Out-of-town Home Buyers and City Welfare [*]

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Abstract

The major cities of the world have attracted a flurry of interest from out-of-town (OOT) home buyers. Such capital inflows in local real estate have implications for affordability through their effects on prices and rents, but also for construction, local labor markets, the spatial distribution of residents, and ultimately economic welfare. We develop a spatial equilibrium model of a city that features heterogeneous households that make optimal decisions on consumption, savings, labor supply, tenure status, and location. The model generates realistic wealth accumulation and home ownership patterns over the life-cycle and in the cross-section. An inflow of OOT real estate buyers pushes up prices, rents, and wages. It increases the concentration of young, high-productivity, and wealthy households in the city center (gentrification). When OOT investors buy 10% of the housing stock, city welfare goes down by 0.3% of permanent consumption levels. The average renter suffers a large welfare loss while the average owner gains modestly. We calibrate the model to the New York metro area using data on OOT purchases. The observed increase in OOT purchases is associated with 1.1% higher house prices and a 0.1% welfare loss. A tax on OOT home buyers, as introduced in Vancouver, can reduce the welfare loss.

JEL classification: R10, R20, R30, R40, R51, G11, G12, H41, H70, J61
keywords: Dynamic spatial equilibrium, house prices, foreign investors, affordable housing, gentrification

1 Introduction

Residential investment in major urban centers by out-of-town (OOT), including foreign, investors has been on the rise.[1] These investment flows are controversial since they tend to concentrate in the most attractive parts of the city and leave highly desirable real estate under-utilized. Investors displace local residents whose longer commutes may hamper their productivity and quality of life. They change the socio-economic composition of the neighborhood. They raise the cost of living, pushing up rents and house prices, fueling the affordability issue these cities already struggle with. Public opposition to OOT investor flows has led Vancouver to introduce a 15% transaction tax on non-local residential real estate buyers in August 2016, followed by similar measures in Toronto and Sydney in 2017, and has spurred talk of higher stamp duties on non-locals in London and elsewhere. On the other hand, OOT investors bring benefits as well. They may spur new construction which requires local labor. This demand for construction services (and for other non-tradeables like restaurants) increases wages for local workers. They generate property tax revenue which finances local education and infrastructure. Most importantly, they increase property values for local home owners. The net effect of these forces is unknown. Are OOT buyers of local real estate good or bad for the city's overall welfare? Are taxes on OOT buyers welfare improving?

We set up and solve a model that is able to address these questions. Our city consists of two zones, the city center or central business district (zone 1), and the rest of the metropolitan area (zone 2). Working-age households who live in zone 2 commute to zone 1 for work. The model is an overlapping generations model with risk averse households that face labor income risk during their life-cycle and make dynamic decisions on consumption, savings, labor supply, tenure status (own or rent), and where in the city to locate. The model generates a cross-sectional distribution over age, labor income, tenure status, housing wealth, and financial wealth. This richness is necessary to study the winners and losers from the OOT purchases. The model also generates realistic wealth accumulation and home ownership patterns over the life-cycle and in the cross-section. The city produces tradable goods and residential housing. While interest rates and goods prices are taken as given, wages, house prices, and rents are determined in the city's equilibrium.

We shock this city with an inflow of OOT real estate investors. We assume these investors use the home as a pied-à-terre rather than renting it out to locals. From the perspective of the locals, OOT housing demand is a source of aggregate risk. Local residents form beliefs over the

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[1]Knight Frank estimates that 28% of Central London homes above 1 million pounds were sold to non-resident foreigners. Non-resident foreigners bought $54 billion worth of U.S. homes in 2015. Chinese investors alone plowed A$30 billion into Australia's housing markets in 2015-16.

expected duration of low- and high-OOT investment spells. We ask how much households would be willing to pay to avoid an inflow of OOT real estate investors. More precisely, how much lifetime consumption would the average local be willing to forgo to avoid a transition from a low-OOT to a high-OOT housing demand?

To build intuition, we start with a simple model where both zones are symmetric in size and there are no commuting costs. Each zone of the city contains half of the population and housing stock, and has an identical distribution of age, income, and wealth. We let this economy undergo a transition from a situation with no OOT demand to one where OOT investors buy 10% of the housing stock in each zone. Given imperfectly elastic housing supply, an inflow of OOT investors gets partially absorbed by new construction (+2.6%) and mostly by higher rents (+8.9%). House prices increase substantially (+4.9%), but by less than rents, because house prices capitalize the possibility of a reversal to lower future OOT investor demand and hence lower future rents. New construction and lower price-rent ratios dampen the fall in the home ownership rate among locals caused by the OOT housing demand. City-wide wages rise (+0.9%) due to the boom in the construction sector. Because income growth falls short of house price growth, the price-income ratio rises (4.6%) reducing "affordability."

Renters, whose cost of living rises, suffer welfare losses from the OOT demand shock. They would be willing to forgo 1.4% of annual consumption to avoid it. Owners, on the other hand, benefit not only from the higher wages but also from the capital gains. The younger owners however face higher future housing costs. The average owner's welfare gain is 0.3%. Aggregating the welfare of all local residents, city welfare falls by 0.3% following a 10% increase in OOT demand.

In a second step, we introduce commuting costs from zone 2 to zone 1, both a time cost and a financial cost. Heterogeneous households optimally sort spatially. Zone 1 is more attractive because of its proximity to work and attracts a larger population share and a larger share of the housing stock in equilibrium. Zone 1 has higher density and the typical dwelling is smaller. Zone 1 residents are younger, more productive (higher-income), and less wealthy, in part because they are younger and tend to rent. Zone 2 attracts more retirees who tend to be lower-income but wealthier. Realistic commuting costs deliver rents and prices that are 25% higher in zone 1 than in zone 2. The home ownership rate is 56% in zone 1 but 69% in zone 2, matching the observed differences between center-city and suburban ownership rates for the average U.S. metropolitan area.

We then introduce the same OOT shock in the model with commuting costs. OOT investors disproportionately push local residents out of the city center. As a result of this spatial relocation, the housing stock, house prices, and rents all grow slightly faster in zone 2 than in zone 1. In

zone 1, they increase slightly more than in the no commuting cost model (rents +9.1%, prices +5.0%). Age, income and wealth differences between the local residents of zone 1 and zone 2 increases. Income and wealth inequality between the urban core and periphery rise. In other words, OOT investors accelerate gentrification. Home ownership rates fall modestly but hardly at all in zone 2 since fairly high income renters who are pushed out of zone 1 are able to transition to owner-occupied housing in zone 2. Owners benefit from OOT investors entering and renters lose. The more realistic urban structure has large implications for the absolute magnitude of the welfare gains and losses. The owner's gain of +0.6% is double that in the no commuting cost model. The renters' loss is larger as well. The net effect is a similar welfare loss of 0.3%.

We examine larger OOT purchases, less persistent OOT purchases, and more concentrated purchases in the urban core. We also solve a simpler model that generates too little wealth inequality, a simpler model without renters, and a model where OOT investors rent out their properties. With two exceptions, these models generate similar net welfare costs of OOT buyers. The model without renters and the model where OOT investors rent out there property generates welfare costs that are de minimis. In other words, the removal of housing available for local residents is the source of the welfare loss.

We consider two applications of our framework to New York and Vancouver, both of which are at the epicenter of the OOT home buyer debate. We use novel data from CoreLogic on the fraction of OOT purchases for New York. OOT buyers account for 5.3% of all New York metro residential sales, with a much larger share in Manhattan (zone 1, 11.6%) than it is in the other 24 counties in the metro area (zone 2, 4.6%). Both OOT shares have increased steadily over the last thirteen years. We calibrate the model to fit the observed OOT demand increases. We also capture the relative amount of buildable residential square footage in the two zones in the New York metro and the metro-wide income distribution. We extend the model to capture rent regulation because a large fraction of the renter-occupied housing stock in New York is regulated. And we extend the model to feature neighborhood consumption externalities. The model does a good job capturing the stark income, rent, and house price differences across the two zones. We find that the observed OOT purchase increases lead to a net welfare loss for New York of 0.1% in consumption equivalent units.

Our second application aims to study the effects of a tax on OOT buyers. This exercise is motivated by the introduction of such a tax in Vancouver in August 2016. We make OOT purchases price-elastic, and calibrate the elasticity to the observed response of OOT purchases to the tax. The extra tax revenue funds additional public goods, over which local residents derive utility. We recalibrate the model to the geography, income distribution, pension system, and rent regulation of the Vancouver metro. We find that a positive OOT tax reduces the net cost

from OOT purchases. For a strong enough preference for public goods and/or a high enough OOT tax rate, city welfare may even improve after the increase.

Related Literature Our key contribution is a synthesis of the macro-finance and urban economics literatures. We introduce a spatial dimension in the macro-finance literature and a finance dimension in the urban economics literature.

On the one hand, a large literature in finance solves partial-equilibrium models of portfolio choice between housing (extensive and intensive margin), financial assets, and mortgages.[2] More recent work in macro-finance has solved such models in general equilibrium, adding aggregate risk, endogenizing house prices and sometimes also interest rates.[3] Like the former literature, our model features a life-cycle and a rich portfolio choice problem. It aims to capture key quantitative features of observed wealth accumulation and home ownership over the life-cycle. Like the latter literature, house prices, rents, and wages are determined in equilibrium. Because we model one city, interest rates are naturally taken as given. Like the macro-finance literature, we aim to capture key features of house prices, income inequality, and wealth inequality.

On the other hand, a voluminous literature in urban economics studies the spatial location of households and firms in urban areas.[4] On the consumer side, this literature studies the trade-off between the commuting costs of workers, the housing prices they face, and the housing expenditures they make. These models tend to be static and households tend to be risk neutral or have quasi-linear preferences.[5] The lack of risk, investment demand for housing, and wealth effects makes it hard to connect these spatial models to the finance literature.[6] Studying the

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[2]Early examples are Campbell and Cocco (2003), Cocco (2005) and Yao and Zhang (2004). A recent example is Berger, Guerrieri, Lorenzoni, and Vavra (2015). Davis and Van Nieuwerburgh (2015) provides a recent summary of this literature.

[3]E.g., Favilukis, Ludvigson, and Van Nieuwerburgh (2017) and Kaplan, Mitman, and Violante (2016). Davis and Van Nieuwerburgh (2015) provides a recent summary of this literature as well. One related study to ours is Imrohoroglu, Matoba, and Tuzel (2016) who study the effect of the 1978 passage of Proposition 13 which lowered property taxes in California. They find quantitatively meaningful effects on house prices, moving rates, and welfare. Our model adds a spatial dimension and aggregate risk but abstracts from housing transaction costs.

[4]Brueckner (1987) summarizes the Muth-Mills monocentric city model. Rappaport (2014) introduces leisure as a source of utility and argues that the monocentric model remains empirically relevant. Rosen (1979) and Roback (1982) introduce spatial equilibrium in a static setting.

[5]Van Nieuwerburgh and Weill (2010) solve a dynamic spatial equilibrium model with many cities and many household types. However, households have quasi-linear preferences. Recent work on spatial sorting across cities includes Behrens, Duranton, and Robert-Nicoud (2014) and Eeckhout, Pinheiro, and Schmidheiny (2014). Guerrieri, Hartley, and Hurst (2013) study house price dynamics in a city and focus on neighborhood consumption externalities, in part based on empirical evidence in Rossi-Hansberg, Sarte, and Owens (2010).

[6]Hizmo (2015) and Ortalo-Magné and Prat (2016) study a portfolio choice problem where households make a once-and-for-all location choice between cities. Conditional on the location choice, they are exposed to local labor income risk and make an optimal portfolio choice. They have constant absolute risk aversion preferences and consume at the end of life. The models are complementary to ours in that they solve a richer portfolio choice problem in closed-form, and have a location choice across cities. We solve a within-city location choice, but allow

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welfare effects of OOT investors on the local economy requires a model with wealth effects. Our model studies spatial equilibrium within a city. Households are free to move across neighborhoods each period, rent or own, and choose how much housing to consume. We close the housing market in that local landlords who own more housing than they consume rent to other locals.

Because it is a heterogeneous-agent, incomplete-markets model, agents choices and equilibrium prices depend on the entire wealth distribution. Because of the spatial dimension, households' location is an additional state variable that needs to be kept track of. We use state-of-the-art methods to solve the model.[7] The resulting model is a new laboratory which can be used to explore many important questions like the impact of zoning laws on house prices, inequality, and affordability.

Our model also connects to a growing literature that studies the effect of OOT home buyers on local housing markets. Badarinza and Ramadorai (2016) attribute foreign inflows in the London real estate market to political risk in the countries from which the capital flows originate. Using political shocks in a source country as an exogenous instrument, they estimate the effects of OOT buyers on house prices in London neighborhoods with a large pre-existing share of residents born in that source country. They find substantial price effects in such areas, which they interpret as safe haven effects. Sá (2016) also studies the effect of foreign investment on UK house prices and home ownership rates. Cvijanovic and Spaenjers (2015) finds that non-resident foreigners crowd out residents in highly desirable neighborhoods of Paris and cause house prices to rise. They also show empirically that relatively few properties bought by non-residents are rented out, and assumption we will make in our main analysis. Chinco and Mayer (2016) argue that OOT buyers of second homes behave like misinformed speculators and drove up house prices in cities like Phoenix, Las Vegas, and Miami in the mid-2000s.[8] We provide a model to confront this empirical evidence with. When calibrated to the empirical evidence, such a model can be used for counter-factuals and policy analysis. We provide new testable implications relating to the effects on wages, on location choice for local residents, the socio-economic make-up of neighborhoods, and within-city inequality that future empirical work could test. Our modeling of OOT investor flows as exogenous accords well with the notion that they are driven by political risk or originate from less sophisticated speculators. Finally, this literature provides evidence on the share of OOT investors that informs our calibration.

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for preferences that admit wealth effects, and allow for consumption and mobility each period.

[7]We extend the approach of Favilukis et al. (2017), which itself extends Gomes and Michaelides (2008) and Krusell and Smith (1998) before that.

[8]In related work, Bayer, Geissler, Magnum, and Roberts (2011) study the role of investors in the housing market, but without an emphasis on local versus out-of-town investors. DeFusco, Nathanson, and Zwick (2017) provide new empirical evidence of the importance of investors in the determination of house prices and provide a model of speculative demand with investors to account for price and volume dynamics.

The rest of the paper is organized as follows. Section 2 sets up the model. Section 3 calibrates the baseline model. Section 4 discusses its main results. Section 5 extends the model to include rent control and then calibrates it to the New York metro area. The Vancouver model in Section 6 discusses a tax on OOT buyers. Section 7 concludes.

2 Model

The model consists of two geographies, the "urban core" and the "periphery", whose union forms the "metropolitan area" or "city." The urban core is the central business district or city center where all employment takes place. We will refer to it as zone 1. The urban periphery are the outer boroughs of the city as well as the suburban areas that belong to the metropolitan area, from which residents commute to the city center. We will refer to it as zone 2.[9] The key difference between zone 1 and zone 2 from the perspective of the model is that people can live in both zones but only work in zone 1. While clearly an abstraction of the more complex production and commuting patterns in large cities, the assumption captures the essence of such commuting patterns. The two zones can differ in size. The city has a fixed population normalized to one.[10]

2.1 Households

Preferences The economy consists of overlapping generations of households. There is a continuum of households of a given age. Each household maximizes utility u over consumption goods c, housing h, and labor supply n, and utility is allowed to depend on location ℓ. Housing is divisible and there are no moving costs.[11] The dependence on location allows us to capture the commuting time and amenity differences across locations. We use a Cobb-Douglas aggregator:

$$U(c_t, h_t, n_t, \ell) = \frac{u(c_t, h_t, n_t, \ell)^{1-\gamma}}{1-\gamma}, \quad u(c_t, h_t, n_t, \ell) = c_t^{\alpha_c} h_t^{\alpha_h} \left(1 - n_t - \phi_T^\ell\right)^{1-\alpha_c-\alpha_h}.$$

The time cost of commuting is ϕ_T^ℓ; the total (non-sleeping) hours in a period of time are normalized to 1. There also is a financial cost ϕ_F^ℓ associated with commuting from zone ℓ. We normalize

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[9]For example, the New York metropolitan area can be split into Manhattan county (zone 1) and the other 24 counties that make up the MSA (zone 2).

[10]One could introduce a reservation utility from moving elsewhere. This cost could be calibrated to deliver a fixed population of one absent out-of-town buyers. A non-zero out-of-town housing demand in the presence of that fixed reservation utility would then have implications for migration of the local population. We do not pursue this extension here since the reservation utility parameter would ultimately remain a free parameter.

[11]Moving costs could be added but only at the expense of additional numerical complexity. Moreover, households are fairly mobile over periods of four years, which is the length of a period in our calibration, suggesting modest mobility costs.

the financial and time cost of commuting from within zone 1 to zero.[12]

There are two types of households in terms of subjective time discount factor. One group of households have a high degree of patience β^H while the rest have a low degree of patience β^L. This preference heterogeneity helps the model match observed patterns of home ownership and wealth accumulation over the life cycle.

Endowments A household's labor income depends on the number of hours worked n, the wage per hour worked W, a deterministic component $G(a)$ which captures the hump-shaped pattern in average labor income over the life-cycle, and an idiosyncratic labor productivity shock z.

There is an exogenous retirement age. After retirement, households earn a pension which is the product of an aggregate component $\overline{\Psi}$ and an idiosyncratic component ψ^{a,z_t} which has cross-sectional mean of one. Labor income is taxed at rate τ^{SS} to finance the pension system.

Households face mortality risk which depends on age, p^a. Although there is no intentional bequest motive, agents who die leave accidental bequests. We assume that the number of people who die with positive wealth leave a bequest to the same number of agents alive of ages 21 to 65. These agents are randomly chosen, with one restriction. Patient agents (β^H) only leave bequests to other patient agents and impatient agents (β^L) only leave bequests to other impatient agents.[13] Conditional on receiving a bequest, the size of the bequest $\widehat{b}_{t+1}$ is a draw from the relevant distribution (different for β^H and β^L types). Because housing wealth is part of the bequest and the house price depends on the aggregate state of the economy, the size of the bequest is stochastic. Agents know the distribution of bequests, conditional on β. The model captures several features of real-world bequests: many households receive no bequest, and there is substantial heterogeneity among bequest sizes for those who do.[14]

Location and Tenure Choice Let S_t be the aggregate state of the world, which includes the wage W_t, as well as the housing price P_t^ℓ, rental cost R_t^ℓ and previous housing stock H_{t-1}^ℓ for each location ℓ. The household's individual state variables are its net worth at the start of the period x_t, its idiosyncratic productivity level z_t, and its age a. The household is also in one of two patience categories, $\beta = \beta^L$ or $\beta = \beta^H$. We suppress the dependence on β-types in the problem formulation below, but note that there is one set of Bellman equations for each β type. The household chooses in which location ℓ to live, and whether to be an owner or a renter. Denote

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[12]The costs of commuting from any other part of the city to the center can be thought of as the incremental costs relative to the cost of commuting from within the center.

[13]One interpretation is that attitudes towards saving are passed on from parents to children.

[14]As in Tabellini (1991), the young benefit from the unexpected house price appreciation of their owner parents through the type-specific bequest channel. Our bequest specification also captures that children have some idea about the kind of bequest they may expect to receive.

by V the value functions over these choices, with subscript R denoting a choice of renting and O one of owning. The household solves

$$V = \max_{s \in (R,O),\ell} V_{s,\ell},$$

where $V_{R,\ell}$ and $V_{O,\ell}$ are defined below.

Renter Problem   If a household of age a chooses to become a renter in location ℓ, it will choose non-durable consumption c_t, housing consumption h_t, and working hours n_t to solve:

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\begin{aligned}
V_{R,\ell}(x_t, z_t, a, S_t) &= \max_{c_t, h_t, n_t} U(c_t, h_t, n_t, \ell) + (1-p^a)\beta E_t[V(x_{t+1}, z_{t+1}, a+1, S_{t+1})] \text{ s.t.} \\
c_t &+ R_t^\ell h_t + Q_t b_{t+1} + \phi_F^\ell = (1-\tau^{SS})W_t n_t G^a z_t + \overline{\Psi}\psi^{a,z_t} + x_t \\
x_{t+1} &= b_{t+1} + \widehat{b}_{t+1} \geq 0 \\
n_t &\geq 0
\end{aligned}
\tag{1}
$$

The renter's savings in the risk-free bond, b_{t+1}, are obtained from the budget constraint. Next period's financial wealth consists of these savings plus any accidental bequest received.

