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 0.5% of permanent consumption levels. The average renter suffers a much larger loss while the average owner gains. When we extend and calibrate our model to the New York metropolitan area, the average household experiences a much smaller 0.01% lifetime consumption equivalent loss from foreigners buying Manhattan real estate, because displaced households are able to move to other parts of the NYC metro area.
JEL classification:

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1 Introduction

Residential investment in major urban centers such as London, New York, Singapore, Vancouver, by out-of-town (OOT), including foreign, investors has been on the rise. 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 commute 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, and contributing to 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, spurred talk of higher stamp duties on non-locals in London, with similar discussions elsewhere. On the other hand, OOT investors bring many benefits as well. They may spur new construction which requires local labor. This demand for housing services (and for other non-trabables like restaurants) increases wages for local workers. They bring in property tax revenue. 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?

We set up and solve a model that is able to address this question. Our city consists of two zones, the city center sometimes referred to as the 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 rich cross-sectional distribution over age, labor income, tenure status, housing wealth, and financial wealth. It 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 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-a-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 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. This model is equivalent to a one-zone city. Naturally, each zone contains half of the population and half of the housing stock. The age, income, and wealth mix is identical in both zones. The economy then transitions 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 higher rents (+9.6%) and partially by new construction (+2.4%). House prices increase substantially (+5.2%), but by less than rents because house prices already capitalize the possibility of a reversal to lower future OOT investor demand. Price-rent ratios fall upon the inflow. Because of the lower price-rent ratios, the city's home ownership rate increases modestly (+0.6%) as some locals shift from renting to owning, notwithstanding the inflow of OOT owners. Wages rise (+1%) due to the boom in the construction sector. But income growth falls short of house price growth and the price-income ratio rises. Renters, whose cost of living rises, suffer welfare losses from the OOT demand shock. They would be willing to forgo 1.8% of annual consumption to avoid it. Owners, on the other hand, benefit not only from the higher wages but also from the capital gains. In aggregate, city welfare falls by 0.44% following a 10% increase in OOT investment 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. Because zone 1 is more attractive, it has a larger population share and a larger share of the housing stock in equilibrium. It 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 and wealthier. Realistic commuting costs deliver rents and prices per square foot that are 28% higher in zone 1 than in zone 2. The home ownership rate is 50% in zone 1 but 65% in zone 2, matching the observed differences in U.S. metropolitan areas.

We then introduce the same OOT investment shock in the model with commuting costs. OOT investors reduce the share of locals living in 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 as much as in the no commuting cost model. Age, income and wealth differences between the local residents of zone 1 and zone 2 increases. In that sense, OOT investors accelerate gentrification. Home ownership rates now fall slightly upon the inflow. Owners benefit from OOT investors entering, almost 50% more so than in the no commuting cost model. But renters suffer more as well. The net effect is a slightly larger welfare loss of 0.48%.

We apply our model to the New York metropolitan area. We bring to bear data on the fraction of OOT purchases using Manhattan deed records data for 2004-2016. The data suggest that OOT buyers account for about 12% of all Manhattan residential sales. Their share has increased steadily over the last decade; the increase is about 2% points depending on the specific metric. We fit the model to the income distribution in the New York metro and introduce asymmetry in the size of zones 1 and 2 to capture the relative land area. We extend the model to capture rent regulation because a large fraction of the renter-occupied housing stock in New York is regulated.

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.[1] More recent work in macro-finance has solved such models in general equilibrium, adding aggregate risk, endogenizing house prices and sometimes also interest rates.[2] 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

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

[2] E.g., Favilukis et al. (forthcoming) and Kaplan et al. (2016). Davis and Van Nieuwerburgh (2015) provides a recent summary of this literature as well.

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.[3] 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.[4] The lack of risk, investment demand for housing, and wealth effects makes it hard to connect these spatial models to the finance literature.[5] Studying the 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 won, 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.[6] 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

[3]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.

[4]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 et al. (2014) and Eeckhout et al. (2014). Guerrieri et al. (2013) study house price dynamics in a city and focus on neighborhood consumption externalities, in part based on empirical evidence in Rossi-Hansberg et al. (2010).

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

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

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 housing markets but measures foreign investment directly. He also finds large effects on house prices, not only at the high-end but all across the house price distribution. He also studies heterogeneity in the house price response across regions in England and Wales. He finds no effect on the housing stock and a negative effect on home ownership rates among locals following an increase OOT purchases. 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. 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.[7] 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. Finally, our modeling of OOT investor flows as exogenous (price-inelastic) 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.

The rest of the paper is organized as follows. Section 2 sets up the model. Section 3 calibrates the baseline model and Section 4 discusses its main results. Section 5 extends the model to include rent control and then calibrates it to the New York metropolitan area. Section 6 discusses policy implications and concludes.

[7] In related work, Bayer et al. (2011) study the role of investors in the housing market, but without an emphasis on local versus out-of-town investors.

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.[8] 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.

2.1 Households

Preferences The economy consists of overlapping generations of households. There is a continuum of households of a given age. Each households maximize utility u over consumption goods c, housing h, and labor supply n, and utility is allowed to depend on location ℓ and age a. The dependence on location allows us to capture the commuting time and amenity differences across locations. The dependence on age may capture variation in the preference for housing over the life cycle. For example, households with children may desire more housing. We use a Cobb-Douglas aggregator:

$$U(c_t, h_t, n_t, \ell, a) = \frac{u(c_t, h_t, n_t, \ell, a)^{1-\gamma}}{1-\gamma}, \quad u(c_t, h_t, n_t, \ell, a) = c_t^{\alpha_{c,a}} h_t^{\alpha_{h,a}} \left(1 - n_t - \phi_T^\ell\right)^{\alpha_n}.$$

We assume that $\alpha_{c,a} + \alpha_{h,a} + \alpha_n = 1$, so that $\alpha_{c,a} + \alpha_{h,a} = 1 - \alpha_n$ is a constant. 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 the financial and time cost of commuting from within zone 1 to zero.[9]

There are two types of households in terms of subjective time discount factor. Half of the

[8] 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).

[9] 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.

households are a high degree of patience β^H while the other half 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^H) only leave bequests to other impatient agents.[10] 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.

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 by V the value functions over these choices, with subscript R denoting a choice of renting and

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

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:

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

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:

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

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. Investment housing incurs an additional financial cost which is a fraction $\delta_{inv} > 0$ of the value of the property. Both $Ph\delta$ and $P\widehat{h}\delta_{inv}$ are financial costs, i.e., a maintenance cost. As shown in equation (7) below, the physical depreciation $Ph\delta$ can be replaced by residential investment undertaken by the construction sector.[11] Property taxes on the housing owned in period t are paid in year $t+1$; the tax rate is τ^P.

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.[12] 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 $N_{c,t} = \left(\frac{\rho_c}{W_t}\right)^{\frac{1}{1-\rho_c}}$.

[11] 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.

[12] 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.

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 consumption good firms, construction firms are owned by national equity owners, and all profits are distributed outside of the city. 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:

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

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.[13] 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. Their demand is stochastic and is the only source of aggregate risk in the model. 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

[13] 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).

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 parameter π governing its persistence. Housing owned by out-of-town buyers is not rented out to locals; we experiment with relaxing this assumption in one of our model versions. Out-of-town buyers do not work in the local labor market.

