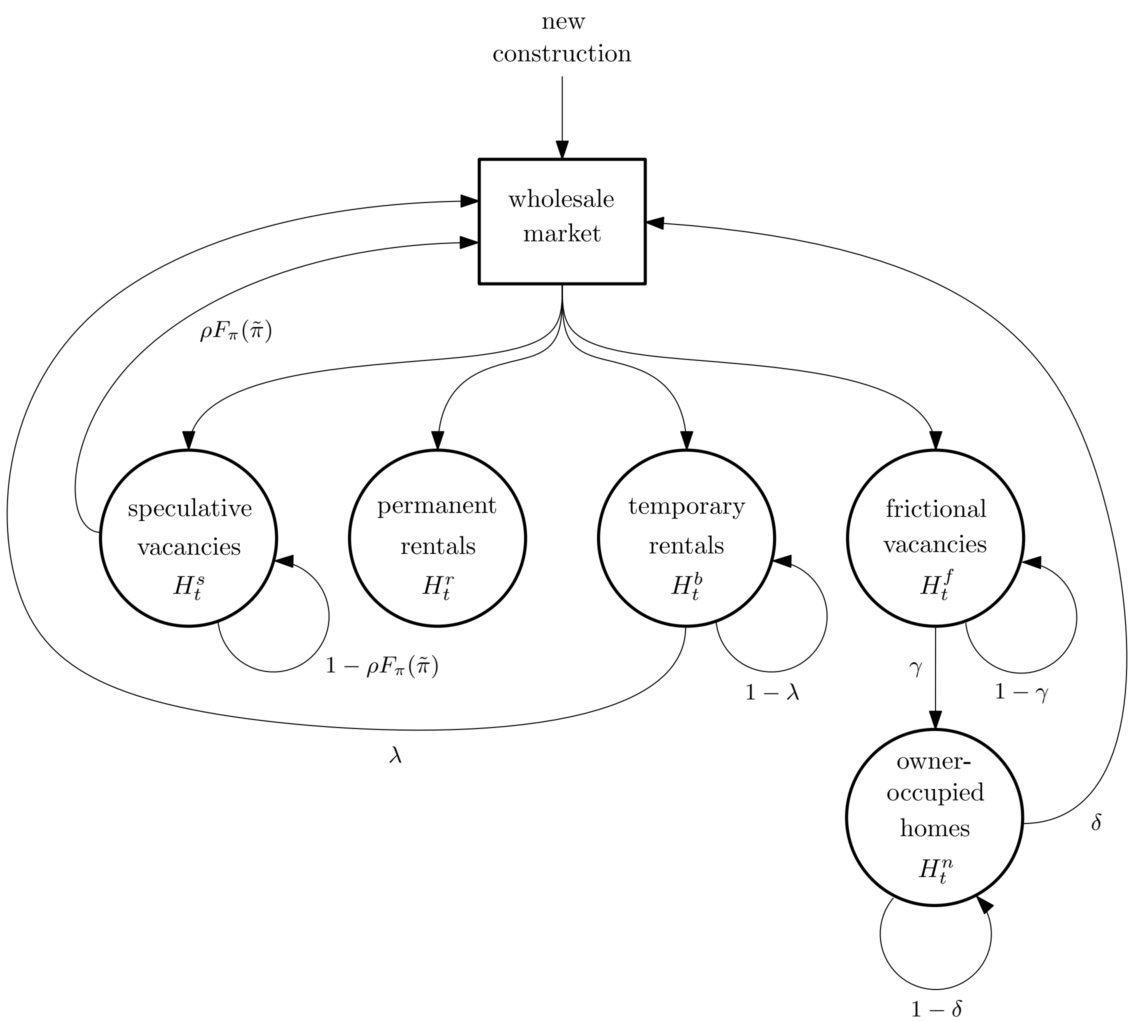


Figure 12: housing stocks and flows

homes held vacant by investors is

$$h_t^s = \phi[1 - F_\pi(\tilde{\pi}_t(\tilde{\varepsilon}_t))][1 - F_\varepsilon(\tilde{\varepsilon}_t)], \tag{27}$$

where $\tilde{\pi}_t(\tilde{\varepsilon}_t) = \tilde{\varepsilon}_t = (1+\tau)V_t - \beta V_{t+1}$. The vacancies in (26) are *frictional* vacancies, whereas those in (27) are *speculative* vacancies.

Since houses 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

$$h_t = h_t^n + h_t^r + h_t^b + h_t^f + h_t^s \tag{28}$$

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[17]

$$q(h_t) \geq V_t \quad \text{and} \quad h_t(1+\nu) \geq h_{t-1} \tag{29}$$

with complementary slackness.

6.3 Equilibrium Definition

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 and rents,* $\{V_t, x_t\}$*; 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* (16), (17), (18) *and* (22)*, taking house values* $\{V_t\}$*, rents* $\{x_t\}$*, and market tightness* $\{\theta_t(P)\}$ *as given;*

(ii) free entry in the rental market: $\{x_t\}$ *satisfies* (13)*;*

(iii) directed search in the sales market: $\{\theta_t(P)\}$ *satisfies* (19)*, and* $\{P_t\}$ *satisfies* (21) *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* (23), (24), (25), (26), *and* (27)*;*

[17] Define $q(h_t) \equiv q(H_t/L_t, 1) = q(H_t, L_t)$.

(vi) free entry into housing development: $\{V_t, h_t\}$ *satisfy the inequalities in* (29) *with complementary slackness, given aggregation conditions* (28).

6.4 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 (15), (13) and (19) become

$$V = q(h) \tag{30}$$

$$x = (1-\beta)V + m. \tag{31}$$

$$\gamma(\theta(P)) = \frac{(1+(1-\omega)\tau - \beta)V}{\beta(P-V)} \tag{32}$$

Equation (30) ties the value of a vacant house to the cost of construction. Equation (31) then pins down the rental cost of a housing unit. The equilibrium relationship between the price and submarket tightness in the owner-occupied market is established in (32) using the indifference condition for sellers/developers.

We can write stationary versions of Bellman equations (16), (17), and (18), and of the price equation (21):

$$(1-\beta)V^r = y - x \tag{33}$$

$$(1-\beta)V^b = y - x + \beta \max_P \lambda(\theta(P)) \left[V^n - V^b - P\right] \tag{34}$$

$$(1-\beta)V^n = y - m + z - \beta\delta \left[V^n - V^b - V\right], \tag{35}$$

$$P = \eta(\theta)V + (1-\eta(\theta))[V^n - V^b]. \tag{36}$$

Solving this system yields the following price equation for the owner-occupied market:

$$P = V + \frac{1-\eta(\theta)}{1-\beta(1-\delta-\eta(\theta)\lambda(\theta))} z. \tag{37}$$

The stationary version of (22) is

$$V^i(\pi, \varepsilon) = \max\{0, \pi - \min\{\varepsilon, (1 + \tau - \beta)V\}\} + \beta\mathbb{E}[V^i(\pi', \varepsilon)]. \tag{38}$$

Imposing stationarity in (23), (24), (25), (26), (27) and yields

$$h^r = \psi \tag{39}$$

$$h^b = \frac{(\nu + \delta)(1 - \psi)}{\nu + \delta + \lambda(\theta)} \tag{40}$$

$$h^n = \frac{\lambda(\theta)(1 - \psi)}{\nu + \delta + \lambda(\theta)} \tag{41}$$

$$h^f = \frac{h^b}{\theta} \tag{42}$$

$$h^s = \phi[1 - F_\pi(\tilde{\pi}(\tilde{\varepsilon}))][1 - F_\varepsilon(\tilde{\varepsilon})], \tag{43}$$

where $\tilde{\pi}(\tilde{\varepsilon}) = \tilde{\varepsilon} = (1 + \tau - \beta)V$.

Finally, the stationary version of the aggregation condition (28) is

$$h = h^r + h^b + h^n + h^f + h^s. \tag{44}$$

Definition 2 *An equilibrium balanced growth path is a list of values, $\{V^r, V^b, V^n\}$, and a value function, $V^i(\pi, \varepsilon)$; a house value, V, and rent, x; a price P and a function for market tightness, $\theta(P)$; a housing stock, h; and a distribution of houses/households, $\{h^r, h^b, h^n, h^f, h^s\}$; such that*

(i) V^r, V^b, V^n and V^i satisfy (33), (34), (35) *and* (38)*;*

(ii) free entry in the rental market: x satisfies (31)*;*

(iii) directed search: θ satisfies (32), *and P satisfies* (37) *with $\theta = \theta(P)$;*

(iv) stationary distribution of houses/households: h^r, h^b, h^n, h^f and h^s satisfy (39), (40), (41), (42), *and* (43)*;*

(v) free entry into housing development: V and h satisfy (30) *and* (44)*.*

6.5 Analytical Results

We are interested in the implications of the empty-homes-tax, τV_t. To that end, we consider the implications of an increase in the EHT rate, τ, using the equilibrium BGP equations from Section 6.4.

There are two offsetting effects: First, an increase in the EHT rate, τ, reduces *speculative* vacancies, h^s. Using (43), this effect is most straightforward to show under the assumptions that $\xi_1 = 0$ (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):

$$\frac{dh^s}{d\tau} = -\phi V \left\{ [1 - F_\pi(\tilde{\varepsilon})] \, f_\varepsilon(\tilde{\varepsilon}) + [1 - F_\varepsilon(\tilde{\varepsilon})] \, f_\pi(\tilde{\varepsilon}) \right\} < 0. \tag{45}$$

Figure 13 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, while others abstain from acquiring them altogether.

