The Heterogeneous Effect of Local Land-Use Restrictions Across US Households. *

David Lindsay †

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Abstract

Using a structural approach, I quantify the effect of land-use regulations on different age and education groups. Building on the seminal work of Roback, 1982, I estimate a dynamic spatial structural equilibrium model of household location choice, local housing supply, and amenity supply. I show that in the long-run, removing land-use restrictions benefits all household groups and increases aggregate consumption by 7.1%. These consumption gains vary across households, less educated and younger households see increases in consumption about twice as large as more educated or older households. In contrast, in the short-run, removing land-use regulations reduces the consumption of older-richer homeowners while increasing the consumption of younger renters. In a counterfactual 1990-2019 transition, abolishing land-use regulations reduces the consumption of households born before the mid-1960s, while increasing consumption of more recent generations. Given the difficulty in reforming land-use regulations, I explore whether a shift to remote working or creating new urban areas leads to similar consumption gains compared with removing land-use restrictions. Qualitatively, I find the gains are similar, but quantitatively are only about 20% as large as abolishing land-use regulations from existing urban areas.

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†University of California, Los Angeles, lindsayd@ucla.edu,

1 Introduction

> Exclusionary zoning laws enact barriers to entry that constrain housing supply, which, all else equal, translate into an equilibrium with more expensive housing and fewer homes being built . . . The American Jobs Plan takes important steps to eliminate exclusionary zoning. Specifically, the Unlocking Possibilities Program within the American Jobs Plan is a $5 billion competitive grant program that incentivizes reform of exclusionary zoning . . . [it] incentivizes new land-use and zoning policies to remove those barriers.

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In recent decades, house prices in the most productive cities, such as New York and the San Francisco Bay Area, have risen substantially, making these cities unaffordable to many low-wage workers. As argued in Glaeser and Gyourko, 2018, Gyourko and Molloy, 2015, and Glaeser, Gyourko, and Saks, 2005 the literature attributes high housing costs in these cities to local land-use restrictions. Land-use regulations such as height limits, lot size & parking minimums, set-back requirements, environmental reviews, historic preservation, and prolonged approval processes fraught with regulatory discretion, constrain the housing supply and hence raise local housing costs.

These changes to the land-use regulatory environment have led to rising spatial sorting of households along education and city productivity lines (Van Nieuwerburgh and Weill, 2010) as low-wage workers are no longer able to afford housing in high-productivity cities. This increases inequality between workers of different education, as less-educated workers increasingly live in cities that experienced the weakest productivity growth. Furthermore, the tightening of land-use regulations creates inequality between different age cohorts. Older households are usually homeowners and hence are insulated from the increased housing costs and the value of their most important asset rises. In contrast, younger households, who are typically renters, spend an increased fraction of their income on housing and may be unable to afford housing in the more productive cities.

In my paper, I quantify how land-use restrictions affect different age and education cohorts. Owing to the lack of viable natural variability in land-use regulations and general equilibrium effects[1] I build on the seminal work of Roback, 1982 and estimate a dynamic spatial equilibrium model of

[1] The lack of natural experiments is an issue faced by much of this housing literature. With the exception of Diamond, McQuade, and Qian, 2019, natural experiments are few and far between, and hence the reliance on structural methods.

household location choice, local housing supply, and amenity supply. I estimate the local housing supply elasticities and the household's utility parameters. Using the estimated model I show that abolishing land-use regulations increases aggregate output by about 7.1% in the long-run. I show that the benefits from removing land-use restrictions are heterogeneous across age and education groups. The youngest and least educated households see increases in consumption that are about twice as large as the oldest and most educated households. While in the long-run land-use restrictions negatively affect all age and education groups, in the short-run abolishing land-use regulations tends to benefit younger renters at the expense of incumbent older homeowners.

My model features heterogeneous households that differ in terms of their age, homeownership status, education, wealth, and idiosyncratic preference shocks. Each period households choose a city to live in, trading off moving costs, amenities, housing costs, as well as the wage they would receive in each city. Cities with more stringent land-use regulations have lower housing supply elasticities and higher house prices as a result. In equilibrium, housing markets and rental markets clear. The endogenous location choices of households and housing supply functions determine equilibrium house prices and rents.

My model is able to capture two key features of the data. First, there is a positive correlation between city productivity (or amenities) and house prices. This arises as high-productivity or a plentiful supply of amenities induces households to move to the region, increasing house prices. Secondly, there is positive assortative matching wherein more educated households tend to sort into high-productivity high-cost cities, as the rise in their income relative to the rise in housing costs is larger compared to less educated households.

Analyzing policy counterfactuals requires estimates of each city's housing supply elasticity and the household's utility parameters. I estimate housing supply elasticities using international migration shocks as an instrument for housing demand. As has been argued by Saiz, 2010, international migration tends to occur along established networks and is therefore orthogonal to changes in city productivity or housing supply shocks. For example, the decision for a Cuban or Mexican to migrate to Los Angeles or Miami reflects the predetermined migration network and economic and political changes in their home country rather than city-specific changes in Los Angeles or Miami. To structurally estimate the household's utility parameters, I exploit the conditional choice structure of the model and maximize the likelihood function using the 5% Census microdata sample.

My paper has four main counterfactual results. In line with Herkenhoff, Ohanian, and Prescott, 2017 and Hsieh and Moretti, 2019, I show that abolishing land-use regulations increases aggregate output. When land-use regulations are abolished, housing costs are equalized across cities. In the baseline steady-state, prices are higher in more productive regions, so relaxing land-use regulations decreases the relative price of housing in high-productivity cities. Thus, the population of more productive regions expands at the expense of less productive regions, increasing aggregate output. I find that aggregate output rises by approximately 7.1%, when I compare the baseline and counterfactual steady-states. Along with the rise in aggregate output, the utility households receive from amenities also rises by 8.6%, as households tend to relocate to high-productivity and high amenity regions.

Secondly, I show that while all education cohorts witness increased consumption and amenity utility when land-use regulations are relaxed, it is the least educated who see the largest percentage rise in their consumption. When the relative price of housing in high-cost high-productivity cities falls, the consumption of existing low-wage workers rises more, as housing costs consume a larger fraction of their income. Moreover, since affordability relative to income has improved to a greater extent for low-wage workers, they will tend to move to productive cities. Hence, when we compare steady-states, the degree of income dispersion decreases when we relax land-use regulations.

Similarly, I show that when comparing steady-states, younger households see the largest rise in their consumption when land-use regulations are abolished. In my model, all households transition from being a renter when they start their working life to being a homeowner later in life. In the estimated model, wages increase as workers age, reflecting the effect of experience. This combined with a down-payment constraint means that younger workers not only spend a larger fraction of their income renting housing when prices rise, but they also save a larger fraction of their income to meet the down-payment constraint. Quantitatively, I show that the percent rise in consumption is approximately twice as large for young households compared to the oldest cohorts.

Thirdly, in the short-run, I show that land-use regulations can benefit homeowners at the expense of renters. To show this I examine the consumption of different household groups in a transition between steady-states. I create a series for the productivity shocks and amenity supply of each city. The productivity shocks are the Bartik change in city wages using 1990 industry wage bill shares and national changes in wages for each industry, excluding the city itself. Taking these changes as given, I show that transitions with estimated housing supply elasticities tend to benefit existing homeowners at the expense of renters and future generations, as existing homeowners reap large capital gains on their homes, while renters face increasingly costly housing. Given how responsive the political system is to the demands of homeowners, this can perhaps explain the ubiquity of stringent land-use regulations given their seemingly harmful effects.

Motivated by the results from the transitional dynamics as well as how entrenched restrictive land-use regulations are in many cities, I derive my final set of results, examining whether a switch to remote work or creating new cities can replicate the long-run benefits of relaxing land-use regulations. Anecdotally, the rising fraction of remote workers is cited as the cause of the population decline of high-cost cities such as San Francisco and New York during the COVID-19 pandemic. I find that both allowing a fraction of households to work from home and creating new cities increase aggregate output. However, the aggregate rise in output is approximately 1.38% when 20% of workers work remotely or the number of cities increases by 10%. Although I allow all workers to work from home with equal likelihood, the least educated workers see a rise in their consumption about twice as large as the most educated. Similarly, less educated households see consumption growth about three times as large as the most educated households when I increase the number of cities by 10%.

2 Related Literature

While my paper makes a number of distinct contributions to the literature, I highlight several aspects of this study that are particularly important. First, my paper quantifies which household groups bear the costs of land-use regulations. I show that in the long-run, younger and less educated households benefit the most (in consumption terms) from removing restrictions. Secondly, my paper shows that in the short-run, land-use regulations creates winners and losers among households. As the economy transitions between its 1990 and 2019 steady-state, restrictive land-use regulations benefit older cohorts at the expense of younger cohorts. Life-time consumption is larger in transitions with the baseline land-use regulations for cohorts born before the mid-1960s, compared to a transition where land-use regulations are abolished. Finally, I show that compared with relaxing land-use restrictions, the effect of remote working or establishing new cities on household consumption is quantitatively small.

This paper is related to the burgeoning literature on housing and macroeconomics, see Piazzesi and Schneider, 2016 for an overview, and is particularly related to the macroeconomic effects of land-use regulations. Herkenhoff et al., 2017 and Hsieh and Moretti, 2019 examine the impact of land-use regulations have had on aggregate output in the US. Similar to these papers, this study finds that removing land-use restrictions would increase aggregate output. Bunten, 2017 shows that the local nature of land-use regulation creates inefficiencies relative to a national planner. Although the increase in aggregate output I observe is smaller than either Herkenhoff et al., 2017 or Hsieh and Moretti, 2019, it remains substantial. I find smaller aggregate effects because in my model households are heterogeneous in terms of productivity and so the most productive workers are already located in the most productive cities, limiting the gains from expanding the city. Furthermore, my model features idiosyncratic household preferences which reduces the housing demand elasticity for a city, as not all workers will want to move to a high-productivity city even if it is affordable.

The spatial sorting of households across urban areas is analyzed in Van Nieuwerburgh and Weill, 2010, Gyourko, Mayer, and Sinai, 2013, Ganong and Shoag, 2017, and Bilal and Rossi-Hansberg, 2021. [2]. These papers show that heterogeneous education or ability of households leads to the most educated households sorting into so-called "Superstar Cities". In my counterfactual analysis, relaxing land-use restrictions reduces the degree of spatial sorting as lower-wage workers are able to afford these high-productivity regions. Relatedly, Baum-Snow, Freedman, and Pavan, 2018 and Fajgelbaum and Gaubert, 2020 examine spatial sorting and its effect on inequality and efficiency.

Another related strand of literature, is the spatial economics literature first formulated in Sherwin, 1979 and Roback, 1982. My paper shares the dynamic discrete framework of Kennan and Walker, 2011, Diamond, 2016, Monte, Redding, and Rossi-Hansberg, 2018, Almagro and Domınguez-Iino, 2021, and Schubert, 2020. Most closely related to my paper Diamond, 2016 further scrutinizes Moretti, 2013 result: finding that well-being inequality has increased between college and non-college workers over time due to changes in their location choices. Uniquely my paper incorporates overlapping generations of households who smooth consumption over their life-cycle and differences in housing tenure, allowing an analysis of the impact of regulations across cohorts and owners and renters. Moreover, this study analyzes the out-of-steady dynamics of the spatial economy, which is crucial to determine the short-run impacts of changes to fundamentals across different groups.

A core contribution of my paper is to use the structural model to derive the heterogeneous effects from counterfactual changes in land-use restrictions. Kiyotaki, Michaelides, and Nikolov, 2011 and Kiyotaki, Michaelides, and Nikolov, 2020, Favilukis and Van Nieuwerburgh, 2017, Favilukis, Mabille, and Van Nieuwerburgh, 2019 build structural models to examine how housing policies affect different household groups. The former two papers show that monetary policy shocks benefits existing homeowners at the expense of current renters while the latter papers examine

[2] Couture, Gaubert, Handbury, and Hurst, 2020 and Almagro and Domınguez-Iino, 2021 examine spatial sorting at the city-level. Couture et al., 2020 shows that in recent decades, an increasing number of wealthy households now live in downtown areas of cities alongside the existing low-income households, creating a U-shaped pattern of sorting in downtown areas. While Almagro and Domınguez-Iino, 2021 argues that endogenous amenities play a crucial role in location choices in Amsterdam.

city-level policies [3]. Unlike these papers my model features a diverse set of cities from which households can choose from each period.

In terms of estimation methodology my paper uses the conditional choice probability (CCP) techniques borrowed from the industrial organization literature (Rust, 1987, Hotz and Miller, 1993, and Arcidiacono and Miller, 2011, Arcidiacono and Ellickson, 2011). These estimation techniques have spatial featured in Scott, 2014, Almagro and Domınguez-Iino, 2021 and Schubert, 2020. Unlike these papers, the overlapping generations structure of my model allows the CCPs to be computed relatively straightforwardly by backwards recursion. I separately estimate each city's housing supply elasticity using immigration shocks as an instrument for demand shocks. I then estimate the household utility parameters to maximize the (pseudo)-maximum likelihood function given data on household location choices.

The remainder of the paper is organized as follows. Section 3 provides some background to the changes to the US housing market. Section 4 presents the model. Section 5 describes the data. Section 6 reports on the parameterization. In section 7 I outline both the long-run and short-run counterfactual results. Section 8 concludes.

3 Background

Prior to the 1970s land-use regulations were limited in scope, the right to build or demolish existing structures was by in large the right of the property owner. Since then, there has been a transformation of property rights, Glaeser et al., 2005. Owners often face significant obstacles when they wish to transform land from one use to another. Under the guise of historic preservation [4] existing structures cannot be demolished and environmental restrictions, such as urban growth boundaries, limit the supply of new land for residential structures. These changes were most significant in regions that subsequently had high-productivity growth, such as the San Francisco Bay Area and New York.

[3] Empirically Hornbeck and Moretti, 2019 find that local productivity shocks induces inward migration and hence leads to rising rents and house prices, benefiting homeowners at the expense of renters.

[4] Land-use regulations are infamously strict in San Francisco. The city has effectively unlimited discretion in terms of approving new developments, which can lead to bizarre situations such as the preservation of laundromats from the 1980s. Kukura, 2018

3.1 Housing has become expensive

The implication of these restrictions is that housing has become expensive relative to the cost of production. I show this fact in two ways. First, in Figure 1 I plot the difference between the market value and replacement value of real estate in the United States. While this series is volatile, the gap between the market and replacement cost of housing has increased since the 1980s.

One weakness of using land values is that time-varying discount rates may cause this series to change even in absence of any change in land-use regulations. When valuation ratios are high, the market value of housing will increase, even if there is no change in supply restrictions. Thus, a sequence of discount rate shocks could potentially cause the value of land to rise over time.

To rectify these concerns, I therefore also calculate the economic rents earned by the housing sector. Following Barkai, 2020 I define the economic rents earned by the housing sector as the total value added by the housing sector (the value-added of housing services) minus payments to factors, which is principally the return on capital (structures), net taxes, depreciation and expected capital inflation. Since the value-added is derived from market rents, this measure is insensitive to the housing valuation ratios. I plot this series in Figure 2. This figure clearly shows that the economic rents of the housing sector relative to GDP has increased since the early 1990s. By the end of 2019, these economic profits were approximately 4% of GDP.

In both figures 1 and 2 we can see that housing has become expensive relative to the marginal cost of production[5].

3.2 Rising dispersion in incomes across cities

Secondly, in the data, we observe increased dispersion in incomes across cities. While for most of the post-war era incomes across regions converged, the opposite has been true in recent decades. In Figure 3 I plot the coefficient of variation in incomes across US cities from 1970s to present. The coefficient of variation is the standard deviation divided by the mean, and hence is a scale-free measure of dispersion. As we can see from the mid-1990s to the present day, the dispersion in incomes between cities has increased by about 40%. Prior to the mid-1990s, however, income dispersion between regions was approximately constant.

[5] Rognlie, 2015 finds that the housing sector is responsible for much of the decline in labor share post-1980 in the US.

Rising income dispersion between cities could be due to rising spatial sorting or cities with a higher initial level of productivity experiencing more rapid productivity growth [6]. In Figure 4 I plot the change in city-level productivity on the initial productivity level. As explained in detail in section 5, I calculate the initial productivity level as a city-level fixed effect from a regression of log individual wages on controls including industry and education of the worker. Productivity growth is defined as a Bartik shift-share instrument, where I fix the city industry wage bill shares at their 1990 level and use national changes in wages in each industry, excluding the city itself, and sum over all industries to calculate the city productivity shock. From the graph, we can see that there is a positive relationship between the city productivity level and its subsequent productivity growth, suggesting that rising income dispersion is in part due to uneven productivity growth.

Rising spatial sorting could also in part be responsible for the increased dispersion in incomes between cities. If there is an increased tendency for highly educated workers to live in the most productive cities, then the average wage in these cities will rise relative to less productive locations. In Figure 5 I plot the change in the college-educated share of a city on its initial productivity level.

3.3 Positive correlation between income and productivity growth

In Figure 6 I show that that the change in log house prices and city productivity is positively correlated. Cities that experienced faster productivity growth also tended to have faster growth in house prices. I measure productivity growth as the Bartik change in wages for each industry and then scale this by the city wage bill. This Figure shows that the areas which had the greatest increase in wages became increasingly unaffordable. As a result, it has become increasingly difficult for younger and less educated households to move to these regions.

4 The Model

I consider an open economy, so that I take the interest rate as exogenous, with overlapping generations of households in a spatial equilibrium. The model captures the location and consumption savings decisions of richly heterogeneous households over their life-cycle. Households vary in terms of age, education, and wealth. Regions differ in local amenity supply, labor productivity,

[6] Skill biased technological change or capital skill complementary, see Krusell, Ohanian, Ríos-Rull, and Violante, 2000, may also be responsible for rising income dispersion between locations, as cities differ in terms of their skill composition.

and housing costs. Housing costs are a function of local demand and the housing supply elasticity for the city.

