The geography of housing subsidies

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Abstract
We investigate the impact of the U.S. federal mortgage interest deduction (MID) on the location and tenure decisions of households. We build a spatial general equilibrium model at the county level featuring imperfect labor mobility, commuting flows, and endogenous tenure mode. Holding public expenditure constant, our counterfactual analysis indicates that eliminating the MID subsidies would lower homeownership rates by 4.1% but increase welfare by 0.1%. We attribute the welfare gain to the relocation of owners and renters closer to productive urban areas and to a decrease in commuting flows. Our findings imply that housing subsidies worsen urban sprawl.

Keywords: housing subsidies; residential location; commuting; tenure choice; structural estimation

JEL Classification: R10; R50; F10; F20; H20;

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1 Introduction

Governments of many countries offer a variety of fiscal incentives to promote home-ownership. One of the most widespread incentives is the mortgage interest deduction (MID), which allows owner-occupiers to deduct mortgage interests from their taxable income. Forgone tax revenues are considerable. In 2013 the MID represented about 6% of the United States federal income tax revenue, namely 98.5 billion USD. Given the substantial amount of forgone tax revenue and its incidence on the federal budget, a lively political debate is taking place about the legitimacy of subsidies granted to owner-occupiers.¹

Unsurprisingly, subsidies are markedly unequally distributed across space, with high-productivity locations – often characterized by inelastic housing supply – receiving higher subsidies.² In 2013 the average owner-occupier living in New York County (NY) received 1’813 USD of housing subsidies – about 2.13 times as much as the average owner-occupier in the US, whereas owner-occupiers of Sheridan County (WY) received an average of 222 USD per capita – about one fourth of the US average housing subsidy. Despite this disparity in the geographic distribution of the MID, to date little is known about its impact on welfare and on the spatial and tenure distribution of households. The present paper aims to fill this knowledge gap.

We quantify the welfare impact of suddenly repealing the MID while holding public expenditure constant, and investigate the underlying location and tenure equilibrium response of households to this unexpected shock. To this end, we build a spatial general equilibrium model at the county level featuring imperfect labor

¹ Supporters of the MID advocate several reasons to justify this forgone tax revenue. First, homeownership is thought to exert positive externalities. Because owner-occupiers usually commit to long-run capital investment in the area, they are expected to be more engaged in local policy decisions, actively seeking to improve the quality of life of the neighborhood. Second, the MID is often seen by low and middle-class households as a redistributive instrument allowing poorer, younger, and less educated households to gain access to homeownership. Third, the subsidy is seen as necessary to satisfy an idiosyncratic preference for ownership.

² Several factors are responsible for the unequal geographic distribution of the MID. First, tax deductibles of home mortgages depend on the level of local housing prices, leading to regional variation of the direct income effect of up to a factor of almost 12 in the USA (Gyourko and Sinai 2003). Second, the degree of house price capitalization also varies spatially and depends on the supply elasticity of local housing markets, which depend on land use regulations or geographic constraints (Saiz 2010).
mobility, commuting flows, and endogenous tenure mode. The impact of repealing the MID on country welfare is theoretically ambiguous and is affected by the geographic distribution of the subsidy, local characteristics of the labor and housing markets, and households’ idiosyncratic preferences for locations and tenure mode.

On the one hand, to become owner-occupiers and benefit from housing subsidies, households might have relocated from central locations to less expensive suburban and countryside areas, and, whenever possible, commute over longer distances to earn labor income in high-productivity locations. Removing the MID would counter this spatial misallocation of labor, nudging workers to change tenure and move toward more productive areas, likely improving welfare. On the other hand, households might have decided to move to central areas to receive higher housing subsidies and cut their commuting cost. In this case repealing the MID would have the effect of shifting workers toward less productive areas and commute over longer distances, presumably leading to a welfare decrease.

When calibrating our model using county-level data for the United States, we find evidence in line with the first aforementioned explanation. Eliminating the MID increases welfare by 0.1%. Homeownership rates drops by 3.83% in high-productivity places and even more in less productive ones, where homeownership rates decrease by 4.18%. After the repeal the average commuting distance of residents from highly productive location decreases by 0.45%. The real after-tax income of both renters and workers increases by approximately 0.14%. The increase in real income is due to (i) a rise in wages (0.12% for renters and 0.08% for owner-occupiers), (ii) an overall decrease in commuting flows (-0.54%), and (iii) a decrease in housing prices (-1.94%). These positive effects outweigh the increase in housing rents (+4.08%) caused by the shift of the housing demand from the owner-occupied to the rental sector, and the increase in consumption good prices (+0.1%).

Our analysis contributes to two strands of the literature. The first strand investigates the impact of the MID on ownership attainment and various economic outcomes. Existing empirical results suggest that the MID is an ineffective instrument to increase homeownership. Hilber and Turner (2014) empirically show that the U.S. federal and state MIDs capitalize into higher prices in major urban areas characterized by tightly regulated housing market, thus achieving little to improve
homeownership rates. By endogenizing tenure choices and calibrating a two-region framework for Boston (MA), Binner and Day (2015) argue that it might be possible to reform the MID while leaving homeownership rates unchanged. Gruber et al. (2017) empirically analyse a major policy reform in Denmark, which led to a substantial reduction of the MID for top-rate tax payers. Their findings provide strong evidence that removing the subsidy mainly lowered housing prices and had no effects on homeownership attainment. On the contrary, eliminating the MID led to a reduction in indebtedness. Sommer and Sullivan (2018) use a macroeconomic dynamic structural model to show that abolishing the MID in the US would lead to a higher welfare. The equilibrium channels driving this welfare gain are lower house prices, more homeownership, and less mortgage debt.

The second strand of literature to which we contribute, is the one investigating the spatial misallocation of workers due to tax incentives. Calibrating a model for US metropolitan areas, Albouy (2009) analyses the impact of the US federal income taxation on the allocation of workers across space. He persuasively shows that for a given real income, workers in high-density areas end up paying more taxes than those in more remote areas. Fajgelbaum et al. (2019) investigate how the dispersion of US state income tax rates affects location choices of households across states. The authors show that the more the differences in income tax rates between US states are pronounced, the higher the welfare loss for the society, as workers are spatially misallocate across space due to tax differentials.