The second effect is a reduction in *frictional* vacancies when $\omega < 1$. This effect is again relatively straightforward to establish if we maintain the assumption that $\xi_1 = 0$. From (32) and (37), we have

$$\frac{d\theta}{d\tau} = \frac{(1-\omega)V}{\beta z} \frac{[1 - \beta(1 - \delta - \eta(\theta)\lambda(\theta))]^2}{\alpha(\theta)\eta(\theta)\lambda(\theta) \, [1 - \beta(1 - \delta - \lambda(\theta)]} > 0, \tag{46}$$

where

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

Equation (40) then yields

$$\frac{dh^b}{d\tau} = -\frac{\lambda'(\theta) h^b}{\nu + \delta + \lambda(\theta)} \frac{d\theta}{d\tau} > 0 \tag{47}$$

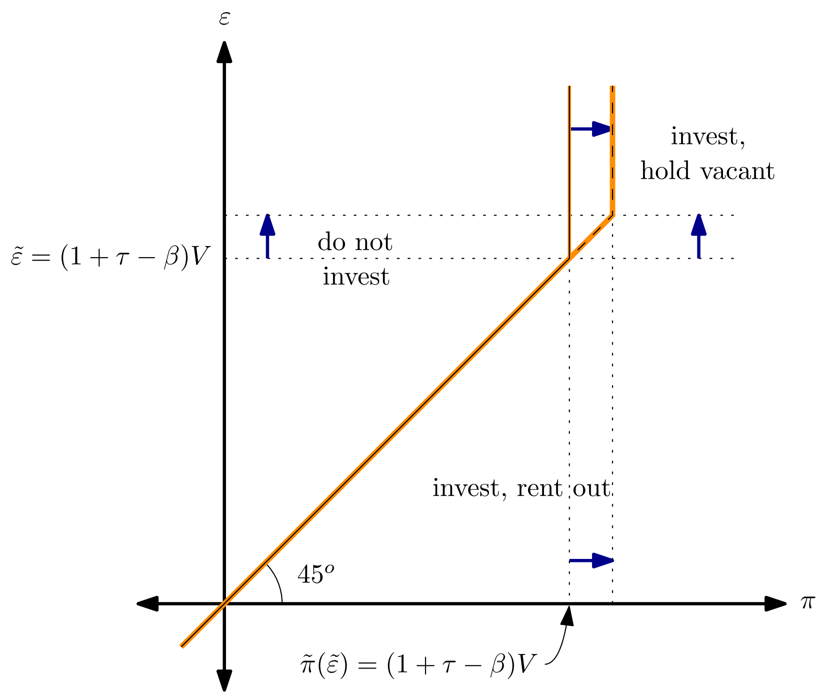


Figure 13: The Effect of τ on the Equilibrium BGP Decisions of Investors.

and

$$\frac{dh^f}{d\tau} = -\frac{h^f}{\theta}\frac{\nu+\delta+\eta(\theta)\lambda(\theta)}{\mu+\delta+\lambda(\theta)}\frac{d\theta}{d\tau} < 0. \tag{48}$$

Given imperfect tax exemption for vacant homes listed for sale and the simplifying assumption that $\xi_1 = 0$, an increase in τ causes a reduction in frictional vacancies. More generally, the reduction in both speculative and frictional vacancies lowers the relative supply of housing, h. When $\xi_1 > 0$, this lowers the cost of housing development, since $q'(h) \geq 0$. In the absence of an empty homes tax, developers build more homes in equilibrium, some of which are sold to investors and left vacant, which raises construction costs. 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 increase the price of owner-occupied homes, and reduce their relative availability in the owner-occupied market. 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 distorting the incentives to supply homes to the owner-occupied market, the EHT shifts the equilibrium BGP composition of housing from owner-occupied to rental:

$$\frac{dh^n}{d\tau} = -\frac{dh^b}{d\tau} < 0. \tag{49}$$

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

These effects on owner-occupied homes are depicted in Figure 14 under the assumption once again that $\xi_1 = 0$ so as to isolate the distortionary effects of the EHT when $\omega < 1$. As can be seen in the Figure, an increase in τ shifts and stretches a developer's indifference cure upward. Because a house can always be supplied to the 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).

The overall effect on the equilibrium BGP price of owner-occupied housing is ambiguous. The lower construction cost that results from an increase in τ when $\xi_1 > 0$ means that the equilibrium wholesale market value of a house is lower, which brings down the price in the owner-occupied market, P. As discussed above and illustrated in Figure 14, an increase in τ can also put upward pressure on price P because it distorts the incentive to supply frictional vacancies when $\omega < 1$. These two effects thus have opposing forces on the affordability of owner-occupancy.

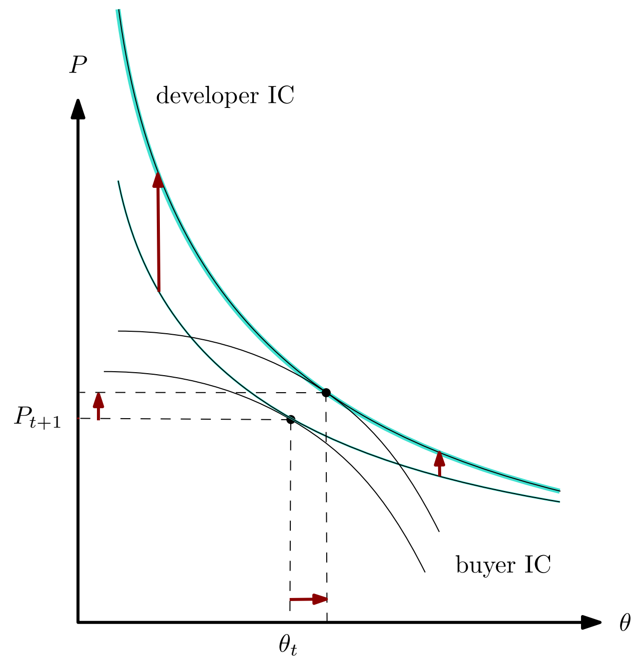


Figure 14: The Effect of τ on the Equilibrium BGP Decisions of Developers.

7 Discussion of the Modeling Assumptions

Model predictions about the effects of the empty-home-tax. In terms of the effects of the EHT rate, τ, the model yields predictions about prices, rents, price-rent ratio, listings, sales, rental transactions, vacancies, time-on-the-market, home-ownership, and new construction. Section 6.4 characterizes and defines the model's equilibrium BGP, and Section 6.5 discusses the comparative statics with respect to the EHT rate, τ. These provide theoretical insights about the *long-run* effects of the EHT. Earlier Sections 6.1, 6.2 and 6.3, on the other hand, characterize and define the dynamic equilibrium more generally. The off-BGP implications of τ are important here because the equilibrium outcomes like prices, sales, and listings may respond differently to the EHT in the short term than in the long term. Below, in Section 8, we parameterize the model and compute the transitional dynamics to a long-run BGP following the introduction of the empty-homes-tax, starting from an initial BGP with $\tau = 0$.

Income and wealth. The assumption that income is constant over time and across households is admittedly simplistic. With linear preferences and the assumption that the interest rate is $1/\beta$, households face no incentive to shift consumption intertemporally or accumulate wealth. This is a convenient feature of the model for tractability because households face risk in the frictional owner-occupied market (because of matching risk and preference shocks) which would complicate the consumption/savings problem of a household with curvature in their utility function. Extending the model to include income heterogeneity, non-linear utility and an endogenous wealth distribution could potentially be accomplished by assuming financial markets are complete (as in Head et al., 2023) or by exploiting block recursivity (as in Garriga and Hedlund, 2021). Income/wealth heterogeneity we think is an important extension: income has been widely cited as an important factor in home-ownership. Insights on whether an EHT would benefit lower income households would be important in a discussion of social welfare.

Selling while occupying. An assumption of the model is that a house must be vacant in order to be listed for sale in the owner-occupied market. Consequently, the value that an *unhappy* (or *mismatched*) homeowner assigns to home-ownership is just V_t, which is the financial value of a vacant house that could either be rented out or listed for sale in the owner-occupied market. This is the the amount that developers are willing to pay for a house. We could instead consider the possibility that mismatched owners could continue to live in their house and thus avoid rental costs while also trying to sell it in the owner-occupied market. In that case, the value of the house to its mismatched owner would exceed its financial value. By the same reasoning, perhaps mismatched homeowners as well as developers could rent out their house while it is listed for sale in the owner-occupied market. These modifications, however, would eliminate most vacancies in the model – all but those owned by investors with high maintenance costs. In other words, it would eliminate *frictional* vacancies, leaving only *structural* vacancies. The assumption that a house listed for sale must be vacant thus ensures that the search-and-matching frictions generate frictional vacancies in equilibrium.

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.[18]

8 Model Calibration and Simulation

The equilibrium BGP implications of the EHT derived in Section 6.5 represent the long-run effects that do not take into account the initial effect of turning speculative vacancies into tenanted and owner-occupied homes. We consider the initial short-run effects of the EHT by calibrating the model numerically computing the equilibrium transitional dynamics following an exogenous introduction of an EHT.

With a quarterly interpretation of the model's time periods, we parameterize the model to match several characteristics of Vancouver's housing markets in the absence of an EHT. We then consider the implications of an exogenous increase in the empty-homes-tax rate by computing the equilibrium transition from an initial equilibrium BGP with $\tau = 0$ to a new equilibrium BGP with $\tau > 0$.

[18] 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.

8.1 Distributional and Functional Form Assumptions

Suppose the matching function takes the following form:

$$\mathcal{M}(b, s) = \frac{bs}{b+s}.$$

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

$$F_\pi = F_\varepsilon = \mathcal{N}(\mu, \sigma).$$

8.2 Model Calibration

The parameter values and calibration targets are reported in Table 3. Whereas most model parameters are calibrated based on the initial pre-EHT equilibrium BGP, a few parameter values (namely, σ, τ and ω), are set to target post-EHT outcomes.

The population growth rate, ν, is set to match that of the total population of the Greater Vancouver Regional District (GVRD) in 2015 and 2016.[19] Annual household income is normalized to unity, and the parameter value for the discount factor, β, reflects an annual risk-free rate of 6 percent.

To calibrate parameter δ, we calculate the five-year mobility rate of homeowners. We use the total number of households that changed residence between 2011 and 2016, which we adjust based on the proportion of movers that are homeowners. These data are maintained and reported by the City of Vancouver. We convert this statistic to a stationary quarterly mobility rate and set the probability of a mobility shock in our calibrated model accordingly. We apply a similar approach to calibrate parameter ρ under the supposition that the five-year

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

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 (%)	6	β	0.9855
five-year mobility rate of homeowners (%), 2011-16	20.4	δ	0.0113
ownership rate (%), 2016	63.7	ψ	0.3453
construction cost relative to house value (%), 2015-16	28.4	ζ_0	0.9061
average annual rent relative to median income (%), 2015-16	25.6	ζ_1	2.1707
average annual maintenance cost relative to house value (%)	2.25	m	0.0179
housing flow value implied by optimal maintenance		z	0.0604
vacancy rate (%), 2014	4.8	ϕ	0.1286
share of homes owned by non-residents (%)	7.6	μ	0.0450
five-year turnover rate for non-resident owners (%), 2011-2016	40.8	ρ	0.0682
empty homes tax rate (%), 2017-19	1.0	τ	0.0025
property transfer exemption (%)	31.1	ω	0.6958
vacancy rate (%), 2017	4.1	σ	0.0486

mobility rate of non-residents is double that of residents. The share of permanent renters, ψ, is set to match the home-ownership rate in Vancouver in 2016.