4.1 Households.

Time is discrete, runs forever and is indexed by $t \in \{1, 2, \ldots\}$. Households are either renters or homeowners. They are heterogeneous in terms of their age $a \in \{1, 2, \ldots, A\}$, education $e \in \{1, 2, \ldots, E\}$, risk-free asset holdings, $b \in \mathbb{R}$, current location $j \in \{1, 2, \ldots, J\}$. The household's age and education determines their effective supply of labor, $f(a, e)$. Each period every household chooses a region j' to live in. When choosing a region, a household trades off moving costs, amenities, their idiosyncratic preference shock, and the regional productivity. A new generation of households are born each period and households die once they reach age A.

At the beginning of the period each household receives an i.i.d. vector of idiosyncratic preference shocks that are distributed according to a standard type one generalized extreme value distribution (G.E.V.). After receiving the preference shock the households choose a location j' to live in. Households receive flow utility from consumption, the local amenities, and their idiosyncratic preference shocks and incur moving costs when moving between regions. A household that previously lived in city j and chooses to live in city j' has flow utility

$$\underbrace{\log(c)}_{\text{Consumption}} + \overbrace{\omega\chi_{j'}}^{\text{Amenities}} - \underbrace{\tau_{jj'}}_{\text{Moving Costs}} + \overbrace{\theta\varepsilon_{ij'}}^{\text{Preference shock}} . \tag{1}$$

I assume that utility is separable in these terms and that household's receive logarithmic utility from consumption c. When the household lives in city j' their amenity consumption is determined by the local supply of amenities, $\chi_{j'}$ and their idiosyncratic preference for living in the location is determined by $\varepsilon_{ij'}$. The moving cost for a household previously in region j who moves to region j' is $\tau_{jj'}$[7]. The parameters ω and θ govern the relative importance of amenities and preference shocks to household utility. A larger θ (ω) increases the relative importance of preference shocks (amenities).

Households can choose to save in a risk-free asset or to borrow subject to a collateral constraint. I assume that all households start with no financial wealth and must end life with non-negative

[7] I assume that there is no moving cost in the first period of life. This ensures that where the households are born doesn't affect the steady-state. If there were moving costs in the first period then the distribution of where households are born would matter for the equilibrium.

financial wealth. Households are renters for part of their life and homeowners otherwise. Specifically, I assume that households are renters prior to age $\overline{a}$ and then own housing after then. The Bellman equation of a household who owns a home, $a \in \{\overline{a}, \ldots, A\}$, is

$$V(a, b, e, j; S) = \max_{j', b'} \{\log(c) + \omega\chi_{j'} - \tau_{jj'} + \theta\varepsilon_{ij'} + \beta\mathbb{E}[V(a+1, b', e, j'; S')]\}, \tag{2}$$

where a is age, b is holdings of risk-free securities, e is education level, j is current location, and S is the aggregate state. The household chooses a new location j' and next periods bond holdings b' to maximize the right-hand side of (2). They discount the future at rate β and their expected value is computed over the support of preference shocks next period. Note that in the final period the expected continuation value equals zero, that is $\mathbb{E}[V(A+1, b', e, k; S')] = 0$. The households problem in (2) is maximized subject to following constraints

$$c + p_{j'} + \frac{b'}{1+r} = (1-\delta)p_j + w_{j'} f(a, e) + b, \tag{3}$$

$$b' \geq -\psi p_{j'}, \tag{4}$$

$$S' = G(S), \ \varepsilon_{ij} \overset{iid}{\sim} G.E.V.(1). \tag{5}$$

Equation (3) is the home owner's budget constraint. The household uses these resources to purchase risk-free securities, b', with interest rate r, amount c of the consumption good, and housing in their current location j'. The price of an owner occupied home in their current location is $p_{j'}$. The right-hand side of the budget constraint consists of the depreciated value of their home in the previous period [8]. The depreciation rate of housing is δ per period. Additionally, households resources include the wage, per effective unit of labor, of region j' multiplied by their effective supply of labor, as well as their current holdings of risk-free securities.

All debt must be collateralized and there exists a down-payment requirement of $1 - \psi$ when purchasing a home. This gives rise to the borrowing constraint in equation (4) [9]. The aggregate state is denoted by S and evolves according to the function G. I defer further discussion of the aggregate state until I define the equilibrium.

For renters, that is households with $a \in \{1, 2, \ldots, \overline{a} - 1\}$, their maximization problem is the same as in (2). However, the resource constraint, (3), and borrowing constraint, (4), are now given by

[8] If the household was a renter in the previous period then this term is not in their budget constraint.

[9] Since all households end life with no wealth I allow them to consume their down-payment in their final period of life. Thus, I drop (4) and the budget constraint in the final period is $c + p_{j'} = (1-\delta)p_j + w_{j'} f(a, e) + b$

the following two equations

$$\frac{b'}{1+r} + c + p_{rj'} = w_{j'} f(a, e) + b, \tag{6}$$

$$b' \geq 0, \tag{7}$$

where $p_{rj'}$ is the price of rental housing in region j'.

Note that the expectation in (2) is taken over the possible realizations of idiosyncratic taste shocks next period. It is helpful to write the conditional value of living in location j', *excluding* the realized taste shocks as $W(a, b, e, j, j'; S)$ and then continuing optimally after then. That is

$$W(a, b, e, j, j'; S) = \max_{b'}\{\log(c) + \omega\chi_{j'} - \tau_{jj'} + \beta\mathbb{E}[V(a+1, b', e, j'; S')]\}. \tag{8}$$

Which implies that we can write equation (2) of the households problem as

$$V(a, b, e, j; S) = \max_{j'}\{W(a, b, e, j, j'; S) + \theta\varepsilon_{ij'}\} \tag{9}$$

Given the assumed distribution of the preference shocks we can write the probability that a household of type (a, b, e, j) chooses location j' as

$$\pi(j'|a, b, e, j; S) = \frac{\exp(W(a, b, e, j, j'; S))^{\frac{1}{\theta}}}{\sum_k \exp(W(a, b, e, j, k; S'))^{\frac{1}{\theta}}}. \tag{10}$$

Furthermore, by standard results, Rust, 1987, Hotz and Miller, 1993, and the assumed distribution of the preference shock implies that the expected value of the household prior to the realization of the taste shocks can be expressed as

$$\mathbb{E}[V(a, b, e, j; S)] = \max_{b'}\{u(c, j, k; S) + \theta\gamma - \theta\log(\pi(k|a, b, e, j; S)) + \beta\mathbb{E}[V(a+1, b', e, k; S')]\}, \tag{11}$$

$$u(c, j, k; S) = \log(c) + \omega\chi_k - \tau_{jk}, \tag{12}$$

where k is an arbitrary location and γ the Euler-Mascheroni constant. The importance of equations (8) to (11) are in aiding the computation of the household's conditional choice probabilities, $\pi(j'|a, b, e, j; S)$. To compute the probability that a household chooses a location we insert the solution of (8) into (10). However, to compute (8) we need next periods expected value, which is taken over realizations of the households preference shocks. Conveniently, the assumption that households preference shocks are distributed G.E.V. (Arcidiacono and Ellickson, 2011) implies that the expected value has the tractable form in (11), which can be solved by backwards recursion and using the fact that $\mathbb{E}[V(A+1, b', e, k; S')] = 0$.

4.2 Housing Sector

Housing is produced in each city using the consumption good and the local productivity of producing housing depends on the city specific supply elasticity. Each construction firm is competitive, however at the city-level there are decreasing returns to scale relative to the aggregate housing stock: as the density of the city increases the productivity of the construction sector falls. This captures the fact that regulatory constraints on new construction tend to limit density or preserve existing low density areas. Motivated by this I therefore assume that new housing is produced using the following production function

As argued in Glaeser and Gyourko, 2018 construction costs are approximately linear in the floor area of a structure beyond a certain threshold. Thus, the gap between replacement costs and market values does not reflect technological constraints such as decreasing returns to scale in the construction sector, but rather regulatory constraints on new housing.

$$Y_{hjt} = A_h \left(\frac{\overline{H_j}}{H_{jt}} \right)^{\alpha_j} x_c. \tag{13}$$

Here x_c is the quantity of consumption good used, and is the only input in constructing new housing. The aggregate housing stock in the city is given by H_{jt} and $\overline{H_j}$ is the land area in the city that's suitable for construction. Thus, the density of the city is $\frac{H_{jt}}{\overline{H_j}}$. Each city has it's own city specific supply elasticity, α_j, [10] this determines how responsive city-level prices are to changes in local population. This supply elasticity is implicitly determined by the local land-use regulations that make it costly to construct new housing in more regulated areas. As α_j are positive as a city's density increases, the productivity of the construction sector declines. The law of motion for the housing stock is given by

$$H_{jt} = (1 - \delta)H_{jt-1} + Y_{hjt}, \tag{14}$$

where δ is the economy wide depreciation rate for housing and Y_{jt} is the quantity of new housing produced in city j. We can write the construction firm's problem as

$$\max_{x_c} p_{jt} A_h \left(\frac{\overline{H_j}}{H_{jt}} \right)^{\alpha_j} x_c - x_c, \tag{15}$$

where we note that the price of the consumption good is normalized to one.

[10] Throughout my paper I assume a single housing supply elasticity for each urban area that is constant over time. My framework could easily be extended to incorporate time varying housing supply elasticities. This could capture the changes in land-use regulation as documented in Gyourko, Hartley, and Krimmel, 2021.

4.3 Rental Sector

There are no frictions in transforming owner occupied housing into rental housing. The fraction of housing in a city that is rental housing is thus an equilibrium object. To simplify matters I assume that the rental housing stock is owned by risk-neutral foreigners with deep pockets. This avoids the need for an additional state variable in the households problem as well as simplifying the market clearing conditions [11]. I assume that these foreigners discount the future using the same risk-free rate r that the household receives on their risk-free bond holdings. In each city j their problem is

$$\max_{q_{jt}\in\mathbb{R}_0^+} \left(p_{rjt} + \left(\frac{1-\delta}{1+r}\right) p_{jt+1} - p_{jt} \right) q_{jt}. \tag{16}$$

In equation (16) q_{jt} is the quantity of rental housing owned the foreign entity in city j at time t. The rental firm solves this problem for each city j.

4.4 Consumption Good Sector.

All workers in city j work in the consumption good sector of city j. The consumption goods sector in each region has a region-specific productivity A_{jt} that is common to all firms in the region. The region-specific productivity is non-stochastic for simplicity. A continuum of competitive firms use local labor to produce tradable consumption goods. The representative competitive firm f produces output according to

$$A_{fjt}N^e_{fjt}, \tag{17}$$

where N^e_{fjt} is the effective units of labor in region j at time t that are employed by firm f. The total measure of effective units of labor in region j is simply $\sum_{e,a}\mu(a,e,j;S)f(a,e)$, the total measure of workers of age a and education e, $\mu(a,e,j;S)$, times their effective supply of labor, $f(a,e)$ [12].

4.5 Equilibrium

I solve for a steady-state equilibrium, that is, an equilibrium where all prices value functions, policy functions, and distribution are constant over time.

[11] In steady-state these foreign entities earn no economic profits and hence the importance of this assumption to inequality is largely along transitions between steady-states.

[12] In this study I assume that there are no local agglomeration economies. Introducing agglomeration economies into the model can lead to multiple steady-states.

The wealth of the household will depend on their age and education as well as their history of location choices. Let this endogenous distribution of household bond wealth conditional on age, education, location prior to moving, be denoted by $\Psi(db|a, e, j)$. I label the measure of households of type a, e in region j as $\mu(a, e, j)$.

A steady-state equilibrium is defined as a set of prices, $p_j, j \in \{1, \dots, J\}$, for housing in each region j and a set of prices for rental housing in each region $p_{rj}, j \in \{1, \dots, J\}$, a value function, $V(a, b, e, j; S)$ for the household, a policy function for the household $b'(a, b, e, j, j'; S)$, conditional choice probabilities for the household, $\pi(j'|a, b, e, j; S)$, a household wealth distribution, $\Psi(db|a, e, j)$, and $\mu(a, e, j)$ measures of households across locations, such that,

1. Given the set of prices all agents choose optimally. That is the households solve their problem, (2) to (7), the construction firm solves the problem given by (15) and the foreign owners of the rental housing solve their problem, in equation (16). For the household their value function $V(a, b, e, j; S)$ and policy functions $\pi(j'|a, b, e, j; S)$ and $b'(a, b, e, j, j'; S)$, jointly solve their Belman equation.

2. Given the solutions to the agent's problems all markets clear.

3. The measure $\mu(a, e, j)$ is consistent with the policy functions $\pi(j'|a, b, e, j; S)$ and the wealth distribution $\Psi(db|a, e, j)$.

4. $\Psi(db|a, e, j)$ is consistent with the policy function $b'(a, b, e, j, j')$ and the probabilities $\pi(j'|a, b, e, j; S)$.

Since this is an open economy so there is no market clearing condition for the bond market.

4.6 Solution

Given the complexity of the model it is of no surprise that there is no closed form solution and so I resort to numerical methods. To simplify this, I first derive some steady-state equilibrium relationships for the housing rents and the price of housing.

Since the rental housing stock is owned by a competitive foreigner with deep pockets a no arbitrage condition between rental and owner-occupied housing must hold. That is the price of a home must also equal the present discounted value of future rents. If we let the price of rental housing in city j be p_{rjt} then it must be that

$$p_{rjt} = p_{jt} - \left(\frac{1-\delta}{1+r}\right) p_{jt+1}. \tag{18}$$

Equation (18) comes directly from solving the rental firm's problem. Using this we can easily solve for the price of rental housing in terms of the owner occupied housing. Note that in steady-state since all prices are constant this implies that $p_{rj} = \frac{r+\delta}{1+r} p_j$.

Furthermore, the competitive nature of the construction sector means we can solve for the representative construction firm's problem to solve for house prices in each region in terms of the measure of households in the region. It is thus easy to show that the equilibrium house prices in each region is given by

$$p_j = \frac{1}{A_h}\left(\frac{H_j}{\overline{\overline{H}}_j}\right)^{\alpha_j}, \tag{19}$$

where $H_j = \sum_{a,e} \mu(a,e,j)$, is the measure of households in region j at time t. Again, in steady-state this measure must be constant. In equation (19) we can see that there is an increasing relationship between the price of housing in a region it's population density. As density increases regulations that limit the supply become more important and hence the price of housing will begin to rise.

Given a set of prices one can compute the conditional value function for a household living in location j', *excluding* the realized taste shocks (i.e. $W(a,b,e,j,j';S)$, and call this the conditional value function), by backwards recursion. Beginning in the final period of life we know that $\mathbb{E}[V(A+1,b',e,k;S')] = 0$, so the conditional value function can be computed easily. We can then use the conditional value function to calculate conditional choice probabilities and use these probabilities to evaluate the expected value function in the next to last period, $\mathbb{E}[V(A,b',e,k;S')]$, as in (11). This allows us to solve the households conditional value function in the second to last period. I continue this process until we reach the period in which the first period of life.

Specifically, I discretize the bond grid and interpolate over this grid. The remaining state variables a,e,j,j' are discrete and therefore are exactly represented on the grid. Note however, that even conditional on a,e,j we have a non-degenerate wealth distribution. This is because the entire history of locations that were visited matters for total earnings and spending on housing. Thus, the true endogenous wealth distribution of the model is a high dimensional object and cannot be represented exactly [13].

[13] In my quantitative exercise the true endogenous wealth distribution will have approximately 3.23×10^{15} points in steady-state, and hence is not computable.

Following Krusell and Smith, 1998 I approximate the true wealth distribution using a lower dimensional object. While it is tempting to use the first few moments of the unconditional wealth distribution to approximate the true wealth distribution this does not appear to accurately represent the true distribution well. This is likely due to the highly heterogeneous nature of the households. Wealth depends on age, education, location as well the history of locations the household visited.

Motivated by this I use the mean of wealth conditional on age, education and current location as my low dimensional approximation of the true wealth distribution. This removes the location history dependence from the wealth distribution. Simply put I assume that $b(a, b, e, j)$ is a constant in b. I solve for prices where households treat the mean level of wealth conditional on a, e, j as the true distribution[14].

I am thus left with a fixed-point problem where we need to solve simultaneously for equilibrium prices and equilibrium measures in each region. Computationally, I start with an initial price guess for the price of housing in each city. Then using this price guess, I solve the households problem and hence the implied measure of households in each city. The housing supply, in (19), maps these measures to implied supply prices. I then update the price guess using these supply prices. I repeat this until I converge to a predetermined tolerance. A more complete description of the solution method is in Appendix (A).

4.7 Model Discussion

The model in this paper differs from Diamond, 2016 or Schubert, 2020 in several key ways, one of which I highlight here. In my paper, households can be either homeowners or renters in my model and have a dynamic income-consumption problem. They can smooth their consumption and housing expenditures over their lifetimes using the risk-free asset. In my model households begin adult life as renters with little wealth, then save for a down payment, and become homeowners in middle age. This creates a life-cycle pattern of housing wealth and differences in the portfolio composition across households. These differences in housing wealth is one potential reason the impact of changes to land-use regulations might be heterogeneous across households.

In equilibrium housing demand is increasing in the region's productivity and amenity supply. A region with high-productivity or amenities is a more desirable location to live and so an all-else

[14] When I simulate the model using a large number of households using the steady-state prices I find that the measure of households that are in each city to be very close to the measures I found using the approximate wealth distribution.

equal rise in either local productivity or amenity supply will increase housing demand in the region. Therefore, except in the case that the local housing supply is infinitely elastic, the equilibrium house price will be increasing in local productivity and local amenity supply. However, differences in local housing supply elasticities and imperfect correlation between amenity supply and productivity will mean that there is not a perfect rank correlation between city productivity or amenity supply and house prices.

The model generates assortative matching between a worker's education and the city's productivity, in the sense that highly educated workers are more likely to locate in high-cost high-productivity cities. I show this in a simplified version of the model in Appendix C. Intuitively, since workers demand only one home, as a worker's income increases the expenditure share on housing declines and so they are better able to afford the high-cost high-productivity locations [15]. As equilibrium house prices are typically increasing in the regions productivity the model generates sorting along education and city productivity lines.