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 $Nret$ is the total number of retirees, which is a constant.[14]

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 foreign 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 foreign 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 $\Delta^L_{t,i}$ in consumption equivalent units to stay in the low foreign demand state, where:

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

Analogously, if foreign demand at t is high, then agent i would be willing to give up $\Delta^H_{t,i}$ in consumption equivalent units to stay in the high state, where:

$$\Delta^H_{t,i} = -1 + \left(\frac{V_{t+1,i}(HH)}{V_{t+1,i}(HL)}\right)^{\frac{1}{(1-\gamma)(1-\alpha_n)}}.$$

We compute aggregate welfare effects from "inflows" by summing $\Delta^L_{t,i}$ across agents. We compute aggregate welfare effects from "outflows" by summing $\Delta^H_{t,i}$. We can sum across all agents, or separately among owners (at time t) and renters (at time t). We can also sum separately by age, income, or wealth groups.

[14]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.

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. Table 1 presents the chosen model parameters. In the next section, we study the case of New York City, which features its own calibration as well as a few additional model ingredients.

We consider two versions of the baseline model in order to better illustrate the workings of the model. In the first version of the baseline model, the "no commuting cost 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," the commuting cost and time from zone 2 are strictly positive, which makes zone 1 a more desirable place to live.

Geography, Production, and Construction The baseline model has two 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.

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. Mortality rates are calibrated to data from the Census Bureau.[15,16]

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).

[15] 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.

[16] 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.

Table 1: Calibration

Description	Parameter	No CC model	CC model	Comment
	Panel A: **Demographics**			
Birth age		21		Beginning of working life
Retirement age		65		Start of Social Security payments
Death probability	p^a			Census Bureau mortality tables
	Panel B: **Income and Pension**			
Age-Income profile	G^a			Average age-income profile in SCF data
StDev[Z] (unconditional)		0.7		Average income of bottom 25%, middle 50%, top 25%
AC[Z] (unconditional)		0.9		Storesletten, Telmer, and Yaron
Pension distribution	ψ^{a,z_t}	[0.4838 0.9656 1.5851]		Social Security payout by productivity for ages $\geq$ 65
Pension tax	τ^{SS}	0.10		Average Social Security contribution
	Panel C: **Utility**			
Leisure weight	α_n	0.5		Share of non-working, non-sleep hours
Non-durable consumption weight	$\alpha_{c,a}$	0.334		Share of non-housing consumption expenditure
Housing consumption weight	$\alpha_{h,a}$	0.166		Share of housing consumption expenditure
Risk aversion	γ	5		Standard risk aversion coefficient in asset pricing
Time Preference	(β^H, β^L)	(0.94,.60)		(1.6%, 13.6%) discount rate per year
	Panel D: **Finance and Regulatory**			
Bond Price	Q	0.826		4.9% return on savings per year
Maximum residential LTV	θ_{res}	0.80		Modal LTV ratio in U.S.
Maximum investment LTV	θ_{inv}	0.80		No difference in LTV for investment property
Property tax	τ^P	0.04		1% per year, U.S. average
	Panel E: **Production and Geography**			
Return to scale	$\rho_c = \rho_1 = \rho_2$	0.66		Labor share of 2/3
Available space	$\overline{H^1} = \overline{H^2}$	50		Essentially unconstrained space
Owner-occupied property depreciation	δ	0.12		3% per year
Additional renter-occupied depr.	δ_{inv}	0		
Time-Commuting cost	ϕ_T^2	0	0.04	4% of non-sleeping time in CC model
Financial-Commuting cost	ϕ_F^2	0	0.007	2% of average income in CC model
OOT demand transition prob.	π	0.90		Expected duration of 80 years per state
OOT demand, low state	$OOT^{1,L} = OOT^{2,L}$	0	0	No OOT demand in low state
OOT demand, high state	$(OOT^{1,H}, OOT^{2,H})$	(0.066,0.066)	(0.078,0.051)	OOT demand $\approx$ 10% of housing stock in each zone

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), and a brief explanation of what the parameter measures or targets.

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.[17] The standard deviation and autocorrelation of the idiosyncratic component of labor income are 0.7 and 0.9, respectively. The Social Security tax is 10%, which approximately matches the data.[18] We use Social Security rules to estimate each productivity group's ψ^{a,z_t}, which measures its pension relative to the average pension.

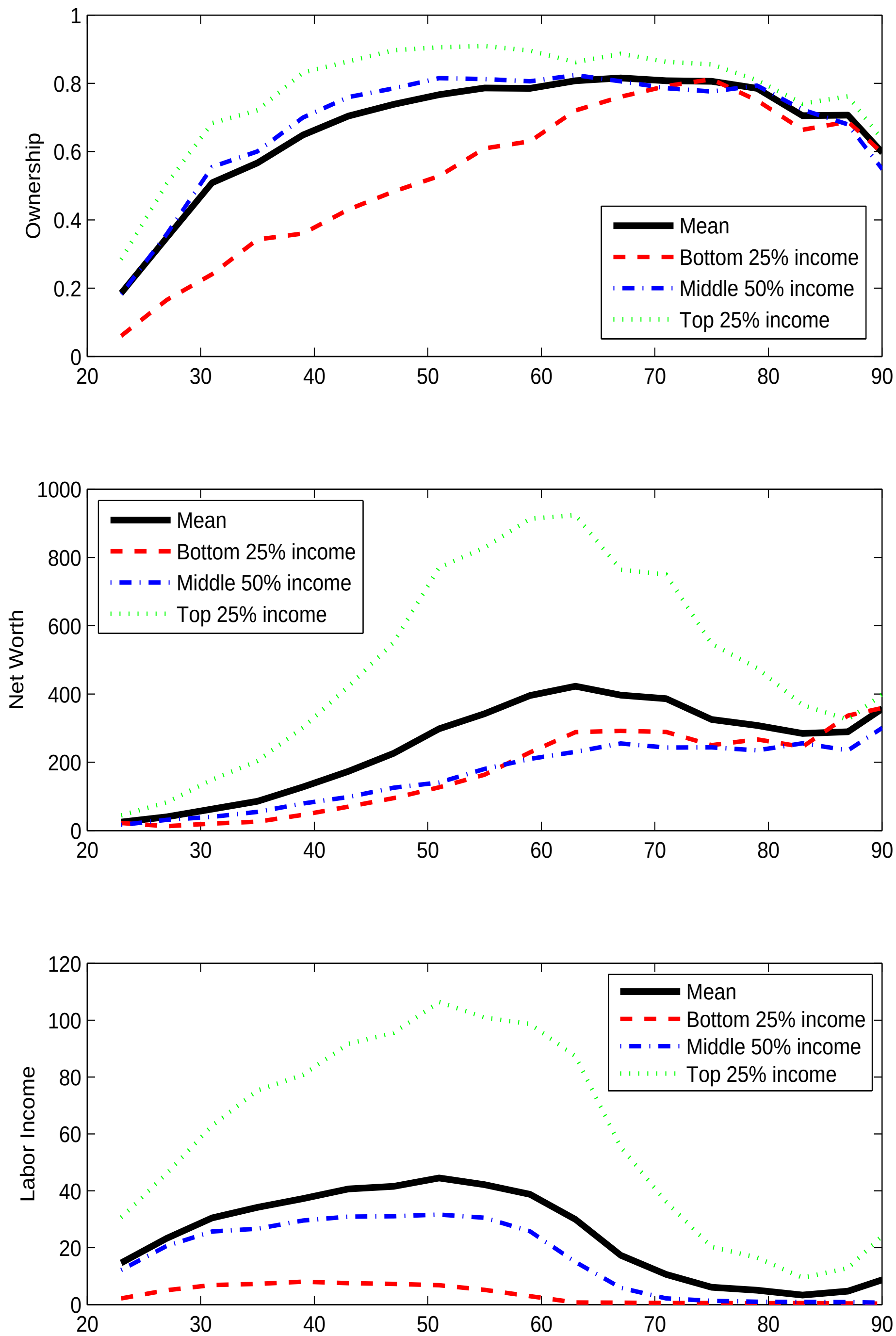
The bottom panel of Figure 1 shows labor income by age in the data. The solid black line shows the well-known hump-shaped labor income profile over the life cycle for the median household. The dashed red line shows labor income in the bottom 25 percent of the labor income distribution, the dash-dotted 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 panel of Figure 2 shows the same income profiles in the baseline model. By virtue of our calibration, we match the observed labor income profiles closely.