The construction cost parameters, ζ_0 and ζ_1 are calibrated so that the initial pre-EHT equilibrium BGP matches the following two Vancouver statistics: the average annual rent to median income ratio and the average build cost relative to house price. The average annual rent is calculated from CMHC data, and the median income is obtained from the City of Vancouver's 2016 Census Income Data Release. The average cost of new housing construction is taken to be the median square footage of 1,068 times the construction cost per square foot of $225, relative to the median Vancouver house price from Vancouver MLS data of $845,000. The maintenance cost parameter, m, is set so that annual maintenance expenses amount to 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.[20] The flow value of housing is then derived from the solution to an optimal maintenance problem, given a depreciation rate of 2.5 percent.[21]

According to equation (43), the per capita measure of speculative vacancies depends on parameter ϕ as well as the distributions F_ε and F_π. Our approach is to shift the distributions with parameter μ and calibrate parameter ϕ to match Vancouver's pre-EHT vacancy rate and the share of residential properties owned by non-residents. We use the vacancy rate of residential properties according to Ecotagious' Analysis of Housing Occupancy in the City of Vancouver Using Electricity Meter Data Analytics,[22] which is 4.8 percent. The share of residential properties in Vancouver owned by non-residents is 7.6 percent according to the Canadian Housing Statistics Program.[23] The standard deviation, σ, of distributions F_ε and F_π determines the response of speculative vacancies to the EHT, and we describe our calibration approach for σ below.

While there is no EHT (i.e., $\tau = 0$) in the initial equilibrium BGP, we consider the equilibrium transition path to a final equilibrium BGP following the unexpected introduction of an EHT. More specifically, we exogenously increase the EHT rate to a level that matches the initial annual tax rate in Vancouver, which is one percent of a property's assessed taxable value. Accordingly, we set $\tau = 0.0025$ so that the EHT amounts to one percent of V_t annually.

We calibrate the EHT exemption for frictional vacancies to align with the information about exemptions contained in the Empty Homes Tax Annual Report (City of Vancouver, 2019). According to the report, 31.08 percent of empty homes in 2017 (2,462 out of 7,921)

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

[21] See Head et al. (2014) page 1189 for details. The basic idea is that the warm glow of homeownership is increasing in house quality, which is a stock variable that depreciates over time. The homeowner maintains the optimal quality of their house 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.

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

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

were exempt from the EHT because of a property transfer. We therefore set the exemption rate for frictional vacancies, ω, so that

$$\frac{\omega h^f}{h^f + h^s} = 0.3108.$$

Finally, we set σ so that the post-EHT equilibrium BGP features a residential vacancy rate of 4.1 percent. This aligns with the fraction of properties that were empty in 2017 as reported in the 2021 Empty Homes Tax Annual Report (City of Vancouver, 2021).

Computing the equilibrium transition path is complicated by the fact that the free entry condition for developers may not always bind (recall equation (29)). We therefore start with an initial guess, $\{h_t\}$ and hence $\{V_t\} = \{q(h_t)\}$, and solve backwards in time for rents, prices, tightness, values, and structural vacancies, $\{x_t, P_t, \theta_t, V_t^n, V_t^b, h_t^s\}$, using the first-order difference equations from Sections 6.1 and 6.2. The distribution of households and houses, $\{h_t^r, h_t^b, h_t^n, h_t^f\}$, are solved forwards in time. We then check market clearing period-by-period. If $h_{t+1}(1+\nu) < h_t$, we calculate what the value of a house in the wholesale market needs to be in order for the ownership decisions of investors to restore market clearing, $h_{t+1}(1+\nu) = h_t$. This generates a new series, $\{V_t\}$. These steps are repeated until the series of values converge.

8.3 Equilibrium Transition Path with EHT

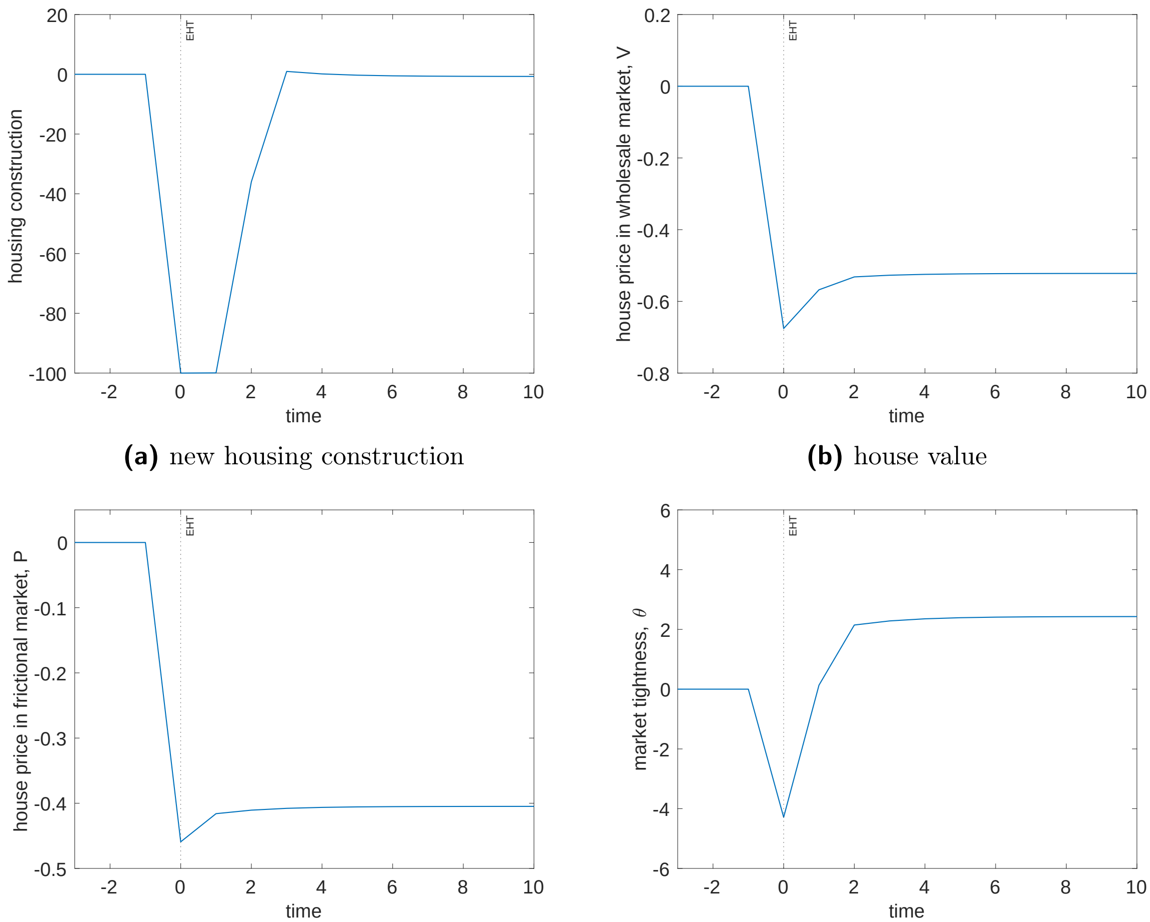
The implementation of the EHT induces some investors with vacant homes to sell them back to the wholesale market. This creates an excess supply of homes, which temporarily halts the construction of new housing and causes the value of a home in the wholesale market to fall below the cost of construction. The immediate fall in V_t coinciding with the introduction of the EHT is depicted in Figure 15b. Figure 15a displays how new construction falls to zero, but resumes two periods after the introduction of the tax.

In the frictional owner-occupied market, the abundance of homes causes an immediate price decline (Figure 15c). Since frictional vacancies are not fully exempt from the policy (i.e., $\omega < 1$), market tightness ultimately converges to a level above that in the initial BGP (Figure 15d). The lower price in the long-run indicates that the reduced cost of new housing development more than offsets the distortionary effect of the EHT. The distortionary effect would be more severe if owners of frictional vacancies faced a higher expected tax burden (i.e., if $\omega < 0.6958$), in which case the final price could converge to a level strictly above the initial price. A scenario in which frictional vacancies are not fully exempt from the tax is important for generating the result that house prices in the frictional market exhibit a smaller proportional decrease than construction costs (equivalently, house values in the wholesale market), and that tightness ends up higher than before the introduction of the EHT. In such settings, a price premium and shorter expected time-to-sell compensate supply side participants for creating frictional vacancies. Consequently, owner-occupied homes become more scarce and more expensive relative to rental homes.

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. 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.

The stock of buyers falls in the period following the implementation of the EHT (Figure 17b) because it becomes easier to buy a house when they are in abundance. After this initial decline, however, the relative measure of buyers increases and the measure of homeowners (Figure 17a) declines to the new stationary levels because 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 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 15b. Figure 15a displays how new construction falls to zero, but resumes two periods after the introduction of the tax.