Owner's Problem   If a household of age a chooses to become an owner in location ℓ, it will choose non-durable consumption c_t, housing consumption h_t, working hours n_t, and investment property size $\widehat{h}_t$ to solve:

$$
\begin{aligned}
V_{O,\ell}(x_t, z_t, a, S_t) &= \max_{c_t, h_t, \widehat{h}_t, n_t} U(c_t, h_t, n_t, \ell) + (1-p^a)\beta E_t[V(x_{t+1}, z_{t+1}, a+1, S_{t+1})] \text{ s.t.} \\
c_t &+ P_t^\ell h_t + Q_t b_{t+1} + (P_t^\ell - R_t^\ell)\widehat{h}_t + \phi_F^\ell = (1-\tau^{SS})W_t n_t G^a z_t + \overline{\Psi}\psi^{a,z_t} + x_t \\
x_{t+1} &= b_{t+1} + \widehat{b}_{t+1} + P_{t+1}^\ell(h_t + \widehat{h}_t)(1 - \delta - \tau^P) \\
-Q_t b_{t+1} &\leq P_t^\ell(\theta_{res} h_t + \theta_{inv}\widehat{h}_t) \\
n_t &\geq 0 \\
\widehat{h}_t &\geq 0
\end{aligned}
\tag{2}
$$

By having renters, the model must also allow for households who own more housing units than they occupy themselves. For simplicity, we assume that renters cannot buy investment property and that owners can only buy investment property in the location of their primary residence. Owners earn rental income on their investment units.

The physical rate of depreciation for all housing units is δ. The term $Ph\delta$ is a financial costs, i.e., a maintenance cost.[15] As shown in equation (7) below, the physical depreciation $Ph\delta$ can

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[15]It is easy to solve for a model where investment housing incurs an additional maintenance cost which is a fraction $\delta_{inv} \geq 0$ of the value of the property. Increasing δ_{inv} makes renting less attractive and increases the

be replaced by residential investment undertaken by the construction sector.[16]

Property taxes on the housing owned in period t are paid in year $t + 1$; the tax rate is τ^P. Property tax revenue is used for local government spending. In the baseline model, government spending confers no utility to the agents. In the Vancouver model, property tax revenue finances a local public good that enters the local residents' utility function.

Housing serves as a collateral asset for debt. For simplicity, mortgages are negative short-term safe assets. Households can borrow a fraction θ_{res} of the market value of their primary residence and a potentially different fraction θ_{inv} against investment property. We envision that households can borrow at least as much against their primary residence: $\theta_{res} \geq \theta_{inv}$.

In the appendix we show that for renters, the choices of h_t and n_t are analytic functions of c_t, therefore the renter's problem can be rewritten with just two choices: consumption c_t and location ℓ. For the owner, the choices of h_t and n_t are analytic functions of c_t and $\widehat{h}_t$, therefore the owner's problem can be rewritten with just three choices: consumption c_t, investment property size $\widehat{h}_t$, and location ℓ.

2.2 Firms

Goods Producers There are a large number n_f of identical, competitive firms located in the urban core (zone 1), all of which produce the numeraire consumption good.[17] This good is traded nationally; its price is unaffected by events in the city and normalized to 1. These firms are owned by national equity owners, and all profits are distributed outside of the city. The firms have decreasing returns to scale and choose labor inputs to maximize profit each period:

$$\Pi_{c,t} = \max_{N_{c,t}} N_{c,t}^{\rho_c} - N_{c,t} W_t \tag{3}$$

The first order conditions imply that each firm's labor demand is $N_{c,t} = \left(\frac{\rho_c}{W_t}\right)^{\frac{1}{1-\rho_c}}$.

Developers In each location ℓ there is a large number n_f of identical, competitive construction firms which produce new housing units and sell them locally at a price P_t^ℓ per unit. For simplicity, we assume that all developers are headquartered in the urban core, regardless of where their construction takes place. All employees of the developers commute to the city center. Like the

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home ownership rate.

[16]This treatment of depreciation and the additional maintenance cost for investment property avoids having to keep track of the aggregate owner-occupied fraction of housing as an additional state variable.

[17]We assume that the number of firms is proportional to the number of households in the city when solving the model. With this assumption, our numerical solution is invariant to the number of households. Without this assumption, due to decreasing return to scale, the numerical solution would depend on the number of households.

consumption good firms, construction firms are owned by national equity owners, and all profits are distributed outside of the city.[18] Let H_{t-1}^{ℓ} be the existing housing stock in location ℓ. The construction firms have decreasing returns to scale and choose labor to maximize profit each period:

$$\Pi_t^{\ell} = \max_{N_{\ell,t}} \left(1 - \frac{H_{t-1}^{\ell}}{\overline{H^{\ell}}} \right) P_t^{\ell} N_{\ell,t}^{\rho_{\ell}} - N_{\ell,t} W_t \qquad (4)$$

The production function of housing has two nonlinearities. First, production of housing depends on $1 - \frac{H_{t-1}^{\ell}}{\overline{H^{\ell}}}$, where $\overline{H^{\ell}}$ is an upper bound on the total housing that can be built in Zone ℓ. It captures the total amount of space zoned for residential housing in each location.[19] This term captures that the more housing is already built in a location, the more expensive it is to build additional housing. For example, additional housing may have to take the form of taller structures, buildings on less suitable terrain, or irregular infill lots. Second, because $\rho_{\ell} < 1$, there are decreasing returns to scale. Therefore, producing twice as much housing requires more than twice as much labor.

The first order conditions imply that a firm in Zone ℓ has labor demand $N_{\ell,t} = \left(\frac{\left(1 - \frac{H_{t-1}^{\ell}}{\overline{H^{\ell}}} \right) P_t^{\ell} \rho_{\ell}}{W_t} \right)^{\frac{1}{1-\rho_{\ell}}}$.

When $\overline{H^{\ell}}$ is sufficiently high, the model's solution becomes independent of $\overline{H^{\ell}}$, and the supply of housing is governed solely by ρ_{ℓ}. When $\overline{H^{\ell}}$ is sufficiently low, the housing supply depends on both $\overline{H^{\ell}}$ and ρ_{ℓ}.

2.3 Out-of-town Buyers

We assume that out-of-town buyers inelastically demand some amount of housing. In Section 6, we will relax this assumption and introduce a non-zero elasticity of OOT demand to house prices. Their demand is stochastic and is the only source of aggregate risk in the model.[20] Out-of-town (OOT) home buyer demand follows a 2-state Markov process with a low state $OOT_t^{\ell} = OOT^{\ell,L}$ and a high state $OOT_t^{\ell} = OOT^{\ell,H} > OOT^{\ell,L}$. While the amount of OOT housing demand in the high or in the low state can differ by zone ℓ, we assume that all zones are always in the high and low state together. We assume a symmetric transition probability matrix with the

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[18]If some of the firms were owned locally, OOT demand would affect profits which would flow back to the locals. While our model misses this effect, there are two reasons why the effect is likely to be small. First, the capital share is only 1/3 of output. Our model captures 2/3 of the effect through labor payments. Second, while the construction profits go up, the consumption sector profits go down. The net effect is likely small, and would depend on what fraction of the firms in each sector are locally or nationally owned.

[19]We interpret $\overline{H^{\ell}}$ as the total land area zoned for residential real estate multiplied by the number of floors that could be built on this land (floor area ratio or FAR).

[20]One can think of shocks to the oil price, shocks to the exchange rate, or political shocks in the country of origin (Badarinza and Ramadorai, 2016) as the underlying drivers of this stochastic OOT process.

parameter π governing its persistence. A key assumption is that housing owned by out-of-town buyers is not rented out to locals. Cvijanovic and Spaenjers (2015) provide empirical support for this assumption. Below, we also solve a version of the model that assumes OOT housing is rented out. Out-of-town buyers do not work in the local labor market, do not consumer local public goods, and are not counted in city welfare.

2.4 Equilibrium

Given parameters (including the bond price) and a stochastic process for out-of-town housing demand $\{OOT_t\}$, a competitive equilibrium is a price vector $(W_t, P_t^\ell, R_t^\ell)$ and an allocation, namely aggregate residential demand by renters $H_t^{r,\ell}$ and owners $H_t^{o,\ell}$, aggregate investment demand by owners $\widehat{H}_t^{o,\ell}$, aggregate labor supply N_t, aggregate labor demand by goods and housing producing firms $(N_{c,t}, N_{\ell,t})$, and aggregate housing supply, such that households and firms optimize and markets clear.

The following conditions characterize the equilibrium. First, firms optimize:

$$N_{c,t} = \left(\frac{\rho_c}{W_t}\right)^{\frac{1}{1-\rho_c}} \quad \text{and} \quad N_{\ell,t} = \left(\frac{\left(1 - \frac{H_{t-1}^\ell}{\overline{H}^\ell}\right) P_t^\ell \rho_\ell}{W_t}\right)^{\frac{1}{1-\rho_\ell}}. \tag{5}$$

Second, labor markets clear:

$$n_f\left(N_{c,t} + \sum_\ell N_{\ell,t}\right) = N_t. \tag{6}$$

Third, the housing market clears in each location ℓ:

$$(1-\delta)H_{t-1}^\ell + n_f\left(1 - \frac{H_{t-1}^\ell}{\overline{H}^\ell}\right) N_{\ell,t}^{\rho_\ell} = \widehat{H}_t^{o,\ell} + H_t^{o,\ell} + OOT_t^\ell. \tag{7}$$

The left-hand-side is the supply of housing which consists of the non-depreciated housing stock and new residential investment. The right-hand-side is the use of housing by local renters, local owners, and out-of-towners. Fourth, the rental market clears in each location ℓ:

$$\widehat{H}_t^{o,\ell} = H_t^{r,\ell} \tag{8}$$

Fifth, average pension payments equal to average labor income taxes collected:

$$\overline{\Psi} N_{ret} = \tau^{SS} E\left[N_t W_t\right], \tag{9}$$

where we used the fact that G_a and z average to 1 in the cross-section, and N_{ret} is the total number of retirees, which is a constant.[21] Sixth, the aggregate state S_t evolves according to rational expectations. Seventh, the value of all bequests received is equal to the wealth of all agents who die.

2.5   Welfare effects on Locals from Out-of-town Buyers

We compute the welfare effect of OOT home buyers using the following procedure. Suppose that OOT demand in period t is low and that it stays low in period at $t+1$. Denote agent i's welfare at $t+1$ as $V_{t+1,i}(LL)$. Suppose instead that OOT demand at $t+1$ switches to high and denote agent i's welfare in this situation as $V_{t+1,i}(LH)$. Agent i would be willing to give up $\Delta_{t,i}$ in consumption equivalent units to stay in the low foreign demand state, where:

$$\Delta_{t,i} = -1 + \left(\frac{V_{t+1,i}(LL)}{V_{t+1,i}(LH)} \right)^{\frac{1}{(1-\gamma)(1-\alpha_n)}} .$$

We compute aggregate welfare effects from "inflows" by summing $\Delta_{t,i}$ across agents, calling the resulting aggregate welfare measure Δ. We also sum separately among owners (at time t) and renters, and for different age groups. Alternative summations by income or wealth are easy to do.

3   Calibration

In this section, we discuss the calibration of the baseline model. The baseline model does not represent any specific city, but rather aims to illustrate the model's mechanisms in a relatively simple way. It is calibrated to the average U.S. metropolitan area. In the "no commuting cost model," (No CC model) the commuting time and financial cost of commuting are set equal to zero. In equilibrium both zones are identical, and this model can be thought of as a single-zone model. In a second version of the baseline model, the "commuting cost model," (CC model) the commuting cost and time from zone 2 are strictly positive, which makes zone 1 a more desirable place to live. Section 5 studies New York, while Section 6 discusses our calibration to Vancouver. Table 1 presents the chosen model parameters.

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[21]For simplicity, we assume that the total pension payments are equal to the average of all social security payments, averaged across high and low OOT demand states. OOT demand affect wages and therefore the total social security tax collected in a city. We do not think that letting the pension fluctuate with OOT demand of local real estate would be desirable. In the U.S., Social Security is maintained at the national level, and pension payments do not depend on local-area variation in wages.

Table: Calibration

Description	Parameter	No CC model	**CC model**	NY model	Vancouver model
Panel A: Labor Income and Pension					
Income states	z	[0.254 0.763 2.221]	[0.254 0.763 2.221]	[0.255 0.753 1.453 3.522]	[0.251 0.705 1.310 2.949]
Pension distr.	ψ^{a,z_t}	[0.484 0.966 1.585]	[0.484 0.966 1.585]	[0.520 1.147 1.436 1.436]	[0.696, 1.135, 1.138, 1.138]
Pension tax	τ^{SS}	0.10	0.10	0.10	0.105
Panel B: Preferences					
Time Preference (4yr)	(β^H, β^L)	(0.999,.80)	(0.999,.80)	(0.999,.80)	(0.999,.80)
Risk aversion	γ	5	5	5	5
Leisure weight	α_n	0.5	0.5	0.5	0.5
Non-durable consumption weight	α_c	0.334	0.334	0.334	0.334
Housing consumption weight	α_h	0.166	0.166	0.166	0.166
Panel D: Finance and Regulatory					
Bond Price (4yr)	Q	0.826	0.826	0.826	0.826
Maximum residential LTV	θ_{res}	0.90	0.90	0.90	0.90
Maximum investment LTV	θ_{inv}	0.80	0.80	0.80	0.80
Property tax (4yr)	τ^P	4%	4%	4%	2.6%
Panel E: Production and Geography					
Return to scale	$\rho_c = \rho_1 = \rho_2$	0.66	0.66	0.66	0.66
Available space	$(\overline{H^1}, \overline{H^2})$	(50,50)	(50,50)	(0.11,4.70)	(0.75,12.24)
Owner-occupied property depreciation	δ	0.12	0.12	0.12	0.12
Time-Commuting cost	ϕ_T^2	0	0.04	0.031	0.019
Financial-Commuting cost	ϕ_F^2	0	0.007	0.010	0.007
OOT demand transition prob.	π	0.90	0.90	0.90	0.90
OOT demand, low state	$(OOT^{1,L}, OOT^{2,L})$	(0,0)	(0,0)	(0.096,0.036)	(0,0)
OOT demand, high state	$(OOT^{1,H}, OOT^{2,H})$	(0.066,0.066)	(0.078,0.051)	(0.134,0.058)	(0.0304,0.0782)
Panel F: Consumption Externalities and Rent Control					
Cons. externality threshold	$\underline{c}$	–	–	0.7	0.5
Extra utility Z1 workers	χ^W	–	–	0.0498	0.0243
Extra utility Z1 retirees	χ^R	–	–	0.0861	0.1225
Fraction rent control	(η^1, η^2)	–	–	(0.169,0.104)	(0.232,0.166)
Rental discount		–	–	49.9%	47%

Notes: The table reports the parameters of the model, their values in the baseline no construction cost model (No CC model), in the baseline construction cost model (CC model), the New York model (NY model), and the Vancouver model. The explanation for the parameter choices is given in the main text.

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Demographics The model is calibrated so that one model period is equivalent to 4 years. Households enter the model at age 21, work until age 65, and retire with a pension after age 65. Survival probabilities $p(a)$ are calibrated to mortality data from the Census Bureau.[22,23]

Labor Income A household's idiosyncratic labor productivity has two components. The first component, G^a is deterministic and is computed from the Survey of Consumer Finance (SCF). Within each survey year (every third year between 1983 and 2010) we compute average real labor income for each 4-year age group between ages 21 and 65 and divide it by average real income for all groups to have a mean of one. We then compute G^a as the average across all survey years.

The second component is the idiosyncratic productivity process z which we discretize as a 3-state Markov chain. The values for the three states are chosen so that the average income of households in the bottom 25%, middle 50%, and top 25% of the income distribution in the model matches those same objects in the SCF. We assume a parsimonious transition probability matrix for z, where the probability of staying in the same productivity state is 90% for workers and 100% for retirees.[24] The implied standard deviation and autocorrelation of the idiosyncratic component of labor income are 0.7 and 0.9, respectively. These numbers match the evidence in Storesletten et al. (2006).

The Social Security tax is 10%, which approximately matches the data.[25] We use Social Security rules to estimate each productivity group's ψ^{a,z_t}, which measures its pension relative to the average pension.

The bottom left panel of Figure 1 shows labor income by age in the data. The solid black line shows the well-known hump-shaped labor income profile over the life cycle for the median household. The dashed red line shows average labor income in the bottom 25 percent of the

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[22]To speed up computation, we assume that the probability of dying is zero before age 44. The observed probability is below 1% for each 4-year period before age 44. When the number of agents is not sufficiently large, a small probability of death induces idiosyncratic demographic risk, which leads to idiosyncratic variation in the wage. Smoothing out this idiosyncratic variation would require a very large number of agents (as opposed to when the probability of death is larger). To avoid modeling this very large number of agents, we assume zero probability of death for households younger than 44.

[23]We use mortality tables from 1960 rather than the latest available ones so as to generate the observed share of agents above age 65 in the current population. People above age 65 comprise 21% of the population above age 21 in the data and 22% in the model.

[24]The productivity states for the baseline model take on three values, for the bottom 25%, middle 50%, and top 25% groups. These values differ by age. This is done by regressing the income for each age-group combination on age, and rescaling so that, for each age, the mean income state is 1. Making labor income states age-dependent allows to capture the fact that the variance of labor income grows with age. The transition probability matrix for productivity is age-invariant, but depends on β: it is [0.9 0.1 0; 0.05 0.9 0.05; 0 0.15 0.85] for low β types and [0.9 0.1 0; 0.05 0.9 0.05; 0 0.04 0.96] for high β types. We choose these values so that there is a positive correlation between β-type and average income income. This allows us to better match the 75th percentile of the labor income distribution, while keeping the average autocorrelation of idiosyncratic productivity at 0.9.

[25]In the data, employees contribute 6% and employers contribute an additional 6%, but only on income below $118,500.

labor income distribution, the dash-dotted blue line reports average income among the middle 50 percent of the income distribution, and the dotted green line shows the average income among the top 25 percent of the distribution. The bottom right panel of Figure 1 shows the same income profiles in the baseline model. By virtue of our calibration, we match the observed labor income profiles closely. Our assumption of a constant income in retirement after age 65 causes a more discrete decline in income than in the data.

Preferences Total non-sleep hours are normalized to one. We set $\alpha_n = 0.5$ so that leisure hours as a fraction of non-sleep hours is one half for an unconstrained, working-age household that is not commuting. Retirees are assumed to have zero working hours. We set $\alpha_c = 0.334$ and $\alpha_h = 0.166$ so that for an unconstrained household, $1/3$ of total expenditures goes towards housing. This is inside the $[0.17, 0.37]$ interquartile range for the rent-to-wage ratio for the average U.S. MSA in the year 2000, calculated by Davis and Ortalo-Magne (2011). Zillow calculates that U.S. share of income spent on rent is 29.2% in 2016.Q4, substantially above the 25.8% average for 1985-2000.

We set risk aversion $\gamma = 5$, a standard value in the asset pricing literature.

We set $\beta^H = 0.999$ (0.999 per year) and $\beta^L = 0.80$ (0.945 per year). A 25% share of agents has β^H, the rest has β^L. This delivers an average β of 0.847, set to match the average wealth-income ratio, which is 6.4 in the SCF data and 6.7 in the model. The dispersion in betas matches the observed wealth Gini coefficient of 0.75.

The probability of receiving a bequest equals the number of households between ages 21 and 65 divided by the number of dead households. It is equal to 10% over each 4-year period, and identical for β^H and β^L household types. Under our calibration, about 1.2% of wealth is bequeathed each year, matching the data.

Geography, Production, and Construction The No CC and CC models have zones of equal size. The maximal buildable amount of housing is set to $\overline{H}^1 = \overline{H}^2 = 50$. This number implies that the baseline model is fairly close to unconstrained in terms of housing supply.

We assume that the return to scale $\rho_c = \rho_1 = \rho_2$ in each sector is 0.66. This implies a labor share of 66%, consistent with the data.

Housing We choose a price for the one-period (4-year) bond of $Q = 0.826$. This implies an annual 4.9% discount rate (yield-to-maturity). Since risk-free bonds are the only savings vehicle in the economy, it is reasonable to choose a somewhat higher value than the observed real yield on a four-year Treasury bond, to capture the higher observed rate of return on a broader set of savings instruments.