Consumption and Wealth 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

[17] The actual productivity states for the baseline model take on three values. These values differ by age. Making labor income states age-dependent allows us to capture the fact that the variance of labor income grows with age in the data. The transition probability matrix for productivity is age invariant, but does depend on β type: 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 income, which allows us to better match the 75^{th} percentile of the labor income distribution, while keeping the average autocorrelation of idiosyncratic productivity at 0.9.

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

Figure 1: Ownership, Net Worth, and Income across Age and Income groups: Data



goes towards housing, and is consistent with empirical evidence.

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

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

The average level of $\frac{1}{2}\beta^H + \frac{1}{2}\beta^L$ is set to 0.77 in order to match the average wealth-income ratio, which is around 5 in the data. One parameter controls the spread in the two groups' subjective time discount factor. We set $\beta^H = 0.77 * (1 + 0.22) = 0.94$ (0.984 per year) and $\beta^L = 0.77 * (1 - 0.22) = 0.60$ (0.880 per year) in order to match the observed wealth inequality, a Gini coefficient of about 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.

Housing We set the maximum loan-to-value ratio (LTV) for both residential and investment property $\theta_{res} = \theta_{inv} = 0.8$ implying a 20% down payment requirement. The median LTV ratio for agency mortgages in the U.S. is 80% (Greenwald, 2016).

We assume that property depreciates at 3.2% per year and set $\delta = 0.12$. We assume that there is no additional depreciation on renter-occupied property $\delta_{inv} = 0$. We set the property tax rate $\tau^P = 0.04$ or 1% per year. We assume that the revenue from this tax is a dead weight loss to society.

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. The average annual price-rent ratio in the U.S. is 13.1 for the period 1987-2016.[19]

[19] 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.

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 37 minutes each.[20]

We also assume a *financial* cost of commuting $\phi_F^2 > 0$ for workers equal to 2% of average income.

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.

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 2 plots the home ownership rate in the baseline model with commuting costs. The middle panel plots household net worth in the model. 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 home ownership rate of 60.4%. This is close to the 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. Households accumulate about \$200,000 by age 45 and \$400,000 by age 65, on average. Wealth gradually declines in retirement, in part because

[20] 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.

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.[21]

The model does a good job capturing the large gap in home ownership rates between the low- and middle income households. 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 \$800,000 in the model, very similar to the \$850,000 in the data. The model generates a Gini coefficient for wealth of 0.71, which is substantially above that of income of 0.49.

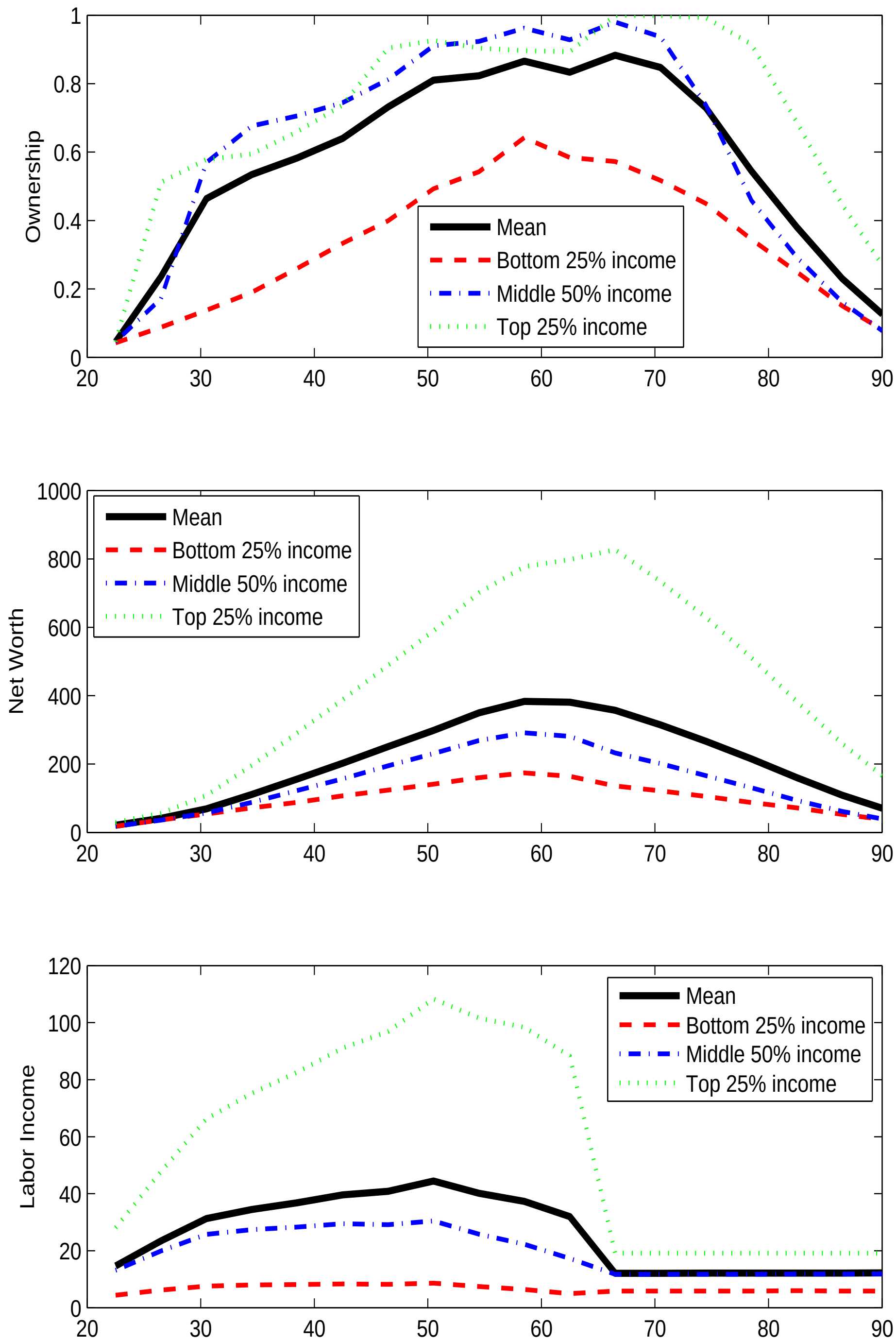
4.2 No Commuting Cost Model

We now study 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, age, income, 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,

[21] Allowing for an intentional bequest motive and/or adding late-in-life medical/long-term care risk would given households additional motives to slow down wealth decumulation (Ameriks et al., 2011). Adding these motives would overly complicate the model whose main purpose is to analyze the effect of out-of-town buyers.