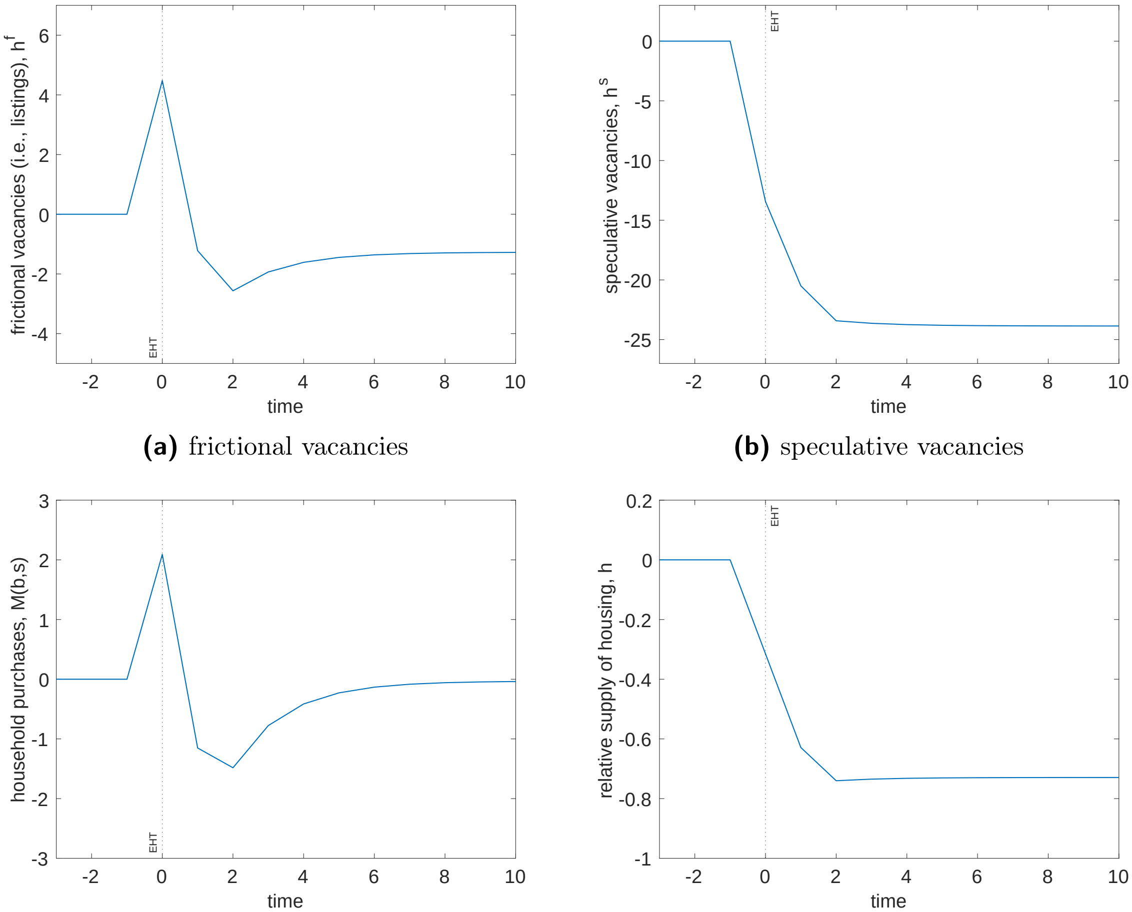
(a) new housing construction

(b) house value

(c) house price

(d) market tightness

Figure 15: Percentage deviation (from initial pre-EHT equilibrium BGP) of equilibrium construction, house values, prices, and tightness in response to EHT.



(a) frictional vacancies

(b) speculative vacancies

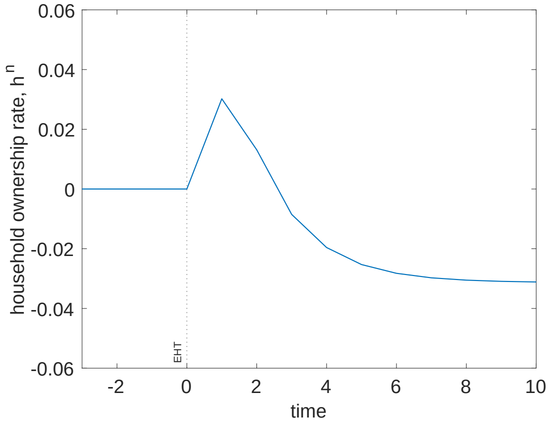
(c) sales in frictional market

(d) housing supply

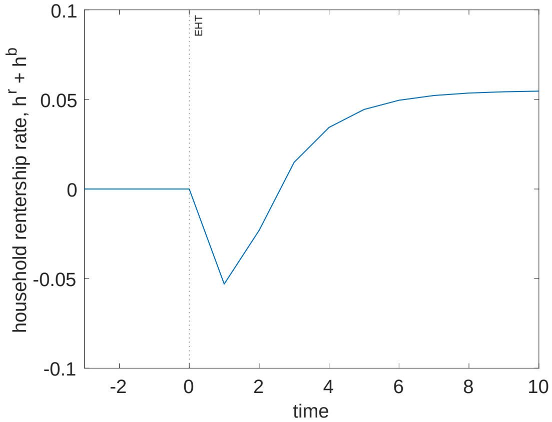
Figure 16: Percentage deviation (from initial pre-EHT equilibrium BGP) of equilibrium vacancies, sales, and housing supply in response to EHT.

8.4 Welfare Analysis

We use our calibrated model to explore the welfare implications of the EHT. In a market with search frictions, a certain amount of frictional vacancies are needed for the efficient or household-welfare-maximizing level of turnover in the owner-occupied market. Speculative vacancies, in contrast, are welfare-reducing because they increase the cost of supplying homes to the households that want to occupy them. Since the EHT reduces both types of vacancies,



(a) home-ownership rate



(b) rentership rate

Figure 17: Percentage deviation (from initial pre-EHT equilibrium BGP) of equilibrium ownership and rentership rates in response to EHT.

as shown analytically, it yields offsetting welfare effects.

In the short-run immediately following the introduction of the tax, however, some of these effects are exactly the opposite of what was just described, as the rental and owner-occupied markets first need to absorb some of the speculative vacancies that are supplied to both markets in response to the EHT. This is policy-relevant because an increase in housing availability and affordability immediately following the introduction of an EHT (or an increase in the tax rate) could obfuscate the longer-term adverse effects of the policy. The numerical computation of the calibrated model allows us to describe the welfare consequences of the EHT along the equilibrium transition path following the introduction and implementation of the EHT.

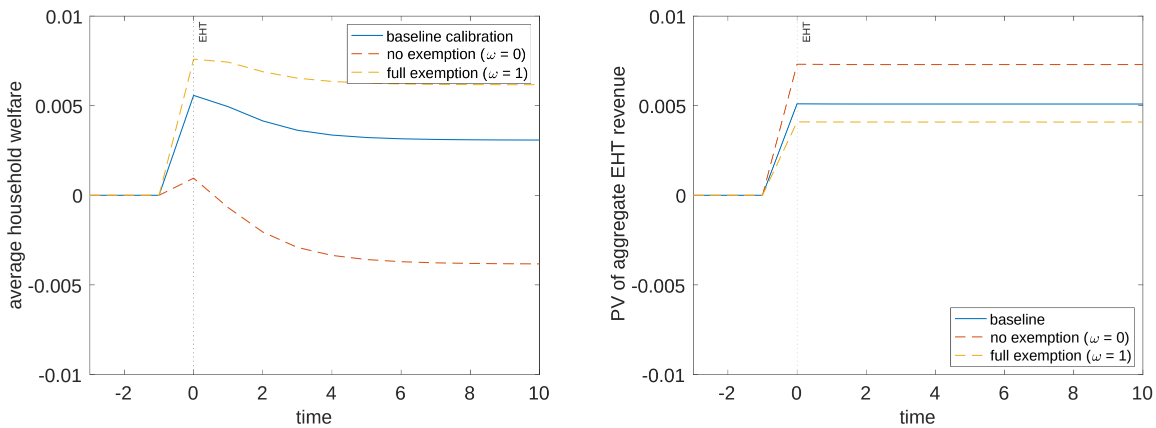
The welfare consequences for households are the focus of our normative analysis. Our measure of household welfare at time t is a weighted average of the present discounted values of lifetime utility derived from consumption and homeownership for renters, buyers and owners. The weights are the per capita measures of renters, buyers and owners:

$$W_t = h_t^r V_t^r + h_t^b V_t^b + h_t^n V_t^n. \tag{50}$$

Our analysis should also account for the EHT revenue collected from the owners of empty homes. According to the 2021 Empty Homes Tax Annual Report (City of Vancouver, 2021), net revenues from Vancouver's EHT are allocated to affordable housing initiatives. While social housing programs are beyond the scope of our model, we can nonetheless consider EHT revenues as augmenting or offsetting the model's welfare implications. In our dynamic welfare analysis, we measure household welfare at time t as per equation (50), and concurrently, we perform an accounting exercise to express the present value of aggregate EHT revenues on a per-household basis:

$$R_t = \tau \left[(1-\omega) h_t^f + h_t^s \right] + \beta R_{t+1}. \tag{51}$$

Figure 18 depicts the evolution of our measures of welfare and tax revenue per-household from equations (50) and (51) in response to the EHT. The solid blue lines correspond to the benchmark calibration with $\omega = 0.6958$, and the dashed yellow and red lines correspond to alternative scenarios in which frictional vacancies are fully exempt (i.e., $\omega = 1$) and not at all exempt (i.e., $\omega = 0$) from the EHT. The long run impact of the EHT on average household welfare depends crucially on the exemption for frictional vacancies. The EHT has a large positive net impact on household welfare under full exemption. By discouraging speculative vacancies and hence reducing in the relative supply of housing, the tax benefits both renters and owner-occupiers in equilibrium by lowering the cost of housing development. In our baseline calibration with less-than-full exemption, the distortionary effect of the EHT on frictional vacancies counteracts the welfare benefits of reduced construction costs. In the absence of any exemption, the long-run impact of the tax is in fact negative because its large distortionary effect on frictional vacancies limits the accessibility and affordability of homeownership. Even in this case, however, the tax revenues collected from developers and investors are more than enough to compensate households for the negative long-run welfare effects of the EHT. In the short-run, there is an additional but transitory positive impact of the EHT on household welfare as speculative vacancies are made available to households at more affordable prices than they were previously.



(a) household welfare

(b) PV of EHT revenue per household

Figure 18: Household welfare and EHT tax revenue in response to EHT.

Changes in average household welfare reflect changes in the expected present discounted values for renters, $\{V_t^r\}$, buyer-renters, $\{V_t^b\}$, and owner-occupiers, $\{V_t^n\}$. As depicted in Figures 17a and 17b, however, the EHT also changes the composition of households. For our calibrated model, it turns out that most of the EHT's impact on average household welfare is captured in the values. This is in part because the values themselves reflect changes in the distribution of households in the sense that they depend on the matching probabilities that govern the distribution of households. Additionally, recall from Figures 17a and 17b that the distribution of households changes only slightly in response to the EHT.

Table 4 provides a decomposition of the long-run welfare consequences of the EHT. Differences in household welfare between the pre- and post-EHT equilibrium BGPs are captured separately for a renter, buyer-renter, and owner-occupier in V^r, V^b and V^n. The welfare effects of an EHT-induced change in a specific equilibrium outcome can be isolated by keeping everything else the same as in the pre-EHT equilibrium BGP when solving the system of equations in Section 6.4. Each isolated welfare effect is then calculated and expressed in Table 4 as a percentage change in income in every future period for a renter, buyer-renter, and owner-occupier.

The welfare effect of all housing-related outcomes on renters, buyer-renters and owner-occupiers, reported in the bottom row of Table 4, reveal that the net benefit of the EHT is positive for renters and buyers, but negative for owner-occupiers.[24] Renters benefit from lower housing costs, whereas homeowners suffer a loss in home equity due to the price effect of the tax. The higher rows of Table 4 provide a decomposition of these housing-related welfare effects into various components. Housing availability is affected by the EHT because the increase in market tightness affects homeownership. More specifically, a rightward movement along the developer's indifference curve (see Figure 8) means that frictional vacancies become more scarce, which increases expected time-to-buy and lowers the stationary rate of homeownership. Finally, the EHT influences housing affordability as it affects both the cost of new housing construction and, with less-than-full exemption for frictional vacancies, the price premium for owner-occupied homes. Finally, the bottom row of Table 4 concerns EHT revenues. Tax revenues are allocated to renters, buyer-renters and owner-occupiers as if each household holds an equal entitlement to these public funds.