Our contribution to the above literature is fourfold. First, we investigate the spatial equilibrium implications of repealing the MID for the whole of the US. In contrast to previous empirical work, we model spatial linkages in residential and labor markets (via migration and commuting) and endogenize tenure choices. This approach allows us to quantify and separate direct income and housing market effects from indirect (spillover) effects created by other regions. Second, we extend

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3 For example, the MID induces owner-occupiers to move to locations where the benefits of MID are highest, thus shifting the housing demand. This creates an indirect effect of the MID in regions losing citizens as housing markets become less scarce in those regions. Similarly, with regard to the mode of tenure, our framework allows us to study spillovers of the MID on renters occurring through the endogenous choice of tenure. To the extent that the MID is effective in increasing homeownership rates in given areas, part of the housing demand is shifted from the rental to the owner-occupied market, thus leading to lower rents. Hence, by emphasizing the role of indirect effects we are able to fully assess the regional impact of the MID.
and deepen previous analyses based on aggregate units of observations – such as metropolitan areas, states, or whole countries – by including countrywide channels, such as endogenous tenure choices and the response of the local labor supply. Our analysis indicates that the MID repeal has a heterogeneous geographic impact that can vary significantly within and outside metropolitan areas. Third, the structural approach allows us to estimate households’ location and tenure response to a repeal that flattens to zero the distribution of the MID. We argue that this is a considerable advantage over empirical analysis that estimate the (linear) impact of the MID at the margin. Fourth, we calibrate the responsiveness of local housing supply by estimating county-level price-elasticities.

Our general equilibrium framework is based on recent advances in the quantitative analysis of economic geography. Monte et al. (2018) integrate the spatial interdependence of trade, commuting, and migration in a tractable model. Bin- ner and Day (2015) endogenize the tenure choice decision in an equilibrium sorting model to analyze possible reforms to the MID in Boston. They find that it is possible to remove the MID and maintain prevailing rates of homeownership. Similarly, Favilukis and Van Nieuwerburgh (2017) assess the effect of out-of-town home buyers on major cities like New York in a model where heterogeneous households choose tenure and an optimal portfolio. In a dynamic optimal portfolio-choice framework, Sommer and Sullivan (2018) show that repealing the mortgage interest deduction in the USA results in lower house prices, more homeownership, and less mortgage debt. Building on these theoretical frameworks, we introduce significant extensions to investigate the economic impact of MID regarding household’s joint choices of residential location, working place, and housing tenure.

The remainder of the paper is structured as follows. Section 2 presents the spatial equilibrium model. Section 3 describes the data. Section 4 discusses the simulation and counterfactual analysis. Section 5 concludes.
2 A Quantitative Spatial Model featuring Housing Subsidies

We consider an economy given by \( n, i \in N \) locations (counties) populated by a continuous measure \( \bar{L} \) of workers that supply one unit of labor inelastically. The federal government levies a tax \( \tau \) on labor income \( w_i \) across locations and uses the collected tax revenue to provide a space-invariant public good \( G \), such as national defense. Workers living in location \( n \) that own their house can deduct the interest \( m_{ni} \) paid to mortgage lenders from their taxable income. Workers obtain an after-tax income \( y_{\omega_{ni}} \) where \( \omega \in \{O, R\} \) denotes the tenure mode. In Section D in the Appendix we extend our framework to include state income taxation and local public good provision, and property taxation.\(^4\)

2.1 Households’ heterogeneous preferences

Building on the theoretical framework outlined by Monte et al. (2018), workers maximize their indirect utility across space by deciding where to live, where to work, and whether to own or rent a house. The indirect Cobb-Douglas utility function \( V^\omega_{ni}(h) \) of households \( h \) living in location \( n \), working in location \( i \), and having a tenure mode \( \omega \) is given by

\[
V^\omega_{ni}(h) = \frac{b^\omega_{ni}(h)}{\kappa_{ni}} G^\beta \left( \frac{y^\omega_{ni}}{P_n \tau^\alpha_{ni}} \right)^{1-\beta}.
\]

The term \( b^\omega_{ni}(h) \) denotes the worker’s idiosyncratic taste for a specific place of residence/ place of work/ tenure combination. These idiosyncratic tastes are assumed to be i.i.d. across workers, locations, and tenure. We assume that the scalar taste shifter \( b^\omega_{ni}(h) \) specific to each worker is the realization of a random variable \( b^\omega_{ni} \) having a Fréchet distribution with a cumulative density function \( \Omega^\omega_{ni}(b) = e^{-B^\omega_{ni} b^{-\epsilon}} \). The scale parameter \( B^\omega_{ni} > 0 \) determines the average idiosyncratic value workers attach to a residence/ workplace/ tenure combination, whereas the shape parameter \( \epsilon > 1 \)

\(^4\) The reasons why we abstract from income taxes and MID at the state level in our main analysis are that i) only 64% of the states in the USA currently allow to deduct mortgage payment from the taxable income, ii) the modest magnitude of income tax rates with respect to the federal one, and iii) despite of academic interest, simulating a policy change both at the federal and state level seems politically unrealistic.
affects the dispersion of workers’ tastes. The higher the value of $\epsilon$, the less dispersed the distribution of tastes for a given combination.

The remaining components of the indirect utility are common to all workers. The variable $\kappa_{ni}$ denotes exogenous commuting costs in terms of utility beared by workers living in location $n$ and working in $i$. Workers preferences are defined over a public good $G$ provided by the federal government and real after-tax income $y_{ni}^\omega/P_n^{\alpha_n}$, where $y_{ni}^\omega$ denotes the after-tax labor income, $P_n$ is the price index of the aggregate consumption good, and $r_n^\omega$ is the tenure-specific cost of housing per unit of surface. The share of income spent for the composite consumption good is given by the parameter $\alpha \in [0,1]$. The parameter $\beta \in [0,1]$ governs the workers’ fondness of for the public good with respect to their real after-tax income.

Each location specializes in the production of a single tradable consumption good. Workers consume a composite basket of goods $C_n$ according to the following CES function

$$C_n = \left( \sum_{i \in N} c_{ni}^{\sigma} \right)^{\frac{\sigma}{\sigma-1}},$$

where $c_{ni}$ denotes the aggregate consumption in location $n$ of the good produced in $i$. The parameter $\sigma$ denotes the elasticity of substitution between the traded goods. In equilibrium, we have that $c_{ni} = \alpha \bar{y}_n R_n p_{ni}^{-\sigma} P_n^{\sigma-1}$, where $R_n$ is the number of residents and $\bar{y}_n$ is location’s $n$ average per-capita disposable income. The price index $P_n$ of the aggregate consumption good is a weighted sum of variety prices $p_{ni}$, i.e. $P_n = \left[ \sum_{i \in N} p_{ni}^{1-\sigma} \right]^{1/(1-\sigma)}$. The price $p_{ni}$ equals a local price $p_i$ determined where the good is produced times iceberg trade costs $d_{ni}$ between any two locations.