Figure 1: Ownership, Net Worth, and Income across Age and Income groups
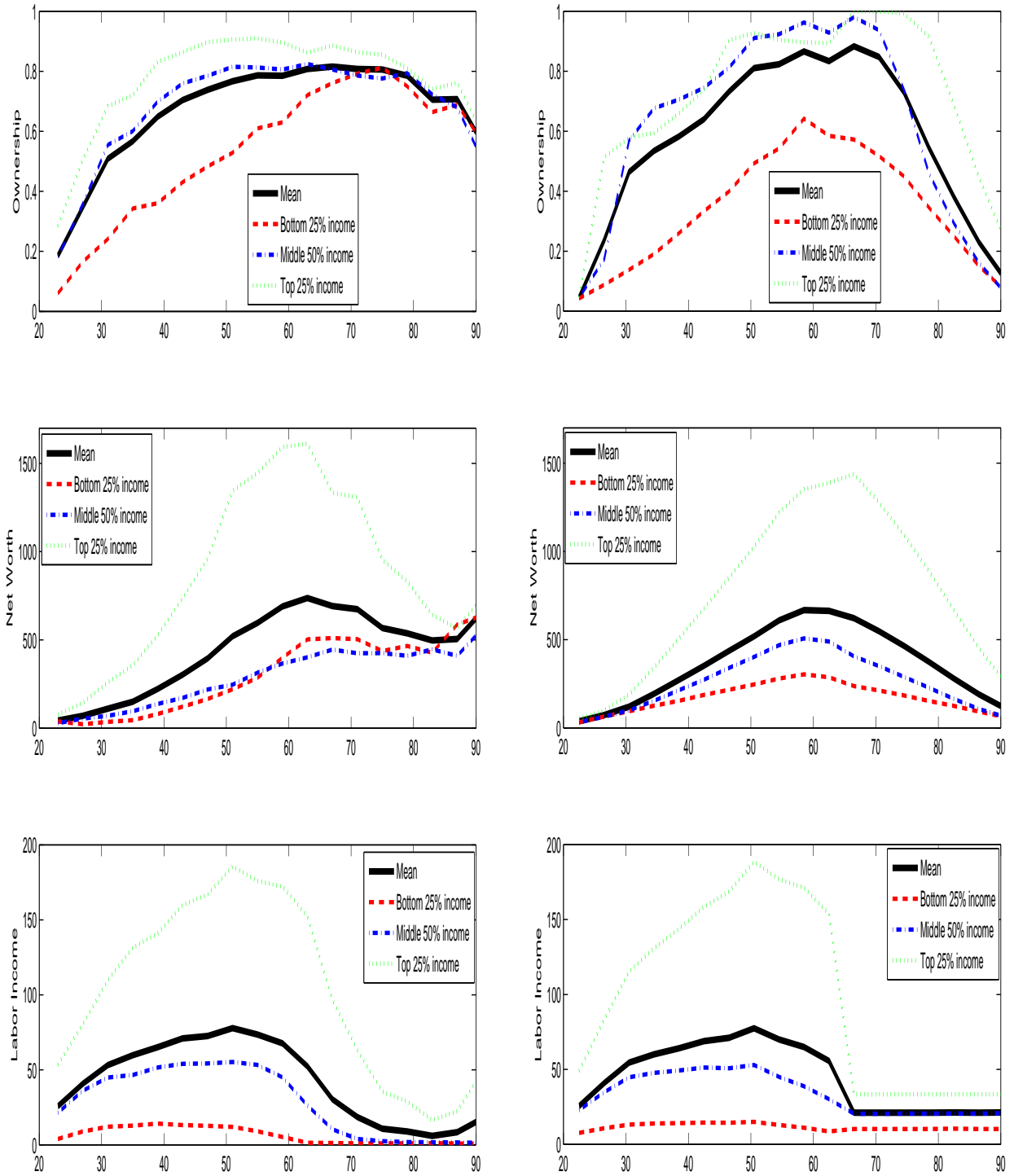
Notes: The left panels are for the data and based on the Survey of Consumer Finance (all 1983-2010 waves). The right panels are for the benchmark model with commuting costs. The top row denotes the home ownership rate. The middle row denotes household wealth. The bottom row denotes household labor income.

We set the maximum loan-to-value ratio (LTV) for the primary residence at 90% ($\theta_{res} = 0.8$), implying a 10% down payment requirement. The observed mean combined LTV ratio at origination for U.S. mortgages in the U.S. is 87.3% as of October 2016 according to the Urban Institute and has consistently been above 80% since the start of the data in 2001. The LTV for investment property is set at 80% ($\theta_{inv} = 0.8$), consistent with higher downpayment requirements for investment properties.

We assume that property depreciates at 3.2% per year and set $\delta = 0.12$. We set the property tax rate $\tau^P = 0.04$ or 1% per year. We assume that the revenue from this tax is used to fund local public goods. In the baseline model, locals derive no utility from public goods. We will change this assumption in Section 6.

The choices for Q, δ, and τ^P imply a steady state 4-year price-rent ratio of $(1 - Q \times (1 - \delta - \tau^P))^{-1} = 3.275$. The price-annual rent ratio is 13.1, exactly matching the average annual price-rent ratio in the U.S. over the period 1987-2016.[26]

Commuting Costs In the model with commuting costs, we break the symmetry across the two zones by adding a commuting cost from zone 2 to zone 1. Specifically, we set a *time cost* of $\phi_T^2 = 0.04$ or 4% of non-sleeping hours. This amounts to 4.5 hours per week spent on commuting for any worker living in zone 2, or ten one-way trips to or from the office of 27 minutes each.[27]

We also assume a *financial* cost of commuting $\phi_F^2 > 0$ for workers equal to 2% of average income, consistent with observed household spending on transportation.

Retirees living in zone 2 have time and financial commuting cost that are 20% of those of workers. We envision that retirees make fewer trips, travel at off-peak hours, and receive discounts. Table 1 shows the parameters for the commuting cost (CC) model.

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[26]Rent changes are measured as changes in the CPI series for housing. Price changes are measured as changes in the Case-Shiller national home value index. The latter series starts in January 1987. We choose December 1999 as our base year and set the price-rent ratio equal to 12.06 in December 1999. This 12.06 number equals the aggregate value of the residential housing stock from the Flow of Funds divided by aggregate housing consumption in the U.S. from NIPA. The resulting price-rent ratio series is available monthly from January 1987 until September 2016. We take the average of this series. Its value in September 2016 is 14.8.

[27]This number is the relative cost of commuting for workers in zone 2. If workers in zone 1 commuted 17 minutes, workers in zone 2 would be commuting 17+27=44 minutes. If 68% of workers lived in zone 1 and 32% in zone 2, the average commuting time would be 25.6 minutes. This is very close to the observed average commuting time in the U.S. in 2015 of 25.4 minutes according to the U.S. Census Bureau.

4 Baseline Model Results

4.1 Home Ownership and Wealth Accumulation

A first check on the model concerns its ability to broadly match observed patterns in home ownership and wealth accumulation over the life cycle. The top panel of Figure 1 plots the home ownership rate in the baseline model with commuting costs. The middle panel plots household net worth in the model. Net worth is defined as real estate wealth plus financial wealth minus debt. The bottom panel is labor income in the model, as discussed above. Figure 1 plots the same statistics in the data, expressed in 2010 real dollars.

On average, the model with commuting costs generates a city-wide home ownership rate of 62.1%. This exactly matches the observed home ownership rate of 62.1% for U.S. metropolitan areas in the third quarter of 2016.

The baseline model fits the life-cycle patterns of home ownership and wealth accumulation quite well. The average home ownership rate starts out below 20% for the youngest households and displays a hump-shaped pattern over the life-cycle. It peaks at about 80% around ages 60-70 in both model and data. It then declines in retirement.

The model also generates about the right amount of average wealth at different ages during the working stage of life. Households accumulate about $250,000 by age 40 and $650,000 by age 60, on average. Wealth gradually declines in retirement, in part because home ownership rates decline. Both the decline in home ownership and total wealth are steeper in the model than in the data, and closely connected to each other.[28]

The model does a good job capturing the large gap in home ownership rates between the low- and middle income households. At age 40, that gap is 40 percentage points in model and data. Furthermore, the model generates substantial cross-sectional variation in wealth across cohorts and income groups that is broadly consistent with the data. The households in the top-25% of the income distribution have average wealth that peaks around $1,400,000 in the model, very similar to the $1,500,000 in the data. The model generates a Gini coefficient for wealth of 0.71, which is substantially above that of income of 0.49.

Given this close fit to the data, we conclude that our model is well positioned to evaluate both the average and the distributional consequences of out-of-town purchases.

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[28]Allowing for an intentional bequest motive and/or adding late-in-life medical/long-term care risk would give households additional motives to slow down wealth decumulation (Ameriks et al., 2011). So would giving elderly people a preference for "aging in place" or letting them forgo housing maintenance (Cocco and Lopes, 2017). Adding these motives would overly complicate the model whose main purpose is to analyze the effect of out-of-town buyers.

4.2 No Commuting Cost Model

We start by studying the effect of out-of-town (OOT) home buyer demand on the equilibrium of the "no commuting cost" model. We explore a symmetric OOT housing demand in both zones. Recall that OOT demand takes on two values and is the only source of aggregate risk in the economy. We assume that OOT buyers demand 0.066 units of housing in the high state and zero in the low state. The demand of 0.066 units corresponds to approximately 10% of the total housing stock. The transition probability matrix between the low and the high OOT demand states is $[\pi, 1 - \pi; 1 - \pi, \pi]$, with an autocorrelation of $\pi = 0.90$. Conditional on a switch, each regime is expected to last 40 years (10 times 4). Because of the high persistence of the OOT demand process, the model with stochastic OOT demand that is in the low (zero) OOT demand state produces moments that are similar to the model without any OOT demand. When we study New York City below, we will use actual data on the fraction of OOT buyers.

The top panel in Table 2 shows wages, house prices, and rents from the no commuting cost model. The unconditional averages are in the first row, the averages conditional on low (high) OOT demand in the second (third) row. The second panel reports demographic variables such as population share, housing stock, density, resident age, income, wealth, and home ownership rate. Variables with superscript 1 refer to zone 1, the city center, while superscript 2 refers to zone 2, which represents the rest of the metro area/city. The variables preceded by "Rel" refer to ratios of zone 1 to zone 2 variables. Since there is no difference between the zones in the symmetric model, prices, rents, population, housing stock, home ownership rate, average age, and average income are all identical. The "Rel" variables are equal to one.

An increase in OOT demand for housing (going from zero to high) has the following effects. First, new construction takes place and the housing stock grows (+2.6%). Because of decreasing returns to scale ($\rho < 1$) and limited land $\overline{H}$, housing supply is not perfectly elastic. Housing supply rises by only 0.017 units or 25% of the additional OOT demand. To clear housing markets, locals must consume less housing. Rents rise by 8.9% to induce a sufficiently large decline in local housing demand. House prices rise by 4.9%. These numbers are conditional averages. In the first period of the increase in OOT demand, the increase in rents and prices is larger still: rents increase by 12.1% and prices by 6.9%.

The increase in rents exceeds that in price, so that the price-rent ratio falls modestly from 13.3 to 12.8 (-3.6%). What explains the decline in the P/R ratio? Because the OOT demand process is stationary, a high OOT state today implies lower future OOT demand and lower expected rental growth. The decline in the price-rent ratio reflects that lower expected future demand. The risk premium associated with the OOT demand is small, and does not fluctuate much with the OOT state. Discount rate variation explains little of the price-rent dynamics.

The home ownership rate increases by 2.6% (1.8% points) when OOT buyers enter. To measure home ownership, we include the OOT buyers, as is done in the data. Foreign buyers are owners who displace local owners since the housing stock does not expand in proportion to OOT housing demand. Indeed, among local residents, the home ownership rate declines by 0.8% points. The reason the decline in ownership among locals is not larger is that the decline in the P/R ratio makes ownership more attractive relative to rentership, and that local owners adjust by living in smaller housing units.

OOT demand also drives up wages by 0.9%. This happens because a higher housing stock requires more workers in the housing sector and hence fewer in the non-housing sector. The non-housing sector has decreasing returns to scale, and charges a constant price for its output, which is a tradable good sold both in and outside of the city. Therefore, a lower demand for labor in the non-housing sector implies a higher wage. The higher city-wide wage leads to a lower overall labor demand, with hours worked being 0.8% lower when OOT demand is high. However, the construction sector experiences a boom. After a positive foreign demand shock, the share of construction employment increases from 11.3% to 13.5% as additional housing is being built. It then slowly falls but stays at a higher level as long as foreign demand remains high because the higher housing stock requires more maintenance.

The price-income ratio in the model is computed as the average house price (per square foot) in a zone multiplied by the average house size of owner-occupied units (in square feet) divided by the average labor income earned by the locals in that zone. Because we want to compare the same house across OOT states, we hold the average house size in a zone fixed at its unconditional average (average across both high and low OOT states). The price-income ratio increases substantially from 7.23 to 7.56, an increase of 4.6%. By this metric, OOT buyers make housing less affordable.

What are the welfare effects from an increase in OOT demand? Our model features a rich cross-section of agents in terms of age, productivity (labor income), home ownership, and wealth. The price, rent, and wage changes induced by an increase in OOT demand will affect these agents differently. Panel A of Table 3 reports the welfare effect for various households, sorted by age (rows) and ownership status (columns). The average household in the baseline model is worse off from OOT buyers of local real estate, with a welfare loss of 0.30% in consumption equivalent units, as indicated in the last row.

To understand this number, it is important to consider how different types of agents are affected. The average renter is severely hurt by the inflow and would be willing to give up 1.43% of lifetime consumption to avoid the OOT capital inflow. In contrast, an average home owner benefits by 0.31% of lifetime consumption. Renters are unequivocally hurt by the higher foreign

Table 2: Effect of OOT Demand

				Panel A: **No Commuting Cost Model**					
	W	R^1	R^2	P^1	P^2	$\frac{P^1}{R^1}$	$\frac{P^2}{R^2}$	$\frac{HP^1}{Inc^1}$	$\frac{HP^2}{Inc^2}$
Average	0.975	0.124	0.124	0.407	0.407	13.08	13.08	7.38	7.38
Low OOT	0.971	0.120	0.120	0.398	0.398	13.31	13.31	7.23	7.23
High OOT	0.980	0.130	0.130	0.418	0.417	12.83	12.83	7.56	7.56
% change	0.86	8.9	8.9	4.9	4.9	-3.6	-3.6	4.6	4.6

	Pop^1	H^1	H^2	Rel HS	Rel Dens	Rel Age	Rel Inc	Rel Wealth	HO^1	HO^2
Average	0.500	0.658	0.658	1.000	1.000	1.000	1.000	1.000	0.708	0.708
Low OOT	0.500	0.650	0.650	1.000	1.000	1.000	1.000	1.000	0.699	0.699
High OOT	0.500	0.667	0.667	1.000	1.000	1.000	1.000	1.000	0.717	0.717
% change	0.0	2.6	2.6	0.0	0.0	0.0	0.0	0.0	2.6	2.6

				Panel B: **Commuting Costs Model**					
	W	R^1	R^2	P^1	P^2	$\frac{P^1}{R^1}$	$\frac{P^2}{R^2}$	$\frac{HP^1}{Inc^1}$	$\frac{HP^2}{Inc^2}$
Average	0.976	0.136	0.109	0.446	0.356	13.06	13.06	5.77	15.46
Low OOT	0.971	0.131	0.104	0.435	0.347	13.32	13.33	5.64	14.90
High OOT	0.980	0.142	0.114	0.456	0.366	12.82	12.81	5.91	16.03
% change	0.91	9.1	9.5	5.0	5.2	-3.8	-3.9	4.8	7.6

	Pop^1	H^1	H^2	Rel HS	Rel Dens	Rel Age	Rel Inc	Rel Wealth	HO^1	HO^2
Average	0.688	0.778	0.512	0.654	2.210	0.615	2.560	0.269	0.582	0.708
Low OOT	0.689	0.768	0.505	0.686	2.217	0.614	2.529	0.266	0.566	0.695
High OOT	0.688	0.788	0.519	0.622	2.202	0.615	2.592	0.271	0.597	0.720
% change	-0.2	2.7	2.8	-9.3	-0.7	0.1	2.5	1.9	5.5	3.6

				Panel C: **New York Metro Area Model**					
	W	R^1	R^2	P^1	P^2	$\frac{P^1}{R^1}$	$\frac{P^2}{R^2}$	$\frac{HP^1}{Inc^1}$	$\frac{HP^2}{Inc^2}$
Average	0.981	0.302	0.180	0.986	0.587	13.07	13.07	13.40	8.64
Low OOT	0.980	0.300	0.178	0.981	0.584	13.10	13.10	13.35	8.62
High OOT	0.981	0.304	0.181	0.992	0.590	13.04	13.04	13.45	8.66
% change	0.10	1.6	1.6	1.1	1.1	-0.5	-0.5	0.7	0.4

	Pop^1	H^1	H^2	Rel HS	Rel Dens	Rel Age	Rel Inc	Rel Wealth	HO^1	HO^2
Average	0.119	0.090	0.790	0.794	5.659	0.805	1.448	1.227	0.298	0.486
Low OOT	0.119	0.089	0.787	0.840	5.663	0.805	1.450	1.236	0.297	0.488
High OOT	0.119	0.091	0.793	0.742	5.654	0.804	1.445	1.217	0.300	0.483
% change	-0.2	2.5	0.8	-11.7	-0.2	-0.1	-0.3	-1.5	1.2	-0.9

Notes: The table reports averages from a long simulation of the baseline model without commuting costs (Panel A), the baseline model with commuting costs (Panel B), and the New York metro area model (Panel C). We report the hourly wage W, the rent per sqft in the city center R^1 and outside the center R^2, the house price per sqft in zone 1 P^1 and in zone 2 P^2, the price-rent ratio in each zone (each expressed per square foot) and the home value-to-income ratio in each area. The latter two ratios are reported as annual numbers. The home value-to-income ratio is the ratio of the price per square foot times the average house size of owner-occupied units in a zone to the average income in a zone. The average house size is held constant across OOT regimes for the calculation of this ratio. The second panel reports the share of the population that locates in the city center (Pop^1), the housing stock in each zone (H^1, H^2), the ratio of the average house size in zone 1 to the average house size in zone 2 (Rel HS), the ratio of the density in zone 1 to the density in zone 2 (Rel Dens), where density is defined as population per housing unit, the ratio of the average age of residents of zone 1 to the average age of zone 2 residents (Rel Age), the ratio of the average income of zone 1 to zone 2 residents (Rel Inc), the ratio of the average financial plus housing wealth of zone 1 to zone 2 residents (Rel Wealth), the home ownership rate in zone 1 (HO^1) and in zone 2 (HO^2). The row "Average" denotes the average moments for a long simulation of the model, averaging across states with low OOT demand and high OOT demand. The row "Low OOT" reports averages, conditional on being in the low OOT demand state, while the row "High OOT" conditions on being in the high OOT demand state. What constitutes low and high OOT states differs by panel and is described in the main text.

Table 3: Welfare change, Baseline model

Age	A: Symmetric Zones Model			B: Commuting Cost Model			C: New York Model		
	Owners	Renters	All	Owners	Renters	All	Owners	Renters	All
21	–	-1.38	-1.38	–	-1.40	-1.40	–	-0.18	-0.18
25	0.11	-1.16	-1.08	0.43	-1.16	-1.09	0.05	-0.16	-0.15
29	0.27	-1.12	-0.72	0.47	-1.13	-0.74	0.06	-0.16	-0.10
33	0.37	-1.17	-0.45	0.64	-1.17	-0.32	0.07	-0.17	-0.09
37	0.40	-1.19	-0.03	0.76	-1.22	-0.16	0.07	-0.17	-0.08
41	0.40	-1.18	0.13	0.78	-1.25	-0.08	0.07	-0.18	-0.07
45	0.41	-1.20	0.14	0.81	-1.32	0.07	0.07	-0.19	-0.06
49	0.39	-1.27	0.15	0.79	-1.39	0.20	0.07	-0.21	-0.06
53	0.40	-1.37	0.20	0.81	-1.52	0.38	0.08	-0.23	-0.04
57	0.35	-1.59	0.16	0.75	-1.76	0.28	0.08	-0.26	-0.04
61	0.28	-2.06	0.07	0.63	-2.11	0.24	0.08	-0.31	-0.05
65	0.39	-2.40	0.10	0.80	-2.41	0.24	0.10	-0.36	-0.08
69	-0.11	-2.55	-0.35	0.03	-2.70	-0.29	0.03	-0.37	-0.13
73	-0.04	-2.70	-0.33	0.10	-2.84	-0.34	0.05	-0.37	-0.13
77	0.11	-2.85	-0.35	0.22	-2.97	-0.61	0.07	-0.39	-0.15
81	0.31	-2.98	-0.88	0.40	-3.12	-1.20	0.11	-0.39	-0.16
85	0.62	-3.14	-1.19	0.71	-3.28	-1.77	0.16	-0.41	-0.20
89	1.04	-3.25	-1.87	1.26	-3.43	-2.34	0.24	-0.42	-0.23
93	1.97	-3.38	-3.00	2.21	-3.62	-2.94	0.41	-0.41	-0.26
97	5.70	-3.62	-3.59	5.92	-3.84	-3.80	0.87	-0.39	-0.25
All	**0.31**	**-1.43**	**-0.30**	**0.62**	**-1.50**	**-0.31**	**0.07**	**-0.22**	**-0.10**

Notes: This table presents the consumption-equivalent welfare change from either an increase or a decrease of foreign investment in the baseline model. All numbers are in percent, thus -0.48 in the bottom right corner means that an average household would need to receive 0.48% of its average consumption to be as well off as it would be if foreign investment remained low.

demand, as their current and future housing expenditures rise. Renters receive some relief in the form of higher current and future wages. This benefits the young more, given their longer expected work life. An 81-year old renter would be willing to give up 3% of lifetime consumption to avoid foreign purchases, a 41-year old renter less than half as much (1.18%).