This welfare 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 housing 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

[24]Note that buyer-renters and owner-occupiers transition stochastically based on homeownership status. As such, the overall welfare effect on a homeowner, for example, takes into account expectations about becoming a renter and searching to buy again in the future.

Equilibrium Outcome	Welfare Effects Renter	 Buyer-Renter	 Owner-Occupier
Housing Availability			
Market Tightness in Frictional Market	0.0000	−0.0003	−0.0001
Housing Affordability			
Construction Cost	0.0962	0.1012	0.0022
Price Premium in Frictional Market	0.0000	−0.0503	−0.0219
All Housing Outcomes	0.0962	0.0514	−0.0195
EHT Revenue	0.0295	0.0295	0.0295

Notes: Welfare effects are calculated as an equivalent adjustment to perpetual consumption and expressed as a percentage change in permanent income.

Table 4: Welfare Effects Between Pre- and Post-EHT Equilibrium Balanced Growth Paths

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 (Steacy, 2023).

9 Conclusion

Using individual housing transactions data from Vancouver, this paper estimates the housing market's dynamic responses to a recent empty homes tax. Our analysis reveals a sharp drop in both prices and rents in the short run but a reversal in the longer term for prices but not rents, accompanied by an increase in sales, listings and time-on-the-market in the short run as well as a reversal of these trends in the longer term. Thus, while the EHT initially appears to achieve the desired objective of improving housing availability and affordability, its effects diminish over time in the owner-occupied sector but remain stable in the rental sector.

We develop a search-theoretic model that captures the novel effects of an empty homes tax on the rental market, the owner-occupied market, and new housing construction. Our model offers two key insights. First, an EHT turns speculative vacancies into more affordable tenanted rentals, which represents an improvement in housing availability and affordability. Second, the vacancy tax can distort the incentives to supply homes to the owner-occupied market, which can worsen housing affordability and reduce home ownership.

The calibrated model explains the empirical findings and points to a novel welfare cost of the empty home tax. The distinction between speculative and frictional vacancies is key to understanding these patterns in the data. The initial increases in listings and sales and decreases in prices and rents reflect an excess supply of housing as speculative vacancies are supplied to rental and owner-occupied markets. The opposite longer-term effects on listings, sales, and prices are explained by the distortionary effect of the EHT on 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:

$$y_{jt} = \alpha + \beta_1 \tau_{jt}^{EHT} + X_{jt}\beta + \mu_{jt} \tag{52}$$

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.

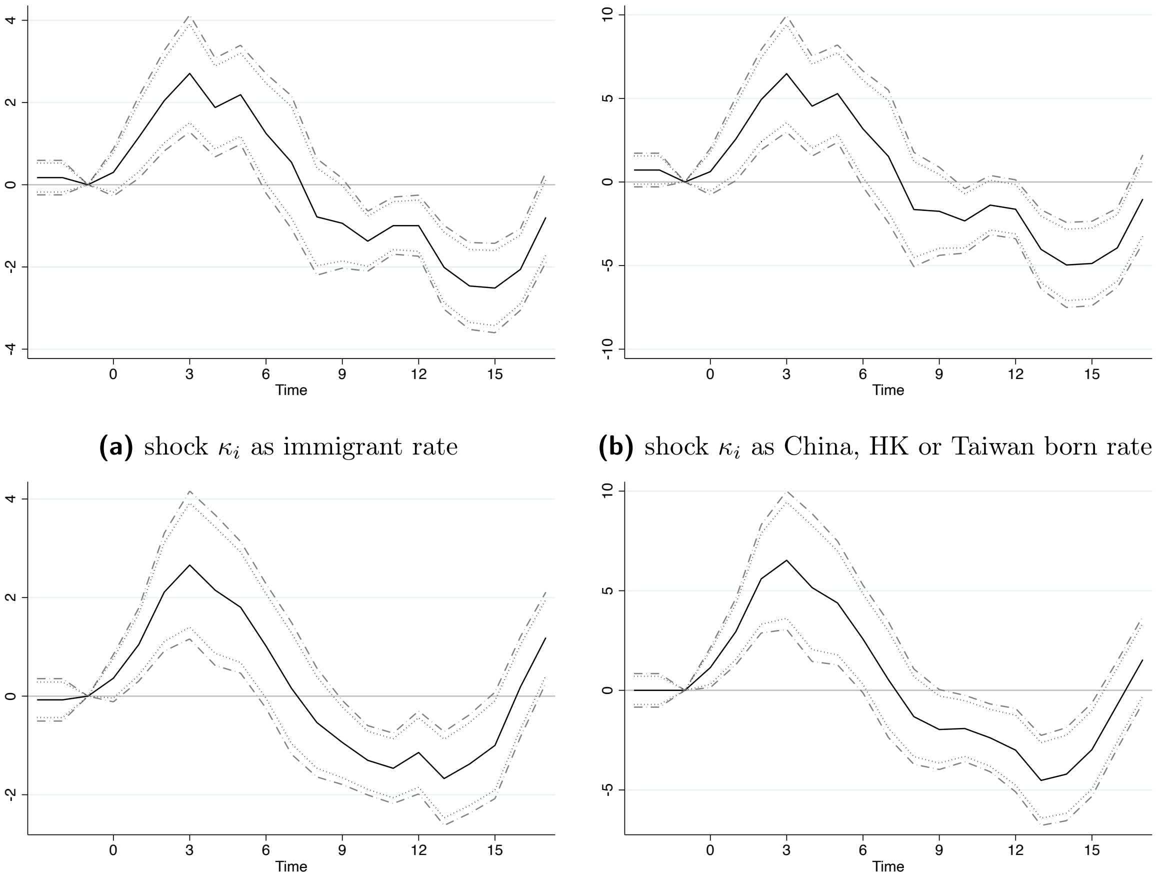
The table below shows the results of the above regression in columns (1) and (2) for all outcome characteristics. The majority of the housing characteristics show a nonsignificant or very small coefficient. Only the age of the property shows a significant coefficient, suggesting that the age of the properties 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 serves 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 5: Housing characteristics composition in the neighborhoods affted 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 cpde 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 previous 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 Robustness Checks on Exposure κ_i



(a) shock κ_i as immigrant rate

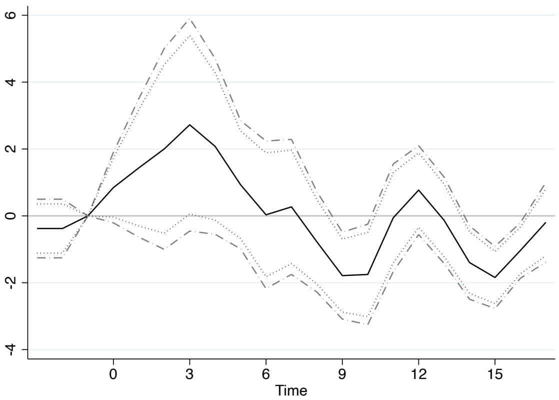
(b) shock κ_i as China, HK or Taiwan born rate

(c) shock κ_i as immigrant rate

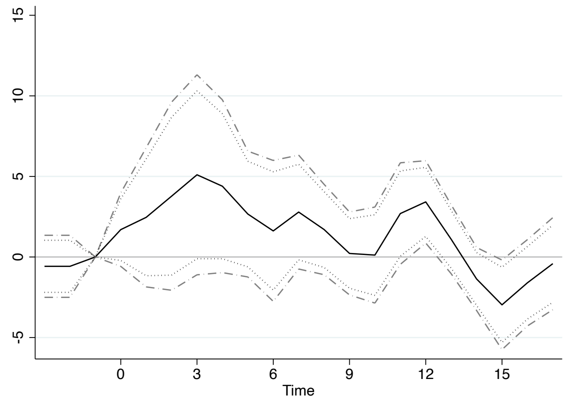
(d) shock κ_i as China, HK or Taiwan born rate

Figure 19: Robustness Checks: Average causal effects of EHT on sales

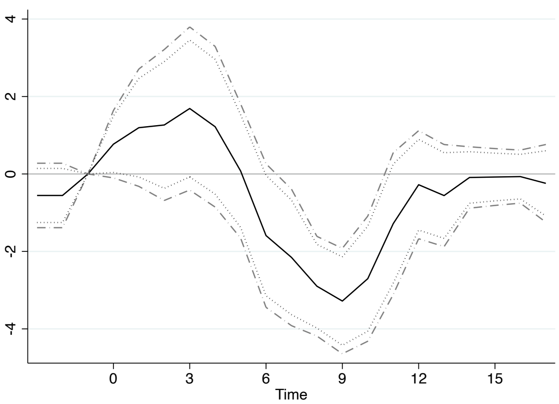
Notes: The figure shows the coefficient of estimating the impulse response equation at each horizon. Panels (a) and (b) correspond to the border sample, while panels (c) and (d) to the whole sample. The local exposure κ_i is normalized by its standard deviation. All regressions include FSA, year/month, and local seasonality FE. The standard errors are clustered by year/month periods. The number of lags, p, is 12. The dotted lines are 95% and 90% CI.