My model also generates a similar pattern of sorting along education and amenity lines. Since more educated households have a smaller marginal utility from consumption, they will tend to sort into expensive locations with a high amenity supply. Again, all else equal housing costs will be increasing in the local amenity supply and so the wealthy will tend to locate in high amenity locations. However, the presence of idiosyncratic preference shocks means that the model does not generate perfect sorting along education and city productivity lines, as we see in Van Nieuwerburgh and Weill, 2010. Some highly educated households will select less productive areas as their idiosyncratic preferences for living in a location are sufficiently large to offset the reduced consumption or amenity utility.

5 Data

This paper uses the Core-based Statistical Area (CBSA) from the Office of Management and Budget as its definition of a city. The paper's main data source is the US Census 5% microdata samples from IPUMS (Ruggles, Flood, Foster, Goeken, Pacas, Schouweiler, and Sobek, 2021). My sample consists of workers aged 25-66 living in US metropolitan areas. I aggregate counties into CBSAs using the NBER crosswalk where appropriate. I estimate the model taking 1990 as a steady-state. Summary statistics for the Census sample data are in table 1

[15] In the data I find that a 10% increase in household income increases expenditure on housing by about 2% when a city-level fixed effect is included.

Wages: From the 5% microdata samples I obtain wages for individuals. This gives wages conditional on location, age, education, worker-industry, and hours worked.

Migration: The 5% microsample includes the location of the worker five years ago. International migration rates and annual total city population comes from the Census Bureau.

House prices: A quarterly index panel of house prices for the top 100 cities is available for US cities beginning in 1990 from the Federal Housing Finance Authority (FHA). I use this data as it is based in actual transactions rather than appraised housing values. I use the 1990 5% sample to get the initial level of house prices in each city. Using the FHA data I obtain the log annual house price growth for each city by taking the log annual difference in the house price index over time [16]. I combine this with the land-use regulation index from Gyourko, Saiz, and Summers, 2008 and the fraction of land that's available for development from Saiz, 2010.

City land area: I obtain data on the city size from the US Census Bureau. I define the $\overline{H}_j$ of the city to be the metropolitan land area in square miles and I normalize this measure so that the total land area sums to one. These city-level summary statistics are in table 2.

Amenities: Local amenities supply consists of per capita supply of services establishments, from the Quarterly Census of Employment and Wages. As described in section 6 I combine this with per capita violent crime from the FBI to create the local amenity supply of the city using a principal components analysis. Summary statistics are in table 3.

Local Productivity Growth: Using the Quarterly Census of Employment and Wages I create Bartik productivity shocks to calculate the changes in productivity in each region. Specifically, I use the 1990 county-level three-digit NAIC industry wage-bill shares [17] and aggregate these up to the CBSA level[18]. In constructing the national productivity change for industry i for city j I exclude the city j's contribution to that national change. Thus, the productivity shock for industry i in city j is the product of the 1990 wage bill share times the all but j change in real hourly wage in industry i. The total productivity shock for city j is then the sum of wage bill for industry i times the all but j change in real hourly wage for industry i. Specifically, the wage bill

[16] All prices are deflated to their 1990 values using the personal consumption expenditures index from the BLS.

[17] In calculating the productivity shock I hold the wage bill shares fixed at their 1990 level, as the industry composition is likely endogenous to the skill makeup of the area. So endogenous changes in the skill make-up the region could affect the measurement of productivity.

[18] I aggregate up from the county level to the CBSA level as when a lower unit is censored for anonymity reasons all higher units associated with it be censored. Thus, aggregating from lowest level unit (counties) leads to the least amount of censoring.

shares for industry i in city j is given by

$$WB_{ij} = \frac{\text{Hourly wage } 1990_{ij} \times \text{Hours } 1990_{ij}}{\sum_k \text{Hourly wage } 1990_{kj} \times \text{Hours } 1990_{kj}}. \tag{20}$$

Given these wage bill shares the productivity shock for city j in year $t+1$ is given by

$$\Delta \log(\tilde{w}_{jt+1}) = \log(\sum_i WB_{ij} w_{i-jt+1}) - \log(\sum_i WB_{ij} w_{i-jt}), \tag{21}$$

where w_{i-jt} is the all but j hourly wage for industry i in year t. Table 2 contains summary statistics for the city-level data used in the paper.

6 Parameterization

For the quantitative exercises I parameterize the model so that one period is five years as this maps easily into the Census data on intercity migration. I assume that education takes five values, less-than high-school, high-school, some-college, bachelors, and more than bachelors. I develop an estimate for local amenity supply, estimate the housing supply elasticities and preference parameters of the workers. The remaining parameters of the model are either calibrated from the literature or estimated directly.

I parameterize the model so that one period represents five years, as intercity migration data conditional on education and age is at the five-year frequency. Life begins at age 25 and ends at age 65. I reduce the dimension of amenities to a single variable, calibrate and estimate the model's parameters.

6.1 Amenities

To calculate amenities, I use per person establishment counts from the Quarterly Census of Employment and Wages. The following amenity producing industries are counted Arts, Entertainment, and Recreation NAICS 71, Drinking places, NAICS 72241, Restaurants and Other Eating Places, NAICS 72251, Grocery Stores, NAICS 4451, Motion Picture and Video Exhibition, NAICS 51213, and Clothing and Clothing Accessories Stores NAICS 448. Per capita violent crime data comes from the FBI.

Since amenities are assumed to have only one dimension in the model and that many of these amenities are correlated with each other, I follow Diamond, 2016 and perform a principal components analysis (PCA) on the amenities data, pooling all the data from all time periods. I scale the data so that all variables have a mean of zero and a standard deviation of one. The loadings on the first principal component are in table 4. The value amenities in city j at date t is the sum of the product of the loading on each variable on the first principal component times the value of the variable in the city at time t.

As we can see in table 4 the PCA has a positive loadings on the per-capita number of amenity establishments in the city. Thus, as one would expect a higher number of service establishments in a city means the amenity supply of the city is larger. We see that there is a negative loading on violent crime, indicating that cities with more violent crime have lower amenities. Again, this is in line with economic intuition as crime is a negative amenity.

In Figure 7 I plot the log level of amenities over time. As we can see the average level of amenities has increased over time, reflecting increased per person services supply and falling violent crime.

6.2 Calibrated Parameters

The assumption that there is no default and that debt must be fully collateralized implies in steady-state that the borrowing constraint must satisfy $\psi \leq 1 - \delta$. A borrowing limit greater than this would mean that the household's debt at the beginning of the next period would be greater than the value of their collateral. In addition assume that the lender doesn't recover the full value of the home. Evidence from Campbell, Giglio, and Pathak, 2011 suggests that homes sold as part of a forced sale are sold below their market value. I therefore follow their paper and assume a 6.5% loss when the borrower defaults, which is their estimate for the loss in value when a home is sold around a bankruptcy by a single seller.

As is well known in the literature, e.g. Arcidiacono and Ellickson, 2011, it is difficult to estimate the discount factor with dynamic discrete choice models. I therefore assume that $\beta = \frac{1}{1+r}$ so that the discount rate of households equals that of the foreign investors. I set the real-interest rate equal to the post-war risk-free rate of 1.3% annual, Jordá, Knoll, Kuvshinov, Schularick, and Taylor, 2019, and hence the discount factor equals $(0.987)^5 = 0.9366$. I set the annual depreciation rate on housing to equal 0.77%, Davis and Heathcote, 2007, which implies that that per period depreciation rate equals 3.9%.

A final model parameter that is calibrated is A_h, the productivity at which consumption is converted to housing. In calibrating this parameter, I target the average house-price across cities in

1990 and use the estimated housing supply elasticities that are derived later. After estimating α_j for each city I use the IPUMS data I calculate the measure of households in each region and then using the estimated elasticities and city sizes I can calculate the predicted house price in each region. Using the equilibrium condition for house prices I set A_h to match the population weighted mean of house prices across cities. That is $A_h = \sum_j \frac{1}{p_j} \left(\frac{H_j}{\overline{H_j}}\right)^{\alpha_j} \frac{Pop_j}{\sum_k Pop_k}$. All calibrated parameters are in table 5. [19].

6.3 Estimating City Productivity and Effective Labor Supply

Since workers sort into cities, it is difficult to estimate the initial level of productivity, as more productive regions will tend to have workers who are more educated on average. This positive assortative matching between the worker's effective supply of labor and the city's productivity means that comparing average hourly wages between regions will tend to overstate the productivity differences between them.

From the labor consumption goods equilibrium we the wage of a worker of age a and education e in city j is given by $f(a, e)$

$$Wage_{jae} = A_j f(a, e). \tag{22}$$

Taking logs of 22 and assuming that age and education have separable effects on wages [20], that is $f(a, e) = g(a)s(e)$. Then I can write the log wage of worker l with education e working hours h per week living in city j as

$$\log(Wage_{ljeiah}) = \delta_j + \delta_e + \delta_a + \delta_i + \delta_h + \varepsilon_{ljeiah}. \tag{23}$$

where I include an additional fixed effect, δ_i, for the worker's industry. The estimates of δ_j are the city's 1990 productivity level. The estimates of δ_e are used to calculate the effect of education on wages and represent our estimate of $s(e)$. The δ_a will be used to capture the effect of age on earnings, that is our estimate of $g(e)$. The remaining terms are controls that don't map explicitly to model objects. The results of this regression are in table 6.

[19]It is possible to allow A_h to vary between cities reflecting underlying construction productivity differences, e.g. due location specific technologies, such as the need for buildings to be resistant to earthquakes in California. For this paper however I assume that the construction sector productivity is constant across regions.

[20]Including an interaction term between the workers age and education does little to affect the measurement of initial city productivity. Results available upon request.

6.4 Estimating Elasticities

A key parameter that needs to be estimated is the housing supply elasticity. The housing supply elasticity determines the responsiveness of local house prices to a change in the population (or equivalently the housing stock) of the city. I allow elasticities to vary across cities reflecting how the supply elasticity varies across regions but assume that this elasticity are a function of local land-use regulation.

From the construction firm's first order condition I can solve for equilibrium price of housing in each city. The inverse housing supply relationship is:

$$p_{jt} = \frac{1}{A_h}\left(\frac{H_{jt}}{\overline{\overline{H}}_j}\right)^{\alpha_j}, \tag{24}$$

which determines the price of housing in each city. Note that by taking the derivative of the log of 24 that we can see that the housing price elasticity for city j is equal to

$$\frac{1}{\alpha_j}. \tag{25}$$

To estimate the value of α_j in each city I take log differences of (24) and obtain

$$\Delta \log(p_{jt}) = \alpha_j \Delta \log(H_{jt}) + \Delta \log(A_{ht}) + \Delta u_{jt}. \tag{26}$$

In (26) I allow the construction sector productivity to vary across regions and over time, as Δu_{jt} may be non-zero. Regressing $\Delta \log(p_{jt})$ on the $\Delta \log(H_{jt})$ may lead to inconsistent estimates of α_j as the error term, Δu_{jt}, could be correlated with $\Delta \log(H_{jt})$. This is because construction sector supply-side shocks would change equilibrium quantities and prices. For example, an improvement in local construction sector productivity would likely reduce the equilibrium house price and hence increase the regional population. Hence, using OLS to estimate (26) would lead to inconsistent estimates for α_j.

To alleviate these endogeneity issues, I propose using international migration as an instrument for local housing demand shocks. The literature has argued that international migration takes place along established networks reflecting the cultural nature of migration Saiz, 2010. This implies that international migration patterns are unrelated to local construction sector productivity and hence that they are a valid instrument for H_{jt} [21].

[21] Diamond, 2016 and Schubert, 2020 instrument for housing demand using shift-share productivity shocks similar to what I constructed in section 5. However, recently Goldsmith-Pinkham, Sorkin, and Swift, 2020 raises questions as

As argued by Glaeser and Gyourko, 2018, Glaeser et al., 2005, and Quigley and Rosenthal, 2005 beyond a certain threshold construction costs are approximately linear in floor area. Constructing a ten story building costs approximately twice as much as constructing a five story structure and so without any land-use restrictions there should be no relationship between density and house prices. As these papers argue, by restricting the supply of new housing land-use regulations increases the price of housing in a region. Motivated by this, and similar to Diamond, 2016 I thus assume that local housing supply elasticity depends on the level of land-use regulations within a city. I therefore that the local housing supply elasticity has the following functional form[22]:

$$\alpha_j = \alpha \exp(Regs_j), \tag{27}$$

where $Regs_j$ measures the stringency of land-use regulations of city j, from Gyourko et al., 2008. The value of α_j used is the predicted value from our regression. In addition to the main variable of interest, the interaction of exponential of regulations and log population changes, I include the log of the total population and the log of the land that is not available for development as controls in the regression. The results of this regression are in table 7. Figure 8 plots the geography of the estimated supply elasticities.

6.5 Estimating Household Utility Parameters

I first estimate city productivity levels and growth, the city housing supply elasticity. Then after determining the level of amenities in each city and calibrating the parameters in table 5 I estimate the household utility parameters.

The household's utility parameters, don't map easily to the data. I therefore structurally estimate these parameters by maximizing the likelihood of the model, Rust, 1987, Hotz and Miller, 1993, Aguirregabiria and Mira, 2002, Arcidiacono and Miller, 2011. In my case given a set of model parameters I can calculate the CCP of the household choosing location j' given their state. These CCPs form the the (pseudo) likelihood function of the model and model parameters are selected to maximize this likelihood function.

In the structural estimation I assume that the moving cost has the following functional form

$$\tau_{jj'} = \begin{cases} 0 \text{ if } j = j' \\ \tau \text{ otherwise.} \end{cases} \tag{28}$$

to the validity of shift-share instruments as one would need to assume that the initial industry shares are exogenous.

[22]With a linear functional form for α_j I find negative elasticities for a small number of regions.

6.5.1 Comparative Statics:

Using a likelihood method to estimate the model means all moments are simultaneously used to identify the remaining parameters of the model. However, it is instructive to examine some comparative statics to see how the different parameters determine different observable aggregates. The parameters θ and τ both play a role in determining the degree of sorting in the model. A larger θ will tend to reduce the extent to which more educated households are matched with more productive regions, as idiosyncratic preferences will be more important in deciding where the household lives.

In my model each period each household chooses a location j' conditional on their current state, that is their age, bond wealth, education, and current location. I observe the household's location choice, j', as well as their age, education and current location. The remaining state, the households (non-housing) financial net worth is therefore unobserved.

By contrast a larger moving cost, τ increases the degree of sorting of households along education and city productivity lines. A larger moving cost increases the costs of moving to a city to take advantage of an idiosyncratic preference shock. With a larger moving cost, a household will need a larger idiosyncratic preference shock to induce them to move. Thus, in a sense larger moving costs reduce the relative importance of idiosyncratic preference shocks and hence increase the degree of sorting.

Both θ and τ also impact the moving rates. A higher τ increases the utility loss the household receives when they move between two regions and so decreases the moving rate. A higher θ increases the moving rate. This is because a larger θ increases the size of the i.i.d. preference shocks. Since these shocks become relatively more important the household is more likely to move to a new region to take advantage of their idiosyncratic preference for living in a region.

In Figure 9 I plot the mean moving rate against values of τ for different θ. As one can see a larger θ increases the moving rate for a given value τ and that the mean moving rate is decreasing in τ. To measure the degree of sorting along productivity education lines I measure the correlation between the city-level productivity and the average education level. I plot this correlation in Figure 10.

6.5.2 Identification and Estimation

Owing to the structural assumption on the household's preference shocks the CCP of selecting a particular region takes the tractable form of equation 10. Since households die deterministically these CCPs can be computed by backwards recursion.

In my model each period each households choose a location j' conditional on their current state, that is their age, bond wealth, education, and current location. I observe the household's location choice, j', as well as their age, education and current location. The remaining state, the households (non-housing) financial net worth is unobserved in my data. Denote the individual state excluding their risk-free assets as x_i and the bond wealth as b_i. Households thus choose a location j_i' conditional on observed x_i and b_i.

Denote the household's utility parameters that are to be estimated as Ξ. Let $\pi(j_i'|x_i, b_i; \Xi)$ be the probability that a households chooses location j_i' conditional on state x_i and b_i, given model parameters Ξ. Label the probability distribution of household bond wealth conditional on state x_i as $\phi(b|x_i; \Xi)$ [23]. Then by the law of total probability I can write the likelihood that a household with observed state x_i who chooses location j_i' as

$$\pi(j_i'|x_i; \Xi) = \sum_{b \in Supp(B)} \pi(j_i'|x_i, b; \Xi)\phi(b|x_i; \Xi), \tag{29}$$

where the CCP, $\pi(j_i'|x_i, b; \Xi)$, comes directly solving the households problem, $Supp(B)$ is the support of bond wealth given the state x_i and parameters Ξ. Given observations N of household location choice, conditional on age, education, and previous location, the maximum likelihood estimate of the parameters solves,

$$(\hat{\Xi}, \hat{\phi}) = \arg\max_{\Xi, \phi} \sum_{i=1}^{N} \log(\pi(j_i'|x_i; \Xi)) = \sum_{i=1}^{N} \sum_{b} \log(\pi(j_i'|x_i, b; \Xi)\phi(b|x_i; \Xi)). \tag{30}$$

As (30) is not additively separable estimating Ξ requires an knowledge of ϕ and the distribution of ϕ depends on the estimates Ξ. To estimate this I therefore use the expectation maximization method proposed in Arcidiacono and Miller, 2011. Using the ECCP algorithm requires the following assumption:

Assumption 1. *Every household's individual state follow a Markov process that depends only on the previous realizations of the the household's individual state.*

It is easy to see that states in my model are Markovian. In the model the household's age, education are deterministic and depend on only the previous values of age and education respectively

[23] The model implied distribution of the risk-free will be discrete due to the assumption that all households start with no financial wealth.

and hence are Markovian. The model implies policy functions for bond wealth, $b'(a, b, e, j, j')$, and location choice that depend only on current state and choice. Thus, in the model bond wealth and current location are also Markovian in current state.

Finally, in estimation I assume that 1990 represents a steady-state for the US economy and estimate the model to the 1990 data [24]. The 5% Census microdata sample Ruggles et al., 2021 contains the location choices of individual households conditional on their age, education and previous location. Table 1 contains summary statistics for this data.