Owners benefit from higher foreign demand because they reap capital gains on their house. This increases their wealth and expands their consumption opportunity set. This effect is especially strong for older owners, who have a relatively short horizon and are unconcerned by persistently higher future rents. The capital gains effect is weaker for younger owners because they tend to own relatively little real estate and expect their housing consumption to increase in the future. The positive wage effect we described for renters of course also applies to owners. The confluence of these factors generates non-monotonic welfare effects for middle-aged owners.

Combining the effects on renters and owners with the hump-shaped pattern in home ownership results in positive welfare effects from OOT inflows for the middle-aged (41-65), but welfare losses for the young (21-41) and the old (65+).

4.3 Model with Commuting Costs

Effect of Commuting Cost on Spatial Allocation and Prices   For our main exercise, we remove the symmetry across the two zones by adding a commuting cost from zone 2 to zone 1. Panel B of Table 2 reports the quantity and price moments for the commuting cost model. Zone 1 is now more desirable than zone 2. As a result of the proximity to jobs, zone 1 attracts 68.8% of the population. The density, defined as people per unit of land area, of zone 1 is 2.21 times that of zone 2. Despite having equal land area, zone 1 has 60% of the housing stock (square footage). The total housing stock is 52% larger in zone 1 than in zone 2. Because it is more attractive to live there, there is more construction in zone 1 than in zone 2. With more housing but even more additional people, the average house size (square foot per person) in zone 1 is 0.65 times that in zone 2. I.e., suburban homes are 53% larger than homes in the urban core. Because of decreasing returns to scale in construction, the total housing stock in the metro area is smaller in the commuting cost model (1.289) than in the no commuting cost model (1.315).

The rent and the price per square foot in zone 1 are 25% higher than in zone 2. Because the introduction of a commuting cost has the same effects on prices and rents, the price-rent ratio remains unchanged relative to the no-commuting cost model, and thus remains the same across the two zones.

In terms of demographics, the city center attracts much younger residents: the relative age of residents of zone 1 to zone 2 is 0.615. The age gap arises in part because all retirees choose to live in zone 2 in the baseline model. Retirees make up 22% of the overall population but 70% of the population of zone 2 (22% out of 31.2%). The advantage of living in the city center is much lower for retirees than for workers (despite their lower cost of commuting). Zone 1 dwellers have much higher income than zone 2 dwellers; the ratio is 2.56. The most productive agents (of all working ages) are attracted by the lower time cost of commuting and have the highest value of proximity to work. Income in zone 2 is low in part because retirees earn much lower (social security) income. Also, some agents with low productivity who receive a bequest decide not to work and choose to live in zone 2. The much higher income in zone 1 explains why the house price-to-income ratio is much lower in zone 1 than in zone 2, despite the higher house prices. Because the city center dwellers are on average much younger, they have not accumulated as much wealth yet. The ratio of average wealth (financial plus housing wealth) of zone 1 to zone 2 is 0.269.

Finally, the model endogenously generates large differences in the home ownership rate from modest commuting costs. The home ownership rate is 58.2% in zone 1 while it is 70.8% in zone 2. This gap reflects in large part the demographic and wealth differences between the two zones. Young people have not yet accumulated enough savings to make a down payment. Based

on 2016.Q3 data for U.S. metropolitan areas from the Current Population Survey and Housing Vacancy Survey, the home ownership rate in the core of MSAs is 48.6% while the home ownership rate outside the core is 70.8%. Our simple model accounts for 60% of the home ownership rate difference (12.6% out of 22.2%).

In sum, commuting costs push younger, higher income (holding fixed age and wealth), and lower wealth (holding fixed age and income) households towards zone 1.

Effect of OOT Demand   We now study the effect of stochastic demand for housing by OOT buyers in the model with commuting costs. We continue to assume that OOT buyers purchase a symmetric 10% of the housing stock in each zone. Because the housing stock in zone 1 is now (endogenously) higher, the OOT demand is 0.078 in zone 1 and 0.051 in zone 2.

Similarly to the no commuting cost model, OOT demand drives wages up by 0.9% in the commuting cost model as more workers shift towards the construction sector. In the commuting cost model, wages rise for an additional reason. If OOT buyers displace workers in the urban center, then more workers move to zone 2. These workers must be paid a higher wage to compensate them for the longer commute. OOT buyers prompt an increase in wages and a boom in the non-tradable sector, but also to a loss in competitiveness and a fall in employment of the tradable sector.[29] The additional wage increase relative to the no commuting cost model is 0.05% (0.91% vs 0.86%).

The (absentee) OOT buyers reduce the relative density of zone 1 from 2.22 to 2.20 (-0.7%), as the population share of zone 1 falls by 0.2%. The increase in the housing stock is slightly higher in zone 2 than in zone 1 as construction in zone 2 takes place to absorb the outflow of locals from zone 1. The remaining locals in zone 1 consume substantially less housing per person than zone 2 residents after the OOT capital inflow versus before (-9.3%).

While more housing is built in both areas, the additional construction is insufficient to meet the OOT demand. Rents go up by 9.1% in zone 1 and by 9.5% in zone 2. Similarly to rents, house prices go up by more in zone 2 (5.2%) than in zone 1 (5.0%). Price-rent ratios fall by similar percentages in both zones (around -3.8%).

The home ownership rate including OOT buyers increases by 5.5% points in zone 1 and by 3.6% points in zone 2. This is the direct result of the OOT buyers. The home ownership rate among locals falls by 0.5% point in zone 1 and by 0.1% point in zone 2. The direct effect of OOT buyers displacing local owners is stronger in zone 1. Because house price levels remain much lower in zone 2 than in zone 1 (despite some catch-up growth), some households transition from renting in zone 1 to owning in zone 2. The price-income ratio rises by 4.8% in zone 1 but by

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[29]Although housing is the only non-tradable good in our model, we believe that the same intuition would carry over to a more general model with other non-tradable goods.

7.6% in zone 2, a manifestation of the faster house price growth in zone 2 which itself is partly due to migration from zone 1 to zone 2.

OOT buyers affect the socio-economic make-up of zone 1 and zone 2 in interesting ways. They make zone 1 higher-income and higher-wealth in a process that could be described as *gentrification*. Average income in the urban core relative to that in the periphery increases by 2.5%. The ratio of average wealth rises by 1.9%.

Turning to inequality within each part of the city with find that the income Gini is higher in zone 1 (0.442) than in zone 2 (0.419). These differences are much larger for wealth. The wealth Gini is .708 in zone 1 and 0.595 in zone 2. After the OOT inflow, income and wealth inequality within zone 1 fall modestly as some of the lower income and wealth residents of zone 1 move to zone 2. In zone 2, income and wealth inequality also fall modestly as the new arrivals are similar to the existing zone 2 residents. Thus, the arrival of OOT residents increases inequality between the parts of the city but reduces inequality within them.

The welfare effects for our benchmark model are in panel B of Table 4. The commuting costs amplify the gains and losses. Renters lose a bit more (-1.50%) and owners gain a lot more (+0.62%). Some younger owners now gain almost twice as much from the OOT influx. This is by virtue of the larger price and rent effects from OOT inflows, as well as the slightly larger wage gains, in the commuting cost model. The overall welfare effect, however, barely changes. The average household now loses 0.31% of lifetime consumption when OOT demand for local housing rises, compared to 0.30% in the model without commuting costs.

Political Economy of OOT Purchases Although the net welfare effect is negative, it is not evenly distributed. Even though owners make up 60.4% of the population, and owners on average benefit from an inflow, renters are hurt by much more than the owners gain. If each person received a vote, a majority of 55% of the population would prefer the OOT inflow to occur. However, these preferences are diametrically opposed for owners and renters: 92.1% of owners prefer the inflow, but only 4.9% of renters do. The latter group consists of households who rented last period but received a large bequest, which included real estate wealth. This calculation suggests that policies aimed at curbing OOT purchases not only have redistributive consequences, but they may also be politically unpopular.

4.4   Exploring Variants of the Model

Next, we explore sensitivity of the model to various ingredients and parameter choices. We use the baseline model with commuting costs as the starting point for all of these variations. Table 4 summarizes the welfare effects of OOT demand on city welfare for these experiments.

4.4.1 No Patience Heterogeneity

When all agents have the same subjective time discount factor ($\beta^H = \beta^L$), the model generates an aggregate welfare cost of OOT real estate purchases that is 23% lower than in the baseline model at 0.23%. This model has the undesirable feature that there is too little wealth inequality. For example, the wealth Gini in zone 2 is 0.48 in the single-beta model compared to 0.60 in the baseline model. Because the home ownership rate is higher than in the baseline model, and too high relative to the data, and owners gain, the overall welfare cost is naturally lower in this model.

4.4.2 Size OOT Demand

The size of the foreign inflow matters. We study a case where the foreign inflow is 50% larger than in the baseline. The welfare cost to society is 29% larger. Wages, prices, and rents all increase by about 50% more than in the baseline model. The welfare gains for young owners are close to those in the baseline model because of the steep rise in the future cost of housing, while he gains for older owners are substantially larger. The costs to renters increase uniformly by about 50%. This model sees a much steeper drop in the home ownership rate for the locals in zone 1 of 4.5% points, helping to explain the larger welfare cost.

4.4.3 OOT Demand Concentrated in Zone 1

In the baseline model, OOT demand is 10% of the housing stock in each zone. Now, we explore what happens when all OOT demand is concentrated in the city center. OOT demand in zone 1 in the high state is 10% of the *metro-wide* housing stock while it is 0% in zone 2. We find that both the welfare gains for owners and the welfare losses for renters are much larger than in the baseline model. However, the net effect of these gains and losses is a slightly smaller aggregate welfare loss. The same economics are at play in that OOT demand push locals towards zone 1. However, now, house prices and rents rise more in zone 1 than in zone 2, explaining the larger gains for owners and losses for renters.

4.4.4 OOT Buyers Rent Out Property

The inability or unwillingness of OOT buyers to rent their properties to locals is key for its welfare cost. In a model where OOT buyers rent out 100% of their real estate to local residents, the welfare loss is essentially zero and OOT buyers have no effect on the equilibrium. This is because renters, who previously rented from locals, now rent from OOT buyers. As long as rents do not change, renters are indifferent. The local real estate investors who have been displaced

Table 4: OOT Demand and City Welfare: Model Variants

		Owners	Renters	All
1	Baseline commuting cost model	0.62	-1.50	-0.31
2	No patience heterogeneity	0.57	-1.41	-0.23
3	50% larger OOT demand	0.67	-2.25	-0.40
4	OOT demand concentrated in zone 1	0.74	-1.57	-0.25
5	OOT buyers rent out property	0.03	-0.02	0.00
6	Only owners, no renters	0.17	0.00	0.17

Notes: This table presents the consumption-equivalent welfare change from an increase of OOT housing demand Δ. All numbers are in percent, thus -0.31 in the top right corner means that an average household would need to receive 0.31% of its average lifetime consumption each year to be as well off as it would be if OOT investment remained low. The first row presents the baseline commuting cost model. The second row presents a model where there is only one β-type rather than two. This model features too little wealth inequality. In the third row, the model features 50% more OOT demand (in the high state). In row 4, OOT demand is concentrated in zone 1 and zero in zone 2. In row 5, we change the assumption that OOT buyers do not rent out their property. In row 6, we solve a model where all agents are home owners.

by OOT buyers now invest in the risk free asset. Because the risk premium is small, the risk free asset has a very similar rate of return to real estate, so local investors are also indifferent. Thus prices, quantities, and welfare are nearly unaffected; only the investment portfolio of some local investors changes.

4.4.5 Owners Only

The welfare costs of OOT buyers are also driven by the presence of renters. We solve a model where all locals are home owners. Neither renting nor investing in property are possible. Additionally, we change the bequest distribution such that all bequests go to newborns. In our baseline model, most newborns do not receive bequests and are born without property. With this change to bequests, every household enters with real estate in its portfolio. With this change, the net welfare effect is a positive 0.17% of lifetime consumption. For renters, OOT investors are unambiguously bad. However, for owners, they are not unambiguously good. The price of real estate is always the present value of future rents. An OOT inflow raises future rents and therefore prices. Thus, a local owner who expects his real estate consumption to remain unchanged is indifferent to the inflow (he receives a capital gain but expects to pay higher rents). However, higher real estate prices induce local owners to consume less real estate and more other goods. This creates a welfare gain for owners who do not expect their housing consumption to rise. Young owners' real estate consumption tends to rise as they age, and may experience welfare losses.

5 Application: New York Metro

New York is a prime example of a city that has experienced large capital inflows from out-of-town real estate buyers. This section uses the New York metropolitan area as a case study. We use data from New York to measure the importance of OOT buyers and add a size difference between the zones. In the process, we extend our model to deal with the peculiarities of the New York housing market, specifically rent control and amenity differences between Manhattan and the rest of the metro area.

5.1 Calibration

Most of the parameters are identical to the baseline calibration. Here we describe which parameters are adapted to the New York metro. The data we use are described in Appendix B.

Geography The New York metro consists of three metropolitan divisions and has 25 counties located in New York (12), New Jersey (12), and Pennsylvania (1). We assume that Manhattan (New York county) represents Zone 1 and the other 24 counties of the NY metro make up Zone 2.[30] Given their respective maximum buildable housing stocks, we assume that $\overline{H^1} = 0.0238 \times \overline{H^2}$. We then choose $\overline{H^2}$ such that the fraction of households living in Zone 1 equals 11.8% of the total, as in the data. Since the model has no vacancies, we equate the number of households with the number of occupied housing units. The model has 11.95% of city residents in Manhattan, close to the data.

Commuting Cost The financial cost of commuting is set at 2.6% of average income or $2,500 per household. This is a realistic cost for New York.[31] Conditional on the financial cost, we choose the time cost in order to match the 68% difference in market rents between Manhattan and the rest of NYC MSA using the Zillow rental index. The resulting time cost is 3.1% of available time, or 3.5 hours per week, or 21 minutes per trip for ten commuting trips per week. Positive time and financial costs of commuting lead to higher rents in Zone 1. As discussed in Appendix A, they have different implications for the relative desire to live in Zone 1 depending

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[30] Alternative choices are to designate (i) New York City (five counties coinciding with the five boroughs of NYC) as zone 1 and the rest of the metro as zone 2, or (ii) Manhattan as zone 1 and the other four counties in New York City as zone 2. Both choices ignore that the dominant commuting pattern is from the rest of the metro area to Manhattan.

[31] In NYC, an unlimited subway pass costs $1,400 per year for a single person; many households have more than one commuter. Rail passes from the suburbs cost around $2400-3600 per year, depending on the railway station of departure. The cost of commuting by car are at least as high once the costs of owning, insuring, parking, and fuel a car are factored in.

on wealth and income levels. Modest variations in the financial cost only induce small changes in the composition of Zone 1 residents and deliver similar welfare results.

Labor Income We add a fourth, high-productivity state to the idiosyncratic productivity Markov chain to accommodate some of the very high earners in New York. The highest state has a productivity level that is 3.5 times the average. The productivity states for the New York model are [0.255 0.753 1.453 3.522] with a transition probability matrix [0.933 0.067 0 0; 0.097 0.806 0.097 0; 0 0.11 0.78 0.11; 0 0 0.26 0.74]. The pension payout, relative to the mean pension, is the same in the third and fourth states: [0.520 1.147 1.436 1.436].[32] The model exactly matches the metro-wide income distribution. The income distribution in each zone of the city is endogenously determined.

5.2 OOT Demand

We obtain data from Core Logic on the fraction of OOT housing purchases for Manhattan and for the New York MSA between January 2004 until September 2016. A detailed description is in Appendix B. Figure 2 plots the OOT purchase share at quarterly frequency, averaging among the months in the quarter. Several observations stand out. First, OOT purchases are a non-trivial part of the market throughout the sample period and in both zones. Second, the OOT share is much larger for Manhattan than for the rest of the metro area: 11.6% vs. 4.6%. Third, there is a steady increase in the OOT share in both zones. The increase in the OOT share is larger in absolute value for zone 1 and larger in percentage terms for zone 2. We calibrate a low OOT share to the 2004-07 average of 9.6% in zone 1 and 3.6% in zone 2. We calibrate the high OOT state to the 2012-16 average of a 13.4% share in zone 1 and a 5.8% share in zone 2.

These data are consistent with the OOT shares found in the literature. Chinco and Mayer (2016) use housing transactions merged with tax assessor data to identify out-of-town buyers, using the property tax billing address. They find that the OOT share rises as high as 17 percent in some boom markets like Las Vegas. Bayer et al. (2011) use transaction data for the period

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[32]To determine these four income group means and their population shares, we use county-level earnings data for the 25 counties of the New York MSA. The average earnings of the group of households making between 0 and $50,000 is $24,930 or 0.255 times the metro average. This group consists of 39.1% of households in the metro. The average earnings of the group of households making between $50,000 and $100,000 is $73,461 or 0.753 times the metro average. This group consists of 27.2% of households in the metro. The average earnings of the group of households making between $100,000 and $200,000 is $141,817 or 1.453 times the metro average. This group consists of 23.7% of households in the metro. Finally, the average earnings of the group of households making more than $200,000 is $343,693 or 3.522 times the metro average. This group consists of 10.0% of households in the metro. The data is top-coded. For each country, we observe the number of households whose earnings exceed $200,000. Because we also observe average earnings, we can easily infer the average income of those in the top coded group.

Figure 2: OOT Purchase Share New York
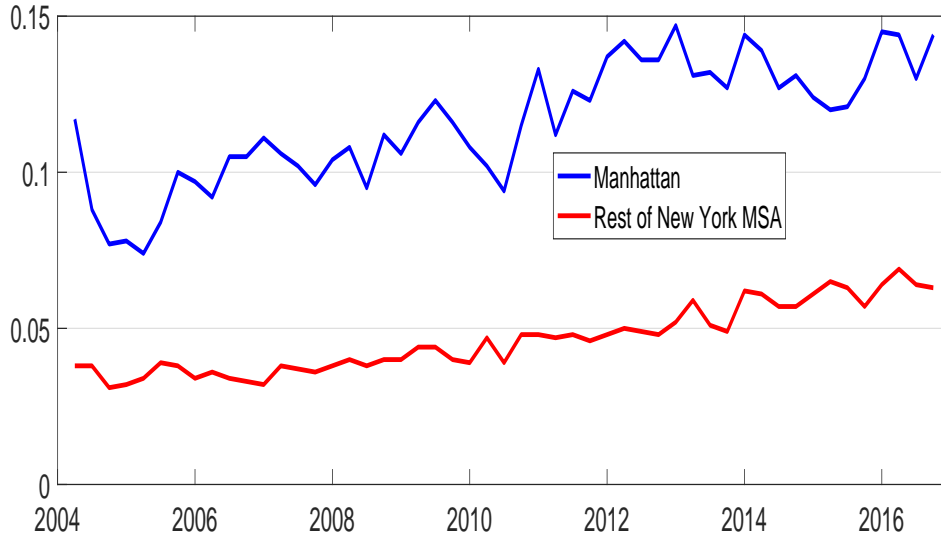
1988-2009 for Los Angeles county. They focus on the role of all investors, without distinguishing between local and out-of-town investors. Using three different measures, the investor share triples between the early 1990 to the peak of the boom in 2003-06.[33]

5.3 Extension 1: A Taste for Manhattan

The fraction of retirees to the population above age 21 in Manhattan (17.8%) is only slightly lower than in the rest of the NY metro (19.5%). In the benchmark commuting cost model, all retirees live in Zone 2 because they have no need to live close to work. Moreover, financial commuting costs push low wealth and low income households towards Zone 1 in the model. In the data, income per household in Manhattan is 42% higher than in the rest of the metro. To induce more retired and high-income households to live in Zone 1, we add a taste shifter for Manhattan to the utility function.