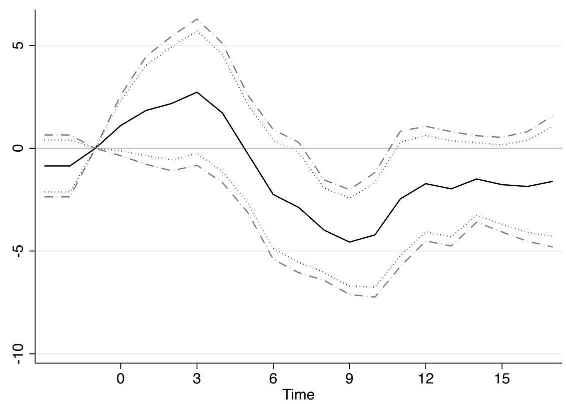
(a) shock κ_i as immigrant rate



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



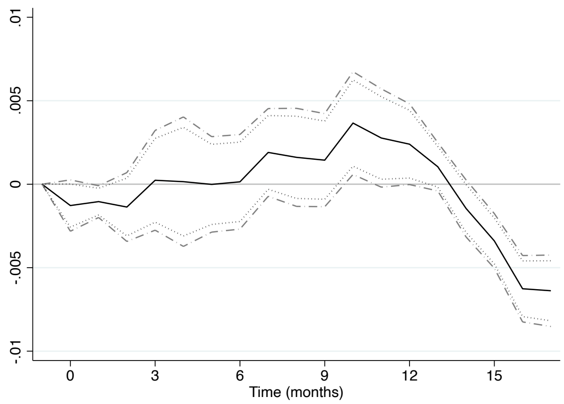
(c) shock κ_i as immigrant rate



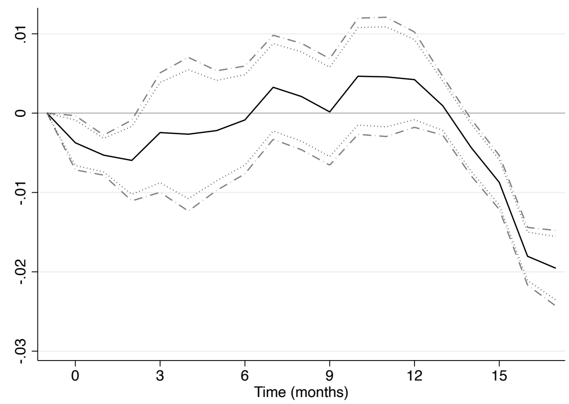
(d) shock κ_i as China, HK or Taiwan born rate

Figure 20: Robustness Checks: Average causal effects of EHT on listings

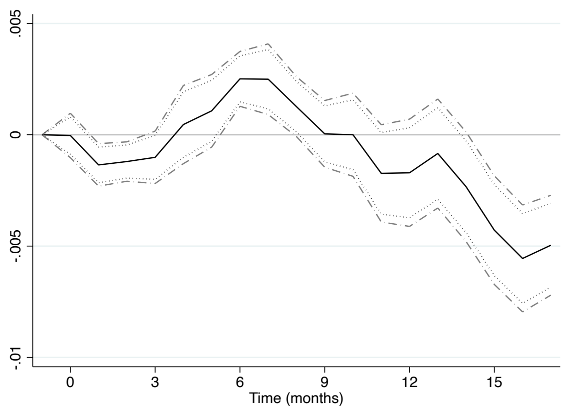
Notes: The figure shows the coefficient of estimating the impulse response equation at each horizon. Panels (a) and (b) correspond to the border sample, while panels (c) and (d) to the whole sample. The local exposure κ_i is normalized by its standard deviation. All regressions include FSA, year/month, and local seasonality FE. The standard errors are clustered by year/month periods. The number of lags, p, is 12. The dotted lines are 95% and 90% CI.



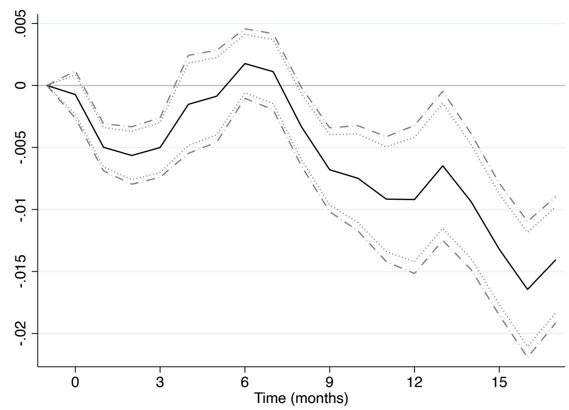
(a) shock κ_i as immigrant rate



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



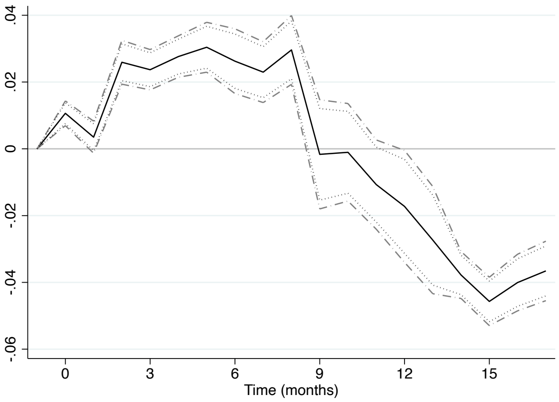
(c) shock κ_i as immigrant rate



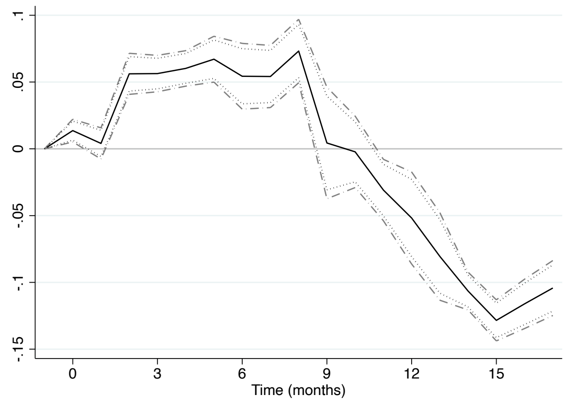
(d) shock κ_i as China, HK or Taiwan born rate

Figure 21: Robustness Checks: Average causal effects of EHT on prices

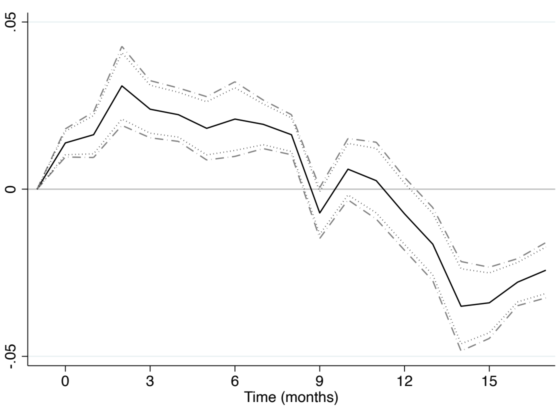
Notes: The figure shows the coefficient of estimating the impulse response equation at each horizon. Panels (a) and (b) correspond to the border sample, while panels (c) and (d) to the whole sample. The local exposure κ_i is normalized by its standard deviation. All regressions include FSA, year/month, and local seasonality FE. The standard errors are clustered by year/month periods. The number of lags, p, is 14. The dotted lines are 95% and 90% CI.



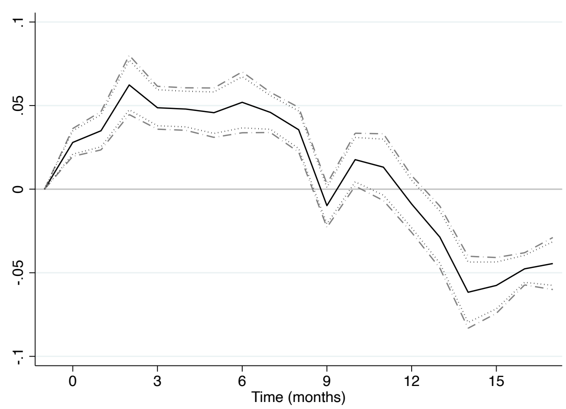
(a) shock κ_i as immigrant rate



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



(c) shock κ_i as immigrant rate

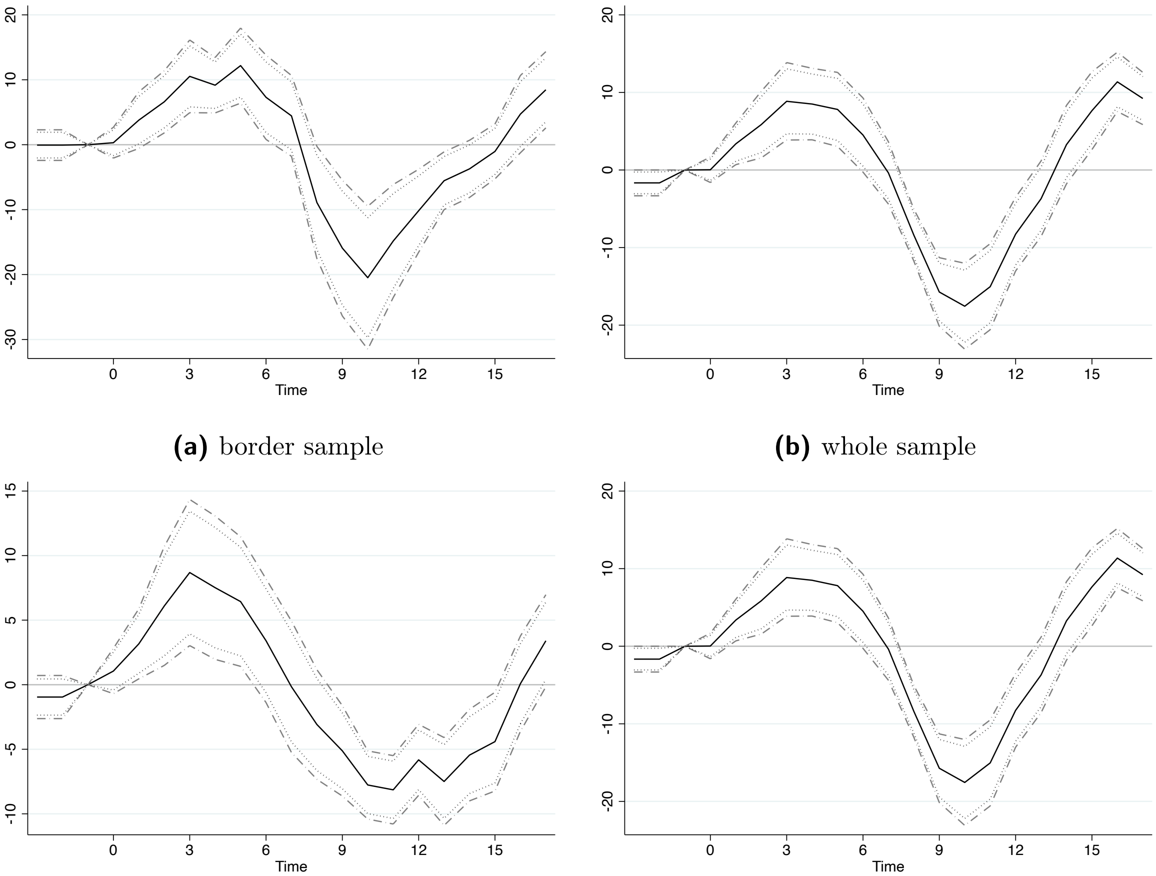


(d) shock κ_i as China, HK or Taiwan born rate

Figure 22: 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 include FSA, year/month, and local seasonality FE. The standard errors are clustered by year/month periods. The number of lags, p, is 14. The dotted lines are 95% and 90% CI.