### 2.2 Location-specific disposable income

Location’s $n$ total disposable income $\bar{y}_n R_n$ depends on the commuting flows of its residents and their tenure decisions. Let us start by describing the per capita income $y_{ni}^O$ of owner-occupiers living in $n$ and working in $i$, which differs in two important aspects from the one of renters having chosen the same commuting pattern. First, homeowners have to pay mortgage interests to the financial institution having provided the mortgage loan. Second, owner-occupiers receive an additional source of
income in the form of an imputed rent, which correspond to the rent the owner-occupier would have to pay if he rented the house he currently lives in.\(^5\) Thus, disposable income of owner-occupiers is given by

\[
y_{ni}^O = (1 - \tau) \left( w_i - (1 - \theta) m_{ni}^O \right) + \frac{H_{ni}^O \phi_{ni}}{L^O \lambda_{ni}^O} - \theta m_{ni}^O, \tag{3}
\]

where \(w_i\) denotes labor income and \(\frac{H_{ni}^O \phi_{ni}}{L^O \lambda_{ni}^O}\) is the imputed rent from owner-occupancy. The exogenous parameter \(\theta \in \{0, 1\}\) governs the share of MID deductible from the taxable income. The higher the deductability of mortgage interests (lower \(\theta\)), the higher tax savings and the higher the disposable income. By Cobb-Douglas preferences households spend a constant fraction \((1 - \alpha)\) of income to finance housing expenditure. It follows that \(\frac{H_{ni}^O \phi_{ni}}{L^O \lambda_{ni}^O} = (1 - \alpha) y_{ni}^O\). Using the definition of mortgage interest in (10) and converting prices into rents as defined in (11) we get that \(m_{ni} = (1 - \alpha) \phi y_{ni}^O\), where \(\phi = \xi \chi (1 + \chi) (1 - (1 + \chi)^{-1})\) defines the size of mortgage interests.\(^6\) Plugging these terms into (3) and rearranging yields (see Appendix B.1 for details)

\[
y_{ni}^O = \frac{(1 - \tau) w_i}{\alpha + \phi (1 - \alpha) + \phi (1 - \alpha) \tau (\theta - 1)}. \tag{4}
\]

Ceteris paribus, the deductability of mortgage interest is higher the higher size of mortgage interests \(\phi\) and the higher the share of expenditure on housing \((1 - \alpha)\). In the counterfactual simulations, we analyze implications of changes in the deductibility of owner-occupied housing mortgage interests, i.e. changes in \(\theta\). As we do not observe the location of the financial institution having issued the mortgage loan, owner-occupiers pay mortgage interests to federal financial institution.\(^7\)

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\(^5\) As pointed out in literature, for example by Sinai and Gyourko (2004) and Sommer et al. (2013), the non-taxation of the imputed rental income provides a fiscal incentive to owner-occupiers to not become landlords and rent out their property.

\(^6\) We refer the reader to Section 2.4 for a detailed discussion about the specification of mortgage interest.

\(^7\) To include the potential link of secondary mortgage markets in our model, in Section D.4 in the Appendix we introduce a global dividend-producing portfolio based on mortgage and rental payment. The dividends of such portfolio are redistributed across locations according to their...
The per-capita disposable income of renters only consists of after-tax labor income

\[ y_n^R = (1 - \tau) w_i. \]  

(5)

While housing rents of owner-occupiers are redistributed across owner-occupiers in equal shares, housing rents of renters are paid to an absent financial institution.\(^8\)

Thus, total disposable income in region \( n \) is

\[ \bar{y}_n R_n = \bar{y}_n^O R_n^O + \bar{y}_n^R R_n^R, \]  

(6)

where \( R_n^\omega \) is the number of residents owning/renting a property. The tenure-specific expected disposable income \( \bar{y}_n^\omega \) is given by

\[ \bar{y}_n^\omega = \sum_{k \in N} \lambda_{nk|n} y_{nk}^\omega, \quad \omega \in O, R \]  

(7)

where \( \lambda_{ni|n} \) is the share of workers residing in \( n \) and working in \( i \) conditional on living in \( n \), i.e. \( \lambda_{ni|n} = \frac{\lambda_{ni}}{\sum_k \lambda_{nk}} \).

### 2.3 Federal income taxation

Federal tax revenue is levied on taxable labor income in each location, i.e. local labor income less mortgage interest payments made by owner-occupiers. Provision of the federal public good \( G \) entering the utility of US workers is equal to per-capita tax revenue,

\[ G = \frac{1}{L} \sum_{n \in N} \left( \tau \bar{L} \sum_{k \in N} \lambda_{nk} w_k - \tau (1 - \theta) \bar{L}_n^O \sum_{k \in N} \lambda_{nk}^O m_{nk} \right). \]  

(8)

Obviously, the provision of \( G \) changes depending on the extent that homeowners can deduct their mortgage interest. A high deductability of mortgage interests (low \( \theta \)) implies lower tax revenues and thus lower public good provision. Therefore, counterfactual simulations based on the parameter \( \theta \) are unable to isolate the pure

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\(^8\) According to the American Community Survey 81% of owner-occupiers in the USA did not get any income from interests, dividends, or rental income in the years from 2009-2013.
effect of housing subsidies on workers’ decisions. To solve this problem, we follow Fajgelbaum et al. (2016) and allow the federal government to adjust the income tax rate to keep the provision of the public good unaffected by changes in $\theta$.