Figure 2: Ownership, Net Worth, and Income across Age and Income groups: Baseline 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. 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% for prices.

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 falls by 0.6% points when OOT buyers enter. On the one hand, foreign buyers are owners who displace local owners since the housing stock does not expand in proportion to OOT housing demand. On the other hand, the decline in the P/R ratio makes ownership more attractive relative to rentership, and local owners can live in smaller housing units. The former effect edges out the latter two effects.

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

Table 2: Effect of OOT Demand in Baseline Model

	Panel A: **No Commuting Cost**									
	W	R^1	R^2	P^1	P^2	$\frac{P^1}{R^1}$	$\frac{P^2}{R^2}$	$\frac{P^1}{Inc^1}$	$\frac{P^2}{Inc^2}$	
Average	0.975	0.124	0.124	0.407	0.407	13.08	13.08	6.09	6.09	
Without OOT	0.971	0.120	0.120	0.398	0.398	13.31	13.31	5.88	5.88	
With OOT	0.980	0.130	0.130	0.418	0.417	12.83	12.83	6.34	6.34	
	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	0.697	0.697
Without OOT	0.500	0.650	0.650	1.000	1.000	1.000	1.000	1.000	0.699	0.699
With OOT	0.500	0.667	0.667	1.000	1.000	1.000	1.000	1.000	0.693	0.693
	Panel B: **Commuting Costs**									
	W	R^1	R^2	P^1	P^2	$\frac{P^1}{R^1}$	$\frac{P^2}{R^2}$	$\frac{P^1}{Inc^1}$	$\frac{P^2}{Inc^2}$	
Average	0.976	0.136	0.109	0.446	0.356	13.06	13.06	4.65	13.97	
Without OOT	0.971	0.131	0.104	0.435	0.347	13.32	13.33	4.46	13.23	
With OOT	0.980	0.142	0.114	0.456	0.366	12.82	12.81	4.84	14.73	
	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	0.565	0.695
Without OOT	0.689	0.768	0.505	0.686	2.217	0.614	2.529	0.266	0.566	0.695
With OOT	0.688	0.788	0.519	0.622	2.202	0.615	2.592	0.271	0.564	0.695

Notes: The table reports averages from a long simulation of the symmetric model without commuting costs (Panel A) and the asymmetric model with commuting costs (Panel B). We report the hourly wage W, the rent in the city center R^1 and outside the center R^2, the house price in zone 1 P^1 and in zone 2 P^2, the price-rent ratio and price-to-income ratio in each area. The latter two ratios are reported as annual numbers. 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 (zero) OOT demand and high OOT demand. The row "Without OOT" reports averages, conditional on being in the low OOT demand state, while the row "With OOT" conditions on being in the high OOT demand state.

higher housing stock requires more maintenance.

The price-income ratio in the model is computed as the average house price in a zone divided by the average labor income earned by the locals in that zone. The price-income ratio increases substantially from 5.88 to 6.34, an increase of 7.8%. In this sense, 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. 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.

To understand this number, it is important to understand how different types of agents are affected. An average renter is especially 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 consumption. Renters are unequivocally hurt by the higher foreign demand, as their current and future housing expenditures rise. Renters receive some relief in the form of higher wages, and this benefits the young more given their longer expected work life. A 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 th 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, but welfare losses for the young and the old.

Table 3: Welfare change, Baseline model

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

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.

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 now 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 housing 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 in zone 1 are 25% higher than those 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 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 56.0% in zone 1 while it is 69.5% in zone 2. This 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 (13.5% 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

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 baseline symmetric model, OOT demand drives wages up by 0.9% 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.[22] The additional wage increase relative to the no commuting cost model is 0.05%.

The (absentee) OOT buyers reduce the relative density of zone 1 from 2.217 to 2.202, 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 after the OOT capital inflow (-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 (around -3.8%) in both zones. The home ownership rate falls by 0.5% point in zone 1 and by 0.1% point in zone 2. This in part because the direct effect of OOT buyers displacing local owners is stronger in zone 1, and in part because house prices 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.

OOT buyers also affect the socio-economic make-up of zone 1 and zone 2. They make zone 1 higher-income and higher-wealth in a process that could be described as gentrification. Income inequality between the urban core and the periphery increases by 2.5%; wealth inequality by 1.9%. The price-income ratio falls in zone 1 but rises in zone 2.

The welfare effects of this case are in the last three columns 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%). The overall welfare effect, however, barely changes. The average household now loses

[22] 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.

Table 4: OOT Demand and City Welfare: Model Variants

	Owners	Renters	All
Baseline commuting cost model	0.62	-1.50	-0.31
No patience heterogeneity	0.57	-1.41	-0.23
50% larger OOT demand	0.67	-2.25	-0.40
OOT demand concentrated in zone 1	0.74	-1.57	-0.25
OOT buyers rent out property	0.03	-0.02	0.00
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 (inflow). All numbers are in percent, thus -0.34 in the top left corner means that an average household would need to receive 0.34% of its average lifetime consumption to be as well off as it would be if foreign investment remained low. The first row presents the baseline commuting cost model. The second row presents a model with 50% more foreign demand, and the third row presents a model with 50% times less foreign demand compared to the baseline model. The fourth presents a model where the foreign demand process is less persistent than the baseline model. The fifth row presents a model with 20 times more land than the baseline model, and the sixth row has five times less land than the baseline model. The seventh row presents a model with commuting costs for anyone living in Zone 2. The eighth row presents a model with commuting costs and where all foreign demand is concentrated in Zone 1. The ninth row presents a model identical to the baseline model, but where all foreign owned properties are rented to locals.

0.31% of lifetime consumption when OOT demand for local housing rises, compared to 0.30% in the model without commuting costs. Some younger owners now gain almost twice as much from the OOT influx. This is due both to the larger wage gain and the larger increase in home values.

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 are households who rented last period but received a large bequest, which included real estate wealth. This suggests that policies aimed at curbing OOT purchases not only have redistributive consequences, 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 in zone 1 of 4.5% points, adding to the 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 important for the welfare effects. 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 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 a period with real estate in its portfolio.

With this change, the net welfare effect is a positive 0.17% of lifetime consumption. The key intuition is that 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 a 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 to refine the calibration of the model. In the process, we extend our model to deal with the peculiarities of the New York housing market.

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.[23] Given their respective land areas of 23 and 8,271 square miles, we assume that $\overline{H^1} = 0.0028 \times \overline{H^2}$. We then choose $\overline{H^2}$ such that the fraction of households living in Zone 1 is equal to 11.8% of the total, as in the data.[24] The model matches the observed relative density (people per square mile) of the two zones, which is 42.7 times greater in zone 1 than in zone 2.