6.5.3 Interpretation of Estimates

The results of the estimation are in table 8. In line with theory all parameter estimates are positive and significant. In isolation the estimated parameters are difficult to interpret. To ease the interpretation I calculate a first order approximation to the compensating variation when the parameter is change for the hypothetical mean household. I define this mean household as a household with the mean consumption of households across age, education, and location[25]. I then interpret the parameters in dollar terms by calculating the change in utility, $\Delta U(x)$, as a result of a change in parameter x, and calculating change in consumption required to make the household indifferent to this change. This is given by

$$\Delta c u'(c) \approx \Delta U(x). \tag{31}$$

The Δc term then is an approximate change in consumption required to keep the household indifferent.

From table 8 we see that the estimated parameter ω is 0.0027. This implies that the average worker would be indifferent between a one standard deviation increase in amenities and a 0.43% increase in consumption or approximately \$165 in 1990 terms. However, the concave nature of consumption utility mean that this differs across households. The most educated households would be indifferent between \$263 increase in consumption and a one standard deviation increase in local amenity supply.

In line with the literature, Kennan and Walker, 2011, the estimated intercity moving costs are large. The estimated value of τ is 3.1. This is equivalent to \$118,577 for the average household in

[24] This is of course a strong assumption. However, given the difficulty in computing an out-of-steady equilibrium, and the need for repeated computation in estimation I defer further discussion to future research. See Ahlfeldt, Bald, Roth, and Seidel, 2020 for a more detailed discussion of transitional dynamics in models with migration costs.

[25] I exclude the youngest cohort as they have no moving costs by assumption

the model. A large migration cost is to be expected in this model given the only 11.7% percent of households report moving cities in the past five years.

The final parameter that needs to be interpreted is θ, which governs the importance of preference shocks to the household. To interpret this parameter, I use equation 11, the expected utility prior to the realization of the preference shock. On average for a household at location j who remains in location j they would be indifferent between a $12,922 increase in yearly consumption and not receiving preference shocks.

For households that receive a preference shock large enough to induce them to move they would expect to be indifferent between an increase in consumption of $96,869 and not receiving the shock. While this seems large, given how large the estimated moving costs are it is no surprise that households need a large preference shock to induce them to move [26].

6.6 Evaluating the Model

Here I explore some steady-state results from the model. I solve for the steady-state of the model in 1990 using the estimated parameters. I then use this to derive some comparisons. In the model we have that the mean moving rate across all households is 10.12%, which is somewhat smaller than the 11.7% observed in the data. [27]

I calculate the correlation between city-level productivity and the the 1990 share of the population with at least a bachelors degree in the data and in the model. Roughly speaking the stronger this correlation is the greater the degree of spatial sorting along education and city productivity lines. The city-level productivity in both the model and the data is calculated the city-level fixed effect from the regression in (23). In the data I find a positive correlation of 0.32 between the share of the population with a college degree and the city's labor productivity. In the 1990 steady-state of the model the same correlation is 0.62, or about twice as large as the data. Thus, the model predicts more sorting along education and city productivity lines than we see in the data.

As discussed in section 3 in the data there is strong correlation between the return on housing in the city and the productivity shock. In Table 9 I show the results of a regression of the log change of the region's house price between 1990 and 2019 on the shift-share productivity shock for the city during the same period. I perform this regression using both the observed changes

[26] One could of course view the sum of the preference shock and the moving costs as a single random variable where the mean differs depending whether the household currently lives in the city.

[27] Recall that we in effect choose the parameters of the model to match *all* the moments of the data and so we don't match the moving rate exactly.

in regional house prices and 1990 and 2019 steady-state prices from the model. In both cases the coefficients are positive and highly significant. While this regression is purely to illustrate the observed correlation, in the data a 1% increase in the city productivity shock increases the local real house price by 4.7% over the 1990 to 2019 period. In the model a 1% increase in productivity over this period increases the steady-state price by 7.4%.

7 Counterfactuals

Using the estimated model, I can evaluate the heterogeneous effects of several counterfactuals on different cohorts. Increases in housing elasticities make high-productivity and high amenity cities more affordable. In steady-state consumption and amenity utility increases more for young than for older cohorts. In the short-run however, older households may see the values of their homes decrease relative to the world where the housing supply is restricted.

In addition to changing the land-use regulatory environment I explore whether other changes can generate similar changes in consumption. During the COVID-19 the fraction of workers who work from home increased dramatically, motivated by this I examine the long-term impact that this change would have consumption across different household groups. Finally, I examine how creating new urban areas impacts different household groups.

7.1 long-run Impact of Removing Land-use Regulations

To assess the long-run impact of changes in land-use regulations and other policies I compare the steady-state of the counterfactual economy to the steady-state of the baseline economy. In particular I compare how consumption and the utility from amenities changes for different households between these different steady-states.

I compare the 2019 steady-state with the estimated local housing supply elasticities to one where I remove all land-use regulations. Since the land-use regulation measure has real support, this implies that $\alpha_j = 0$ for all cities j[28]. This implies that the local housing supply is infinitely elastic. When supply elasticity is infinity it is easy to see that the price of housing is equalized in all regions. In both steady-states city amenities, city productivity levels, and total population measure are set to their 2019 level.

[28]In practice the smallest value of α_j that I observe in the baseline economy is 0.22. Deregulating all cities to this level leads to a rise in aggregate consumption of 6.59% versus 7.13% when all regulations are abolished. The other results are also quantitatively similar.

There are three potential sources of changes in household well-being when comparing these two steady-states. First consumption may increase as households move to higher productivity regions. Intuitively local area productivity will be positively correlated with house prices, as households will prefer areas with high-productivity to those with low productivity, which raises local housing demand. Thus, when these elasticities rise, households will tend to move to regions with higher productivity, increasing their income. Secondly, housing costs will decrease within a region. This increases the after housing costs income of households within the city and hence their consumption. Finally, since regions with good amenities have expensive housing, increasing elasticities will tend to increase household amenity utility, are able to afford high these high amenity supply cities.

In aggregate I find that removing all land-use restrictions increases aggregate consumption by 7.13%. Steady-state incomes rises by 3.34%. The remaining increase in aggregate consumption is due to decreased housing costs. Income dispersion between cities, measured by the coefficient in variation in incomes between them, declines by 22.09%, as highly productive cities now have a greater number of less educated workers. In total amenity utility grows by 8.55% between these two steady-states as workers move from low amenity locations to high amenity areas.

In Figure 11 I plot how the equilibrium consumption changes for different household groups from the baseline 2019 steady-state to a steady-state where land-use regulations are abolished. The top portion of Figure 11 plots the percent change in consumption between the two steady-states conditional on household education. From the figure we can see that consumption growth between the steady-states is largest for households with the lowest level of education and that consumption growth monotonically decreases as household education increases. The rise in consumption for the least educated group is over 9.5%, while the percent increase in consumption for the most educated group is 5.1%. Thus, removing land-use regulations leads to a reduction in consumption inequality between household groups.

The bottom portion of Figure 11 plots the percentage change in consumption for households conditional on age between these two steady-states. The oldest households see the smallest gain in consumption when we compare these two steady-states, with a consumption gain of approximately 3.8%, or less than half that of the youngest households. Interestingly households aged 45 are the ones with the largest gains in consumption. Their consumption grows by 9.5% between the two steady-states. This is an artifact of the life-cycle pattern of housing ownership and the household borrowing constraint. When a household enters the period in their life where they become a homeowner the borrowing constraint incentivizes them to move from being a renter in a high-cost region to a homeowner in a lower cost region or to significantly reduce their consumption that period. When housing prices are equalized across regions the incentives to move disappear and the reduction in prices means the borrowing constraint becomes less binding.

In Figure 12 I plot the growth in amenity consumption between the two steady-states conditional on education and age. In the upper portion of Figure 12 I plot the growth in amenity utility between the two steady-states conditional on education. This figure shows that there is a strong relationship between household education and the increase in amenities between the two steady-states. The least educated households see the largest gains in amenities, with an increase in amenity consumption of about 16%. In comparison the most educated household group see a rise in amenity utility of just 3.19% between the two steady-states. Thus, removing land-use restrictions reduces amenity inequality between households.

The lower section of 12 plots how amenity consumption grows between the steady-states conditional on age. Unlike consumption there is only a weak relationship between age and amenity consumption growth between the two steady-states. All age cohorts receive similar gains in amenity consumption, due to the persistence in location choice over the household's life and the imperfect correlation between amenities and productivity. The oldest age group see the smallest increase in amenity consumption with a rise of approximately 8.5%. The growth in amenity utility is 9.24% for the 30 year old group.

7.2 short-run Impact of Removing Land-use Regulations

In steady-state I showed that relaxing land-use regulations increased consumption of all education and age cohorts. In reality there is substantial opposition to new development in many parts of the country. Not in My Backyard (NIMBY) organisations exists on all sides of the political spectrum and have succeeded in blocking new construction in their area, citing disruption caused by construction and congestion externalities due to increased population. However, it is difficult to separate concerns about negative externalities, from the substantial economic benefits that existing homeowners receive when they limit the supply of new housing.

Existing homeowners reap substantial capital gains on their homes when they limit the supply of new housing. Older homeowners purchased their homes in an era where land-use regulations were less pervasive and hence the housing supply was much more elastic. When local homeowners vote for stricter land-use regulations in their city, they increase the marginal cost of producing housing and hence increase its price. As housing is the largest asset in the portfolios of most households the life-time consumption benefits from these capital gains can be substantial.

These gains come at the expense of younger households, as they have no housing wealth and must purchase a home to live in [29].

To quantify the winners and losers from land-use regulation I examine a transition between steady-states with the baseline values of land-use regulations and when land-use regulations are abolished. In these transitions I begin at the 1990 steady-state. I assume that changes to local amenity supply, national population, and productivity are completely unanticipated, but fully known upon impact. Local amenity supply is the supply in the region at each time. Productivity is the 1990 productivity plus the shift-share productivity shock up until that period. Specifically, to compute the productivity growth I use the cities 1990 wage bill shares across all 3-digit level industries and multiply that by the national change in wages for that industry excluding the city itself. Summing across all industries yields the city's change in productivity. The construction of local productivity is detailed in section 5. I assume that 70 years after the last shock we reach the new steady-state[30]. The total population will equal the total US population in the cities in my study.

To compute the equilibrium transition prices I compute a series of temporary equilibria and iterate until the expectations used in the temporary equilibria converge to realized equilibrium prices. To do this I first create a guess a sequence of prices for each city. Then working forward in time, I compute a temporary equilibrium, that is I compute the equilibrium price vector at the date, given the past computed equilibrium prices and the future price guess. Once I have computed all temporary equilibria, I restart computing the temporary equilibria beginning again in the first period and working forward, now using the previous sequence of temporary equilibria as the price guess. I continue to iterate until the differences in temporary equilibrium prices is small[31]. A full explanation of the solution method is in Appendix B.

I first examine how the return on housing evolves along the transition. In Figure 13 I plot the 1990 population weighted annualized return to owner-occupied housing during the transition. This return is simply the capital gain on a home in the region. As we can see homeowners experienced substantial unanticipated appreciation on their homes, increasing their net worth. After 2020

[29] It is possible that rent controls could impose further costs on the youngest cohorts. Diamond et al., 2019 finds that rent control reduced the supply of rental housing in San Francisco and hence increased rents for new households, while protecting incumbents.

[30] The curse of dimensionality significantly magnifies the difficulties that arise with computing the wealth distribution along a transition compared with the steady-state case, as the dependence on time increases the state-space considerably.

[31] In these transitions assume that households fully anticipated the entire path of the changes to productivity, amenities etc. upon impact. The actual expectations in 1990 may not match this exactly. However, alternative methods for forming expectations can easily be incorporated into my framework. I leave this as something for further research.

there are no further shocks to the economy, and I allow the economy to gradually approach the new steady-state. This Figure shows that homeowners, particularly the oldest generations, experienced substantial anticipated capital gains on their housing.

To calculate which cohorts are winners and which are losers I calculate the present discounted mean consumption of different generations along both the actual and the alternative transition. I then plot the percentage difference in household consumption between these two transitions in Figure 14. As we can see from Figure for cohorts born before mid-1960s their life-time consumption is larger when land-use regulations are equal to their baseline level. This is because the capital gains they receive on their housing more than offsets the fact that relative to the counterfactual households live in less productive cities.

From Figure 14 we can see that for younger cohorts and particularly those born after the 1970s their consumption is larger in the counterfactual transition where I remove all land-use regulations. This is because these groups are largely renters when the shock occurs and hence don't receive most of the capital gains on housing. In the counterfactual world these households will tend to locate in higher productivity cities, which increases their wages. Furthermore, when they purchase their home they benefit directly from cheaper housing, increasing their consumption.

7.3 Switch to Working from Home

While the direct influence of policy makers on the ability of workers to work from home is limited, the COVID-19 pandemic has exposed that workers can increasingly work remotely, Brynjolfsson, Horton, Ozimek, Rock, Sharma, and TuYe, 2020. While it is not possible to accurately forecast any long-term changes in work arrangements, it seems likely that an increased fraction of households will work from home rather than commute, Barrero, Bloom, and Davis, 2021, Gupta, Mittal, Peeters, and Van Nieuwerburgh, 2021 [32]. It is thus interesting to consider how the reallocation across space of workers due to a rising fraction of households working from home will change welfare.

When a worker's productivity is no longer tied to their location, they may relocate to take advantage of better amenities or reduced housing costs. Anecdotally many workers, who were now working from home, left the San Francisco Bay area during the COVID-19 pandemic to take advantage of lower housing costs in other regions Bowles, 2021. Workers leaving a city when they can work from home causes housing costs to fall, increasing the after-housing cost income

[32] As the model is estimated so that a single period represents five years it is ill-suited to examining the very short-term impact of households leaving cities during the COVID-19 pandemic.

of workers who remain [33]. In steady-state, new workers, who by assumption cannot work from home, may enter the city now that prices are lower, and hence increase the productivity that's available to them.

A rising fraction of households working from home is not Pareto improving, however. Workers who don't work from home and are living in low-cost cities that experience an inflow of workers will be worse off if they stay. This is because in steady-state housing costs will increase and their wages will not change. This is similar to what happened in many smaller low cost cities, such as Boise, during the COVID-19 pandemic [34].

To model a work from home policy I follow the literature and assume that 20% of workers can now work remotely. I assume that a worker who works from home receives the national average productivity for their education type from the previous 2019 steady-state. That will be the weighted average city-level productivity, with weights that depend on the measure of type e in each city. I then solve for the new steady-state of the model, which will show the long-run effect of a shift to working from home. This means that the productivity of a household who is working remotely may increase or decrease. For those living in a low productivity region it will rise, while those in high-productivity regions it will decrease.

I find that aggregate consumption grows by a modest 1.39% across all workers. Workers who don't work remotely see a rise of 1.12%, while workers who work from home see a rise in their consumption of 2.42%, implying that the workers who benefit the most from the change in the work environment are those that can work from home. However, the model does not encompass all the benefits of the shift to working from home. Commuting times will fall, as many workers no longer need to commute and workers who don't work remotely face less congestion.

In Figure 15 I show that the least educated workers see the largest increases in consumption of workers. This Figure plots how consumption changes between the baseline 2019 steady-state and a steady-state where 20% of workers work from home. From the Figure we can see that on average households with a post-graduate education see consumption gains of about 1.1%, while those with less than high school education see gains of about 1.7%. Recall that I assumed that all workers are affected by the switch to working from home equally. So, this result is not due to

[33] There are several difficulties that arise in quantifying the short-run impact of the COVID-19 pandemic on different housing markets. First, since many of these high-cost cities, such as New York, were most affected by the initial pandemic waves, the expected duration of the pandemic would play a crucial role in determining the movement of workers and prices. Moreover, many high-cost high-amenity regions had more stringent lock-down policies, reducing amenity supply to a greater extent than in other cities. This would further reduce housing demand for these regions.

[34] See https://www.apartmentlist.com/research/national-rent-data for trends in city rent data.

difference in the propensity to work remotely but rather due to differences in the likelihood of reallocating across cities and variation in spending on housing across households.

I find that the change in consumption caused by the switch to remote working is non-monotonic in age and approximately U-shaped. In Figure 16 I show that while the youngest cohorts see the largest increase in consumption, middle-aged households see almost no rise in their consumption and the oldest cohorts see a moderate rise in their consumption. The youngest group see an increase in consumption of 1.72% while the 50 year old group see approximately no change in consumption. This non-monotonic relationship arises as the workers productivity is hump shaped in their age. Thus, as young workers approach middle age, they tend to relocate to higher productivity places. As a worker continues to age their individual level productivity begins to fall and so they move to lower cost, less productive places. When working from home this incentive to move between regions of different productivity disappears and so we observe this non-monotonic relationship.

7.4 Creation of New Cities

Despite recent progress in reforming land-use regulations in states such as California [35], it seems unlikely that there will be a complete removal of all land-use regulations in the near future. An alternative to deregulating zoning in existing cities could be the creation of new cities on unincorporated land. In states such as California incorporating new cities was used to increase the housing supply in the early post-war era. In the 1960s 46 cities were incorporated in the state, while there have been no new incorporated cities in the past decade.

To simulate the impact of creating a new urban area I increase the number of urban areas in the model by 10%. I assume that each of these new cities has the population weighted mean productivity, amenities, and housing supply elasticity from the 2019 steady-state[36]. I then solve for the steady-state of the model. The creation of new cities in the model mirrors how new urban areas were created and existing ones saw the development of new suburban communities in the post-war era.

I find that a 10% increase in the number of urban areas leads to a 1.41% increase in aggregate consumption compared to the 2019 baseline steady-state. The rise in aggregate consumption is

[35] With the signing into law of state level legislation S.B. 9 and S.B. 11 in September 2021 state law will now override many local zoning restrictions

[36] The magnitude of the changes that creating new cities induces is sensitive to the assumed amenity supply and productivity of the new cities. The more productive the new regions the larger the magnitudes.

exclusively due to the reduction in housing costs. In fact average incomes are approximately unchanged between the two steady-states. In the model all else equal adding a new region will decrease the probability that a household selects from the existing places. Thus, in equilibrium the creation of new cities reduces demand for all existing regions, decreasing housing costs in these regions. This in turn increases the after-housing costs income of households and hence their consumption.