2.4 Housing Markets

Housing expenditure in our model is tenure specific due to i) the idiosyncratic tastes of workers for owning a house in a specific location, and ii) the fiscal incentive provided by housing subsidies. Given workers’ Cobb-Douglas preferences, tenure-specific expenditure for housing of workers living in location $n$ and working in $i$ is given by

$$r_n^\omega H_n^\omega = (1 - \alpha)\bar{y}_n^\omega \bar{L}^\omega \lambda_n^\omega,$$

(9)

where $H_n^\omega$ is the tenure-specific housing demand for workers living in $n$ and working in $i$ and $r_n^\omega$ is the housing cost.\footnote{Summing up the housing demand of all residential location $n$ yields $r_n^\omega H_n^\omega = (1 - \alpha)\bar{y}_n^\omega R_n^\omega$, where $H_n^\omega$ is the aggregate tenure-specific demand in terms of housing surface in location $n$. The left hand side of (9) can be derived by summing over all housing rents of all commuters to get $\sum_i H_n^\omega r_n^i = H_n^\omega r_n^\omega$. The right hand side of (9) follows the same way as $\sum_i (1 - \alpha)\bar{y}_n^i \bar{L}^\omega \lambda_n^\omega = (1 - \alpha)\bar{y}_n^\omega R_n^\omega$.}

Owner occupiers subscribe mortgages with absent financial institutions charging mortgage interests at an exogenous rate $\chi$ set by international capital markets. Aggregate mortgage interests of owners living in location $n$ working in $i$ are a constant fraction of the total owner-occupied housing value in that location

$$\bar{L}_n^O \lambda_n^O m_n^O = H_n^O P_n^O \xi \chi,$$

(10)

where $P_n^O$ is the value of housing per unit of surface and $\xi$ is the loan-to-value ratio. To convert the house value $P_n^\omega$ into a periodic (annual) cost $r_n^\omega$, we use a standard long-horizon present-value formula

$$r_n^\omega = \psi P_n^\omega,$$

(11)

where $\psi = \frac{\chi}{(1+\chi)(1-(1+\chi)^{-t})}$ and $t$ is the life-span of the residential unit.

In line with Hsieh and Moretti (2018) and Monte et al. (2018), we define aggregate
housing supply in location $n$ as

$$H_n^\omega = \bar{H}_n \rho_n^{\omega}, \eta_n,$$  \hspace{1cm} (12)

where $\bar{H}_n$ is an unobserved scale parameter and $\eta_n \in [0, \infty]$ is the local housing supply elasticity. As empirically investigated by Saiz (2010), geographic and regulatory constraints reduce the responsiveness of the housing supply in a given location. The simplicity of equation (12) allows us to empirically estimate this responsiveness and calibrate it into the model.

In equilibrium, housing demand equals housing supply, leading to the following expression

$$r_n^\omega = \left( \frac{(1 - \alpha) \bar{y}_n \rho_n^{\omega}}{H_n^{\omega} \eta_n} \right)^{ \frac{1}{\sigma + \eta_n} }.$$  \hspace{1cm} (13)

2.5 Production

Under perfect local competition and constant returns to scale as in Armington (1969), each location specializes in the production of one type of tradable consumption good. Production amenities of region $n$ are

$$a_n = \bar{a}_n L_n^\nu,$$  \hspace{1cm} (14)

where $\bar{a}_n$ is a local exogenous productivity shock and $L_n$ is the amount of labor. External agglomeration economies, captured by the term $L_n^\nu$, are affected by the aggregate amount of workers in each location and by an exogenous agglomeration parameter $\nu$. Due to this agglomeration parameter, workers supplying labor in larger labor markets are more productive and, ceteris paribus, earn higher nominal wages.

Because of the constant elasticity of substitution in (2) the aggregate value of bilateral trade flows $X_{ni}$ is

$$X_{ni} = p_{ni} c_{ni} = \alpha \bar{y}_n R_n \frac{p_{ni}^{1-\sigma}}{F_n^{1-\sigma}},$$  \hspace{1cm} (15)

where profit maximizing firms cause prices to equal marginal production costs: $p_{ni} = \frac{d_{ni} w_i}{a_i}$. Inserting profit-maximizing prices yields the location $n$’s expenditure share
for goods produced in location \( i \)

\[
\pi_{ni} = \left( \frac{d_{ni}w_i}{a_i} \right)^{1-\sigma} \left/ \sum_{k \in N} \left( \frac{d_{nk}w_k}{a_k} \right)^{1-\sigma} \right.,
\]

and the corresponding price index of the composite consumption good

\[
P_n = \left( \frac{1}{\pi_{nn}} \right)^{1/(1-\sigma)} \frac{d_{nn}w_n}{a_n}.
\]

To clear traded goods markets, location’s \( n \) workplace income must equal its expenditure on the goods produced in that location

\[
w_nL_n = \alpha \sum_{k \in N} \pi_{kn}y_kR_k.
\]

### 2.6 Labor mobility and tenure choice

Workers are mobile and jointly choose the location \( n \) where to live, the location \( i \) where to work, and tenure \( \omega \) to maximize their indirect utility \( V^\omega_{ni}(h) \) across all possible choices. Let \( \bar{V}(h) \) denote this maximum utility level:

\[
\bar{V}(h) = \max_{n,i,\omega} V^\omega_{ni}(h).
\]

As explained in section 2.1, the stochastic nature of the indirect utility \( V^\omega_{ni}(h) \) comes from an idiosyncratic preference term \( b^\omega_{ni} \) that is Fréchet distributed. Because \( b^\omega_{ni} \) shifts multiplicatively the deterministic component of \( V^\omega_{ni} \); \( V^\omega_{ni} \) is also Fréchet distributed. We can thus write its cumulative distribution \( \Psi \) as

\[
\Psi^\omega_{ni}(v) = e^{-\frac{\psi^\omega_{ni}}{\pi_{ni}} \left( \frac{v}{\bar{V}^\omega_{ni}} \right)^{1-\beta} \varepsilon^{-\varepsilon}}.
\]

The share of workers \( \lambda^\omega_{ni} \) living in \( n \), working in \( i \), and having tenure \( \omega \) is given by the probability that the utility provided by this specific combination exceeds the maximal attainable utility across all other choices, i.e. \( \lambda^\omega_{ni} = Pr(V^\omega_{ni} \geq \max_{r,k,l} V^l_{rk}, \forall r,k,l) \). Using the fact that the variable \( \max_{r,k,l} V^l_{rk} \) is also Fréchet
distributed and that \( \lambda_{ni} = \mathbb{E}[P(\max_{r,k,l} V_{r_k}^l \leq v | V_{ni}^\omega = v)] \), we have that

\[
\lambda_{ni} = \frac{B_{ni}^\omega \left( G^\beta \left( \frac{y_{ni}}{P_{ni}^\alpha r_{ni}^{1-\alpha}} \right)^{1-\beta} \right)^\epsilon}{\sum_{k \in N} \sum_{f \in N} \sum_{l \in \omega} B_{l k f}^1 \left( G^\beta \left( \frac{y_{l k f}}{P_{l k f}^\alpha r_{l k f}^{1-\alpha}} \right)^{1-\beta} \right)^\epsilon}.
\]  \( (21) \)