Specifically, we set $u(c_t, h_t, n_t, \ell) = f(c_t)c_t^{\alpha_c}h_t^{\alpha_h}(1 - n_t - \phi_{t,\ell})^{\alpha_n}$. The taste shifter $f(c)$ takes on the value one if a household chooses to live in Zone 2 or if the household chooses to live in Zone 1 and its consumption is below a cutoff $\underline{c}$. If the household lives in zone 1 and consumption is higher than $\underline{c}$, then the taste shifter takes on the value $f(c) = 1 + \chi$. Furthermore, because retirees have a weaker preference for Zone 1 than workers, all else equal, we allow χ to depend

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[33]Their measures of investors are (i) whether an individual owns two homes at the same time –this measure rises to a nearly 30% share in 2006,– (ii) purchases that were resold within two years –15% of all homes bought in 2003-05 were resold within a two year period,– and (iii) flippers defined as the fraction of purchasers who buy at least two houses while holding them for less than two years –this measure peaks at 5% in 2006.

on worker versus retiree status. If $\underline{c} > 0$, then zone 1 becomes more desirable for high-income and high-wealth households. There is a complementarity between living in zone 1 and high consumption levels. This modeling device stands in for a certain luxury consumption good bundle (high-end entertainment and restaurants) that is only available in Manhattan. This is similar to the neighborhood consumption externalities modeled in Guerrieri et al. (2013).

We choose $\chi^W = 0.0498$, $\chi^R = 0.0861$, $\underline{c} = 0.70$. The latter number implies that 11% of the population is above the consumption cutoff. We chose these parameters to get our model closer to the data along the following ratios of zone 1 relative to zone 2 variables: the fraction of retirees' ratio of 0.91 (0.92 in model), household income ratio of 1.42 (1.45 in model), and the price-to-income ratio in Z1 to Z2 of 2.10 (1.49 in the model).

5.4   Extension 2: Rent Control

Rent regulation plays a major role in the New York housing market. According to the New York City Housing and Vacancy Survey and county-level data on affordable housing for the New York metro area counties outside of New York City, 16.9% of the renters in zone 1 and 10.4% of the renters in zone 2 live in rent-regulated units. The average rent in rent-regulated properties is 49.9% below that in all other rentals. Appendix B discusses the data construction in detail.

Our treatment of rent regulation is stylized but captures its main features. Landlords in the model are required to buy η^ℓ square feet of rent regulated property for every $1 - \eta^\ell$ square feet of market property, where η^ℓ is chosen to match the fraction of rent-regulated units in each zone. We set $\eta^1 = 0.2147$ and $\eta^2 = 0.1329$.[34] Rent regulated property earns a rent that is 49.9% below the market rent in each zone, as in the data. Since the regulated rent is just a multiple of the market rent, the regulated price must be the same multiple of the market price, and therefore the return on investing in regulated units is identical to the return from investing in market units. As a result, landlords are not directly affected by rent regulation. Since the average price paid per square foot of investment property is now $1 - \eta^\ell + \eta^\ell(1 - 0.499)$ of the market price in an unregulated model, construction firms will produce less housing. This housing supply effect is the most direct way in which rent regulation affects the model's results.

Who qualifies for rent regulation? All households in the model enter in the rent regulation lottery. Any household that wins the lottery receives the option to move into a rent-regulated apartment in a zone assigned by the lottery. A winning household can choose to reject the lottery win, and live in a market priced unit in the location of its choice, as a renter or an owner. If the household accepts the lottery win, it must abide by two conditions: (i) its income must be below

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[34]Developers in New York City often build 80-20 apartment buildings where 20% of the project consists of affordable units under inclusionary zoning rules.

a cutoff set at 200% of the average NY metro income, (ii) the rent paid must be less than 20% of average income in New York. Both of these conditions are consistent with NYC rent regulation rules.[35]

The probability of winning the lottery for each zone is set such that the demand of rent regulated apartments in each zone is equal to the observed supply of these apartments. Households have a belief about this probability, which can be state dependent. This belief is updated during our numerical algorithm, and must be consistent with rational expectations. In the model, most high- and middle-income households who win the lottery turn down rent-regulated housing. The maximum rent or maximum income restrictions are too unappealing from a utility perspective (recall labor supply is endogenous). Most low-income households accept the lottery if they win. Their labor supply choice is unaltered since their optimal choice of hours implies an income that is below the threshold. Some lower-middle income households who win the lottery end up reducing their hours in order to meet the income criterion. This has adverse implications for the city-wide labor supply and production. Low-income households who win the lottery and are unconstrained by the maximum rent tend to demand more housing than they would under market conditions.

5.5   Results

Home Ownership, Wealth, and Income over the Life-cycle   Figure 3 shows the ownership rate, wealth, and income by age for the top 25%, middle 50%, and top 25% in the NYC model. Because of the fourth income state, there is much more inequality than in the baseline model (bottom panel). The top panel shows that the model is capable of generating a much lower home ownership rate as in the baseline model. The middle panel shows that the model endoegenously generates substantial wealth accumulation for the average New York metro area resident and especially a very large amount of wealth inequality between income groups.

Differences across Zones   Table 5 reports the data targets (listed in column 1) for the New York metro (column 2), zone 1 (column 3), zone 2 (column 4), and the ratio of the variable in zone 1 to zone 2 (column 5). The last two columns report the metro-wide value (column 6) and the ratio of zone 1 to zone 2 in the NY model (column 7). For completeness, we also report a full set of results of the earlier format in Panel C of Table 2. The main take-aways from both tables are (i) that adding asymmetry in the size of the two zones makes a big difference, and

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[35]The Rent Act of 2011 sets a household income threshold of $200,000 for deregulating a rent controlled apartment. This is about 200% of the $97,577 average income in NY metro. The assumed regulated rent cap is $1626 per month. Since rent controlled rent is 49.9% below the market rent, this implies a market rent of $3260 per month.

Figure 3: Ownership, Net Worth, and Income across Age and Income groups: NYC model
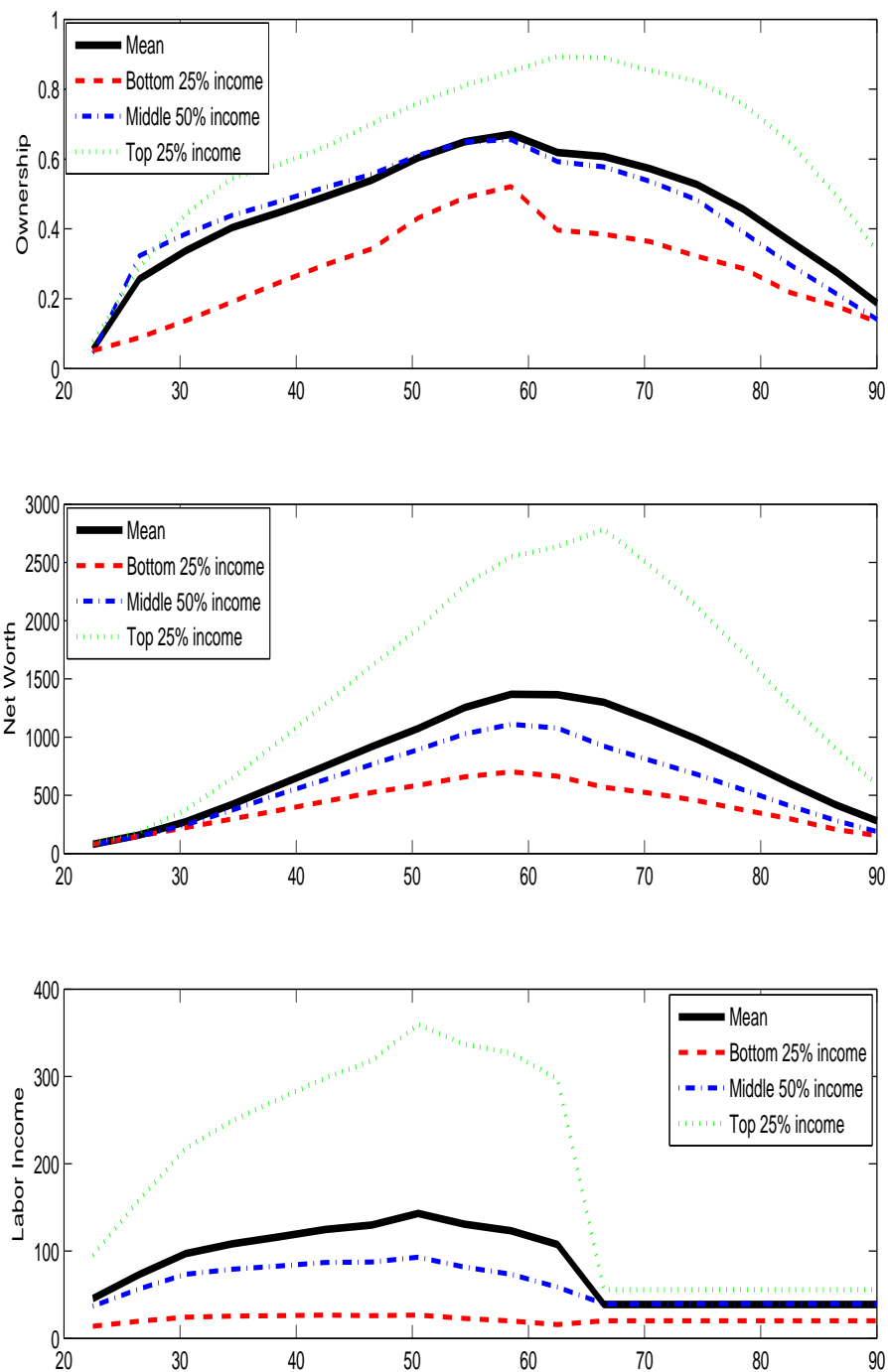
(ii) that the model manages to drive a large wedge between house prices, rents, income, home ownership rates between zones 1 and 2. The model matches the data in many respects but falls short on some others. A comparison with the baseline commuting cost model suggests that the model has moved substantially closer to the data.

The first two rows of Table 5 show that the model captures the relative size of the two areas (by construction), and more importantly, that the observed fraction of people endogenously chooses to live in the two zones. The third row shows that the model generates about the right home ownership rate: 48.1% in the model versus 50.8% in the data. The home ownership rate is much lower in Z1 than in Z2. The ratio is 0.64 in the model and even lower at 0.44 in the data. Row 4 shows that the model generates the right income level for the metro area through the calibration of the income process, but also matches the relative income in the two zones, helped by the "luxury amenity" parameter of living in Z1.

The model also matches the fraction of retirees in each zone (row 5) and the fraction of rent regulated units (row 6), as discussed above.

Row 7 shows that the model drives a big wedge between house values in the two zones. In the model, we measure this ratio as the average value of an owner occupied unit in Z1 to the average value in Z2. The ratio is 2.16 in the model compared to 2.98 in the data. The New York model is able to derive a much larger wedge between home values in the two zones than the baseline model because Z1 housing is scarcer than Z1 housing in the baseline model, and because of the additional amenity value of Manhattan housing absent in the baseline model.

Row 8 shows that the model matches the ratio of rent per renter-occupied unit of 1.68. In the model, we measure this ratio as the ratio of the per square foot market rent times the same-size apartment. That is, we interpret the Zillow rental index as pertaining to similar rental housing units in each area (constant size/quality).[36]

Similarly, the model does a good job capturing the city-wide price/rent ratio level (row 9), which in the model is constructed as the price per square foot divided by the rent per square foot. Since this ratio is mostly pinned down by the interest rate, property tax rate, and depreciation rate, and we opted to keep these parameters fixed at the baseline values, the New York metro model generates the same 13.07 price/rent ratio as the baseline model, and the same across zones.[37] Simply put, the model has no mechanism of creating a gap between price-rent ratios

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[36]Indeed, this is how Zillow's web site describes its rental index. A machine learning algorithm adjusts for differences in hedonics of the transacted properties across space and time.

[37]For New York City, the property-value weighted average residential property tax rate paid as a fraction of estimated market value is 1.65%. This amounts to 6.6% per 4 years compared to the 4% value we use. No comparable precise data are available for the other 20 counties in Z2. If we were to apply this property tax rate to the entire metro, we could lower the depreciation rate from 3% per year to 1.25% per year (arguably a more realistic value), keeping the interest rate the same as in he baseline, to match the observed 14.85 price/rent ratio in the New York metro.

across zones because the housing risk premium is relatively small and stable.

Row 10 shows that the model overstates the average price/income ratio because it overstates the average home value (row 6). While the model generates price/income ratios that are 49% larger in Z1 than Z2, that ratio is even larger in the data at 110%. Since the model matches the average income ratio across zones, this is a direct consequence of not generating enough house price variation across zones.

The average rental share of income in row 11 is somewhat lower in model than in data (23% vs. 30%). Because of the much smaller rental units in Z1 than in Z2 (which is realistic), Z1 residents spend a lower share of income on rent than Z2 residents, which is contrary to the data.[38]

Overall, we conclude that the model matches many features of the data and provides a good enough fit to take the welfare calculations from OOT purchases seriously.

Table 5: New York Metro Data Targets and Model Fit

| | | | NY Data | | | NY Model | |
		MSA	Zone 1	Zone 2	ratio Z1/Z2	MSA	ratio Z1/Z2
1	Maximum residential area (mi sqft)	77,989	1,813	76,176	2.38%	77,989	2.38%
2	Households (thousands)	7,124.9	751.2	6,373.7	11.8%	7,124.9	11.9%
3	% Home ownership	50.8	23.5	54.1	0.44	48.1	0.67
4	Income per household ($)	97,577	132,838	93,441	1.42	97,577	1.45
5	% Rent regulated	11.5	16.9	10.4	1.63	11.4	1.64
6	People over 65 as % over 21	19.3	17.8	19.5	0.91	21.8	0.92
7	Price per owner-occupied housing unit ($)	435,316	1,182,500	396,959	2.98	790,529	2.16
8	Rent per renter-occupied housing unit($)	29,318	44,364	26,366	1.68	22,593	1.68
9	Price/rent ratio (annual)	14.85	26.65	15.06	1.77	13.07	1.00
10	Price/income ratio (annual)	4.46	8.90	4.25	2.10	8.10	1.49
11	Rent to income (%)	30.0	33.4	28.2	1.18	23.2	0.66

Notes: Columns 2-5 reports the values for the data of the variables listed in the first column. Data sources and construction are described in detail in Appendix B. Column 5 reports the ratio of the zone 1 value to the zone 2 value in the data. Column 6 reports the same ratio in the model.

Inequality The model generates substantial inequality in each zone. The labor income gini is 0.672 in Z1 and 0.525 in Z2; both are substantially higher than in the generic U.S. city calibration. In the model 20% of Z1 residents earn over 200K a year, almost double the 11% fraction of Z2 residents with income in that bracket. The corresponding numbers in the New York income data are similar at 18% and 9%.

The wealth gini is 0.783 in Z1 and 0.742 in Z2. Consistent with the data, there is more financial wealth inequality (1.181 in Z1 and 0.981 in Z2) than housing wealth inequality (0.737 in Z1 and 0.713 in Z2). In Manhattan, 5.4% of households have total wealth between $750,000 and $1 million, while another 8.2% have wealth above $1 million. In the rest of the New York

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[38]In both data and model, we compute the rent/income ratio as the ratio of the average rent per renter-occupied housing unit divided by the average income of all residents of that zone.

metro, only 2.2% and 3.7% of households respectively fall are in those two wealth brackets. A substantial part of that top-wealth inequality is driven by real estate wealth.

Effect of OOT Purchases on Prices and Quantities   Panel C of Table 2 displays the effects of the observed, zone-specific increase in OOT purchases in New York. Recall that we calibrate to the observed OOT shares in the data: a transition from an OOT share of 9.6% to 13.4% in Z1 and 3.6% to 5.8% in Z2. The observed changes cause an increase in house prices of 1.1% and an increase in rents by 1.6% in both zones. Price/rent ratios fall by 0.5% while price/income ratios rise by 0.7% in Z1 and 0.4% in Z2. There is additional construction, which is more pronounced in Z1 (+2.5%) than in Z2 (+0.8%). The 11.7% decline in the relative dwelling size of Z1 to Z2 is larger than in the baseline commuting cost model. In contrast to the benchmark model, we see that OOT purchases in New York reduce the income and wealth gap between Z1 and Z2, as more high-income and high-wealth households move from Z1 to Z2. Despite the direct effect of OOT purchases, the overall home ownership rate actually falls in Z2.

Welfare Effects of OOT Investors   The welfare effects from OOT investors in New York are displayed in panel C of Table 3. Like in the benchmark commuting cost model, owners gain and renters lose. The welfare losses to renters become larger with age, while the gains for owners are fairly flat until they too start rising late in life. Overall, the gains and losses are smaller in the New York economy. This is because the OOT shock is more muted than the one in the benchmark model. The aggregate effect of these observed OOT inflows for the New York metro is a welfare loss of 0.10% consumption equivalent variation.

6   Taxation of OOT Buyers: The Case of Vancouver

Having established a net welfare loss from OOT purchases, we now study a policy that levies additional taxes on OOT buyers. Such policies have been introduced in Vancouver, Toronto, Sydney, Singapore, and are being considered by several other cities.[39] For concreteness, we focus on the case of Vancouver. We recalibrate the model to Vancouver metro area data. We introduce two new model ingredients to render the policy exercise more realistic and meaningful. First, we make OOT purchases sensitive to the price of real estate. Second, we introduce a local public good which enters in the utility function of the locals. The extra revenue raised by the tax on OOT investors increases the provision of the local public good.

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[39]Switzerland severely restricts residential real estate purchases by non-residents. The U.K. has raised stamp duty on second or third property purchases, and at the high end of the market.

6.1 OOT Tax

Vancouver introduced a 15% transaction tax on foreign buyers on August 1, 2016. The government later clarified that the tax did not apply to those who have work permits and pay taxes in British Columbia. The OOT buyers in the model do not work in the city either. Introducing a transaction tax would require an additional state variable in the model (lagged OOT). To avoid this complication, we model the OOT tax as an additional property tax beyond the one locals pay. Specifically, we assume that OOT buyers pay an additional tax rate τ^{OOT}. Taking into account the time value of money as well as the transition probabilities between the OOT regimes, a tax rate of $\tau^{OOT} = 3.465\%$ per four years (0.86% per year) is equivalent in present value terms as a one-time 15% transaction tax. We will explore a range of values for τ^{OOT} from 0% (baseline) to 15% per four years.[40]

6.2 Price-Elastic OOT Purchases

The OOT purchases continues to follow a two-state Markov chain. In the low state, $OOT^{\ell,L} = 0$, as in the baseline model. OOT purchases in the high state now depend on the equilibrium house price in that zone:

$$\log\left(OOT_t^{\ell,H}\right) = a - b \log\left(P_t^\ell (1 + \tau^{OOT})\right) \tag{10}$$

When the price elasticity of OOT demand $b = 0$, we recover the baseline model. The share of OOT purchases in the years prior to the OOT tax was about 10%.[41] After the tax was introduced the OOT share fell to 4.1% of purchases.[42] We set the price elasticity $b = 6.4$ to reflect the actual response in OOT demand to the 15% increase in the effective price faced by OOT buyers: $6.4 = (\log(0.041) - \log(0.10))/(\log(1.15) - \log(1))$. We set a to deliver the same

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[40]In the model, transaction taxes and property taxes are equivalent given the high persistence of the OOT state. One difference in reality between a transaction tax and an additional property tax is that a transaction tax does not affect existing OOT home owners. A property tax has a broader tax base and is more appropriate for that reason. UBC economists proposed an annual surcharge on properties owned by OOT investors that are left vacant, rather than a one-time transaction tax. See http://www.housingaffordability.org/uploads/7/0/1/8/70187537/bchaf_proposal.pdf.