C Spillovers and Anticipation Robustness Checks



(a) border sample

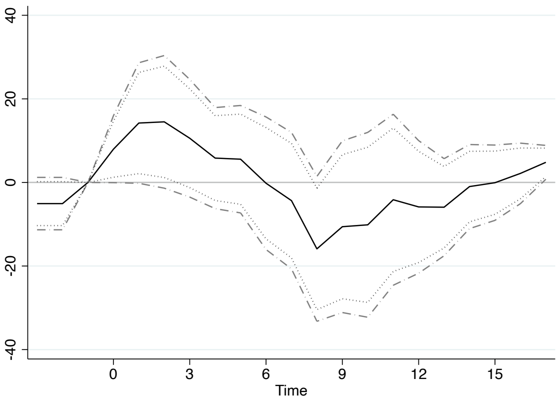
(b) whole sample

(c) non-border sample and all periods

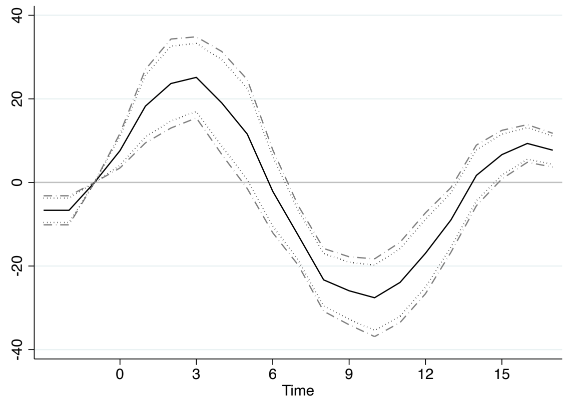
(d) non-border sample

Figure 23: Anticipation period Jan 2016- May 2016 removed for number of sales.

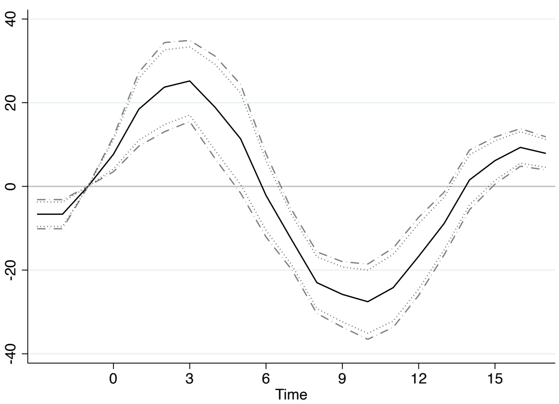
Notes: The figure shows the coefficient of estimating the impulse response equation at each horizon. All regressions include FSA, year/month, vacancy, and local seasonality FE. The treatment month is June of 2016. The number of lags, p, is 12. The standard errors are clustered by year/month periods. The dotted lines are 95% and 90% CI.



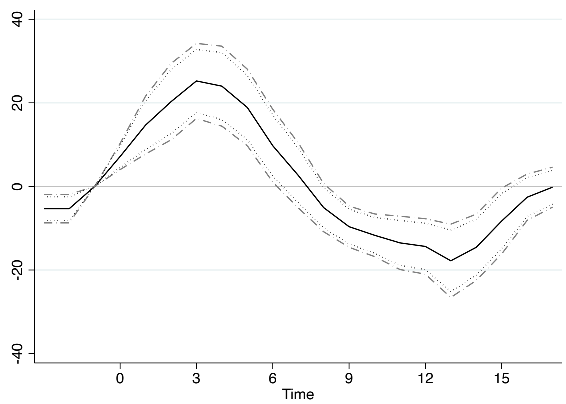
(a) border sample



(b) whole sample



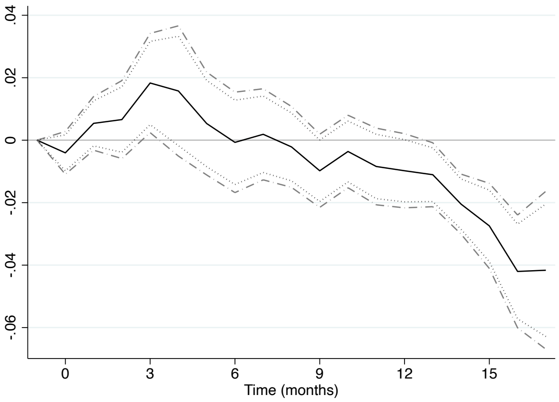
(c) non-border sample and all periods



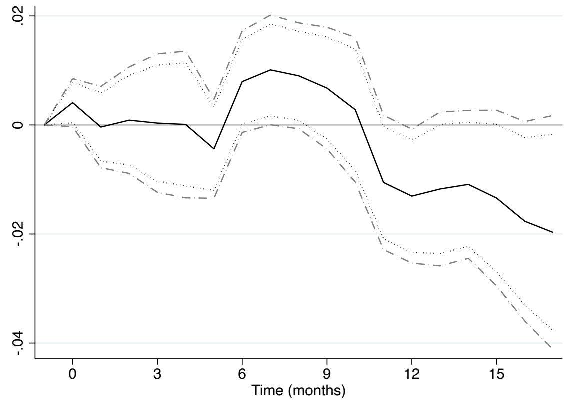
(d) non-border sample

Figure 24: Anticipation period Jan 2016- May 2016 removed for number of listings.

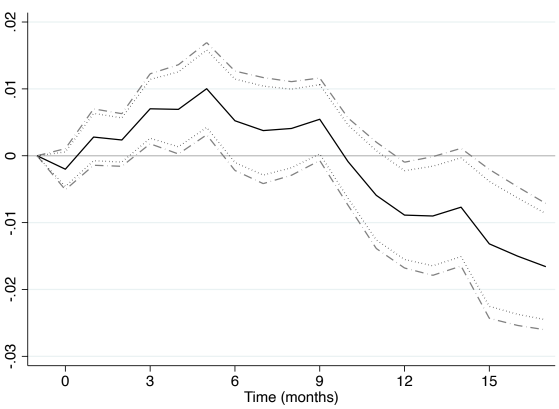
Notes: The figure shows the coefficient of estimating the impulse response equation at each horizon. All regressions include FSA, year/month, vacancy, and local seasonality FE. The treatment month is June of 2016. The number of lags, p, is 12. The standard errors are clustered by year/month periods. The dotted lines are 95% and 90% CI.



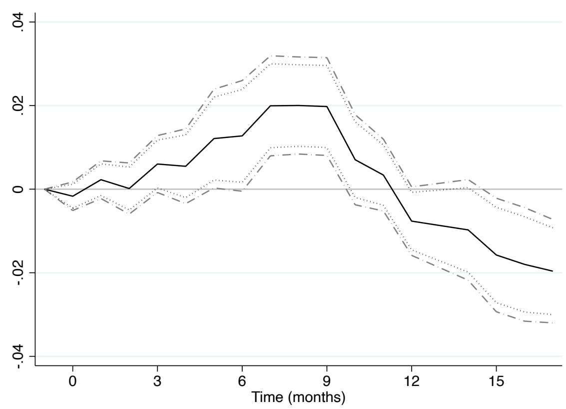
(a) border sample



(b) whole sample



(c) non-border sample and all periods



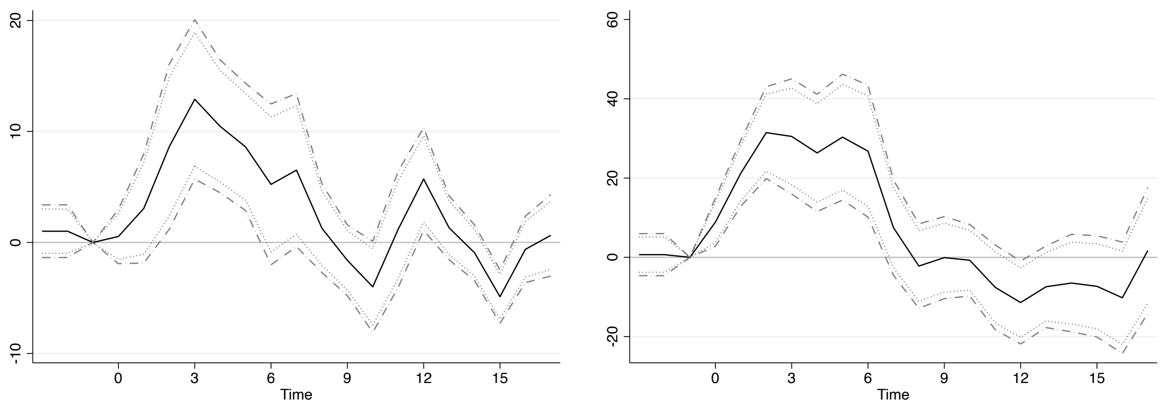
(d) non-border sample

Figure 25: Anticipation period Jan 2016- May 2016 removed for price index.

Notes: The figure shows the coefficient of estimating the impulse response equation at each horizon. All regressions include FSA, year/month, vacancy, and local seasonality FE. The treatment month is June of 2016. The number of lags, p, is 12. The standard errors are clustered by year/month periods. The dotted lines are 95% and 90% CI.

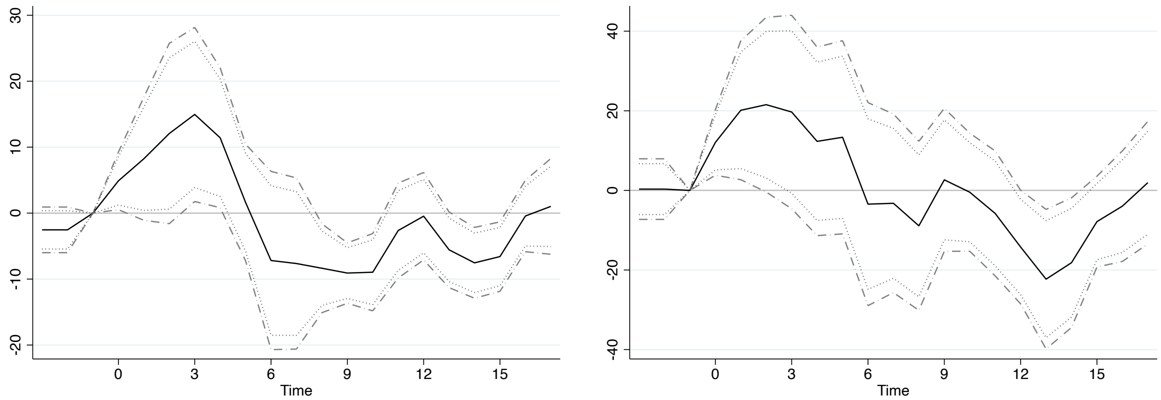
D Robustness Checks on Definition on Border Sample

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.