The parameter \( \epsilon \), which governs the distribution of idiosyncratic tastes, affects the mobility degree of workers. In the case of no taste heterogeneity across locations and tenure (\( \epsilon \to \infty \)), local labor supply is perfectly elastic, implying perfect population mobility. On the contrary, when idiosyncratic tastes vary massively (\( \epsilon \to 0 \)), the share of workers across locations and tenure is not affected by deterministic utility components representing moving cost, public good provision, and real income. The expected utility for the residence and workplace combination \( ni \) is

\[
E[V_{ni}^\omega] = \bar{V} = \delta \left[ \sum_{k \in N} \sum_{f \in N} \sum_{l \in \omega} \sum_{e \in \omega} B_{l k f}^1 \left( G^\beta \left( \frac{y_{l k f}}{P_{l k f}^\alpha r_{l k f}^{1-\alpha}} \right)^{1-\beta} \right)^\epsilon \right]^{\frac{1}{\epsilon}},
\]  \( (22) \)

where the expectation is taken over the Fréchet distributed idiosyncratic taste for amenities and \( \delta = \Gamma(\frac{\epsilon-1}{\epsilon}) \) is a Gamma function of \( \Gamma() \) of the dispersion of tastes \( \epsilon \).

Inserting commuting shares \( (21) \) into expected utility for the residence and workplace combination \( (22) \) yields

\[
E[V_{ni}^\omega] = \delta \left( \frac{1}{\lambda_{ni}^\epsilon} \right)^\frac{1}{\epsilon} \left( G^\beta \left( \frac{y_{ni}^\omega}{P_{ni}^\alpha r_{ni}^{1-\alpha}} \right)^{1-\beta} \right).
\]  \( (23) \)

In equilibrium, we assume that workers don’t want to change their place of residence, place of work, and tenure. This implies that the number of worker having chosen a specific combination must be equal to the corresponding number resulting from the distribution of idiosyncratic tastes. More precisely, summing over the probabilities across workplaces for residence \( n \), yields the number of tenure-specific residents in location \( n \)

\[
R_n^w = \bar{L}^\omega \sum_{k \in N} \lambda_{nk}^w.
\]  \( (24) \)

Similarly, summing over the probabilities across residences for workplace \( n \), yields
the numbers of tenure-specific workers in location $n$

$$L_n^w = \bar{L}^\omega \sum_{k \in N} \lambda_{k_n}^w.$$ \hfill (25)

### 2.7 Equilibrium characterization

We characterize the model’s equilibrium as follows:

1. The budget of the federal government is balanced according to (8).
2. Local housing markets clear according to (13).
3. Traded goods markets clear in every county according to (18).
4. The distribution of workers across place of residence, place of work, and tenure is stable according to equations (24) and (25).

As shown in Monte et al. (2018), this theoretical framework can be translated into a system of equations where Allen et al. (2016) theorem ensuring the existence and uniqueness of the equilibrium can be applied. Monte et al. (2018) proof of the existence and uniqueness of an equilibrium is valid for an arbitrary choice set. Therefore, extending their choice set by including tenure decisions does not invalidate the proof.

### 3 Data and estimation

In this section, we describe the data sources available at the US county level for the observed variables $\{\lambda_{n_i}^w, w_n, r_n^\omega, \bar{y}_n^\omega, y_{n_i}^\omega, \tau_n, \bar{L}^\omega, R_n^\omega, L_n^\omega, \eta_n^\omega\}$. Additionally, we discuss the calibrations and estimation of the model’s exogenous parameters required to conduct counterfactual simulations. Note that we perform numerous robustness checks based on different parameter constellations. An overview of the calibrated parameters is provided in the Appendix A.1, additional details on data are contained in Appendix A.2 and Appendix A.3 provides descriptive maps of the observed variables.
3.1 Data

Below we discuss the calibration of our parameters and our usage of data to recover the variables from the model.

**Parameters provided by the literature:** We set households’ elasticity of substitution between the different varieties of tradable consumption goods equal to \( \sigma = 5 \), as suggested by Simonovska and Waugh (2014). Following Davis and Ortalo-Magne (2011) and Redding (2016), we fix the households’ income share spent for consumption goods as \( \alpha = 0.7 \). We set the Fréchet parameter of households’ idiosyncratic taste for locations equal to \( \epsilon = 3.3 \), as in Monte et al. (2018) and Bryan and Morten (2015). The households’ taste for public goods consumption is given by \( \beta = 0.22 \), which is in line with Fajgelbaum et al. (2016) reporting that taxes in the USA are 22% of nominal GDP. We set the strength of the agglomeration force \( \nu = 0.1 \), as done by Allen and Arkolakis (2014). Trade costs are a measure of distance between counties and trade cost elasticity \( \psi \), such that \( d_{ni}^{1-\sigma} = \text{dist}_{ni}^\psi \). The former is computed using GIS data. The latter is calibrated according to Monte et al. (2018), who estimate \( \psi = -1.29 \) using U.S. trade flow data coming from the Commodity Flow Survey (CFS). The life-span of a house is \( t = 40 \).

**Housing data:** Based on data published by FRED, we set the country mortgage interest rate equal to \( \chi = 0.04 \). This rate corresponds to the mean mortgage interest rate offered by financial institutions in 2013 for a 30-year fixed mortgage. Using the American Community Survey (ACS), we collect the share of homeowners at the county level. We calibrate the loan to value ratio \( \xi = 0.51 \), in line with the Financial Accounts of the Board of Governors of the Federal Reserve System (BGFRS). More specifically, from the balance sheet of households and nonprofit organizations we divide home mortgages by real estate assets. We convert data on median monthly gross rents from ACS to annual rental costs \( r^n_R \). Using home values of owner-occupied houses \( P^n_O \) provided by the ACS, we compute the annual housing cost \( r^n_O \) paid by owner-occupiers using the present value formula (11).