[41]Official statistics were not kept until 2016. However, several articles indicate that a foreign purchase share of 10-13% was common for metro Vancouver in the pre-period. E.g., http://www.rew.ca/news/foreign-purchases-of-vancouver-homes-rise-slightly-as-market-adjusts-to-tax-1.341 In the months before the tax was introduced, the foreign share skyrocketed to 17%, but there are reasons to believe that some purchases took place right before the tax came into effect. To be conservative, we set the OOT share in the pre-period to 10%.

[42]The 4.1% share is for January 2017. Because of the initial bunching of OOT purchases prior to August 2016, there was a sharp drop-off in the immediate aftermath of the introduction of the tax. The foreign share was only 1.8% in September 2016 and gradually started to normalize to 3-4% in the October 2016-January 2017 period.

unconditional OOT demand in the model with $b = 6.4$ as in the baseline price-inelastic model.[43]

6.3   Local Public Goods

We change the utility function to give local residents additional utility over a local public good G. This public good is funded with property tax revenue. The additional property tax revenue coming from the surcharge for OOT buyers increases the supply of the local public good. The period utility function we use is:

$$F(G_t)U(c_t, h_t, n_t, \ell) = e^{((1-\gamma)\theta G_t)} \times \frac{u(c_t, h_t, n_t, \ell)^{1-\gamma}}{1 - \gamma} \tag{11}$$

The parameter $\theta \geq 0$ governs the relative importance of the public good the the utility function.[44] The case of $\theta = 0$ recovers our baseline model without utility over public goods (wasteful spending of property tax revenue). The public finance literature provides little guidance on how to set θ. We explore a range of values for θ.[45]

6.4   Calibration

We only discuss the parameters that are different for Vancouver. All other parameters are the same as in our baseline model.

Like for the NYC model, we keep four income states. Based on the micro data described in Appendix C, we find that the bottom 31.1% of households ear on average 0.251 times the metro area income. The next 29.6% of households earn on average 0.705 times average income. The next 26.8% of households earn 1.310 times the average, and the top 12.3% of households earn 2.949 times the metro average. The metro average income for Vancouver is $97,878.

We adapt the calibration to the specifics of the Canadian Social Security System.[46] This results in retirement income states for the four income groups of [0.696, 1.135, 1.138, 1.138]

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[43]Denote by a_0 the mean log OOT share when $b = 0$. We choose a to generate the same mean log OOT share a_0 when $b = 6.4$. This is done zone by zone.

[44]The parameter θ incorporates the government's efficacy at converting a given amount of tax revenue into valuable public goods. An alternative functional form for utility over public goods would feature additivity. We have solved that model as well. Results are similar and available upon request from the authors.

[45]One way of bounding the relevant range of θ is to compute the utility-maximizing tax revenue for a range of θ values. For values of θ below 1 the average agent is unwilling to forgo private consumption for more public goods. For values of θ above 2, the average agent wants to forgo so much private consumption, that government tax revenue would be nearly 50% of private consumption. In the Vancouver model, property tax revenue is 5% of private consumption. This level of tax revenue is optimal for θ between 1.10 and 1.15.

[46]There are two components. Old Age Security (OAS) provides $6,800 per year basic pension. Canada Pension Plan (CPP) pays 25% of an individual average lifetime's income, where that income is capped at $53,000.

times the Vancouver average pension. The latter is determined endogenously as a pay-as-you-go system. This pension system is funded by an income tax of 10.5%.[47]

The size of zone 1, $\overline{H}^1$, is chosen to match population share in Z1. The size of zone 2 is set based on relative land mass; zone 1 is 6.1% of the size of zone 2.

The time cost of commuting is set to 0.19% of available time in order to match relative rents across zones.[48] The financial cost of commuting is 0.007, or 1.8% of average income. This number is similar to the baseline value and helps the model generate reasonable ratios of wealth and price/income between zones. As before, the commuting cost parameters for retirees are 20% of those for working-age households.

The property tax rate for locals is 0.65% per year.[49]

The three parameters that govern the relative desirability of Z1 are set at $\chi^W = 0.0243$, $\chi^R = 0.1225$, $\underline{c} = 0.5$. Like in the NY calibration, these parameters help to get better match the following ratios of zone 1 relative to zone 2 variables: the fraction of retirees, household income, and the price-to-income ratio.

Like New York, Vancouver has a system of rent control. The details on the Vancouver rent control system are described in the Appendix. We match the fraction of rent-controlled units in Z1 (23.2%) and in Z2 (16.6%). The maximum income to qualify for rent controlled housing in Vancouver is 53% of average income.[50] Rent controlled units rent for a 47% reduction over the market rent.

6.5   Goodness of Fit

The Vancouver calibration does a reasonable job matching a range of moments on income, rents, and house prices. Table 6 summarizes the data targets and the corresponding moments in the model. Compared to New York, income, house price, and rent differences across zones are smaller. Price-rent levels are much larger. For New York, we had price and rent series for comparable units from Zillow. Data for comparable units are unavailable for Vancouver, therefore we calculate the price-rent ratio in the Vancouver model in the same way as in the Vancouver data; as the average price of owner-occupied units divided by the rent of renter-occupied units. While prices

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[47]In 2014, 1/3 of all personal tax revenue went to fund OAS. The average personal tax rate was 12%, so that 4% of personal income was used to pay for OAS. To pay for CPP, individuals and firms combined pay 9% of personal income up to $53,000. From the income distribution, approximately 73% of all income is taxed at 9%, implying a 6.5% average tax rate to pay for CPP. The two taxes combined are $4\% + 6.5\% = 10.5\%$.

[48]This cost is relatively low compared to the New York calibration. This may be consistent with a smaller fraction of zone 2 residents that need to commute into zone 1 for work.

[49]Total residential variable rate taxes yielded $416.5 million on a house value base of $62,506.3 million in 2016.

[50]This is for a couple with one child. The income limits differ slightly by family composition and area of the city.

are similar, rents are much lower than in New York, leading to much higher price-rent ratios. The higher price-rent ratios may, in part, reflect differences between owner- and renter-occupied units. But price-income ratios are also much larger for Vancouver than New York, suggesting that housing is simply more expensive relative to fundamentals.

Table 6: Vancouver Metro Targets and Model Fit

		Vancouver Data				Vancouver Model	
		MSA	Zone 1	Zone 2	ratio Z1/Z2	MSA	ratio Z1/Z2
1	Maximum residential area (sq km land)	2,011	115	1,896	6.1%	2,011	6.1%
2	Households (thousands)	886.45	264.57	621.88	42.5%	886.45	42.5%
3	% Home ownership	65.5	48.5	72.7	0.67	51.3	0.71
4	Income per household ($)	97,878	94,104	99,484	0.95	97,878	0.95
5	% Rent regulated	16.5	17.3	15.8	1.09	16.2	1.09
6	People over 65 as % over 21	17.5	16.6	17.9	0.93	21.8	0.89
7	Price per owner-occupied housing unit ($)	869,026	1,098,720	771,305	1.42	743,469	1.54
8	Rent per renter-occupied housing unit($)	14,109	15,888	13,352	1.19	23,546	1.19
9	Price/rent ratio (annual)	61.95	69.15	57.77	1.20	31.70	2.11
10	Price/income ratio (annual)	8.88	11.68	7.75	1.51	7.60	1.63
11	Rent/income (%)	14.4	16.9	13.4	1.26	24.1	0.78

Notes: Columns 2-5 reports the values for the data of the variables listed in the first column. Data sources and construction are described in detail in Appendix C. Column 5 reports the ratio of the zone 1 value to the zone 2 value in the data. Column 6 reports the same ratio in the model.

The model generate an average house price close to the data, as well as a realistic ratio for the relative housing price. It generates rents that are too high, relative to the (very low) levels in the data. This results in a very high price/rent ratio in the model of 31, which nevertheless is a factor of 2 different form the data. It also results in a rent/income ratio which is higher in the model than in the data. The model does a good job on the average price/income ratio, as well as on its ratio across zones. Overall, the model provides a good enough fit to study the implications of a tax policy.

6.6 Welfare Effects from OOT Tax

Table 7 shows the results for the main tax experiment for various tax rates on OOT buyers τ^{OOT}, presented in the rows of the table, and different values for the utility benefit from public goods θ, presented in the columns. For convenience, the second column reports the one-time tax that is equivalent in present value terms to the per-period tax rate in the first column. The table reports the aggregate welfare effect Δ of OOT purchases, expressed in percent consumption equivalent (as in Table 3). In the model without public goods utility and without additional taxes on OOT buyers, the average agent would be willing to give up 0.34% of consumption each year to avoid the high OOT state.

Table 7: Welfare Effects From Vancouver Tax Policy

OOT tax		Public Good Utility Paremeter θ				
τ^{OOT} (4yr)	transaction tax	0	0.1	0.5	1	2
0%	0%	-0.34	-0.33	-0.29	-0.24	-0.10
2%	8.66%	-0.32	-0.31	-0.24	-0.16	0.07
3.46%	15.0%	-0.31	-0.30	-0.21	-0.12	0.16
5%	21.64%	-0.30	-0.29	-0.18	-0.07	0.24
10%	43.28%	-0.25	-0.24	-0.11	0.02	0.39
15%	64.91%	-0.21	-0.19	-0.05	0.09	0.46

Notes: The table reports the net aggregate welfare effect Δ of OOT purchases, aggregated across all the agents in the economy. The numbers represent a consumption equivalent variation, expressed in percent. Each entry is for a different combination of the OOT tax rate τ^{OOT} (per 4 years), listed in the first column, and the utility parameter for local public goods θ, listed in the top row. The second column transforms the OOT tax rate into a present-value equivalent one-time transaction tax rate.

The main result is that introducing a tax on OOT buyers is welfare increasing. As the tax goes from 0% to 15% per four-year period, the welfare cost of OOT buyers falls, for every value of θ. When the extra tax revenue the tax brings in is wasted, the welfare cost of OOT buyers falls from 0.34% to 0.21%. Essentially, the tax reduces the OOT inflow and mitigates its welfare implications. The welfare effects are concave in the OOT tax rate. When taxes become very high, the share of OOT purchases becomes very small. The additional tax revenue that is generated becomes small; the economy is on the wrong side of the Laffer curve.

The greater the utility value locals derive from public goods, the larger the welfare gain from the tax. As θ increases from 1 to 2, a 15% transaction tax turns a net welfare cost into a net welfare gain for the city. The locus of (τ^{OOT}, θ) combinations for which OOT purchases are welfare neutral is downward sloping.

7 Conclusions

Analyzing the effects of out-of-town (OOT) home buyers on city welfare requires a general equilibrium analysis. This paper develops a novel spatial equilibrium model with wealth effects that is amenable to quantitative analysis. The model not only matches patterns of wealth accumulation and home ownership over the life-cycle, but also results in realistic house prices, rents, and wages for the city center and the surrounding parts of the metro area. OOT buyers who do not rent out their properties to locals impose a net welfare cost to the city. A tax on OOT purchases, calibrated to the 2016 Vancouver tax, which pays for more local public goods can offset or even overturn the negative effects from OOT purchases. In future work, we plan to use this framework to study how to best address the problem of the high cost of housing in the major cities of the world.

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A   Appendix

A.1   Eliminating idiosyncratic productivity from state space

Suppose that the idiosyncratic productivity process follows a random walk: $z_{t+1} = z_t A_{t+1}$ where A_{t+1} is a random variable which is independent of z_t (we can allow the mean or the variance of A to be agent specific, or to depend on age). Then we will conjecture and verify that the value function is linear in $z_t^{(1-\gamma)(1-\alpha_n)}$: $V(x_t, z_t) = z_t^{(1-\gamma)(1-\alpha_n)} v(xs_t)$ where $xs_t = x_t/z_t$ is the net worth scaled by productivity and where $v(xs_t) = V(x_t, 1)$. We can then rewrite the optimization problem in a way that avoids using z_t.

Suppose that our conjecture is true at $t+1$: $V(x_{t+1}, z_{t+1}, a+1, S_{t+1}) = z_{t+1}^{(1-\gamma)(1-\alpha_n)} v(xs_{t+1}, a+1, S_{t+1})$. Note that this conjecture is true in the last period of a household's life if the household has no bequest motive, or if the bequest is over wealth with the curvature $(1-\gamma)(1-\alpha_n)$.[51] Define $cs_t = c_t/z_t$, $hs_t = h_t/z_t$, $\widehat{hs}_t = \widehat{h}_t/z_t$, and $bs_{t+1} = b_{t+1}/z_t$. Then, it should be straight forward to check that the renter's problem can be rewritten as:

$$
\begin{aligned}
v_{R,\ell}(xs_t, a, S_t) = \max_{cs_t, hs_t, n_t} \ & U(cs_t, hs_t, n_t, \ell, a) + \beta E_t[A_{t+1}^{(1-\gamma)(1-\alpha_n)} v(xs_{t+1}, a+1, S_{t+1})] \text{ s.t.} \\
& cs_t + R_t^\ell hs_t + Q * bs_{t+1} = n_t G^a W_t (1 - \tau^{SS}) + xs_t \\
& xs_{t+1} = bs_{t+1}/A_{t+1} \geq 0 \\
& n_t \geq 0
\end{aligned}
\tag{12}
$$

and the owner's as:

$$
\begin{aligned}
v_{O,\ell}(xs_t, a, S_t) = \max_{cs_t, hs_t, \widehat{hs}_t, n_t} \ & U(cs_t, hs_t, n_t, \ell, a) + \beta E_t[A_{t+1}^{(1-\gamma)(1-\alpha_n)} v(xs_{t+1}, a+1, S_{t+1})] \text{ s.t.} \\
& cs_t + P_t^\ell hs_t + Q * bs_{t+1} + (P_t^\ell - R_t^\ell)\widehat{hs}_t = n_t G^a W_t (1 - \tau^{SS}) + xs_t \\
& xs_{t+1} = \left(bs_{t+1} + P_{t+1}^\ell(hs_t + \widehat{hs}_t)(1 - \delta - \tau^P) - P_{t+1}^\ell f(\widehat{hs}_t) \right)/A_{t+1} \\
& Q * bs_{t+1} \geq -P_t^\ell(\theta_{res} hs_t + \theta_{inv}\widehat{hs}_t) \\
& n_t \geq 0
\end{aligned}
\tag{13}
$$

This rescaling is why we require α_n to be constant. If z_t is a stationary process, then we cannot do such a rescaling, and we would not require a constant α_n. Even if z_t is non-stationary, this problem can be solved without rescaling. This is because households have a finite lifespan, therefore z_t is bounded and can be discretized for the numerical solution. However, in both cases, we would need to keep track of z_t as a state variable. Assuming a non-stationary z_t and then rescaling greatly speeds up the numerical procedure.

A.2   Analytical solution for housing and labor supply choices

We will consider the scaled problem, although the same applies to the original problem. We will solve only the worker's problem here. A retiree's problem is analogous, but simpler because there is one fewer choice as $n_t = 0$. For the retirees, out of the four cases described below, only cases one and two are relevant. If z_t is a stationary process, then the scaling is unnecessary; everything in this section applies, but in the choice for hours, G^a must be substituted by $z_t G^a$.

First, consider the renter's problem and let λ_t be the Lagrange multiplier on the budget constraint, ν_t be the Lagrange multiplier on the borrowing constraint, and ξ_t be the Lagrange multiplier on the

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[51]In the first case $V = v = 0$. In the second case $V(x, z) = x^{(1-\gamma)(1-\alpha_n)} = z^{(1-\gamma)(1-\alpha_n)} v(xs)$

labor constraint. The numerical strategy is to choose cs_t in order to maximize the household's utility. Here we will show that the other choices (n_t and h_t) can be written as analytic functions of cs_t.

Case 1: $\nu_t = 0$ and $\xi_t = 0$. In this case the household is unconstrained. The first order conditions are:

$$
\begin{aligned}
(1-\gamma)\alpha_{c,a}cs_t^{-1}U_t &= \lambda_t \\
(1-\gamma)\alpha_n(1-n_t-\phi_\ell)^{-1}U_t &= \lambda_t G^a W_t(1-\tau^{SS}) \\
(1-\gamma)\alpha_{h,a}hs_t^{-1}U_t &= \lambda_t R_t^\ell \\
\lambda_t &= Q\beta E_t[A_{t+1}^{(1-\gamma)(1-\alpha_n)-1}\tfrac{\partial v_{t+1}}{\partial xs_{t+1}}]
\end{aligned}
\tag{14}
$$

By rearranging, it is clear that conditional on choosing a location ℓ, $hs_t = \frac{\alpha_{h,a}}{\alpha_{c,a}}\frac{1}{R_t^\ell}cs_t$ and $n_t = 1-\phi_\ell - \frac{\alpha_n}{\alpha_{c,a}}\frac{1}{G^a W_t(1-\tau^{SS})}cs_t$.

Case 2: $\nu_t > 0$ and $\xi_t = 0$. In this case the borrowing constraint binds and $bs_{t+1} = 0$ but the labor constraint does not. The first order conditions in the first three lines of equation 14 are still correct. It is still the case that conditional on choosing a location ℓ, $hs_t = \frac{\alpha_{h,a}}{\alpha_{c,a}}\frac{1}{R_t^\ell}cs_t$ and $n_t = 1-\phi_\ell - \frac{\alpha_n}{\alpha_{c,a}}\frac{1}{G^a W_t(1-\tau^{SS})}cs_t$. By plugging these into the budget constraint, we can explicitly solve for $cs_t = \alpha_{c,a}\left((1-\phi_\ell)G^a W_t(1-\tau^{SS}) + xs_t\right)$.

Case 3: $\nu_t = 0$ and $\xi_t > 0$. In this case the borrowing constraint does not bind, but the labor constraint does, implying $n_t = 0$. The first order conditions in the first, third, and fourth lines of equation 14 are still correct. As in case 1, conditional on choosing a location ℓ, $hs_t = \frac{\alpha_{h,a}}{\alpha_{c,a}}\frac{1}{R_t^\ell}cs_t$.

Case 4: $\nu_t > 0$ and $\xi_t > 0$. In this case both constraints bind, implying $n_t = 0$ and $bs_{t+1} = 0$. The first order conditions in the first and third lines of equation 14 are still correct. Now, conditional on choosing a location ℓ, $hs_t = \frac{\alpha_{h,a}}{\alpha_{c,a}}\frac{1}{R_t^\ell}cs_t$. By plugging this into the budget constraint, we can explicitly solve for $cs_t = \frac{\alpha_{c,a}}{\alpha_{c,a}+\alpha_{h,a}}xs_t$.

Next, consider the owner's problem and let λ_t be the Lagrange multiplier on the budget constraint, ν_t be the Lagrange multiplier on the borrowing constraint, and ξ_t be the Lagrange multiplier on the labor constraint. The numerical strategy is to choose cs_t and $\widehat{hs}_t$ in order to maximize the household's utility. Here we will show that the other choices (n_t and h_t) can be written as analytic functions of cs_t and $\widehat{hs}_t$.

Case 1: $\nu_t = 0$ and $\xi_t = 0$. In this case the household is unconstrained. The first order conditions are:

$$
\begin{aligned}
(1-\gamma)\alpha_{c,a}cs_t^{-1}U_t &= \lambda_t \\
(1-\gamma)\alpha_n(1-n_t-\phi_\ell)^{-1}U_t &= \lambda_t G^a W_t(1-\tau^{SS}) \\
(1-\gamma)\alpha_{h,a}hs_t^{-1}U_t + \beta E_t[A_{t+1}^{(1-\gamma)(1-\alpha_n)-1}\tfrac{\partial v_{t+1}}{\partial xs_{t+1}}P_{t+1}^\ell(1-\delta-\tau^P)] &= \lambda_t P_t^\ell \\
\beta E_t[A_{t+1}^{(1-\gamma)(1-\alpha_n)-1}\tfrac{\partial v_{t+1}}{\partial xs_{t+1}}P_{t+1}^\ell(1-\delta-\tau^P-f'(\widehat{h}_t))] &= \lambda_t(P_t^\ell-R_t^\ell) \\
\lambda_t &= Q\beta E_t[A_{t+1}^{(1-\gamma)(1-\alpha_n)-1}\tfrac{\partial v_{t+1}}{\partial xs_{t+1}}]
\end{aligned}
\tag{15}
$$

By rearranging, it is clear that conditional on choosing zone ℓ, $hs_t = \frac{\alpha_{h,a}}{\alpha_{c,a}}\frac{1}{R_t^\ell}cs_t * \frac{1-\delta-\tau^P-f'(\widehat{h}_t)}{1-\delta-\tau^P-f'(\widehat{h}_t)\frac{P_t^\ell}{R_t^\ell}}$ and

$n_t = 1-\phi_\ell - \frac{\alpha_n}{\alpha_{c,a}}\frac{1}{G^a W_t(1-\tau^{SS})}cs_t$.