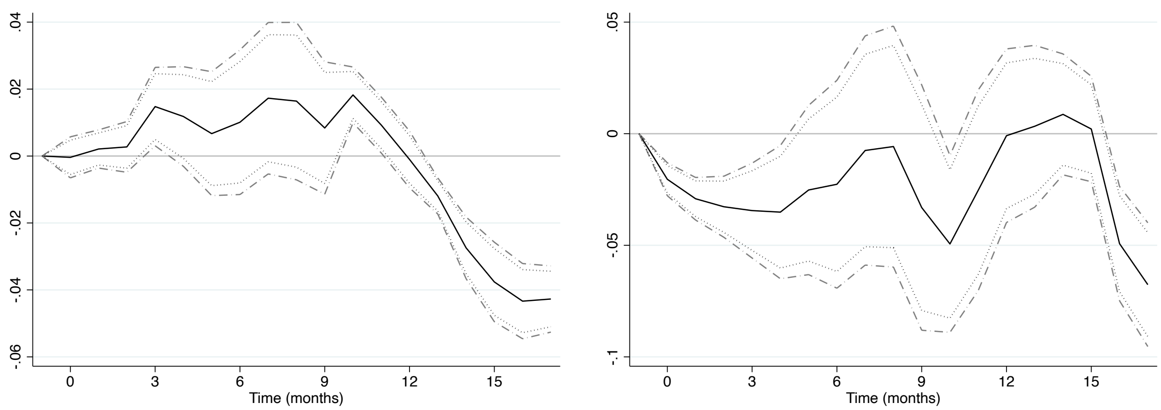
(a) Burnaby/Vancouver **(b)** Richmond/Vancouver

Figure 26: Average causal effects of EHT on sales for alternative border samples



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

Figure 27: Average causal effects of EHT on listings for alternative border samples

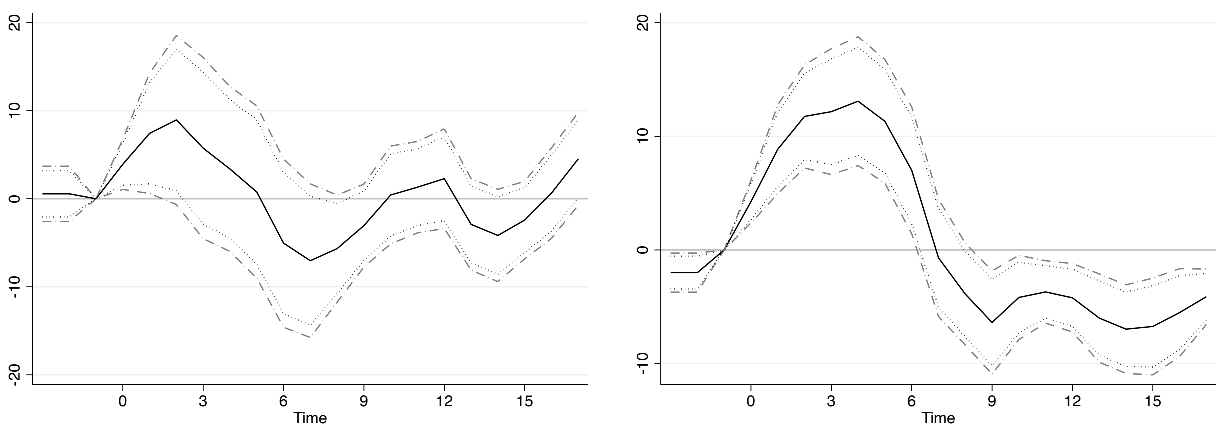


(a) Burnaby/Vancouver **(b)** Richmond/Vancouver

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

E Robustness Checks on Definition of Listings

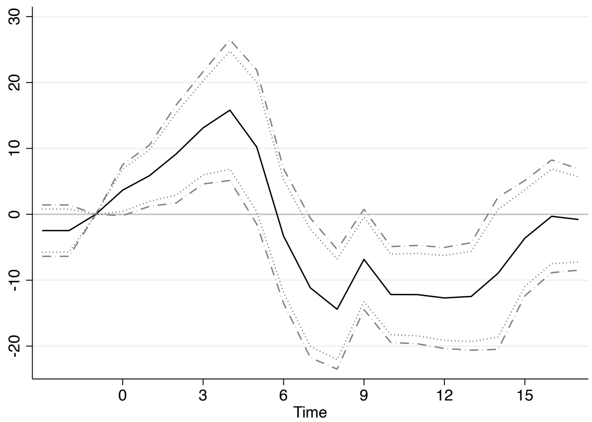
This section performs robustness checks on the definition of listings. We consider two definitions of listings: (1) the total number of listings in the market at a given time (existing listings); and (2) the number of new listings. A listing is counted as existing if it was listed before the beginning 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 29 and Figure 30 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.



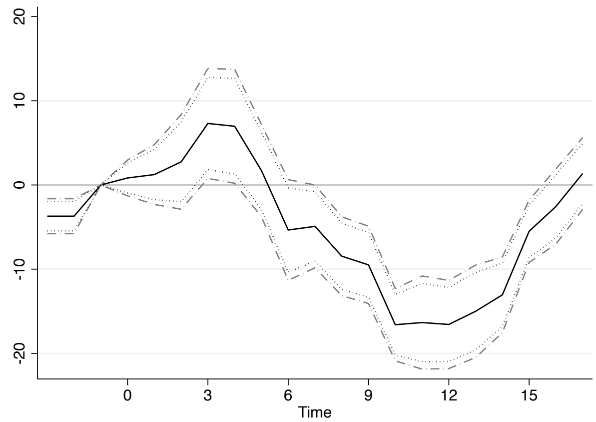
(a) border sample **(b)** whole sample

Figure 29: 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 include FSA, year/month, and local seasonality FE. The treatment month is June of 2016. The number of lags, p, is 14. The standard errors are clustered by year/month periods. The dotted lines are 95% and 90% CI.



(a) border sample



(b) whole sample

Figure 30: 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 include FSA, year/month, and local seasonality FE. The treatment month is June of 2016. The number of lags, p, is 14. The standard errors are clustered by year/month periods. The dotted lines are 95% and 90% CI.

F Sales and Listings Dynamic Difference-in-Difference

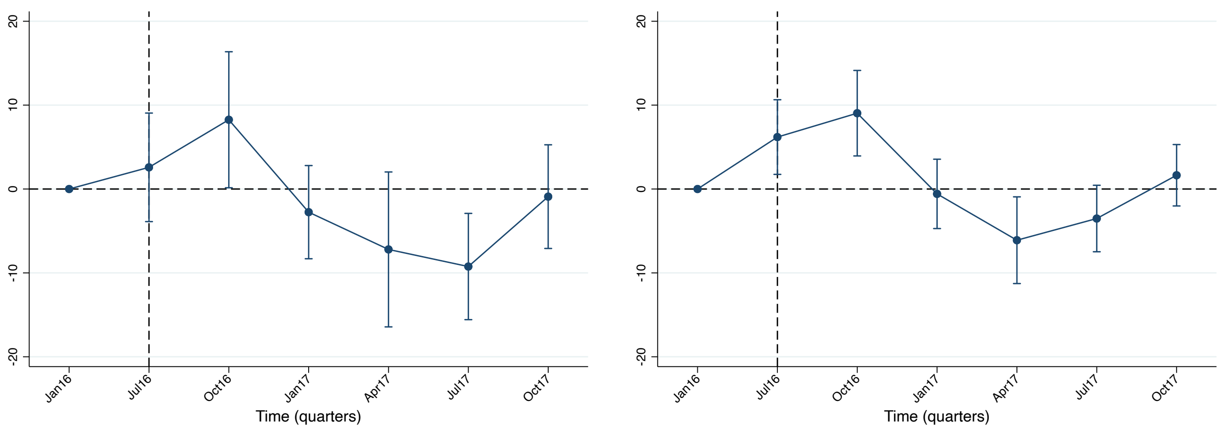
As robustness test, we try for sales and listings an alternative specification. Unlike house price growth, which exhibit positive autocorrelation in the short run and mean reversion in the long run (Glaeser and Gyourko, 2016), sales and listings can be estimated using a more common approach such as difference-in-difference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

$$Y_{jt} = \sum_h \beta_h \times \mathrm{D}_{th} \times \mathrm{Van}_j + \gamma x_{jt} + \alpha_j + \beta_t + \epsilon_{jt} \tag{53}$$

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 31a 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.



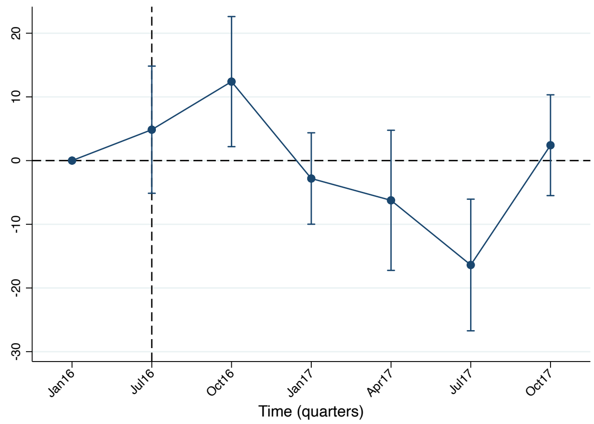
(a) border sample

(b) whole sample

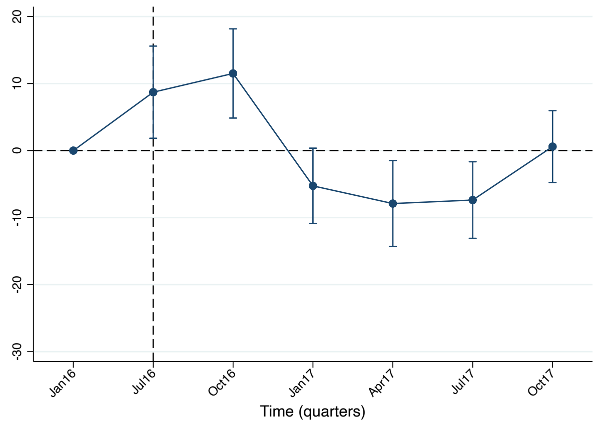
Figure 31: Average causal effects of EHT on number of sales.

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.



(a) border sample



(b) whole sample

Figure 32: 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.