**Labor and income tax rates:** From the Bureau of Economic Analysis (BEA) we collect total wages at place of work \( i \) and number of employees in 2013. By dividing total wages by employment, we obtain per-capita wages by working place \( w_i \). We use
information on federal average income tax rates $\tau$ provided by the TaxSim database of the National Bureau of Economic Research (NBER) in 2013.

**Commuting flows:** Data on bilateral commuting flows $\lambda_{ni}$ at the county level stem from ACS for the years 2009-2013. Because the ACS does not report bilateral commutes by housing tenure, we assume identical commuting flows for owner-occupiers and renters in each county.\(^{10}\) We calculate tenure-choice specific commuting shares $\lambda_{ni}\omega$ by multiplying the share of owner-occupiers and renters per county with the commuting matrix $\lambda_{ni}$. We derive tenure-choice specific total employment $\bar{L}_\omega$ by multiplying employment data for each county with the share of owner-occupiers/renters.

**Income and mortgage payments:** To obtain disposable income of renters $y_{ni}^R$ we use (5) together with data on renters per-capita wages $w_i$ and tax rates $\tau$. The owner’s disposable income $y_{ni}^O$ follows from (4) together with data on per-capita wages $w_i$, where we set $\theta = 0$, which is equivalent to the existing full mortgage interest rate deduction in the USA tax code. Next, we derive the mortgage interest rate $m_{ni}$ to finance owning properties, which follows from substituting (9) and (11) into (10) and data on income $y_{ni}^O$. We substitute bilateral income $y_{ni}\omega$, conditional commuting shares $\lambda_{ni\omega}$, and the total number of workers $\bar{L}_\omega$, into (7) to recover $\bar{y}_n$. Finally, we solve for per-capita expected disposable income $\bar{y}_n$ using (6) and the bilateral income of owner-occupiers $y_{ni}^O$ and renters $y_{ni}^R$.

**Recovering location fundamentals:** We recover regional productivity by substituting trade shares (16) in goods market clearing (18). Given values for $\{L_n, R_n, d_{ni}, w_n, \bar{y}_n\}$ and substituting parameters $\{\sigma, \alpha\}$, and estimates of $d_{ni}$ we obtain productivity $a_n$ and consequently production amenities $\bar{a}_n$ and equilibrium values for bilateral trade shares. To solve for net regional consumption amenities $B_{ni}/\kappa_{ni}$ we substitute prices from (17) and rents (13) in commuting shares (21).

We present summary statistics of our exogenous and recovered variables in Table F.1. An overview of our observed and recovered variables is depicted in Figure A.1.\(^{10}\) This hypothesis is supported by descriptive evidence provided by the ACS Micro-data on travel time by housing tenure, which suggests that, on average, renters commute daily only 1.2 minutes more than owner-occupiers, making it unlikely that their commuting flows significantly differ at the county level.
A number of observations stand out: First, wages as well as production amenities are unevenly distributed and highest in urban areas. Second, central counties show relatively high per-capita public good provision. Third, supply elasticities are evidently highest in cities and tend to be relatively high at the coastline.

3.2 Estimation of county-level housing supply elasticities

We estimate housing supply elasticities $\eta_n$ by log-linearizing and first differencing Equation (12). Based on the work of Saiz (2010), we parsimoniously parameterize the local housing supply elasticity $\eta_n = \eta + \eta_{\text{built}} S_{\text{built}}^n$, where $S_{\text{built}}^n$ is the share of developed land in a given county and $\eta$ and $\eta_{\text{built}}$ are parameters that have to be estimated.\footnote{In contrast to Saiz (2010), we do not aim to disentangle the contribution of geographic and regulatory constraints to county-level housing supply elasticities. The supply heterogeneity derived from $S_{\text{built}}^n$ might capture both. On the one hand, according to Hilber and Robert-Nicoud (2013), more attractive places are developed first and, as a consequence, are more tightly regulated. On the other hand, Saiz (2010) argues that geographic constraints become binding only in developed places.}

The resulting equation is

$$\Delta \log P_{nt} = \alpha + \eta \Delta \log H_{nt} + \eta_{\text{built}} S_{\text{built}}^n \Delta \log H_{nt} + \bar{h}_{nt}^*, \quad (26)$$

where $\Delta \log P_{nt}$ and $\Delta \log H_{nt}$ represent price and stock growth from 1980 to 2000, respectively. The error term $\bar{h}_{nt}^*$ represents unobserved price dynamics. See Appendix E.1 for a derivation of Equation (E.3).

Estimating Equation (E.3) by OLS likely leads to biased estimates due to the simultaneous effect of housing demand and supply in determining equilibrium prices and stock quantities. To solve this issue, instrumenting changes in the housing stock $\Delta \log H_{nt}$. Specifically, to trace out the responsiveness of the supply function, we isolate exogenous variation in the housing stock arising from demand shocks that are not modeled in our structural framework. We predict county-level housing demand shocks using i) mean temperature levels, ii) fertility rates, and iii) a shift-share instrument for changes in the racial composition of residents.

We motivate the choice of instruments as follows. Counties displaying higher average temperatures are (ceteris paribus) more attractive places to live in. We...
thus expect temperature to positively correlate with an increase in demand over time. To the extent that individuals decide to live in the same county in which they are born – due for example to high idiosyncratic migration costs – predetermined fertility rates are also expected to shift housing demand upward as young adults start to bid on local housing markets. Moreover, local housing demand is also expected to evolve according to the racial composition of the residents. We build on this proposition, and assume that the growth in local residents can be predicted by a weighted average of the growth (at the state level) of individuals belonging to a specific race, where the weights are given by the initial distribution of racial groups in predetermined period. 12

Median housing prices of owner-occupied housing units and total housing stock at the county level stem from IPUMS (Manson et al. 2017) and are calculated based on decennial censuses. The share of developed land comes from the GIS raster data ”Enhanced Historical Land-Use and Land-Cover Data Sets” provided by the U.S. Geological Survey. This early land cover data has been used in the literature by Burchfield et al. (2006) and derives information from high-altitude aerial photographs collected over the period from 1971 to 1982, but the most common date is 1976, which is also the median year. For the instruments we use mean temperature in January from the Natural Amenities Scale data published by the Department of Agriculture, fertility rates are live births by place of residence divided by total population and are provided by IPUMS (Manson et al. 2017), which base their measures on the Vital Statistics: Natality & Mortality Data and the decennial census. To calculate the shift-share instrument we use information about race using data from IPUMS (Manson et al. 2017) using decennial census data.