The effect of creating new cities is also heterogeneous across households. In Figure 17 I plot the how consumption changes conditional on the age of the household. From the Figure it is clear that younger households see larger gains in consumption than older households. Consumption for the youngest households rises by 1.76% while for the oldest household groups it grows by only 0.02%. Again, the largest gain in consumption is when the household becomes a homeowner, when consumption grows by a little over 2.1%.

Adding new cities also reduces consumption inequality conditional on education. In Figure 18 I plot the consumption growth between the baseline 2019 steady-state and one where the number of cities is increased by 10%. As one can see from the Figure the percentage increase in consumption is more than twice as large for the least educated households compared with the most educated ones. Households with less than high-school education see increases in consumption of 2.05%, while those with a post-graduate degree see increases in consumption of 0.89%. This differences in the consumption gains are due to differences in expenditure shares on housing for households with different education levels and because low-wage workers are able to afford more productive regions, as prices fall.

8 Conclusion

Pervasive land-use regulations, such as setback requirements, urban growth boundaries, and height limits, have had an enormous effect on the US economy. By increasing housing costs in the most productive cities, they have allocated labor away from these regions towards less productive but cheaper areas. The costs of land-use regulations potentially vary across households due to differences in portfolio composition and their effect on the spatial sorting of households.

My paper quantifies the heterogeneous costs of land-use regulations across households of different ages and education levels. To quantify these costs, I estimate a structural dynamic spatial equilibrium model of household location choice. My model features overlapping generations of households who differ in terms of age, education, wealth, and current location. Households choose a sequence of locations to own or rent housing, trading off local amenities, wages, moving costs, and housing costs. To quantify the effects of land-use regulations, I conduct two sets of counterfactual experiments exploring the long-term and short-term impact of land-use regulations.

To examine the long-run effects of land-use regulations across different household cohorts, I compare steady-states with the estimated land-use regulations to one where all land-use regulations are abolished. In my model removing land-use regulations makes the local housing supply infinitely elastic, equalizing prices across cities. Abolishing land-use regulations increases aggregate consumption by a modest but significant 7.1%, as workers move from less productive areas to the most productive cities. However, abolishing land-use regulations reduces the degree of spatial sorting and hence this effect differs across households depending on their education and age. The least educated households see gains in consumption that are about twice as large as the most educated, and the youngest households see consumption gains that are about three times as large as the oldest cohorts.

My finding that all cohorts benefit from removing land-use regulations raises the question as to why they are so pervasive. To answer this, I examine the transitional dynamics between steady-states. I begin at the 1990 steady-state and feed in the estimated sequence of productivity shocks, amenity supply and total population. I compare how consumption of different generations changes along a transition with the estimated elasticities and one where land-use regulations are abolished. I find that removing land-use regulation hurts cohorts born before the 1960s, while benefiting younger cohorts. This is because the large capital gains that older homeowners receive on their home more than offsets any losses from living in less productive regions.

The results of this paper suggest that while changes in land-use regulations can bring about substantial benefits, particularly to lower-income households, in the short-run many older cohorts will be negatively affected. Since older households tend to be more politically active, it is no surprise that even relatively modest reform proposals, such as S.B. 9 and S.B. 10 in California, face substantial opposition. Motivated by these difficulties, I explore whether allowing workers to work from home or increasing the number of cities can substitute for reducing land-use regulations. My results imply that while the benefits of these alternative policies are qualitatively similar, quantitatively the benefits are only 20% as large as removing land-use regulations from existing urban areas.

The current study can be extended in several directions; an important one is noted. For tractability, this study does not feature any local agglomeration economies. If agglomeration economies proved significant, then strict land-use regulations may decrease long-term total productivity growth. Potentially contributing to the slow-down in total factor productivity growth over the past 30 years.

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A Computing the Steady-State

I first create a non-linear grid for bonds around zero, so that the grid density is higher close to zero. All other state variables are discrete and can be exactly represented on a finite grid.

To compute the steady-state of the economy we I begin with an initial guess for the price of housing in all markets. Conditional on this price guess I can solve the household's value function, working backwards from the final period of life until birth. The next step is to solve forward for the measure of households in each city conditional on the price guess. Given the households value function conditional on choosing j' given its state variables, $v(a, b, e, j, j')$, and equation 10 we have the probability of choosing j' conditional on state variables.

Recall that by assumption in the initial period there are no moving costs so the value function does not depend on j. I also assume that the households starts life with no bond-wealth. Hence choosing an arbitrary initial location, l, the measure of households in each city j' in period zero of their life [37] is

$$\mu(a, e, j') = \frac{\exp(v(a, 0, e, l, j'; S))^{\frac{1}{\theta}}}{\sum_k \exp(v(a, 0, e, l, k))^{\frac{1}{\theta}}} \tag{32}$$

which we compute by interpolating over b and the measure in city j' conditional on type e and age a is written as $\mu(a, e, j')$. We of course set $a = 0$ for the first period of life.

We now need to solve for bond wealth for all future periods of life. This will be an exact function of all previous locations, age, and education. As previously argued, since the number of locations is large it is not possible to compute this exact function. I therefore calculate bond wealth conditional on current location. Let $b(a, e, l, j')$ be bond wealth conditional on age, education, previous location, and current location. For age one we then have that

$$b(1, e, j, j') = b'(0, 0, e, l, j) \tag{33}$$

where we use the policy function for b' at age zero, education e, initial location l, interpolating over zero bond wealth. The next step is to calculate bond wealth is to use the probabilities and measures to get bonds conditional on current location and not past cities. Define a conditional probability $\tilde{\pi}(a, e, k, j')$ as follows,

$$\tilde{\pi}(a, e, k, j') = \frac{\pi(a, b(a, e, k, j'), e, k, j') \times \mu(a, e, k)}{\sum_l \pi(a, b(a, e, l, j'), e, l, j') \times \mu(a, e, l)} \tag{34}$$

[37] I index beginning with zero not one.

where we are interpolating over b in our function $\pi(a, b(a, e, k, j'), e, k, j')$. I then use this to calculate the bond wealth conditional on current location as follows

$$b(a, e, j') = \sum_k \tilde{\pi}(a, e, k, j') \times b(a, e, k, j') \tag{35}$$

I calculate bond wealth conditional on previous location j and current location j' for all ages after one using

$$\zeta(a, e, l, j) = \frac{\pi(a, b(a, e, l), e, l, j) \times \mu(a-1, e, l)}{\sum_k \pi(a, b(a, e, k), e, k, j) \times \mu(a-1, e, k)} \tag{36}$$

$$b(a+1, e, j, j') = \sum_l b'(a, b(a, e, l), e, l, j) \times \zeta(a, e, l, j) \tag{37}$$

We can then iterate forward using the above steps and calculate $\mu(a, e, j')$ for ages and types. Then using the data measure of households with education e, $g(e)$, and the fact that life last $\overline{a}$ periods the measure in each city equals

$$\mu(j') = \sum a, e(1/\overline{a}) \times f(e) \times \mu(a, e, j') \tag{38}$$

where I use the implicitly assumed independence between a and e. [38] With the measure in each city I then use 19 and the measure to create a price implied by housing supply conditional on the level of demand for housing. That is

$$p_j^s = \frac{1}{A_h} \left(\frac{\mu(j)}{\overline{H}_j} \right)^{\alpha_j}. \tag{39}$$

I then calculate the error, defined as the absolute maximum difference between the vector p^s and the initial price guess p. I terminate the program if this error is sufficiently small. If not I update the price guess by taking a weighted average between the two vectors as $p' = (1 - \phi)p + \phi p^s$ and restart the entire iteration. [39] I continue iterating until I reach the preset error.

B Solving for transitional dynamics

To solve for the transitional dynamics between two steady-states we need to find a sequence of prices for points along a path which begins at the pre-shock steady-state price and ends at the

[38]While I could allow for education to vary with age, in this model death occurs at the same deterministic time for all households. So, for a steady-state I need the measure of households with education e to be constant over age.

[39]If the error grows over successive iterations ϕ is reduced, until we begin to converge.

post-shock steady-state prices. The initial distribution of households across cities and wealth is taken to be the initial steady-state values. I create the series for the amenities, productivity, etc. in each city at each time period during the transition. Even after all the shocks have happened we are not necessarily at the steady-state as the endogenous distribution of households over regions and wealth may continue to change. I therefore add many periods after the shocks, amounting to 95 years, during which there are no further shocks.

The algorithm for solving for the price path along the transition is as follows. I first create an initial price guess by interpolating between the two steady-state prices. I use equation 18 to create the initial guess for city rents. I begin at the first period and solve for equilibrium prices under the assumption that all future prices are correct. To do this I solve for the households problem using equations 11, which contains the expected value conditional on choices, bond holdings and future prices. The conditional expected value is computed by backwards induction beginning in the final period of life. So, for a household with a periods of life left we need to solve 11 a times, each time using the previous value.

After completing the household's problem at time zero of the shock I then calculate the conditional choice probabilities using 10. Using the initial steady-state measures of households in cities conditional on a, e, and the initial steady-state bond-wealth distribution I compute the measure of households in each location conditional on age and education as well as the average bond-wealth conditional on age, education and location. Using this measure I can calculate the unconditional measure of households in each location, conditional on the initial price guess.

If the difference between the price guess and the price implied by 19 is sufficiently small I move to the next period. If not I then update the price, but *only* for period zero, using a weighted average of the current assumed price for period zero and the price implied by 19 for period zero. When resolving note that only period zero and period one see changes in rents or house prices, reducing computational needs.

Once period zero has converged to a preset tolerance I continue to period one. I solve for the households problem under the, now using the equilibrium prices and distributions from our solution in period zero. Solving the households problem is similar to period zero. However, I have already computed many of the conditional expected future values, which reduces the computation burden. I proceed in computing all future periods in a similar fashion.

After reaching the end of the time periods in the transition I calculate the absolute maximum difference between the initial price guess and the updated price guess across all cities and all time periods. If this difference is sufficiently small we have converged. Otherwise we restart the inner loop at time zero with the new updated price as the initial price guess. We continue this process until either the difference in prices between subsequent iteration is sufficiently small or we exceed a predetermined maximum number of iterations.

C Sorting Results

Here I outline a simplified version of the model to illustrate the mechanisms that generate the positive assortative matching between worker education and high-cost high-productivity regions. That is that more highly educated workers locate in these high-cost high-productivity regions with a higher probability. high-productivity workers are more likely to choose to locate in high as surplus from a worker locating in a region is increasing in education and regional productivity.

To see this formally, note that from equations (8) and (10) we can write that the probability

$$\pi(j'|a,b,e,j;S) = \frac{\exp(\log(c_{j'}) + \omega\chi_{j'} - \tau_{jj'} + \beta\mathbb{E}[v(a+1,b',e,j')])^{\frac{1}{\theta}}}{\sum_l \exp(\log(c_l) + \omega\chi_l - \tau_{jl} + \beta\mathbb{E}[v(a+1,b_l,e,l))^{\frac{1}{\theta}}} \tag{40}$$

To simplify matters I examine renters with a binding borrowing constraint so that $b = 0$. Then for renters consumption is $c = A_{j'}e - p_{rj'}$ and for homeowners $c = A_{j'}e - p_{j'} + (1-\delta)p_j - \psi p_j + \frac{\psi}{1+r}p_{j'}$. To see the assortative matching let $\frac{p_k}{p_l} > \frac{A_k}{A_l} > 1$. Then for renters we have that

$$\frac{\frac{\pi(a,0,e',j,k;S)}{\pi(a,0,e',j,l;S)}}{\frac{\pi(a,0,e,j,k;S)}{\pi(a,0,e,j,l;S)}} = \left(\frac{\frac{(A_kf(a',e')-p_{rk})\exp(\mathbb{E}[v(a,0,e',k)])}{(A_lf(a',e')-p_{rl})\exp(\mathbb{E}[v(a,0,e',l)])}}{\frac{(A_kf(a,e)-p_{rk})\exp(\mathbb{E}[v(a,0,e,k)])}{(A_lf(a,e)-p_{rl})\exp(\mathbb{E}[v(a,0,e,l)])}}\right)^{\frac{1}{\theta}} \tag{41}$$

In the final period we the expected value term is zero. This simplifies this ratio to

$$\left(\frac{\frac{(A_kf(a',e')-p_{rk})}{(A_lf(a',e')-p_{rl})}}{\frac{(A_kf(a,e)-p_{rk})}{(A_lf(a,e)-p_{rl})}}\right)^{\frac{1}{\theta}} \tag{42}$$

Differentiating this with respect to $f(a',e')$ one can show that

$$\frac{\partial}{\partial f(a',e')}\frac{\frac{\pi(a,0,e',j,k;S)}{\pi(a,0,e',j,l;S)}}{\frac{\pi(a,0,e,j,k;S)}{\pi(a,0,e,j,l;S)}} = \frac{1}{\theta}\left(\frac{A_lf(a,e)-p_{rl}}{A_kf(a,e)-p_{rk}}\right)^{1/\theta}\left(\frac{A_kp_{rl}-A_lp_{rk}}{(A_lf(a',e')-p_{rl})^2}\right)^{\frac{1-\theta}{\theta}} > 0 \tag{43}$$

Since this derivative is increasing in $f(a',e')$ workers with a higher effective labor sort into regions with higher productivity. A similar result can show that this holds for homeowners as well.

The crucial economic force that drives sorting in the model is the non-homothetic demand for housing services. In the model, any household that lives in region j demands one and only one home in the region. Thus, within a region the proportion of expenditure on housing falls as wealth increases. This leads to sorting of more educated households into higher productivity, high housing cost regions. This because when the sorting condition holds, i.e. $\frac{p_k}{p_l} > \frac{A_k}{A_l} > 1$, and $f(a', e') > f(a, e)$ then

$$\frac{A_k f(a', e') - p_k}{A_j f(a', e') - p_j} > \frac{A_k f(a, e) - p_k}{A_j f(a, e) - p_j} \tag{44}$$

So that the ratio of after housing costs income between the two regions is larger for the highly educated worker. Which of course implies that the more highly educated workers are more likely to locate in these high-productivity regions.

Figure 1. This Figure plots the difference between the market value of residential real estate and it's replacement cost divided by nominal GDP. The residential real estate data comes from the Financial Accounts of the United States. Nominal GDP is from the BEA. The data runs from 1951 to 2019. The dashed (red) line is the OLS trend since 1951.

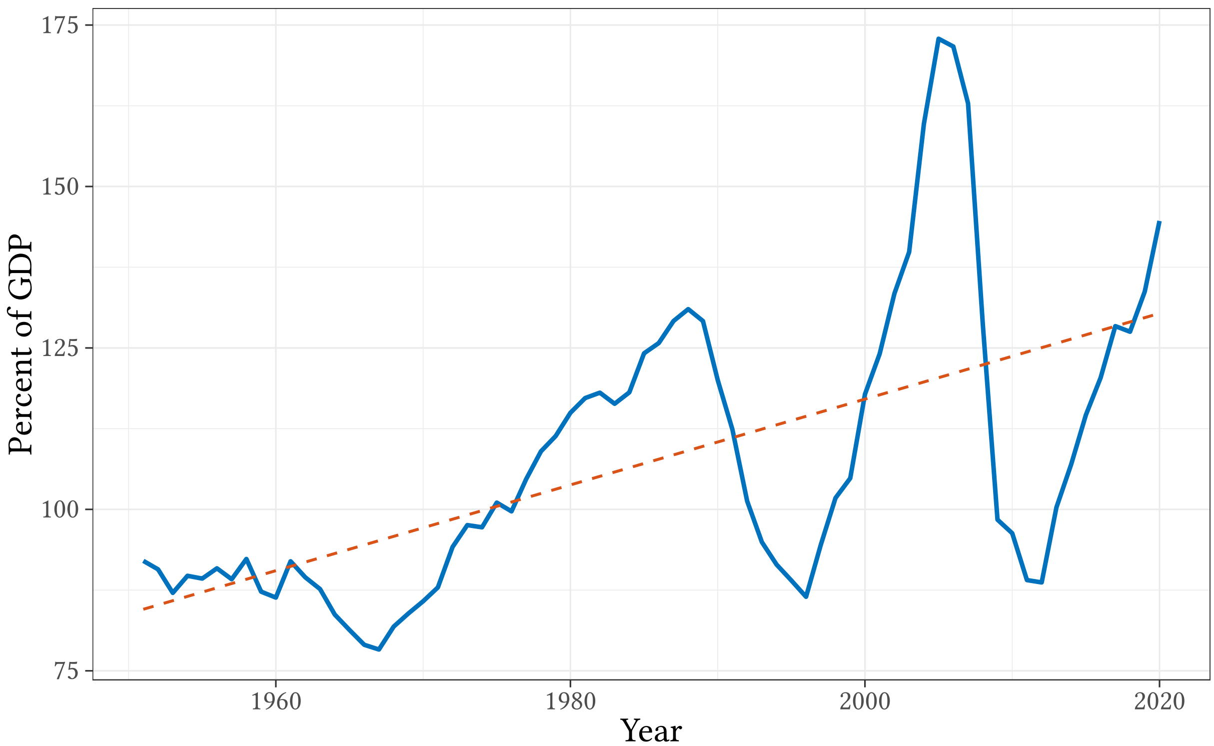

Figure 2. This Figure plots the share of output that's attributed to land or the economic profits earned by the housing sector. The calculation of land's share is described in the Appendix. All data is from the BEA. The data runs from 1967 to 2019. The dashed (red) line is the OLS trend since 1951.