Commuting Cost The financial cost of commuting equal remains at 2% of average income or $1,800 per household. This is a realistic cost for New York.[25] 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

[23] 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.

[24] Since the model has no vacancies, we equate the number of households with the number of occupied housing units.

[25] In NYC, an unlimited subway pass costs $1,400 per year for a single person. 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 owning, parking, and operating a car are factored in.

3.4% of available time, or 3.8 hours per week (23 minutes per trip, 10 trips per week). Higher time and financial costs both lead to higher rents in Zone 1. However, as discussed in the appendix, they have somewhat different implications for the relative desire to live in Zone 1 across different 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.

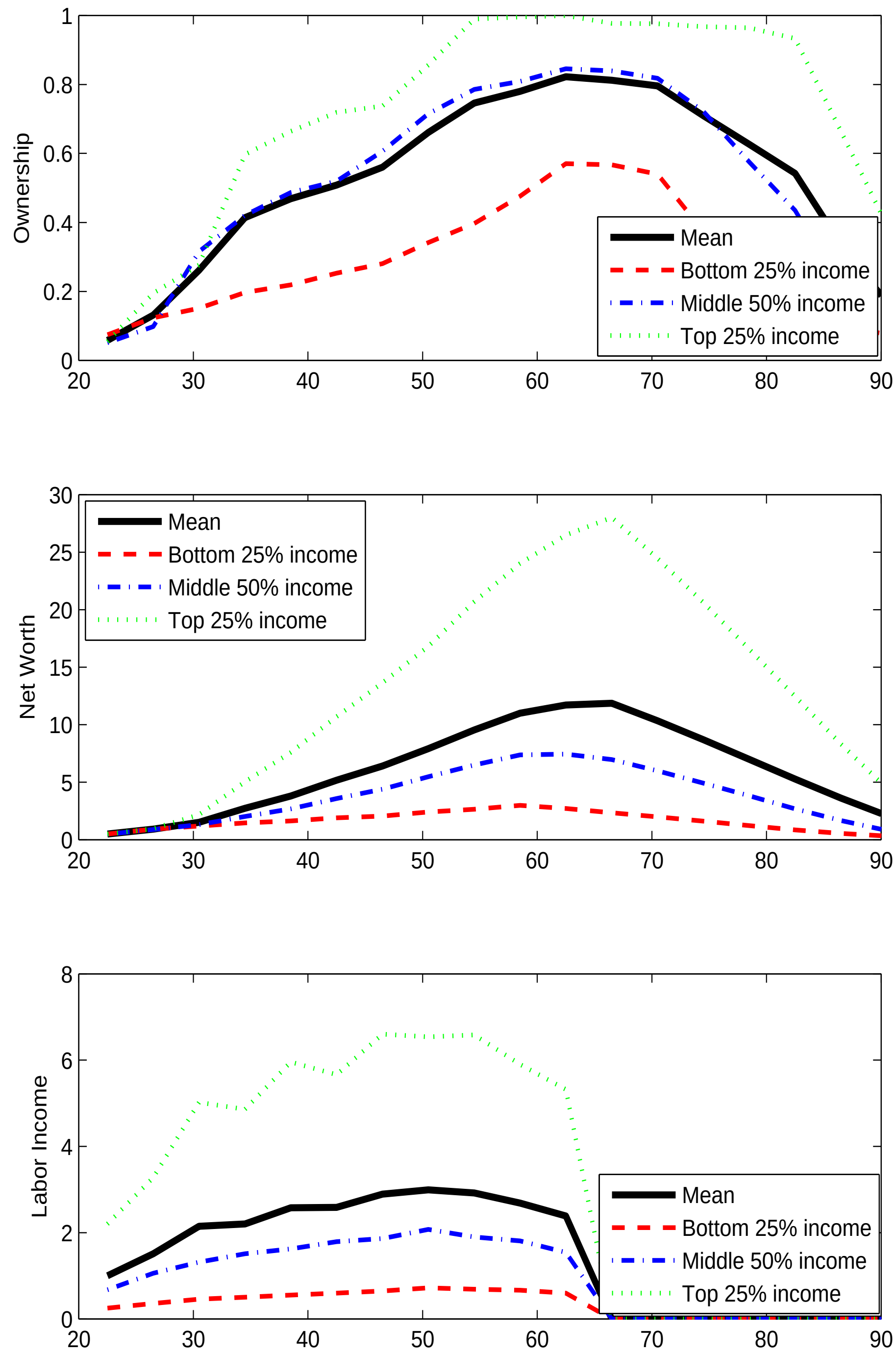
Labor Income We add a fourth, high-productivity state to the idiosyncratic productivity Markov chain to accommodate some of the very high earners in New York. The highest state has a productivity level that is 3.5 times the average. The productivity states for the New York model are [0.255 0.753 1.453 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].

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.[26]

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 more inequality than in the baseline model.

[26]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 3: Ownership, Net Worth, and Income across Age and Income groups: NYC model



5.2 Extension 1: A Taste for Manhattan

In the data, income per household in Manhattan is 42% higher than in the rest of the metro. And although we do not have data on this, Manhattan residents are presumably also much wealthier. The fraction of retirees to the total population of Manhattan (13.9%) is about the same as the rest of the NY metro (13.5%). In the baseline model, all retirees live in Zone 2 because they have little need to commute. Moreover, financial commuting costs push low wealth and low income households towards Zone 1. To induce more wealthy, high-income, and retired households to live in Zone 1, we add a taste shifter to the utility function.

Specifically, we set $u(c_t, h_t, n_t, \ell, a) = f(c_t) c_t^{\alpha_{c,a}} h_t^{\alpha_{h,a}} (1 - n_t - \phi_{t,\ell})^{\alpha_n}$. 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 on worker versus retiree status. If $\underline{c} > 0$, then zone 1 becomes more desirable for high-income and high-wealth households.[27]

We choose $\chi^W = 0.04$, $\chi^R = 0.083$, $\underline{c} = 0.40$. The latter number implies that 20% 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 is 1.03, household income is 1.42, the price-to-income ratio is 2.1, the home ownership rate is 0.44 (23.5% compared to 54.1%).

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 column reports the same ratio of zone 1 to zone 2 in the model. The model manages to drive a large wedge between house prices, rents, income, home ownership rates between zones 1 and 2. The biggest tension is between income and the price-to-income ratio: more retirees in Zone 1 lowers the income difference but raises the price-to-income ratio difference.

[27] 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, expensive restaurants, etc.) that is only available in Manhattan.

Table 5: New York City Data Targets and Model Fit

	NY Data				NY Model
	NY MSA	**Zone 1**	**Zone 2**	**ratio Z1/Z2**	**ratio Z1/Z2**
Land area (square miles)	8,294	23	8,271	0.28%	0.28%
Households (thousands)	7,124.9	751.2	6,373.7	11.8%	11.8%
Housing density (HH/sq mile)	859	32,906	771	42.70	
Home ownership	50.8%	23.5%	54.1%	0.44	
Income per household ($)	97,577	132,838	93,441	1.42	
Price per owner-occupied housing unit ($)	435,316	1,182,500	396,959	2.98	
Rent per renter-occupied housing unit($)	29,318	44,364	26,366	1.68	
Price/rent ratio (annual)	14.85	26.65	15.06	1.77	
Rent to income	30.0%	33.4%	28.2%	1.18	
Price/income (annual)	4.46	8.90	4.25	2.10	
% of People over 65	13.57%	13.92%	13.53%	1.03	
Average Age (years)	38.0	38.9	37.9	1.03	

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.