Table E.1 shows estimated values of the parameters $\eta$ and $\eta^\text{built}$ present in equation (E.3). In columns 1-3 we report parameter estimates if the relative of housing stock is instrumented using every two-way combination of instruments, and in column 4 we report result if all three instruments are used altogether. As required by the theory, the sign of estimated parameters is positive. In particular, the higher the share of developed land in a given county, the higher $\eta_n$, thus resulting into a

---

12 Two of our instruments, average temperature and shift-share of racial composition, relate to those used by Saiz (2010), who predicts demand shocks at the metropolitan statistical area (MSA) level using the average number of sun hours and number of new immigrants.
lower local housing supply elasticity. The magnitude of the estimated coefficient is stable across the set of instruments used to predict housing demand growth.

We conclude this section by computing local housing supply elasticities using the formula $1/\eta_n = 1/(\eta + \eta^{\text{built}} S_n^{\text{built}})$ together with the estimated parameter values of model specification (3) and specific values for $S_n^{\text{built}}$. Given the above, we compare the estimated housing supply elasticities with those estimated Saiz (2010). To do so, in a first step we aggregate local housing supply elasticities at the metropolitan statistical area (MSA) level and find the median value. We then compute the correlation coefficient with the elasticity of Saiz (2010) and obtain a value of 0.60.

We parameterize the housing supply elasticity with $1/\eta_n = 1/(\eta + \eta^{\text{built}} S_n^{\text{built}})$ and use for $\eta$ and $\eta^{\text{built}}$ estimated parameter values of model specification (3) of Table E.1 and data for the share of developed land $S_n^{\text{built}}$. We refer to section E.1 for more details about the estimation of the housing supply elasticity. Our preferred specifications yield values for the housing supply elasticity between 0.4 and 3.1.

4 Simulation and counterfactual analysis

The theoretical framework presented in Section 2 is used to undertake model-based counterfactual estimations. We express the response of the model’s endogenous variables with observable data and the structure of the equilibrium described in Section 2.7. By introducing counterfactual-hat notation as developed in Dekle et al. (2007) we denote a counterfactual change as $\hat{x} = \hat{x}' x'$, where $x$ is the observed variable and $x'$ is the unobserved counterfactual value of $x$. We derive counterfactual changes in commuting shares, public good provision, population, income, price index, and price of housing, which together present a sufficient statistics for the counterfactual change in welfare. A full description of the used system of equations is presented in Section C in the Appendix. The change in welfare across regions can be calculated by dividing the counterfactual with the observed expected utility (23) such that we get

$$\hat{V} = \left( \frac{1}{\lambda^\omega_n} \right)^{\frac{1}{\gamma}} \left( \frac{y^{\omega N}_n}{p^{\omega N}_n \omega^{1-\alpha}_n} \right)^{1-\beta}. \tag{27}$$
From this equation it is evident that a full cost-benefit analysis should not only consider direct effects of housing subsidy on income of owner-occupiers, but also account for changes in population, public good provision, consumption prices, and housing rents and prices. These adjustments are derived by making use of the full system of counterfactual equilibrium equations described in Appendix C. In the following section we discuss effects of different housing subsidy policies, i.e. several possible reforms to the MID policy.

4.1 Quantifying regional effects of eliminating the MID

The first policy we analyze, is the elimination of the MID for the owner-occupiers, i.e. a change from $\theta = 0$ to $\theta = 1$, while keeping the public good provision constant. Since owner-occupiers are no longer able to deduct their mortgage interests from their taxable income, this policy leads to a decrease in owner-occupied after-tax income $y_{ni}^O$ (see equation (3)). Without the MID the government lowers the income tax rate $\tau$ to keep public good provision constant. This benefits both renters and owner-occupiers. However, it does not offset the decrease in after-tax income due to the elimination of the MID for owner-occupiers. Table 1 - panel A - columns (1) to (3) show the impact of the elimination of the MID with population and tenure mobility. As depicted in Figure 1 these impacts vary substantially across space. Eliminating the MID leads to an average 0.38% decrease in regional income for owner-occupiers $\hat{\bar{y}}_{ni}^O$. In contrast, the renters’ regional income $\hat{\bar{y}}_{ni}^R$ increases on average by 1.42%. Note that since there are more owner-occupiers than renters, the total regional income $\hat{\bar{y}}_{ni}$ decreases on average by 0.29%. Since renting becomes more attractive relative to owning, there is a shift from owner-occupancy to renting. Owner-occupiers $\hat{R}_n^O$ decrease by 4.09%, while renters $\hat{R}_n^R$ increase by 7.2%. The higher demand for rental housing leads to an average 4.08% increase in rents $\hat{r}_n^R$. In contrast, the owner-occupiers’ cost of housing $\hat{r}_n^O$ decreases by 1.94%. As can be seen in Figure 1 - panels (e) and (f), owner-occupiers’ cost of housing $\hat{r}_n^O$ decreases and rent $\hat{r}_n^R$ increases, are more pronounced in areas with higher agglomeration economies. These areas, are also the more constrained ones and therefore feature lower housing supply elasticities.

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13 64.7% of the households are owner-occupiers while 35.3% are renters. After the elimination of the MID this changes to 64.7% owner-occupiers and 38% renters.

14 Note that in equilibrium the change in $\hat{R}_n$ must equal the change in $\hat{L}_n$. 

19
This decrease in owner-occupiers’ cost of housing $\hat{r}_n^O$ incites the remaining owner-occupiers to move into areas with higher agglomeration economies. This leads to a 4.05% decrease in commuting distance and to a 0.08% increase in wages for owner-occupiers. The former owner-occupiers that become renters as a result of this policy, also move into the more productive areas. This increases the average wages of renters by 0.12%. The slight increase in wages for owner-occupiers and renters, increases the price index $\hat{P}_n$. Coincidentally, the real incomes for both, renters and owner-occupiers, increase on average 0.14%. While the increase for renters is driven by the increase in regional income $\hat{y}_{ni}$, the increase for owner-occupiers is driven by the decrease in cost of housing $\hat{r}_n^O$. On average both, renters and owner-occupiers, experience an 0.1% increase in welfare.