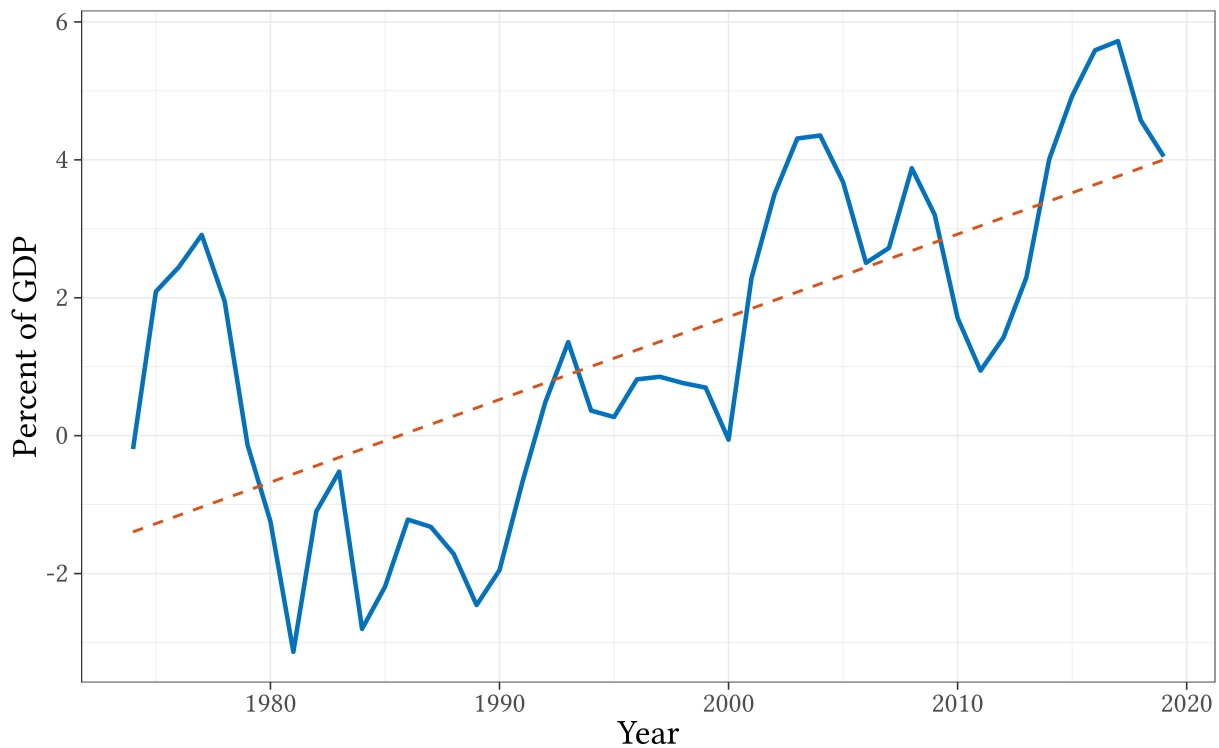

Figure 3. In this Figure I plot coefficient of variation in mean household income across US cities over time. The coefficient of variation is the standard deviation divided by the mean and provides a scale neutral measure of dispersion. Data on mean household income across cities comes from the Census Bureau and runs from 1969 to 2019.

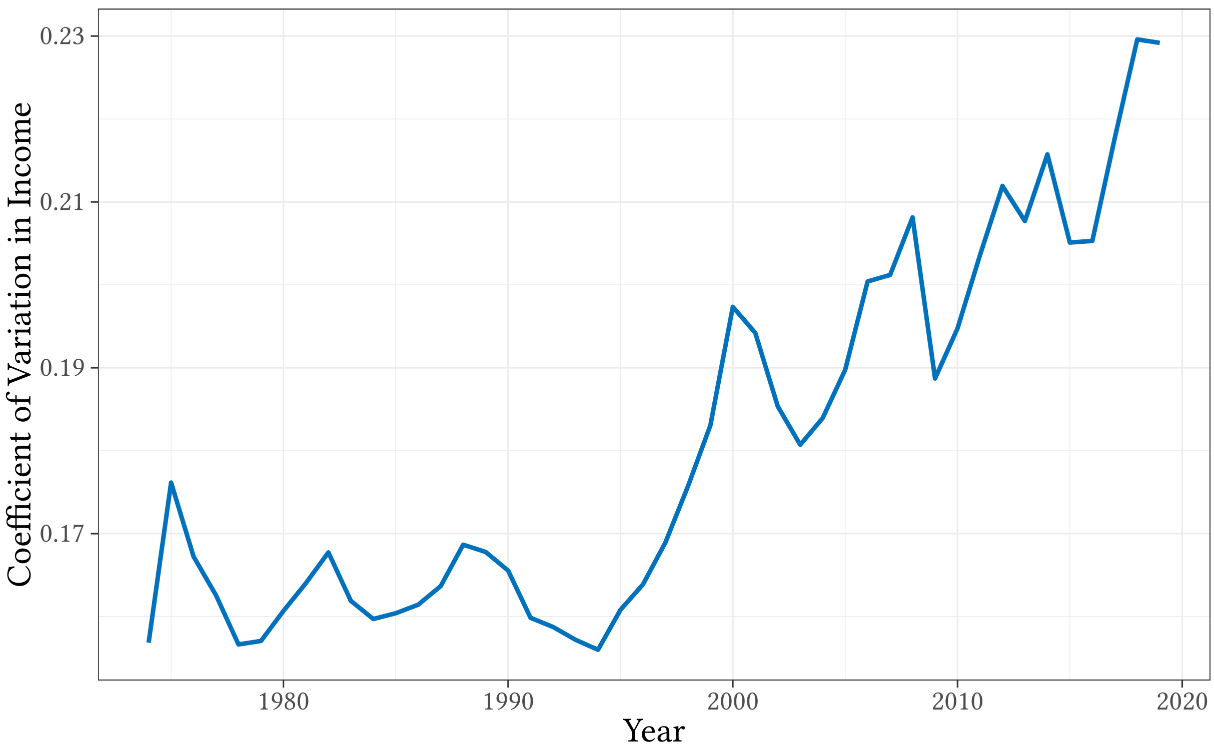

Figure 4. In this Figure I plot change in city productivity on the initial productivity level for US cities. All data is from the Census Bureau. The initial city productivity is the city-level fixed effect from a wage regression. The change in city productivity is the Bartik shock to wages.

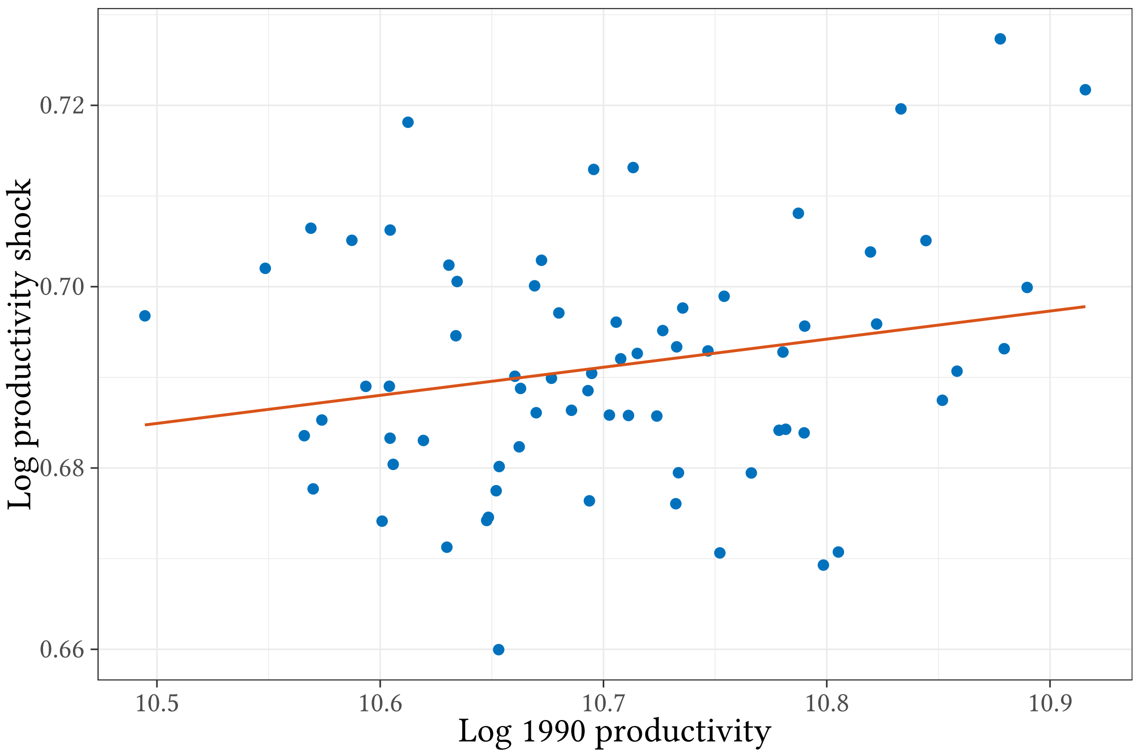

Figure 5. In this Figure I plot the change in the college share in US cities from 1990 to 2019 on the initial city productivity. All data is from the Census Bureau. The initial city productivity is the city-level fixed effect from a wage regression.

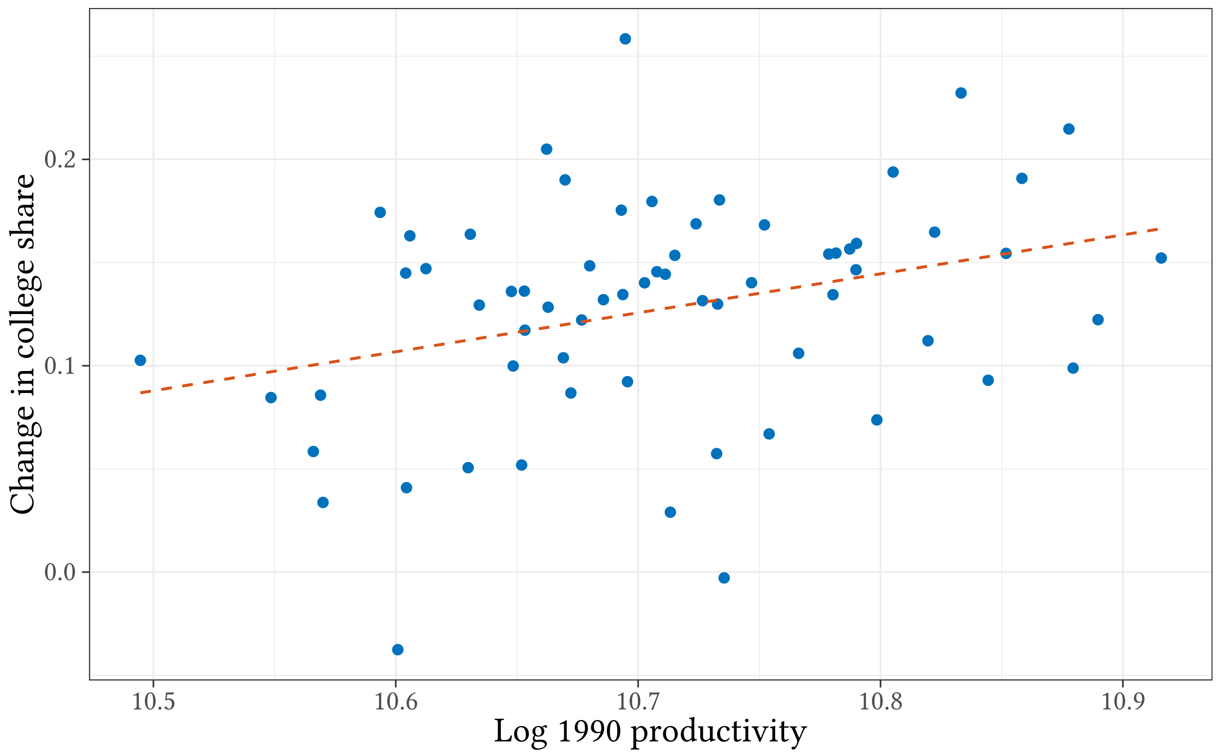

Figure 6. In this Figure I plot the change in log house price in a city against its change in log productivity as well as a regression line. The data runs from 1990 to 2019. The change in the log house prices is measured using data from the FHFA repeat sales index. The productivity shock is the shift-share instrument. This is constructed by fixing the industry shares of a city at their 1990 level and then using the the national change in wages for that industry *excluding* the contribution of the city itself to these changes in wages. Industries are defined at the three digit NAICS level.

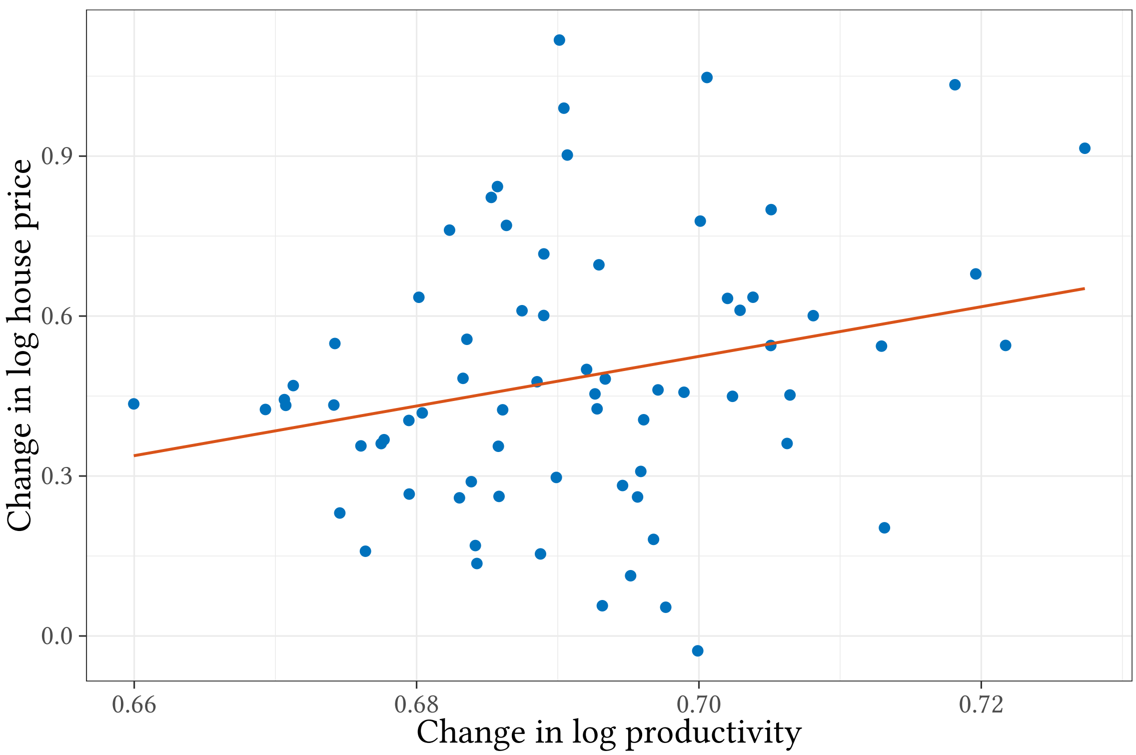

Figure 7. This Figure plots the mean level of the log level of amenities across cities over time. The level of amenities in a city equals the loadings in table 4 times the value of the variable in the city that year. Here I plot an unweighted mean across all cities in my sample.

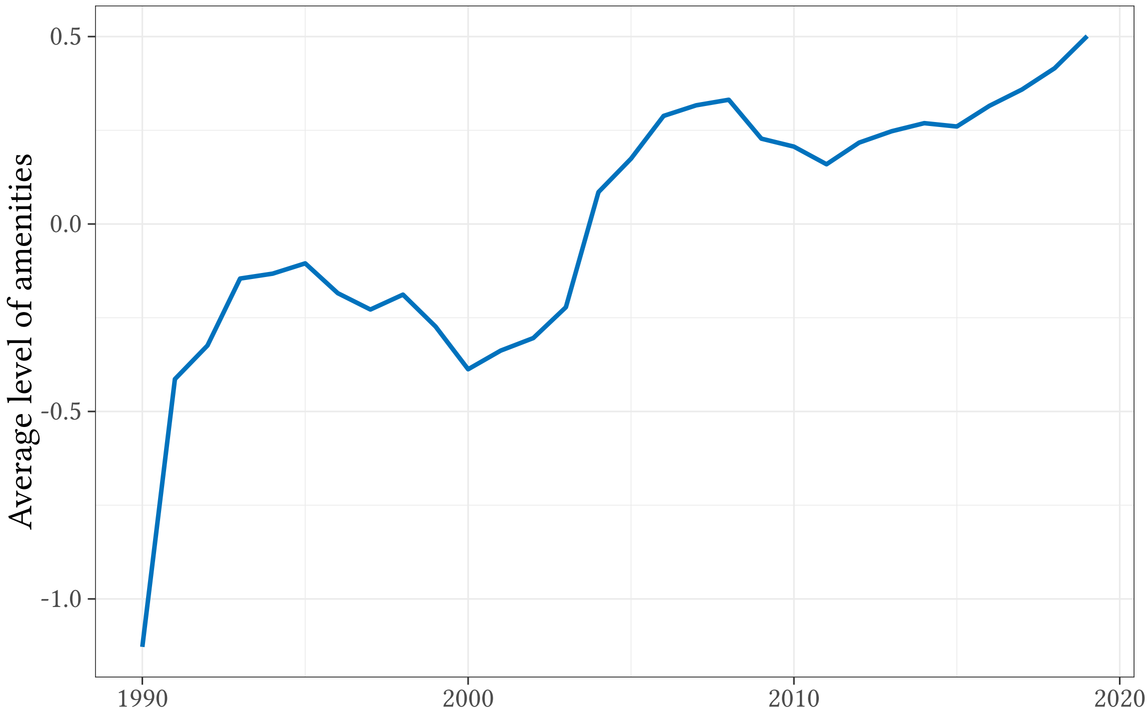

Figure 8. This Figure plots the housing supply elasticity in the cities used in the paper. I estimated the elasticities using equation (26), using international migration as an instrument. The size of the points on the map is proportional to the log population of the city in 1990. As one can see cities in the North-East and West have lower housing supply elasticities, whereas cities in the Midwest and South have higher elasticities.