5.3 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, 68% of the population living in renter-occupied units in zone 1 live in rent-regulated units. As described in Appendix B, we obtain a 37% share of rent-regulated units in zone 2. The average rent in rent-regulated properties in New York City is 43.7% below that in private rentals; we apply this number to the entire metro area.

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 $\eta^1 = 0.362$ and $\eta^2 = 0.153$. These numbers are smaller than the fraction of units that are rent controlled because rent controlled units tend to be smaller than market units. Rent regulated property earns a rent that is 43.7% below the market rent in each zone, as in the data. Since the rent is just a multiple of the market rent, the 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 $1-\eta^\ell+\eta^\ell(1-0.437)$ of the market price in an unregulated model, construction firms will produce less housing. This is the most direct way in which rent regulation affects the model's results.

Who benefits from regulated rents? All households in the model enter in the rent regulation lottery. Any household that wins the lottery receives the option to move in 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 the rent regulated income cutoff, set at 200% of the average NY metro income, ii) the housing size it chooses must be smaller in size than the zone specific rent regulated maximum housing size, set as 60% of the average size of all market priced rental units in a zone. Both of these conditions are consistent with NYC rent regulation rules.[28]

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 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 housing size or maximum income restrictions are too unappealing from a utility perspective. 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.

Households who win the lottery and accept rent regulation tend to demand more housing than they would under market conditions. While some of these households are constrained by the maximum housing size, many choose housing size below this upper bound.

5.4 OOT Demand

We obtain data from Core Logic on the fraction of OOT housing purchases for Manhattan and for the New York MSA for each month from January 2004 until September 2016. Housing purchases are defined as purchases of single-family, 2-4 family, condominiums, and co-ops. OOT buyers are identified based on the mailing address on payment/tax forms. If the address is either abroad

[28]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 $92,000 average income in NY metro. Second, the same Act sets the minimum rent for deregulation at $2,500 per month, compared to average NYC rents above $4,000.

or has a ZIP code that is not one of the 1,304 ZIP codes inside the New York MSA, we classify the transaction as an OOT purchase. One complication arises because not only individuals but also companies purchase residential real estate. We include the following legal 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 NYMSA 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 NYMSA 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 NYMSA 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 NYMSA corporate purchases are by OOT buyers.[29] Since there are a lot more NYMSA corporate purchases than OOT corporate purchases, the OOT share under assumption 2 is higher than under assumption 1. Table 6 reports the resulting OOT buyer shares for zone 1 (Panel A) and zone 2 (Panel B).

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: 9.2% vs. 2.8% under assumption 1 and 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 largest in absolute value for zone 1 and largest in percentage terms for zone 2. The absolute increase between 2004-07 and 2012-16 ranges from 1.9% points to 3.8% points in Panel A and from 0.6 to 2.2% points in Panel B.

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.

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,

[29]We have also compute the OOT share assuming (90%,10%) and (90%,20%) assumptions and the results are in between those for assumption 1 and assumption 2.

Table 6: Fraction of OOT Purchases of Manhattan Housing Units

Assumption:	**2004.01-2016.09**	2004.01 - 2007.12	2008.01 - 2011.12	2012.01 - 2016.09
Panel A: Manhattan (zone 1)				
ass. 1	9.2%	8.2%	9.0%	10.1%
ass. 2	11.6%	9.6%	11.4%	13.4%
Panel B: Rest of New York metro area (zone 2)				
ass. 1	2.8%	2.5%	2.6%	3.1%
ass. 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: ACRIS. Data from 2004 through the third quarter of 2016.

using the property tax billing address. They find that the OOT share rises as high as 17 percent in some boom markets. Bayer et al. (2011) use transaction data for the period 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 from about 5% in the early 1990 to the peak of the boom in 2003-06.[30]

5.5 Results

To be completed.

6 Policy Implications

Since the net effect welfare effect of foreign investors is negative, one obvious welfare improving policy would be to ban OOT investors from buying local residential property. We do not necessarily advocate this policy, furthermore, it is not likely to be politically feasible and it could lead to negative consequences that our outside of our model. Here we explore alternative policies for improving welfare.

- Force them to rent any vacant properties, perhaps by taxing vacant properties
- Tax on OOT investors, redistributed towards transportation infrastructure

[30]Their measures 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.–

- Tax on OOT investors, redistributed towards subsidies for locals. Which group is best to subsidize? Young buyers, young renters, everyone?
- Relaxation of borrowing constraints
- A high enough tax on OOT investors may drive all OOT investors away and be no different from a ban. Use Vancouver tax increase on OOT investors in August 2016 to estimate price elasticity of OOT demand.

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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 $(1-\gamma)(1-\alpha_n)$.[31] 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:

$$\begin{aligned}
& v_{R,\ell}(xs_t, a, S_t) = \max_{cs_t, hs_t, n_t} U(cs_t, hs_t, n_t, \ell, a) + \beta E_t[A_{t+1}^{(1-\gamma)(1-\alpha_n)} v(xs_{t+1}, a+1, S_{t+1})] \text{ s.t.} \\
& cs_t + R_t^\ell hs_t + Q * bs_{t+1} = n_t G^a W_t (1-\tau^{SS}) + xs_t \\
& xs_{t+1} = bs_{t+1}/A_{t+1} \geq 0 \\
& n_t \geq 0
\end{aligned} \tag{10}$$

and the owner's as:

$$\begin{aligned}
& v_{O,\ell}(xs_t, a, S_t) = \max_{cs_t, hs_t, \widehat{hs}_t, n_t} U(cs_t, hs_t, n_t, \ell, a) + \beta E_t[A_{t+1}^{(1-\gamma)(1-\alpha_n)} v(xs_{t+1}, a+1, S_{t+1})] \text{ s.t.} \\
& cs_t + P_t^\ell hs_t + Q * bs_{t+1} + (P_t^\ell - R_t^\ell)\widehat{hs}_t = n_t G^a W_t (1-\tau^{SS}) + xs_t \\
& xs_{t+1} = \left(bs_{t+1} + P_{t+1}^\ell (hs_t + \widehat{hs}_t)(1-\delta-\tau^P) - P_{t+1}^\ell f(\widehat{hs}_t)\right)/A_{t+1} \\
& Q * bs_{t+1} \geq -P_t^\ell (\theta_{res} hs_t + \theta_{inv} \widehat{hs}_t) \\
& n_t \geq 0
\end{aligned} \tag{11}$$

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 Analytic 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 $n_t = 1$. 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 $z_t G^a$.