Case 2: $\nu_t > 0$ and $\xi_t = 0$. In this case the borrowing constraint binds implying $bs_{t+1} = -P_t^\ell(\theta_{res}hs_t + \theta_{inv}\widehat{hs}_t)/Q$, but the labor constraint does not bind. Eliminating bs_{t+1} from the budget constraint, we can rewrite it as

$$
cs_t + P_t^\ell(1-\theta_{res})hs_t + (P_t^\ell(1-\theta_{inv})-R_t^\ell)\widehat{hs}_t = n_t G^a W_t(1-\tau^{SS}) + xs_t
$$

and resolving gives the following set of first order conditions:

$$(1-\gamma)\alpha_{c,a}cs_t^{-1}U_t = \lambda_t$$
$$(1-\gamma)\alpha_n(1-n_t-\phi_\ell)^{-1}U_t = \lambda_t G^a W_t(1-\tau^{SS})$$
$$(1-\gamma)\alpha_{h,a}hs_t^{-1}U_t + \beta E_t[A_{t+1}^{(1-\gamma)(1-\alpha_n)-1}\frac{\partial v_{t+1}}{\partial xs_{t+1}}(P_{t+1}^\ell(1-\delta-\tau^P)-P_t^\ell\theta_{res}/Q)] = \lambda_t P_t^\ell(1-\theta_{res})$$
$$\beta E_t[A_{t+1}^{(1-\gamma)(1-\alpha_n)-1}\frac{\partial v_{t+1}}{\partial xs_{t+1}}(P_{t+1}^\ell(1-\delta-\tau^P-f'(\widehat{h}_t))-P_t^\ell\theta_{inv}/Q)] = \lambda_t(P_t^\ell*(1-\theta_{inv})-R_t^\ell)$$

$$(16)$$

The optimal labor choice is the same as in the previous case: $n_t = 1-\phi_\ell-\frac{\alpha_n}{\alpha_{c,a}}\frac{1}{G^aW_t(1-\tau^{SS})}cs_t$. However, the optimal housing choice may now be different. Recall that the numerical strategy is to choose cs_t and $\widehat{hs}_t$. Given those quantities and the binding borrowing constraint, we can use the budget constraint to solve for

$$hs_t = \left(n_tG^aW_t(1-\tau^{SS})+xs_t-(P_t^\ell(1-\theta_{inv})-R_t^\ell)\widehat{hs}_t-cs_t\right)/\left(P_t^\ell(1-\theta_{res})\right)$$

Case 3: $\nu_t = 0$ *and* $\xi_t > 0$. In this case the borrowing constraint does not bind, but the labor constraint does, implying $n_t = 0$. All but the second line of equation 15 are still correct. Conditional on choosing a location ℓ, hs_t is identical to Case 1.

Case 4: $\nu_t > 0$ *and* $\xi_t > 0$. In this case both constraints bind, implying $n_t = 0$ and $bs_{t+1} = -P_t^\ell(\theta_{res}hs_t+\theta_{inv}\widehat{hs}_t)/Q$. Eliminating bs_{t+1} and n_t from the budget constraint, we can rewrite it as

$$cs_t + P_t^\ell(1-\theta_{res})hs_t + (P_t^\ell(1-\theta_{inv})-R_t^\ell)\widehat{hs}_t = xs_t$$

We can now solve for hs_t as a function of cs_t and $\widehat{hs}_t$ just as in case 2:

$$hs_t = \left(xs_t-(P_t^\ell(1-\theta_{inv})-R_t^\ell)\widehat{hs}_t-cs_t\right)/\left(P_t^\ell(1-\theta_{res})\right)$$

A.3   Special case which can be solved analytically

Consider a perpetual renter who is facing a constant wage W and a constant rent R, who is not choosing location, who is not constrained, who faces no idiosyncratic shocks ($A = 1$), and whose productivity and utility are not age dependent ($G^a = 1$, $\alpha_{c,a} = \alpha_c$, and $\alpha_{h,a} = \alpha_h$ $\forall a$). His problem can be written as:

$$v(xs_t,a) = \max_{cs,hs,n}\frac{1}{1-\gamma}(cs_t^{\alpha_c}hs_t^{\alpha_h}(1-n_t)^{\alpha_n})^{1-\gamma}+\beta E_t[v(xs_{t+1},a+1)] \text{ s.t.}$$
$$xs_{t+1} = \frac{1}{Q}(xs_t+n_tW-cs_t-hs_tR)$$

$$(17)$$

As shown earlier, the optimal housing and labor choices satisfy: $hs_t = \frac{\alpha_h}{\alpha_c}\frac{1}{R}cs_t$ and $n_t = 1-\frac{\alpha_n}{\alpha_c}\frac{1}{W}cs_t$. Redefining $\widehat{cs} = \frac{1}{\alpha_c}cs$ and plugging these into the maximization problem, the problem is rewritten as:

$$v(xs_t,a) = \max_{\widehat{cs}}\frac{\overline{U}}{1-\gamma}\widehat{cs}_t^{1-\gamma}+\beta E_t[v(xs_{t+1},a+1)] \text{ s.t.}$$
$$xs_{t+1} = \frac{1}{Q}(xs_t+W-\widehat{cs}_t)$$

$$(18)$$

where $\overline{U} = \left(\alpha_c^{\alpha_c}\alpha_h^{\alpha_h}\alpha_n^{\alpha_n}R^{-\alpha_h}W^{-\alpha_n}\right)^{1-\gamma}$. Next we can guess and verify that the value function has the form $v(xs_t,a) = \frac{v_a}{1-\gamma}*\left(xs_t+\frac{1}{1-Q_a}W\right)^{1-\gamma}$ where v_a and Q_a are constants that depend on age a.

Suppose this is true for $a+1$. Then the problem is:

$$
\begin{aligned}
v(xs_t, a) &= \max_{\widehat{cs}} \frac{\overline{U}}{1-\gamma}\widehat{cs}_t^{1-\gamma} + \frac{v_{a+1}}{1-\gamma}\beta Q^{-(1-\gamma)}(xs_t + W - \widehat{cs}_t + W\frac{Q}{1-Q_{a+1}})^{1-\gamma} \\
&= \max_{\widehat{cs}} \frac{\overline{U}}{1-\gamma}\widehat{cs}_t^{1-\gamma} + \frac{v_{a+1}}{1-\gamma}\beta Q^{-(1-\gamma)}(xs_t - \widehat{cs}_t + W\frac{1-Q_{a+1}+Q}{1-Q_{a+1}})^{1-\gamma}
\end{aligned}
\tag{19}
$$

Define $X_{a+1} = v_{a+1}Q^{-(1-\gamma)}\beta$. Then the first order condition is: $\overline{U} * \widehat{cs}_t^{-\gamma} = X_{a+1} * (xs_t - \widehat{cs}_t + W\frac{1-Q_{a+1}+Q}{1-Q_{a+1}})^{-\gamma}$. Rearranging, we can solve for optimal consumption:

$$
\begin{aligned}
\widehat{cs}_t &= \frac{\left(\frac{X_{a+1}}{\overline{U}}\right)^{-1/\gamma}}{1+\left(\frac{X_{a+1}}{\overline{U}}\right)^{-1/\gamma}}\left(xs_t + W\frac{1-Q_{a+1}+Q}{1-Q_{a+1}}\right) \\
xs_{t+1} + \frac{1}{1-Q_{a+1}}W &= \frac{1}{1+\left(\frac{X_{a+1}}{\overline{U}}\right)^{-1/\gamma}}\left(xs_t + W\frac{1-Q_{a+1}+Q}{1-Q_{a+1}}\right)
\end{aligned}
\tag{20}
$$

Plugging this back into the original problem:

$$
\begin{aligned}
v(xs_t, a) &= \left(\overline{U}\left(\frac{\left(\frac{X_{a+1}}{\overline{U}}\right)^{-1/\gamma}}{1+\left(\frac{X_{a+1}}{\overline{U}}\right)^{-1/\gamma}}\right)^{1-\gamma} + X_{a+1}\left(\frac{1}{1+\left(\frac{X_{a+1}}{\overline{U}}\right)^{-1/\gamma}}\right)^{1-\gamma}\right)\frac{\left(xs_t + W\frac{1-Q_{a+1}+Q}{1-Q_{a+1}}\right)^{1-\gamma}}{1-\gamma} \\
&= \overline{U}\left(1+\left(\frac{X_{a+1}}{\overline{U}}\right)^{-1/\gamma}\right)^{-(1-\gamma)}\left(\left(\frac{X_{a+1}}{\overline{U}}\right)^{-(1-\gamma)/\gamma} + \left(\frac{X_{a+1}}{\overline{U}}\right)\right)\frac{\left(xs_t + W\frac{1-Q_{a+1}+Q}{1-Q_{a+1}}\right)^{1-\gamma}}{1-\gamma} \\
&= X_{a+1}\left(1+\left(\frac{X_{a+1}}{\overline{U}}\right)^{-1/\gamma}\right)^{\gamma}\frac{\left(xs_t + W\frac{1-Q_{a+1}+Q}{1-Q_{a+1}}\right)^{1-\gamma}}{1-\gamma}
\end{aligned}
\tag{21}
$$

This verifies the conjecture. The age dependent constants take the following form:

$$
\begin{aligned}
v_a &= X_{a+1}\left(1+\left(\frac{X_{a+1}}{\overline{U}}\right)^{-1/\gamma}\right)^{\gamma} \\
&= \beta Q^{-(1-\gamma)}v_{a+1}\left(1+\left(v_{a+1}\beta Q^{-(1-\gamma)}\overline{U}^{-1}\right)^{-1/\gamma}\right)^{\gamma} \\
Q_a &= \frac{Q}{1+Q-Q_{a+1}}
\end{aligned}
\tag{22}
$$

Note that $Q_\infty = Q$ and $v_\infty = \overline{U}\left(1-\beta^{\frac{1}{\gamma}}Q^{\frac{-(1-\gamma)}{\gamma}}\right)^{-\gamma}$.

A.4 Commuting costs and composition of Zone 1

From the household's FOC, we know that $\frac{\partial U}{\partial C} = \frac{\partial U}{\partial N} \times \frac{1}{w}$ where C is the numeraire, N is hours worked, and w is the wage. Suppose that moving one unit of distance towards center decreases the hourly commuting cost by ϕ_T and the financial commuting cost by ϕ_F. Also, suppose that the price is a function of distance from center $P(x)$.

First, consider time costs only ($\phi_F = 0$). The cost of decreasing the commute by d is $d \times H \times P'(x) \times \frac{\partial U}{\partial C}$, this is the amount of housing consumed H, multiplied by the price increase at the current location $P'(x) \times d$, multiplied by the marginal utility of the numeraire good. The benefit of decreasing the commute by d is $d \times \phi_T \times \frac{\partial U}{\partial N} = d \times \phi_T \times w \times \frac{\partial U}{\partial C}$, this is the marginal utility of leisure, multiplied by the extra leisure $d \times \phi_T$. Equating the cost to the benefit and rearranging: $P'(x) = \phi_T \frac{w}{H}$. The left hand side represents one's willingness to pay per square foot implying that agents with high $\frac{w}{H}$ are willing to pay a higher price. For a fixed amount of wealth, high income agents have higher $\frac{w}{H}$ because

individual productivity is stationary, therefore high income agents tend to save relatively more and consume relatively less of their wealth ($\frac{w}{H}$ would be constant if individual productivity had permanent shocks). For a fixed income, high wealth agents have higher $\frac{w}{H}$ because, consistent with the Permanent Income Hypothesis, for a fixed w, high wealth agents are willing to spend more on housing.

Next, consider financial costs only ($\phi_T = 0$). The cost of decreasing the commute is the same as before $d \times H \times P'(x) \times \frac{\partial U}{\partial C}$. The benefit of decreasing the commute is $d \times \phi_F \times \frac{\partial U}{\partial C}$, this is the financial saving $d \times \phi_F$ multiplied by the marginal utility of the numeraire. Equating the cost to the benefit: $P'(x) = \phi_F \frac{1}{H}$. Low H agents are willing to pay a higher price. Agents who have low wealth or low income tend to have lower housing demand H and are willing to pay more per square foot to reduce their commute. The intuition is that the financial cost is fixed, thus agents with low housing demand are willing to pay a much higher price per square foot to 'ammortize' the benefit of not paying the fixed cost.

A.5   One-period case which can be solved analytically

There are m agents, m^c consumption producing firms, m^1 construction firms in zone 1, and m^2 construction firms in zone 2. There are two zones with sizes $m\overline{h^1}$ and $m\overline{h}^2$. Agents have initial wealth $W = 0$ and earn a wage w. They live for one period only, and there is no resale value for the housing that they buy.

Conditional on a zone, a household maximizes $U = c^{\alpha_c} h^{\alpha_h} (1 - \lambda - x)^{\alpha_n}$ subject to $c + P * h = W + w * x$ where λ is a zone specific time cost and P is a zone specific housing price ($\lambda = 0$ in Zone 1). This can be rewritten as:

$$U = \max_{h,x} (W + w * x - P * h)^{\alpha_c} h^{\alpha_h} (1 - \lambda - x)^{\alpha_n} \tag{23}$$

The first order conditions imply the following solution:

$$\begin{aligned}
c &= \alpha_c((1 - \lambda)w + W) \\
h &= \alpha_h((1 - \lambda)w + W) \\
x &= (\alpha_c + \alpha_h)(1 - \lambda) - \alpha_n \frac{W}{w} \\
U &= \left(\frac{1}{P}\right)^{\alpha_h} \left(\frac{1}{w}\right)^{\alpha_n} \alpha_c^{\alpha_c} \alpha_h^{\alpha_h} \alpha_n^{\alpha_n}((1 - \lambda)w + W)
\end{aligned} \tag{24}$$

Here we used $\alpha_c + \alpha_h + \alpha_n = 1$.

Each consumption producing firm chooses hours x_c to maximize $\pi_c = x_c^{\rho_c} - wx_c$ which implies that $w = \rho_c x_c^{\rho_c - 1}$. Each construction firm in zone 1 maximizes $\pi_1 = \left(1 - \frac{H^1}{m\overline{h^1}}\right) P_1 x_1^{\rho_h} - wx_1$ which implies that $w = \left(1 - \frac{H^1}{m\overline{h^1}}\right) P_1 \rho_h x_1^{\rho_h - 1}$. Each construction firm in zone 2 maximizes $\pi_2 = \left(1 - \frac{H^2}{m\overline{h^2}}\right) P_2 x_2^{\rho_h} - wx_2$ which implies that $w = \left(1 - \frac{H^2}{m\overline{h^2}}\right) P_2 \rho_h x_2^{\rho_h - 1}$. Here H^1 and H^2 are the total amount of housing built in each zone.

Equilibrium implies that the following equations must be satisfied.

$$P_2 = P_1(1 - \lambda)^{1/\alpha_h} \tag{25}$$

Equation 25 says that for households to be indifferent between the two zones, their utility of living in each zone must be the same.

$$n_1 = \frac{H^1 P^1}{\alpha_h w} \tag{26}$$

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$$n_2 = \frac{H^2 P^2}{\alpha_h w(1-\lambda)} \tag{27}$$

$$n_1 + n_2 = m \tag{28}$$

Equations 26 and 27 say that the total number of households in each zone (N_1 and N_2) must equal to the total housing in each zone, divided by the housing size an agent in that zone would demand. The housing size comes from the solution of the agent's problem. Equation 28 says that the sum of agents living in zones 1 and 2 must equal to the total number of agents.

$$w = \rho_c x_c^{\rho_c - 1} \tag{29}$$

$$w = \left(1 - \frac{H^1}{m\overline{h^1}}\right) P_1 \rho_h x_1^{\rho_h - 1} \tag{30}$$

$$w = \left(1 - \frac{H^2}{m\overline{h^2}}\right) P_2 \rho_h x_2^{\rho_h - 1} \tag{31}$$

Equations 29, 30, and 31 relate each firm's optimal behavior to the wage.

$$H^1 = \left(1 - \frac{H^1}{m\overline{h^1}}\right) m_1 x_1^{\rho_h} \tag{32}$$

$$H^2 = \left(1 - \frac{H^2}{m\overline{h^2}}\right) m_1 x_2^{\rho_h} \tag{33}$$

Equations 32 and 33 relate each firm's output to the total output of housing in each zone. They can be rewritten as $H^1 = \frac{m\overline{h^1} m_1 x_1^{\rho_h}}{m\overline{h^1} + m_1 x_1^{\rho_h}}$ and $H^2 = \frac{m\overline{h^2} m_2 x_2^{\rho_h}}{m\overline{h^2} + m_2 x_2^{\rho_h}}$.

$$(\alpha_c + \alpha_h)(n_1 + n_2(1-\lambda)) = m_c x_c + m_1 x_1 + m_2 x_2 \tag{34}$$

Equation 34 relates labor supply, on the left side, to labor demand, on the right side.

This is 10 equations and 10 unknowns: prices P_1, P_2; labor demand for each firm type x_1, x_2, x_c; number of households living in each zone n_1, n_2; total housing in each zone H^1, H^2; and the wage w. This can can be reduced to a single equation.

First, plug H and P into equations (30) and (31): $w = P_1 \rho_h \frac{m\overline{h^1} x_1^{\rho_h - 1}}{m\overline{h^1} + m_1 x_1^{\rho_h}} = P_2 \rho_h \frac{m\overline{h^2} x_2^{\rho_h - 1}}{m\overline{h^2} + m_2 x_2^{\rho_h}}$

Second, plug the wage into equations (26) and (27): $n_1 = \frac{m_1 x_1}{\alpha_h \rho_h}$ and $n_2 = \frac{m_2 x_2}{\alpha_h \rho_h (1-\lambda)}$.

Third, plug n_1 and n_2 into equation (28) to solve for x_2 in terms of x_1: $x_2 = \frac{1-\lambda}{m_2}(m\alpha_h \rho_h - m_1 x_1) = A_0 + A_1 x_1$ where $A_0 = \frac{1-\lambda}{m_2} m\alpha_h \rho_h$ and $A_1 = -m_1 \frac{1-\lambda}{m_2}$.

Fourth, plug $x_2 = A_0 + A_1 x_1$ into the equality between Zone 1 and Zone 2 firms' wages derived earlier and use equation (25) to get rid of prices: $\frac{m\overline{h^1} x_1^{\rho_h - 1}}{m\overline{h^1} + m_1 x_1^{\rho_h}} = (1-\lambda)^{1/\alpha_h} \frac{m\overline{h^2}(A_0 + A_1 x_1)^{\rho_h - 1}}{m\overline{h^2} + m_2(A_0 + A_1 x_1)^{\rho_h}}$. This is now one equation with one unknown and can be solved numerically.

Fifth, once we have x_1 we can immediately calculate x_2, n_1, n_2, H^1, H^2 but we still need to solve for w and P_1. We can solve for w as a function of P_1 using equation (30). We can then solve for x_c as a function of P_1 using equation (29). We can then plug this into equation (34) to solve for P_1.

B Data Appendix: New York

B.1 The New York Metro Area

U.S. Office of Management and Budget publishes the list and delineations of Metropolitan Statistical Areas (MSAs) on the Census website (https://www.census.gov/population/metro/data/ metrodef.html). The current delineation is as of July 2015. New York-Newark-Jersey City, NY-NJ-PA MSA (NYC MSA) is the most populous MSA among the 382 MSAs in the nation.

NYC MSA consists of 4 metropolitan divisions and 25 counties, spanning three states around New York City. The complete list of counties with state and zone information is presented in Table 8. As previously defined, only New York County (Manhattan borough) is categorized as Zone 1 and the rest 24 counties are categorized as Zone 2. For informational purposes, the five counties of New York City are appended with parenthesized borough names used in New York City.