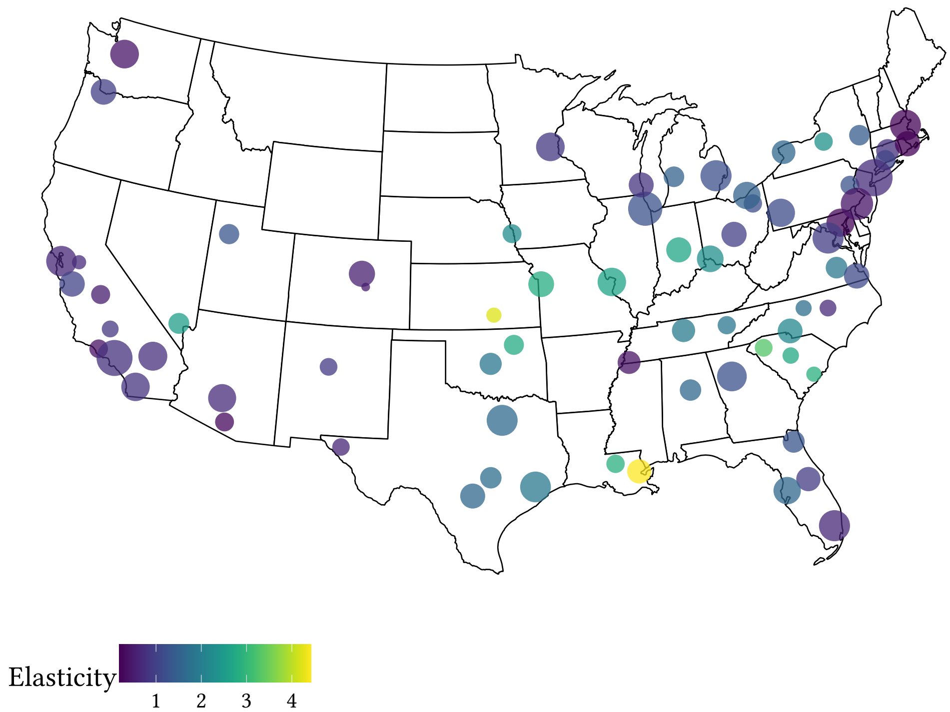

Figure 9. In this Figure I examine some of the comparative statics of the model. I fix ω and plot the mean moving rate against the moving cost, τ, for different values of θ, which determines the relative size of the utility shock. As one would expect a larger τ decreases the moving rate, as all else equal an increase in the moving cost reduces the equilibrium probability of moving. A larger θ increases the equilibrium moving rate as utility shocks are now larger and so households are more likely to move to take advantage of them.

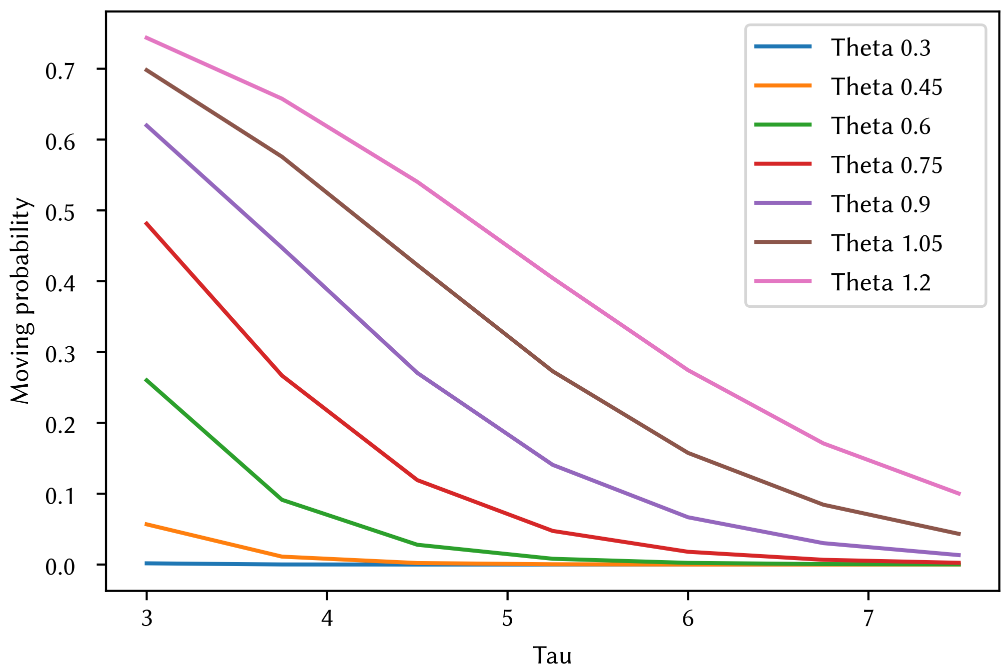

Figure 10. In this Figure I examine some of the comparative statics of the model. I fix ω and plot the the correlation between the average city-level of education and the city productivity against the moving cost, τ, for different values of θ, which determines the relative size of the utility shock. As one would expect a larger τ increases the degree of sorting along education-productivity lines, as all else equal an increase in the moving cost makes it more costly to take advantage of a one time good preference shock. A larger θ reduces the degree of sorting as it increases the relative importance of preference shocks and hence reduces the relative importance that income plays in determining location.

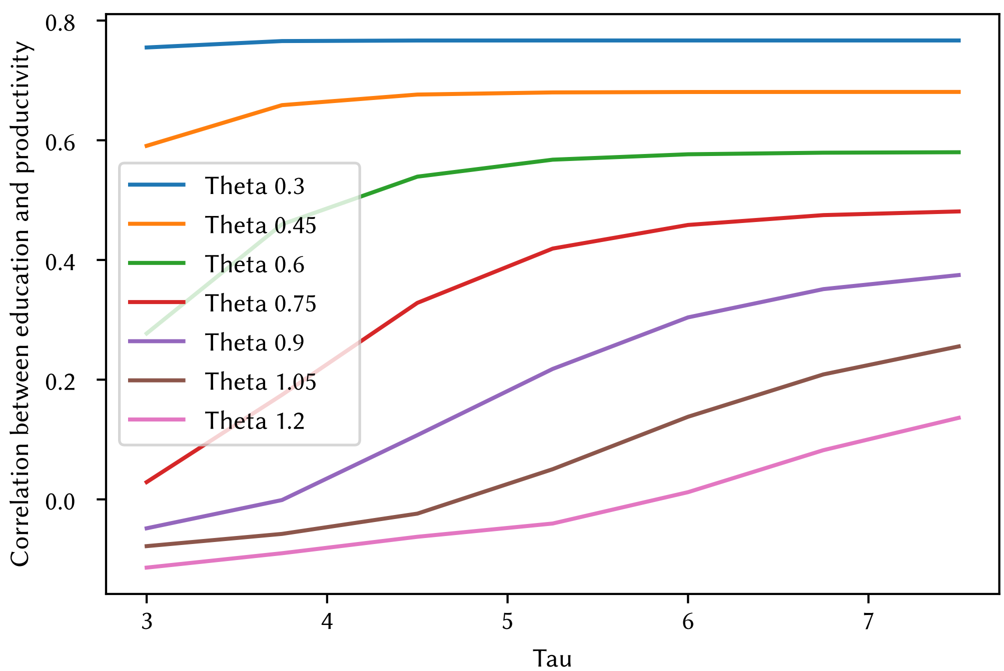

Figure 11. This Figure shows how consumption changes for different education and age cohorts between the baseline 2019 steady-state and one where all land-use restrictions are removed. From the Figure we can see that the least educated and young households see the largest increase in consumption when land-use regulations are abolished. Conditional on age we see that when the households transitions from being a renter to a homeowner (age 45) is when the consumption growth is largest. This is because during this period the borrowing constraint will bind for many households.

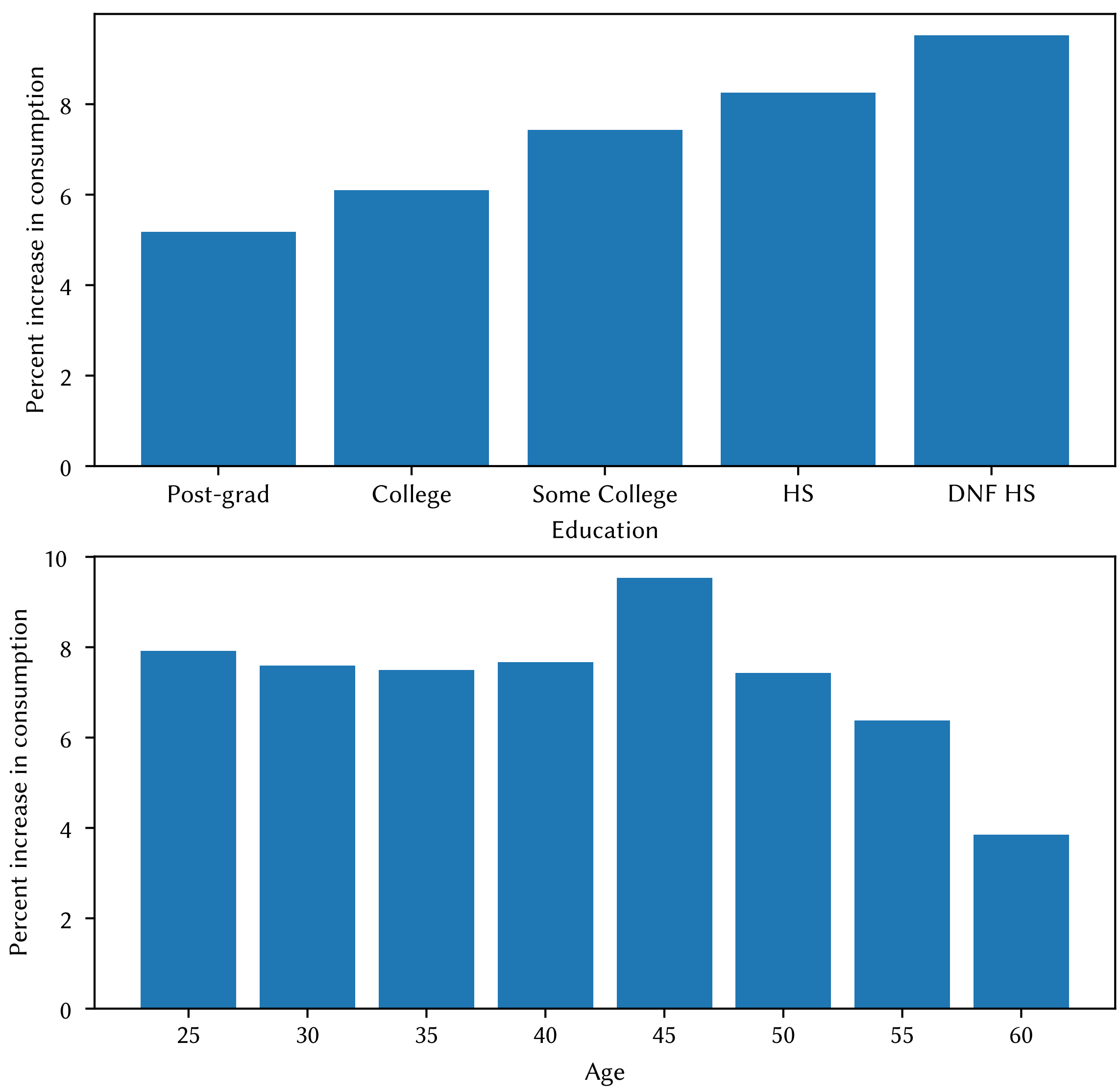

Figure 12. This Figure shows how amenity consumption changes for different education and age cohorts between the baseline 2019 steady-state and one where all land-use restrictions are removed. From the Figure we can see that the least educated see the largest increase in amenity utility when land-use regulations are abolished. Conditional on age we see that all households benefit equally in terms changes in amenity utility. This is due to the persistence of location choice over a households life time.

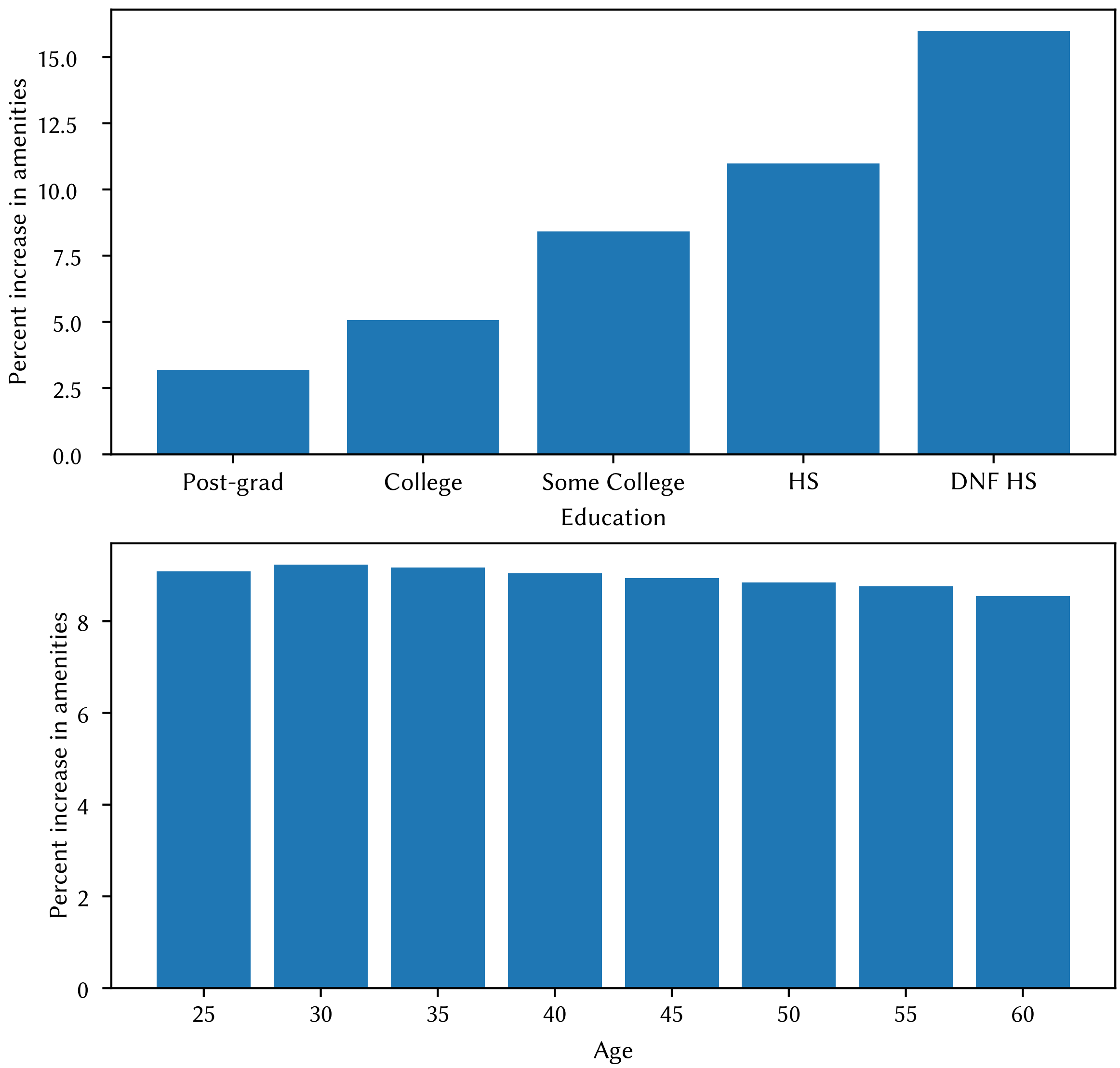

Figure 13. This Figure plots the percent annual real return to owner-occupied housing along the 1990 to 2019 baseline transition. In this transition I feed in the 1990-2019 productivity shocks and local amenity supply. The economy is initialized at the 1990 level and I assume that we reach the new steady-state after 80 years after the last shock.

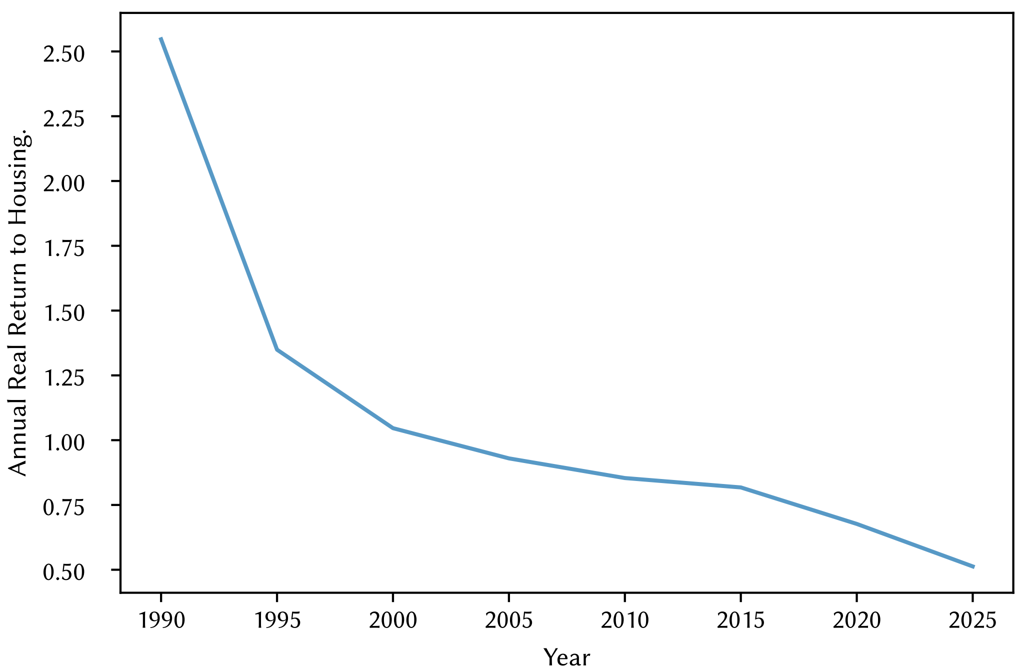

Figure 14. This Figure plots the percent change difference in consumption for different generations of households between a steady-state with the baseline land-use regulations and one where they are removed. I calculate the consumption along a transition between 1990-2019, feeding in the productivity shocks and local amenity supply changes that occurred. The economy is initialized at the 1990 level and I assume that we reach the new steady-state after 80 years after the last shock.