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

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 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:

$$\begin{aligned}
&(1-\gamma)\alpha_{c,a} cs_t^{-1} U_t = \lambda_t \\
&(1-\gamma)\alpha_n (1 - n_t - \phi_\ell)^{-1} U_t = \lambda_t G^a W_t (1 - \tau^{SS}) \\
&(1-\gamma)\alpha_{h,a} hs_t^{-1} U_t = \lambda_t R_t^\ell \\
&\lambda_t = Q\beta E_t[A_{t+1}^{(1-\gamma)(1-\alpha_n)-1} \tfrac{\partial v_{t+1}}{\partial xs_{t+1}}]
\end{aligned} \tag{12}$$

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 12 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 12 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 12 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:

$$\begin{aligned}
&(1-\gamma)\alpha_{c,a} cs_t^{-1} U_t = \lambda_t \\
&(1-\gamma)\alpha_n (1 - n_t - \phi_\ell)^{-1} U_t = \lambda_t G^a W_t (1 - \tau^{SS}) \\
&(1-\gamma)\alpha_{h,a} hs_t^{-1} U_t + \beta E_t[A_{t+1}^{(1-\gamma)(1-\alpha_n)-1} \tfrac{\partial v_{t+1}}{\partial xs_{t+1}} P_{t+1}^\ell (1-\delta-\tau^P)] = \lambda_t P_t^\ell \\
&\beta E_t[A_{t+1}^{(1-\gamma)(1-\alpha_n)-1} \tfrac{\partial v_{t+1}}{\partial xs_{t+1}} P_{t+1}^\ell (1-\delta-\tau^P - f'(\widehat{h}_t)] = \lambda_t (P_t^\ell - R_t^\ell) \\
&\lambda_t = Q\beta E_t[A_{t+1}^{(1-\gamma)(1-\alpha_n)-1} \tfrac{\partial v_{t+1}}{\partial xs_{t+1}}]
\end{aligned} \tag{13}$$

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:

$$\begin{array}{l}
(1-\gamma)\alpha_{c,a} cs_t^{-1} U_t = \lambda_t \\
(1-\gamma)\alpha_n (1-n_t-\phi_\ell)^{-1} U_t = \lambda_t G^a W_t (1-\tau^{SS}) \\
(1-\gamma)\alpha_{h,a} hs_t^{-1} U_t + \beta E_t[A_{t+1}^{(1-\gamma)(1-\alpha_n)-1} \frac{\partial v_{t+1}}{\partial xs_{t+1}} (P_{t+1}^\ell(1-\delta-\tau^P) - P_t^\ell \theta_{res}/Q)] = \lambda_t P_t^\ell (1-\theta_{res}) \\
\beta E_t[A_{t+1}^{(1-\gamma)(1-\alpha_n)-1} \frac{\partial v_{t+1}}{\partial xs_{t+1}} (P_{t+1}^\ell(1-\delta-\tau^P - f'(\widehat{h}_t)) - P_t^\ell \theta_{inv}/Q)] = \lambda_t (P_t^\ell * (1-\theta_{inv}) - R_t^\ell)
\end{array} \tag{14}$$

The optimal labor choice is the same as in the previous case: $n_t = 1 - \phi_\ell - \frac{\alpha_n}{\alpha_{c,a}} \frac{1}{G^a W_t (1-\tau^{SS})} cs_t$. 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

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

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 13 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:

$$\begin{array}{l}
v(xs_t, a) = \max\limits_{cs,hs,n} \frac{1}{1-\gamma}\left(cs_t^{\alpha_c} hs_t^{\alpha_h} (1-n_t)^{\alpha_n}\right)^{1-\gamma} + \beta E_t[v(xs_{t+1}, a+1)] \text{ s.t.} \\
xs_{t+1} = \frac{1}{Q}(xs_t + n_t W - cs_t - hs_t R)
\end{array} \tag{15}$$

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:

$$\begin{array}{l} v(xs_t, a) = \max_{\widehat{cs}} \frac{\overline{U}}{1-\gamma} \widehat{cs}_t^{1-\gamma} + \beta E_t[v(xs_{t+1}, a+1)] \text{ s.t.} \\ xs_{t+1} = \frac{1}{Q}(xs_t + W - \widehat{cs}_t) \end{array} \tag{16}$$

where $\overline{U} = (\alpha_c^{\alpha_c} \alpha_h^{\alpha_h} \alpha_n^{\alpha_n} R^{-\alpha_h} W^{-\alpha_n})^{1-\gamma}$. 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:

$$\begin{array}{rcl} v(xs_t, a) & = & \max_{\widehat{cs}} \frac{\overline{U}}{1-\gamma} \widehat{cs}_t^{1-\gamma} + \frac{v_{a+1}}{1-\gamma} \beta Q^{-(1-\gamma)} (xs_t + W - \widehat{cs}_t + W \frac{Q}{1-Q_{a+1}})^{1-\gamma} \\ & = & \max_{\widehat{cs}} \frac{\overline{U}}{1-\gamma} \widehat{cs}_t^{1-\gamma} + \frac{v_{a+1}}{1-\gamma} \beta Q^{-(1-\gamma)} (xs_t - \widehat{cs}_t + W \frac{1-Q_{a+1}+Q}{1-Q_{a+1}})^{1-\gamma} \end{array} \tag{17}$$

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:

$$\begin{array}{l} \widehat{cs}_t = \frac{\left(\frac{X_{a+1}}{\overline{U}}\right)^{-1/\gamma}}{1+\left(\frac{X_{a+1}}{\overline{U}}\right)^{-1/\gamma}} \left(xs_t + W \frac{1-Q_{a+1}+Q}{1-Q_{a+1}}\right) \\ xs_{t+1} + \frac{1}{1-Q_{a+1}} W = \frac{1}{1+\left(\frac{X_{a+1}}{\overline{U}}\right)^{-1/\gamma}} \left(xs_t + W \frac{1-Q_{a+1}+Q}{1-Q_{a+1}}\right) \end{array} \tag{18}$$

Plugging this back into the original problem:

$$\begin{array}{rcl} v(xs_t, a) & = & \left(\overline{U} \left(\frac{\left(\frac{X_{a+1}}{\overline{U}}\right)^{-1/\gamma}}{1+\left(\frac{X_{a+1}}{\overline{U}}\right)^{-1/\gamma}}\right)^{1-\gamma} + X_{a+1} \left(\frac{1}{1+\left(\frac{X_{a+1}}{\overline{U}}\right)^{-1/\gamma}}\right)^{1-\gamma}\right) \frac{\left(xs_t + W \frac{1-Q_{a+1}+Q}{1-Q_{a+1}}\right)^{1-\gamma}}{1-\gamma} \\ & = & \overline{U} \left(1 + \left(\frac{X_{a+1}}{\overline{U}}\right)^{-1/\gamma}\right)^{-(1-\gamma)} \left(\left(\frac{X_{a+1}}{\overline{U}}\right)^{-(1-\gamma)/\gamma} + \left(\frac{X_{a+1}}{\overline{U}}\right)\right) \frac{\left(xs_t + W \frac{1-Q_{a+1}+Q}{1-Q_{a+1}}\right)^{1-\gamma}}{1-\gamma} \\ & = & X_{a+1} \left(1 + \left(\frac{X_{a+1}}{\overline{U}}\right)^{-1/\gamma}\right)^{\gamma} \frac{\left(xs_t + W \frac{1-Q_{a+1}+Q}{1-Q_{a+1}}\right)^{1-\gamma}}{1-\gamma} \end{array} \tag{19}$$

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

$$\begin{array}{rcl} v_a & = & X_{a+1} \left(1 + \left(\frac{X_{a+1}}{\overline{U}}\right)^{-1/\gamma}\right)^{\gamma} \\ & = & \beta Q^{-(1-\gamma)} v_{a+1} \left(1 + \left(v_{a+1} \beta Q^{-(1-\gamma)} \overline{U}^{-1}\right)^{-1/\gamma}\right)^{\gamma} \\ Q_a & = & \frac{Q}{1+Q-Q_{a+1}} \end{array} \tag{20}$$