Table 8: NYC MSA

County	State	Zone
New York (Manhattan)	NY	Zone 1
Bergen	NJ	Zone 2
Bronx (Bronx)	NY	Zone 2
Dutchess	NY	Zone 2
Essex	NJ	Zone 2
Hudson	NJ	Zone 2
Hunterdon	NJ	Zone 2
Kings (Brooklyn)	NY	Zone 2
Middlesex	NJ	Zone 2
Monmouth	NJ	Zone 2
Morris	NJ	Zone 2
Nassau	NY	Zone 2
Ocean	NJ	Zone 2
Orange	NY	Zone 2
Passaic	NJ	Zone 2
Pike	PA	Zone 2
Putnam	NY	Zone 2
Queens (Queens)	NY	Zone 2
Richmond (Staten Island)	NY	Zone 2
Rockland	NY	Zone 2
Somerset	NJ	Zone 2
Suffolk	NY	Zone 2
Sussex	NJ	Zone 2
Union	NJ	Zone 2
Westchester	NY	Zone 2

B.2 Population, Housing Stock, and Land Area

The main source for population, housing stock and land area is US Census Bureau `American FactFinder` (http://factfiner.census.gov). `American FactFinder` provides comprehensive survey data on a wide range of demographic and housing topics. Using the Advanced Search option on the webpage, topics such as population and housing can be queried alongside geographic filters. We select the DP02 table (selected social characteristics) for population estimates, the DP04 table (selected housing characteristics) for housing estimates, and the GCT-PH1 table (population, housing units, area and density) for land area information. Adding 25 counties separately in the geographic filter, all queried information is retrieved at the county level. We then aggregate the 24 columns as a single Zone 2 column.

Since the ACS (American Community Survey) surveys are conducted regularly, the survey year must be additionally specified. We use the 2015 1-year ACS dataset as it contains the most up-to-date numbers available. For Pike County, PA, the 2015 ACS data is not available and we use the 2014 5-year ACS number instead. Given that Pike County accounts only for 0.3% of Zone 2 population, the effect of using lagged numbers for Pike County is minimal.

The ratio of the land mass of zone 1 (Manhattan) to the land mass of zone 2 (the other 24 counties of the NY MSA) is 0.0028. However, that ratio is not the appropriate measure of the relative maximum availability of housing in each of the zones since Manhattan zoning allows for taller buildings, smaller lot sizes, etc.

Data on the maximum buildable residential area are graciously computed and shared by Chamna Yoon from Baruch College. He combines the maximum allowed floor area ratio (FAR) to each parcel to construct the maximum residential area for each of the five counties (boroughs) that make up New York City. Manhattan has a maximum residential area of 1,812,692,477 square feet. This is our measure for $\bar{H}^1$. The other four boroughs of NYC combine for a maximum buildable residential area of 4,870,924,726 square feet. Using the land area of each of the boroughs (expressed in square feet), we can calculate the ratio of maximum buildable residential area (sqft) to the land area (sqft). For Manhattan, this number is 2.85. For the other four boroughs of NYC it is 0.62. For Staten Island, the most suburban of the boroughs, it is 0.32. We assume that the Staten Island ratio is representative of the 20 counties in the New York MSA that lie outside NYC since these are more suburban. Applying this ratio to their land area of 222,808,633,344 square feet, this delivers a maximum buildable residential square feet for those 20 counties of 71,305,449,967 square feet. Combining that with the four NYC counties in zone 2, we get a maximum buildable residential area for zone 2 of 76,176,377,693 square feet. This is $\bar{H}^2$. The ratio $\bar{H}^1/\bar{H}^2$ is 0.0238. We argue that this ratio better reflects the relative scarcity of space in Manhattan than the corresponding land mass ratio.

B.3 Income

The main source for the income distribution data is again US Census Bureau `American FactFinder` (http://factfiner.census.gov). From table DP03 (selected economic characteristics), we retrieve the number of households in each of 10 income brackets, ranging from "less than $10,000" for the lowest to "$200,000 or more" for the highest bracket. The distribution suffers from top-coding problem, so we additionally estimate the conditional means for the households in each income bracket. For the eight income brackets except for the lowest and the highest, we simply assume the midpoint of the interval as the conditional mean. For example, for the households in $50,000 to $74,999 bracket, the conditional mean income is assumed to be $62,500. For the lowest bracket, (less than $10,000) we assume the conditional mean is $7,500. Then we can calculate the conditional mean of the highest income bracket, using the average household income and conditional means of the other brackets, since the reported unconditional mean is based on all data.

We aggregate the county-level income distribution into a Zone 2 income distribution in two steps. First, the aggregate number of households included in each income bracket is the simple sum of county-level household numbers in the bracket. Second, we calculate the Zone 2 conditional mean of the income brackets using the weighted average methods. For the lower nine income brackets, the conditional means are assumed to be constant across counties, so Zone 2 conditional means are also the same. For the highest income bracket, we use the county-specific conditional mean of the highest bracket, and calculate its weighted average over the 24 counties. Using these conditional means, and the household distribution over 10 income brackets, the Zone 2 average household income can be calculated.

B.4 House Prices, Rental Prices, and Home Ownership

Housing prices and rental prices data come from `Zillow` (http://www.zillow.com/research/data) indices. Zillow publishes Zillow Home Value Index (ZHVI) and Zillow Rent Index (ZRI) monthly. The main advantage of using Zillow indices compared to other indices is that it overcomes sales-composition bias by constantly estimating hypothetical market prices, controlling for hedonics such as house size. We use 2015 year-end data to be consistent with the ACS dataset. There are a few missing counties in ZHVI and ZRI. For the five counties with missing ZHVI index price, we search those counties from `Zillow` (http://www.zillow.com) website, and use the median listing prices instead. For the two counties with missing ZRI index price, we estimate the rents using the price/rent ratio of comparable counties.

Home ownership data is directly from `American FactFinder` (http://factfiner.census.gov). In table DP04 (selected housing characteristics), the *Total housing units* number is divided by *Occupied housing units* and *Vacant housing units*. *Occupied housing units* are further classified into *Owner-occupied* and *Renter-occupied* housing units, which enables us to calculate the home ownership ratio.

B.5 Out-of-town Housing Demand

Out-of-town (OOT) housing demand is estimated using the data set provided by `CoreLogic` (http://www.corelogic.com). The data set contains the monthly time series of number of housing purchases for Manhattan and for NYC MSA between January 2004 and September 2016. Housing purchases are defined as purchases of single-family, 2-4 family, condominiums, and co-ops. OOT purchases are identified using the reported mailing addresses on payment/tax forms. Specifically, if the address of a buyer is either abroad or not contained in the list of 1,304 ZIP codes inside NYC MSA, then the transaction is classified as an OOT purchase.

One complication arises because not only individuals but also companies purchase residential real estate. We include purchases by the following types of corporate entities: LLC, Inc, Corp, and Trust. Combined, these account for 7.28% of all purchases in the New York metro and even 11.13% in Manhattan. We have an address for these corporate purchases as well. Following the same address rules, we obtain the number of OOT corporate purchases and the number of NY MSA corporate purchases in each month. If the buyer of an apartment is a corporation, we can not be certain whether the individual who ultimately owns the apartment is a local or from OOT. Some OOT corporate purchases may be done by locals while some NY MSA corporate purchases may actually hide the identity of OOT investors. Under *assumption 1*, we assume that all OOT corporate purchases are by OOT investors and none of the NY MSA corporate purchases are by OOT buyers. Under *assumption 2*, we assume that 70% of all OOT corporate purchases are by OOT investors and 30% of the NY MSA corporate purchases are by OOT buyers. We have also computed the OOT share assuming (90%,10%) and (80%,20%) assumptions and the results are in between those for assumption 1 and assumption 2. Since there are a lot more NY MSA corporate purchases than OOT corporate purchases, the OOT share under assumption 2 is higher than under assumption 1.

As described in Table 9, the average OOT purchase fractions are 9.2%/2.8% for Zone 1/Zone 2 under *assumption 1*, while the fractions are 11.6%/4.6% under *assumption 2*. Based on conversations with market participants, we believe assumption 2 comes closer to approximating the true OOT share. Therefore, we calibrate a low OOT share of 9.6% in zone 1 and 3.6% in zone 2. We calibrate the high OOT state as a 13.4% share in zone 1 and 5.8% share in zone 2.

Table 9: Fraction of OOT Purchases of New York Housing Units

Panel A: Manhattan (zone 1)				
Assumption	**2004.01-2016.09**	2004.01 - 2007.12	2008.01 - 2011.12	2012.01 - 2016.09
1	9.2%	8.2%	9.0%	10.1%
2	11.6%	9.6%	11.4%	13.4%
Panel B: Rest of New York metro area (zone 2)				
1	2.8%	2.5%	2.6%	3.1%
2	4.6%	3.6%	4.4%	5.8%

Notes: Share of Manhattan residential real estate purchases made by out-of-town (OOT) buyers. Source: Core Logic. Monthly data from January 2004 through September 2016.

B.6   Rent Regulation

The main source for rent regulation data is US Census Bureau New York City Housing and Vacancy Survey (NYCHVS; http://www.census.gov/housing/nychvs). NYCHVS is conducted every three years to comply with New York state and New York City's rent regulation laws. We use the 2014 survey data table, which is the most recent survey data. In Series IA table 14, the number of housing units under various rent-control regulations are available for each of the five NYC boroughs. We define rent-regulated units as those units that are (i) rent controlled, (ii) public housing, (iii) Mitchell Lama housing, (iv) all other government-assisted or regulated housing.

We exclude rent-stabilized units from our definition. Rent stabilized units are restricted in terms of their annual rent increases. The vast majority of units built after 1947 that are rent stabilized are so voluntarily. They receive tax abatements in lieu of subjecting their property to rent stabilization for a defined period of time. Both rent levels and income levels of tenants in rent-stabilized units are in between those of rent-regulated and unregulated units.

We calculate the proportion of rent-regulated units among all the renter-occupied units. The proportion is 16.9% for Manhattan and 13.2% for the other four NYC boroughs.

We use a different data source for the other 20 counties outside of New York City. `Affordable Housing Online` (http://affordablehousingonline.com) provides various rent-related statistics at the county level. For each of the 20 counties outside NYC, we calculate the fraction of rent-regulated units by dividing *Federally Assisted Units* number by *Renter Households* number reported on each county's webpage. We then multiply these %-numbers with the renter-occupied units in ACS data set to calculate the rent-regulated units for the 20 counties. Along with the NYCHVS numbers for the four NYC boroughs, we can aggregate all the 24 counties in zone 2 to calculate the fraction of rent-regulated units. The four NYC boroughs have 1.53 million renter-occupied housing units while the rest of zone 2 has 1.30 million. The resulting fraction of rent-regulated units in zone 2 is 10.4%.

From the NYCHVS, we also calculate the percentage difference in average rent in New York City between our definition of regulated rentals and the others (unregulated plus rent-stabilized). That percentage difference is 49.9%. We apply the same percentage difference to all of the MSA in our model.

Finally, we calculate the percentage difference in average household income (Series IA - Table 9) in New York City between our definition of regulated rentals and the others (unregulated plus rent-stabilized). That percentage difference is 54.2%. This is a moment we can compute in the model and compare to the data.

C Data Appendix: Vancouver

C.1 The Vancouver Metro Area

`Statistics Canada` (http://www.statcan.gc.ca) publishes the list and delineations of Census Metropolitan Areas (CMAs) as a part of the national Census program every five years. Vancouver CMA is the third most populous CMA in Canada, after the Toronto CMA and the Montreal CMA. We use the latest definition of Vancouver CMA from the 2011 Census Program. Vancouver CMA consists of 39 Census subdivisions (CSDs): 12 cities, 5 district municipalities, 3 villages, 1 RDA (Regional District Electoral Area), 1 island municipality, and 17 Indian reserves. Among these, we include cities, district municipalities, villages and the RDA in our definition of the Vancouver Metro Area. We use the terms CSDs and municipalities interchangeably hereafter.

The city of Vancouver is defined as Zone 1, and Zone 2 includes the rest 20 CSDs. Table 10 exhibits the complete list of CSDs and their types in our Vancouver Metro Area zoning definitions.

Table 10: Vancouver CMA

Census Subdivision	CSD Type	Zone
Vancouver	City	Zone 1
Burnaby	City	Zone 2
Coquitlam	City	Zone 2
Langley	City	Zone 2
New Westminster	City	Zone 2
North Vancouver	City	Zone 2
Pitt Meadows	City	Zone 2
Port Coquitlam	City	Zone 2
Port Moody	City	Zone 2
Richmond	City	Zone 2
Surrey	City	Zone 2
White Rock	City	Zone 2
Delta	District Municipality	Zone 2
Langley	District Municipality	Zone 2
Maple Ridge	District Municipality	Zone 2
North Vancouver	District Municipality	Zone 2
West Vancouver	District Municipality	Zone 2
Anmore	Village	Zone 2
Belcarra	Village	Zone 2
Lions Bay	Village	Zone 2
Greater Vancouver A	RDA	Zone 2

C.2 Population, Housing Stock, and Land Area

The main source for population, housing stock, and land area is the `2011 Census` published by Statistics Canada (http://www12.statcan.gc.ca/census-recensement/index-eng.cfm). From the webpage, the name of CSDs can be queried with an additional option to select the data source; the 2011 Census or the 2011 NHS (National Household Survey). After retrieving all the data at the CSD level, we aggregate data into Zone 1 and Zone 2 level data.

Population, housing stocks and land area are all reported in *Population and dwelling counts* section. For housing stocks, the Census distinguishes between *Total dwellings* and *Private dwellings occupied by usual residents*, to account for vacancies. We ignore the vacancies and only use *Private dwellings occupied by usual residents*, which is also equivalent to *Total number of private households* in 2011 NHS. Additionally, the *Age characteristics* section gives details of age distributions, from which we can estimate the average age in each zone as well as the fraction of the population above 65 conditional on being above 21.

Greater Vancouver A (RDA) includes several unincorporated areas in the region, and it contains the vast and unpopulous land in the northern end of the Vancouver CMA. We assume that all the reported population for Greater Vancouver A are living in UEL (University Endowment Land) – the area containing the University of British Columbia – and override the Greater Vancouver A land area (815.59km^2) with the UEL land area (14.13km^2).

C.3 Income

The main source for income distribution is `2011 NHS` (National Household Survey) by Statistics Canada (http://www12.statcan.gc.ca/census-recensement/index-eng.cfm). The CSD-level data can be retrieved by following the same procedure as described in the previous section for 2011 Census program. In the *Income of households in 2010* section of 2011 NHS, the detailed household income distribution is reported.

Since the housing prices and rent prices are all based on 2016 dollars, there is a discrepancy between the timing of income data and price data. The easiest way to correct this would be to use 2016 Census data. However, although the 2016 Census survey has been completed, the data is not publicly available yet. Statistics Canada will sequentially release the 2016 Census data according to the posted schedule (http://www12.statcan.gc.ca/census-recensement/2016/ref/release-dates-diffusion-eng.cfm), and the entire data will be released only at the end of 2017.

Instead, we make an adjustment to income level by using aggregate labor income growth. To this end, we use Table 111-0024 in `CANSIM` database by Statistics Canada, which shows that the average labor income of tax filers with labor income grew by 11% between 2010 and 2014. (http://www5.statcan.gc.ca/cansim/a26?lan By scaling it up to estimate the six-year growth, we estimate that there has been 17% increase in labor income between 2010 and 2016. We assume that all the households have experienced the same income growth by 17%, i.e. we are effectively scaling up the endpoints of income brackets by 17%, without altering the distribution.

To aggregate the CSD-level income distribution into a Zone 2 income distribution, we follow the same procedure as described in Appendix B, Section B.3 for the New York MSA.

C.4 House Prices, Rental Prices, and Home Ownership

Home ownership rate can be easily calculated from 2011 NHS data (http://www12.statcan.gc.ca/ census-recensement/index-eng.cfm). Under the *Household characteristics* section, the *Total number of private households by Tenure* is divided into *Owners* and *Renters*.

The main source for housing prices in Vancouver Metro Area is the *Metro Vancouver Housing Data Book* ("MVHDB") published by `Metro Vancouver` (http://www.metrovancouver.org/services/regional-planning/PlanningPublications/MV_Housing_Data_Book.pdf) revised as of December 2016. Pages 105-107 of MVHDB contain three tables presenting house price information across municipalities, one for each category of housing (single-detached, semi-detached and rowhouse, apartment). These are compilations of survey data originally from *Real Estate Board of Greater Vancouver* (REBGV) and *Fraser Valley Real Estate Board* (FVREB). On page 17 of MVHDB, the number of housing units in each category is presented, which can be easily reproduced from the 2011 Census *Household and dwelling characteristics* section. Using the number of housing units in each category as weights, we calculate a weighted-average house price for each municipality.

In reporting house prices, `REBGV` uses a slightly different geographical division from Census CSDs. The city of Vancouver is further divided into Vancouver East and Vancouver West, and Delta is further divided into Delta(north) and Ladner-Delta(South). Since Census 2011 and NHS 2011 do not distinguish between these sub-areas, we use a different source to further divide the city of Vancouver and Delta housing numbers. `The Globe and Mail House Price Data Center` (http://www.theglobeandmail.com/real-estate /house-price-data-centre-toronto-propels-house-prices-to-new-record/article29697029/) provides a detailed housing sales volume data and average sales price data at the zip code level. We define the following 15 zip codes as Vancouver West: V5Y, V5Z, V6B, V6C, V6E, V6G, V6H, V6J, V6K, V6L, V6M, V6N, V6P, V6R, V6Z. The rest 12 zip codes of the city of Vancouver (V5K, V5L, V5M, V5N, V5P, V5R, V5S, V5T, V5V, V5W, V5X, V6A) are defined as Vancouver East. Since there were 1,289 sales in 2016 Q2 in Vancouver East, and 2,635 sales in Vancouver West, for each category we allocate roughly 67% of housings to Vancouver West, and the rest to Vancouver East. Similarly, we define V4C and V4E as Delta(north), while V4K, V4L and V4M are classified as Ladner-Delta(south) sub-area. Since there were 357 and 349 sales in Delta(south) and Delta(north) during 2016 Q2, respectively, for each category we allocate 51 % of housings to Delta(north) and the rest into Ladner-Delta(south).

The main source for rental price data is *2016 Rental Market Report for Vancouver CMA* published by `Canada Mortgage and Housing Corporation` (https://www.cmhc-schl.gc.ca/odpub /esub/64467/64467_2016_A01. From the *CMHC Report*, we use Table 1.1.2 for private apartment average rents and Table 1.1.3 for the number of private apartment units across municipalities. Zone 2 aggregate rent level is the weighted-average rent using the number of private apartment units as weights. Note that Table 1.1.3 is also reproduced in MVHDB on page 82. When the number of private apartments in two or more municipalities are reported as an aggregate (for example, "Tri-cities" – Coquitlam, Port Moody and Port Coquitlam – are reported as a group) we allocate the aggregated private apartment number into each municipality, using 2011 NHS *renters* as weights. Private apartments account for about 38% of the entire rental units in the region – there are also secondary suites, non-market rental units and privately rented condominium units (see p. 45 of MVHDB). However, since private apartments are considered as the primary rental market, we use these numbers as the benchmark rental prices.

C.5 Rent Regulation

`BC Housing` website provides information on various housing assistance programs (https://www. bchousing.org/housi assistance/rental-housing). To promote the housing affordability in the region, they not only supply non-market rental housings ("social housings" and co-ops) to low-income households, but also subsidize market rentals via the programs such as *Rental Assistance Program* (RAP) and *Shelter Aid for Elderly Renters* (SAFER). The inventory of social housing units and co-ops can be found in MVHDB on page 89. Roughly 17% of Zone 1 rental units, and 16% of Zone 2 rental units are either social housing units or co-op. Since the demand for the non-market housings is higher than the supply, BC Housing keep track of housing needs using Housing Registry, while subsidizes those under market rentals using RAP

and SAFER programs.

BC Housing does not publish any aggregate data on regulated rents (in contrast with the NYC HVS which provides the detailed distributions of rents under each type of rent-regulation program). Moreover, the size of the rental subsidy depends on income, number of children, net asset, house size. Therefore, to compare the subsidized-rents to market rents, we rely on an indirect approach using information from the household income distribution and private-apartment rent levels. Specifically, we use the following assumptions and procedures to estimate the subsidized proportions. In each municipality, we estimate the number of households whose income is low enough so that the 30% of gross income is under the private-apartment market rent (as defined in section C.4) of that municipality. We call these households "subsidized". Since the basic form of subsidized housing is "rent-geared-to-income"[52], i.e., a low-income household pays the 30% of income as rent and the rest is covered by government, we can estimate what proportion of market rent paid by subsidized households is coming from the subsidy. Based on the analysis, Zone 1 average subsidy is roughly 45% (that is, subsidized households on average pay 55% of average market rents) and Zone 2 average subsidy is roughly 49%. These numbers are very similar to the higher-quality data we have for New York City.

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[52]From Section 1 of https://www.bchousing.org/housing-assistance/rental-housing/subsidized-housing