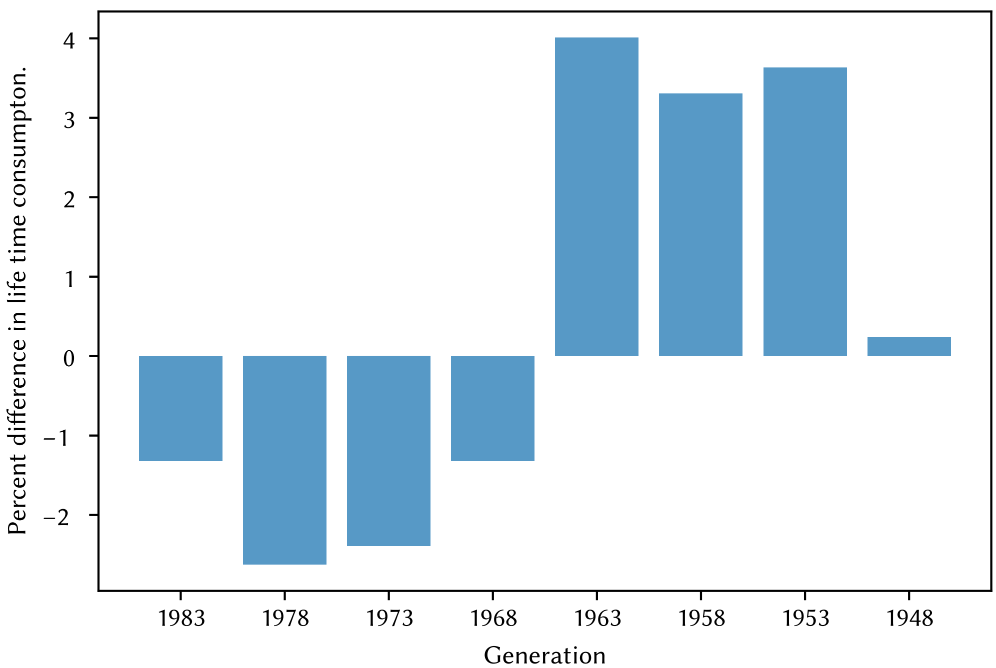

Figure 15. This Figure plots how consumption changes from the baseline steady-state in 2019 to a steady-state where 20% of workers now work from home, conditional on the worker's education level. When a worker workers from home they receive the 2019 population baseline steady-state productivity conditional their education group.

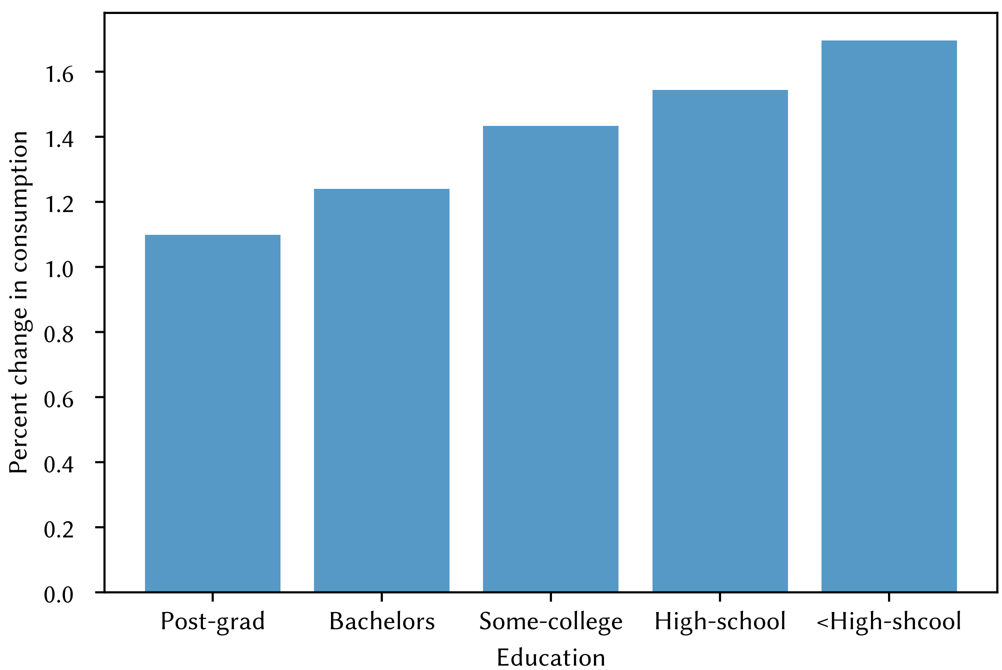

Figure 16. This Figure plots how consumption changes from the baseline steady-state in 2019 to a steady-state where 20% of workers now work from home conditional on the age of the worker. When a worker workers from home they receive the 2019 population baseline steady-state productivity conditional their education group.

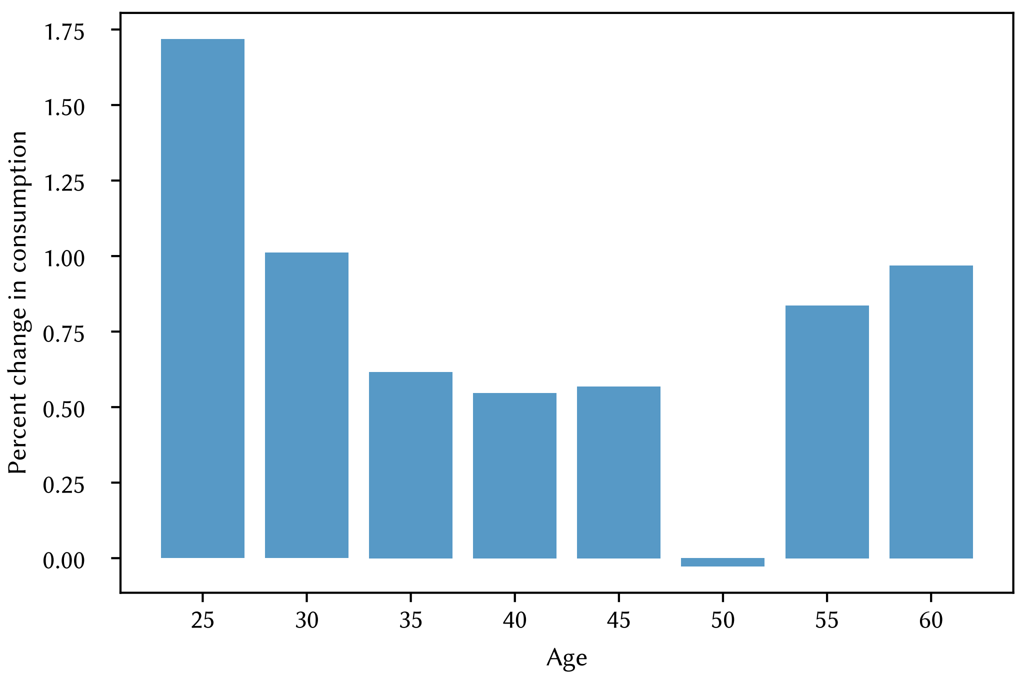

Figure 17. This Figure plots how consumption changes from the baseline steady-state in 2019 to a steady-state where the number of cities is increased by 10%, conditional on the worker's age. I assume that the new cities have the 2019 baseline population weighted mean productivity, amenities, housing supply elasticitiy and city land-area.

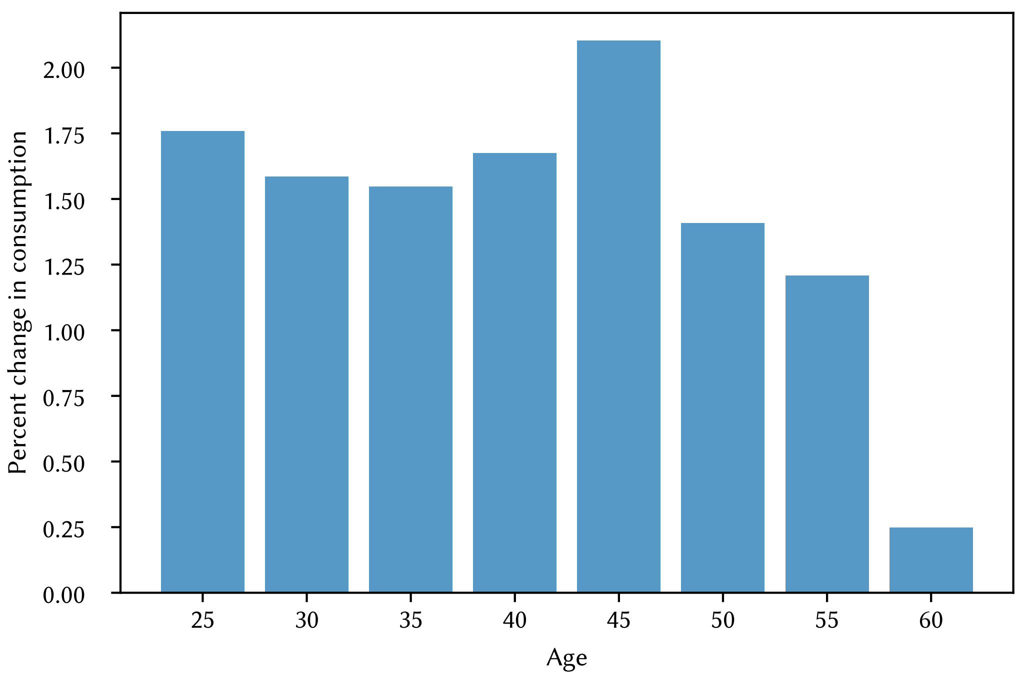

Figure 18. This Figure plots how consumption changes from the baseline steady-state in 2019 to a steady-state where the number of cities is increased by 10%, conditional on the worker's education level. I assume that the new cities have the 2019 baseline population weighted mean productivity, amenities, housing supply elasticitiy and city land-area.

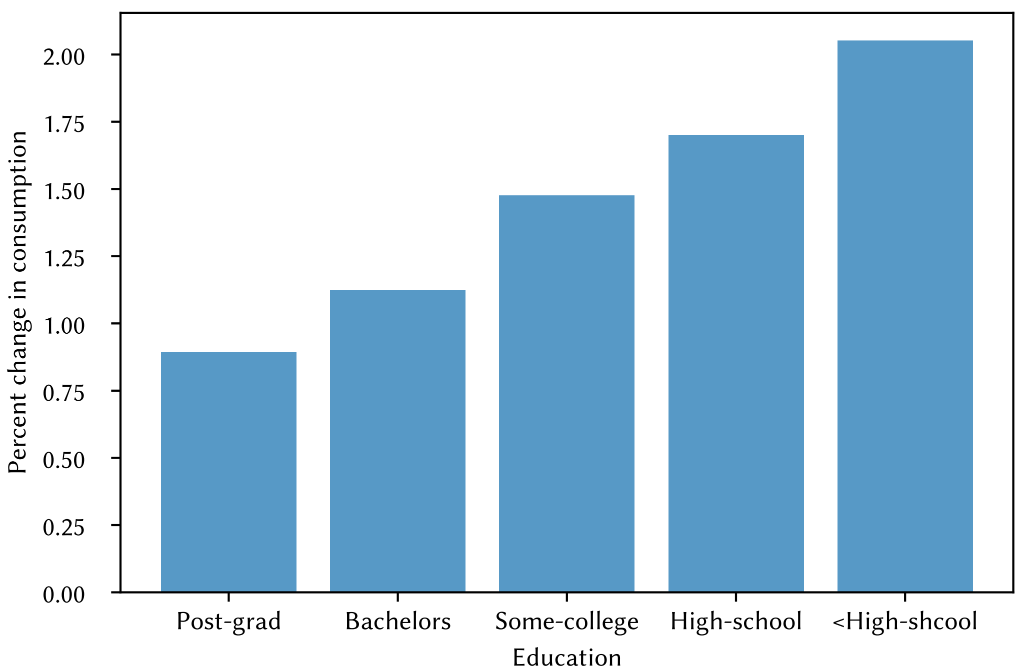

Table 1. Population summary statistics. This table presents the summary statistics for the household level data used to estimate the model. The model is estimated using the 1990 5% sample Census sample. All summary statistics are weighted appropriately to take into account the stratified nature of the data. Annual wage is the annual labor market earnings of the worker. Hours worked refers to the number of hours worked in a usual working week. Age is the age of the person in years. Migrated is a binary variable that equals one if the person lived in a different city in the previous 5 years.

Statistic	N	Mean	St. dev.	Median	Pctl(25)	Pctl(75)
Annual Wage	2, 262, 973	25, 757.790	25, 371.510	21, 000	10, 381	34, 000
Hours worked	2, 262, 973	39.670	13.197	40	40	45
Age	2, 262, 973	40.284	10.484	39	32	48
Migrated	1, 798, 742	0.117	0.321	0	0	0

Table 2. city-level summary statistics. This table present city-level summary statistics. Population, international migration per 1000 persons, and city land area comes from the Census Bureau. The change in the log house price comes from the FHA. The real wage shocks are the Bartik wage shocks and are derived from the Quarterly Census of Employment and Wages. The level of productivity is the city fixed effect from regression 6. The percent of land that cannot be developed is from Saiz, 2010 and the land use regulation index is from Gyourko et al., 2008.

Statistic	N	Mean	St. dev.	Pctl(25)	Median	Pctl(75)
Δ log(Population)	2,130	0.01	0.01	0.005	0.01	0.02
Inter. migration per 1000	2,130	2.85	2.39	1.22	2.20	3.59
Δ log(House prices)	1,740	0.04	0.06	0.02	0.04	0.07
City Amenities	2,400	−0.61	1.60	−1.50	−0.62	0.42
Real wage shock	2,059	0.02	0.01	0.02	0.02	0.03
Population 1990	71	2.11	2.67	0.70	1.31	2.46
Productivity 1990	71	44,681.83	4,190.94	41,530.12	44,121.87	47,688.69
City land area	71	711.26	632.09	313.18	523.03	779.86
Percent of land unavailable	71	25.44	21.07	9.04	19.05	38.22
Land regulation index	71	0.11	0.70	−0.38	0.05	0.54

Table 3. Amenities summary statistics. This table presents the summary statistics for the amenities used in the principal component analysis. All variables are in 1000 establishment/crimes per capita terms. Establishment counts comes from the Quarterly Census of Employment and Wages and violent crime data is from the FBI. Population data is from the Census Bureau.

Statistic	N	Mean	St. Dev.	Pctl(25)	Median	Pctl(75)
Art-recreation	2,400	0.347	0.109	0.284	0.335	0.398
Drinking places	2,400	0.442	0.110	0.365	0.429	0.504
Restaurants	2,400	0.253	0.081	0.196	0.245	0.304
Grocery stores	2,400	0.153	0.094	0.081	0.136	0.199
Cinemas	2,400	0.013	0.006	0.010	0.013	0.016
Clothing stores	2,400	1.426	0.267	1.239	1.432	1.606
Violent crime	2,400	1.744	1.100	1.050	1.586	2.316

Table 4. Amenities PCA loadings. This table presents the PCA loadings used in the calculation of amenities. All of the variables are in per capita terms and are standardized to have mean zero and variance 1.

Variable	Loading
Art-recreation	0.414
Drinking places	0.459
Restaurants	0.299
Grocery stores	0.214
Cinemas	0.383
Clothing stores	0.573
Violent crime	−0.092

Table 5. This table contains the model parameters that that were calibrated as well as the source.

Parameter	Description	Value	Source
$\beta = \frac{1}{1+r}$	Discount rate	0.928	Jordá et al., 2019
ψ	Borrowing limit	0.899	No-default assumption.
δ	Housing depreciation rate	0.039	Davis and Heathcote (2007)
A_h	Construction sector productivity	0.4851	1990 House-prices

Table 6. Individual Wage Regression. This table present the regression used to estimate the effect of age and education on wages, as well as the initial city productivity levels. I regress individual log wages from the 1990 5% census data for workers between ages 25 and 65 on dummies for educational attainment as well as city, age, hours worked, and industry fixed effects. For the education dummies the baseline group is college education and all estimated coefficients are how log wages differ relative to this base line. All Standard errors are clustered at the city and industry level.

Dependent Variable:	$\log(Wage)$
Model:	(1)
Variables	
DNF High-School	-0.6283***
	(0.0179)
High-School	-0.4102***
	(0.0152)
Graduate degree	0.2049***
	(0.0271)
Some College	-0.2618***
	(0.0097)
Fixed-effects	
City	Yes
Age	Yes
Hours	Yes
Industry	Yes
Fit statistics	
Observations	2,797,254
R^2	0.43675
Within R^2	0.08411

Two-way (City & Industry) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Table 7. Elasticity Regression. This table present the regression used to estimate the city-level housing supply elasticities. The model is estimated using international migration as an instrument for the change in population.

Dependent Variable:	Δ log($price$)
Model:	(1)
Variables	
(Intercept)	-0.0460*
	(0.0272)
exp(Regulation) × $\Delta Population$	0.7823***
	(0.2924)
log($Unavailableland$)	0.0011
	(0.0013)
log($Population$)	0.0033*
	(0.0019)
Fit statistics	
Observations	1,951
R^2	0.01761
Adjusted R^2	0.01610

Heteroskedasticity-robust standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Table 8. Structurally Estimated Parameters This table present the estimates of the household's utility parameters as well as the standard errors, Z values, p-values, and a 95% confidence interval. In all cases all parameters are highly significant positive.

Parameter	Estimate	Std. Err.	z	P> |z|	[0.025	0.975]
ω	0.0027	0.00019	14.102	0.000	0.0031	0.0023
θ	0.4937	0.00169	291.981	0.000	0.4969	0.4904
τ	3.0998	0.01098	282.322	0.000	3.121	3.078

Table 9. Population summary statistics. This table contains regressions of the log change in real house prices in a region on the log productivity shock for the same region. In column (1) the dependent variable is the change in log price is the change in the observed FHFA index. In column (2) the dependent variable is the log change in the steady-state price between the 1990 and 2019 steady-states.

Dependent Variable:	Δ Log House Price	
	Data	Model
Model:	(1)	(2)
Variables		
(Intercept)	-2.734**	-4.841***
	(1.242)	(1.042)
Δ Log Productivity	4.655**	7.366***
	(1.808)	(1.515)
Fit statistics		
Observations	71	71
R^2	0.06112	0.31539
Adjusted R^2	0.04751	0.30547

Heteroskedasticity-robust standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*