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:

$$U = \max_{h,x} (W + w * x - P * h)^{\alpha_c} h^{\alpha_h} (1 - \lambda - x)^{\alpha_n} \tag{21}$$

The first order conditions imply the following solution:

$$\begin{aligned} c &= \alpha_c((1-\lambda)w + W) \\ h &= \alpha_h((1-\lambda)w + W) \\ x &= (\alpha_c + \alpha_h)(1-\lambda) - \alpha_n \frac{W}{w} \\ U &= \left(\frac{1}{P}\right)^{\alpha_h} \left(\frac{1}{w}\right)^{\alpha_n} \alpha_c^{\alpha_c} \alpha_h^{\alpha_h} \alpha_n^{\alpha_n} ((1-\lambda)w + W) \end{aligned} \tag{22}$$

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

Each consumption producing firm chooses hours x_c to maximize $\pi_c = x_c^{\rho_c} - w x_c$ which implies that $w = \rho_c x_c^{\rho_c - 1}$. Each construction firm in zone 1 maximizes $\pi_1 = \left(1 - \frac{H^1}{m\overline{h^1}}\right) P_1 x_1^{\rho_h} - w x_1$ 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

$\pi_2 = \left(1 - \frac{H^2}{m\overline{\overline{h}}^2}\right) P_2 x_2^{\rho_h} - w x_2$ which implies that $w = \left(1 - \frac{H^2}{m\overline{\overline{h}}^2}\right) P_2 \rho_h x_2^{\rho_h - 1}$. 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.

$$P_2 = P_1(1-\lambda)^{1/\alpha_h} \tag{23}$$

Equation 23 says that for households to be indifferent between the two zones, their utility of living in each zone must be the same.

$$n_1 = \frac{H^1 P^1}{\alpha_h w} \tag{24}$$

$$n_2 = \frac{H^2 P^2}{\alpha_h w (1-\lambda)} \tag{25}$$

$$n_1 + n_2 = m \tag{26}$$

Equations 24 and 25 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 26 says that the sum of agents living in zones 1 and 2 must equal to the total number of agents.

$$w = \rho_c x_c^{\rho_c - 1} \tag{27}$$

$$w = \left(1 - \frac{H^1}{m\overline{\overline{h}}^1}\right) P_1 \rho_h x_1^{\rho_h - 1} \tag{28}$$

$$w = \left(1 - \frac{H^2}{m\overline{\overline{h}}^2}\right) P_2 \rho_h x_2^{\rho_h - 1} \tag{29}$$

Equations 27, 28, and 29 relate each firm's optimal behavior to the wage.

$$H^1 = \left(1 - \frac{H^1}{m\overline{\overline{h}}^1}\right) m_1 x_1^{\rho_h} \tag{30}$$

$$H^2 = \left(1 - \frac{H^2}{m\overline{\overline{h}}^2}\right) m_1 x_2^{\rho_h} \tag{31}$$

Equations 30 and 31 relate each firm's output to the total output of housing in each zone. They can be rewritten as $H^1 = \frac{m\overline{\overline{h}}^1 m_1 x_1^{\rho_h}}{m\overline{\overline{h}}^1 + m_1 x_1^{\rho_h}}$ and $H^2 = \frac{m\overline{\overline{h}}^2 m_2 x_2^{\rho_h}}{m\overline{\overline{h}}^2 + m_2 x_2^{\rho_h}}$.

$$(\alpha_c + \alpha_h)(n_1 + n_2(1-\lambda)) = m_c x_c + m_1 x_1 + m_2 x_2 \tag{32}$$

Equation 32 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 x and P into equations 28 and 29: $w = P_1 \rho_h \frac{m\overline{\overline{h}}^1 x_1^{\rho_h - 1}}{m\overline{\overline{h}}^1 + m_1 x_1^{\rho_h}} = P_2 \rho_h \frac{m\overline{\overline{h}}^2 x_2^{\rho_h - 1}}{m\overline{\overline{h}}^2 + m_2 x_2^{\rho_h}}$

Second, plug the wage into equations 24 and 25: $n_1 = \frac{m_1 x_1}{\alpha_h \rho_h}$ and $n_2 = \frac{m_2 x_2}{\alpha_h \rho_h (1-\lambda)}$.

Third, plug n_1 and n_2 into equation 26 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 23 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 28. We can then solve for x_c as a function of P_1 using equation 27. We can then plug this into equation 32 to solve for P_1.

B Data Appendix

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 7. 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.

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.

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

Table 7: 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

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 from `ACRIS` database (http://a836-acris.nyc.gov) maintained by New York City Department of Finance. The ACRIS (Automated City Register Information System) records and maintains official documents related to real estate, including deeds, mortgages and leases. We download the raw data files to set up a database, using the same procedure as described and shared in https://github.com/fitnr/acris-download. The database consists of 10 different tables, and we use three of them – *real_property_master*, *real_property_legals*, and *real_property_parties* – joined by *documentid* column. We focus on purchases that take place in Manhattan (New York County). We consider either single condos and single co-ops, or a broader grou of 21 residential property types.

To identify OOT buyers among all transactions, we look at the reported addresses of buyers. When a buyer is not an LLC, the buyer is identified as an OOT buyer if either the address is foreign, or the reported U.S. ZIP code is not one of the 1,304 ZIP codes of NY MSA. If the buyer is a LLC, we can still classify the LLC as OOT or NY MSA using the same procedure. However, since the identity of the real owner of the LLC is not revealed, additional assumptions are required to estimate the size of OOT housing demand. We assume that X80X% of OOT LLCs have OOT buyers behind, while X20X% of NY MSA LLCs have OOT buyers behind. Under the assumption, we estimate that roughly X12X% of transactions in Manhattan between 2004 and now is purchased by OOT buyers.

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 VIIA table 84, the number of housing units under various rent-control regulations are presented for each boroughs. Using this information, we can calculate the proportion of rent-regulated units among all the renter-occupied units. As described in the main text, the proportion is 68% for Manhattan, and 57% for the other four NYC boroughs.

Since we have no information on the fraction rent-regulated apartments in the 20 counties of the MSA outside of New York City, we make the following assumption. We assume that the fraction of rent-regulated units is 15% of renter-occupied units. This is close to and somewhat below the 22% of Staten Island, the most suburban of NYC boroughs and therefore the closest comparable. We then combine this assumption on the 20 counties outside NYC with the four NYC borough data to arrive at the fraction of rent-regulated units for zone 2. Specifically, we use the regulated % from NYCHVS sheet (e.g, 59.4% for Bronx, 76.9% for Brooklyn, etc.) and multiplied these %-numbers with the renter-occupied units in ACS data set, while applying the 15% share to number of observed rental units for the rest of Zone 2 counties. The four NYC boroughs have 1.56 million renter-occupied housing units while the rest of zone 2 has 1.36 million. The resulting fraction of rent-regulated units in zone 2 is 37%.

From the same source, we also calculate the different in average rent in New York City between private rentals and regulated rentals. We apply the same gap to all of the MSA.