Table 1 - panel A - columns (4) to (6) show how the impact of eliminating the MID changes, if the population is not allowed to move nor to change tenure. Evidently, in this case, there are no changes in residents $\hat{R}_n$ and commuting. Under the restrictions of no population mobility and tenure change, eliminating the MID results on average in gains for renters and losses for owner-occupiers.

Table 1 - panel B shows how much of the country-wide average effects resulting from the elimination of the MID (depicted in Table 1 - panel A) are driven by counties within MSAs.\(^\text{15}\)

Our counterfactual analysis shows that on average both renters and owner-occupiers benefit from eliminating the MID if population mobility and tenure change are not restricted. Eliminating the MID leads to a more efficient allocation of labor and to less commuting. As depicted in Figure 1 - panel (a), with this policy, the residents end up living and working in more productive places. Therefore, eliminating the MID leads to less urban sprawl. Or put differently, the subsidies arising form the MID incites owner-occupiers to move to areas where these subsidies are capitalized less into housing prices. Since these less-constrained areas are also the less productive areas, the MID ultimately worsens urban sprawl. Moreover, these subsidies are unequally distributed across space. They are concentrated in areas with the priciest housing markets, which creates distortions. Therefore, eliminating these subsidies while keeping public good provision constant, is on average beneficial.

\(^\text{15}\) We follow Saiz (2010)’s definition of MSAs.
across tenure.
Table 1: Impact of eliminating MID (in % relative to $\theta = 0$ case)

<table>
<thead>
<tr>
<th></th>
<th>With population and tenure mobility</th>
<th>Without population and tenure mobility</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Welfare ($\hat{V}_n$)</td>
<td>[0.10]</td>
<td>[0.10]</td>
</tr>
<tr>
<td>Commuting ($L'\sum_{n\neq i} x'<em>n / L \sum</em>{n\neq i} \lambda_n$)</td>
<td>[7.42]</td>
<td>[4.07]</td>
</tr>
<tr>
<td>Commuting Distance($L'\sum_{n\neq i} Dist x'<em>n / L \sum</em>{n\neq i} Dist \lambda_n$)</td>
<td>[7.43]</td>
<td>[4.05]</td>
</tr>
<tr>
<td>Residents ($\hat{R}_n$)</td>
<td>[7.49]</td>
<td>[4.09]</td>
</tr>
<tr>
<td>Workers ($\hat{L}_n$)</td>
<td>[7.49]</td>
<td>[4.09]</td>
</tr>
<tr>
<td>Regional income ($\hat{y}_n$)</td>
<td>[1.42]</td>
<td>[0.38]</td>
</tr>
<tr>
<td>Wages ($\hat{w}_i$)</td>
<td>[0.12]</td>
<td>[0.08]</td>
</tr>
<tr>
<td>Housing costs ($\hat{r}_n$)</td>
<td>[4.08]</td>
<td>[1.94]</td>
</tr>
<tr>
<td>Price index ($\hat{P}_n$)</td>
<td>[0.10]</td>
<td>[0.09]</td>
</tr>
<tr>
<td>Real income ($\hat{y}_n / P^n \hat{r}_n \hat{P}_n$)</td>
<td>[0.14]</td>
<td>[0.14]</td>
</tr>
<tr>
<td>Public good provision ($\hat{G}_n / \hat{R}_n$)</td>
<td>[0]</td>
<td>[0]</td>
</tr>
</tbody>
</table>

Panel A: Welfare changes and its components

Panel B: Contribution of counties within MSAs to changes in welfare components in Panel A

The table reports weighted mean changes in outcomes relative to the tax system with mortgage interest deduction ($\theta = 0$). The table shows weighted changes of outcomes calculated at the county level, and columns (1)-(3) refer to a counterfactual scenario, where workers can change place of residence, work and mode of tenure, whereas column (4)-(6) show a counterfactual scenario where people do not adjust place of residence, work and mode of tenure. Changes in welfare, line (1), are equalized across counties, changes in commuting, line (2), are weighted by the number of commuters, changes in residents, income, rents, prices and public good provision, lines (3) and (5) are weighted by the number of residents, and changes in workers and wages, lines (4) and (6), are weighted by the number of workers. In all experiments we set counterfactual tax rates such that the sum of tax revenue remains as in the observed case.
Figure 1: Impact of eliminating MID

(a) Residents ($\hat{R}_n$)
(b) Residents owners ($\hat{R}_n^O$)
(c) Residents renters ($\hat{R}_n^R$)

(d) Stayers ($\tilde{\lambda}_{n|n}$)
(e) Housing prices ($\hat{R}_n^O$)
(f) Housing rent ($\hat{R}_n^R$)

(g) Exp. income owners ($\hat{y}_n^O$)
(h) Exp. income renters ($\hat{y}_n^R$)
(i) Public good prov. ($\hat{G}_n/\hat{R}_n$)

Note: The Figure depicts changes in the respective variable reported by quantiles of eliminating MID. A darker shading represents a stronger effect, where a green (red) color illustrates a positive (negative) effect. The unit of observation is at the county level.
5 Conclusions

To be completed.
References


A Data appendix

This section of the web appendix contains further information about our calibration, as well as additional descriptive details of our model variables.

A.1 Summary of calibrated parameters

Table A.1 summarizes the parameters calibrated in our model.

<table>
<thead>
<tr>
<th>Description</th>
<th>Par. Value</th>
<th>Reference / Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Share of consumption expenditure $\alpha$</td>
<td>0.7</td>
<td>Davis and Ortalo-Magne (2011)</td>
</tr>
<tr>
<td>Share of public expenditure $\beta$</td>
<td>0.22</td>
<td>Fajgelbaum et al. (2016)</td>
</tr>
<tr>
<td>Agglomeration force $\nu$</td>
<td>0.1</td>
<td>Allen and Arkolakis (2014)</td>
</tr>
<tr>
<td>Elasticity of substitution $\sigma$</td>
<td>5</td>
<td>Simonovska and Waugh (2014)</td>
</tr>
<tr>
<td>Heterogeneity of preferences $\epsilon$</td>
<td>3.3</td>
<td>Monte et al. (2018)</td>
</tr>
<tr>
<td>Loan to house value ratio $\xi$</td>
<td>0.51</td>
<td>BGFRS</td>
</tr>
<tr>
<td>Mortgage interest rate $\chi$</td>
<td>0.04</td>
<td>ACS</td>
</tr>
<tr>
<td>Trade cost elasticity $\psi$</td>
<td>-1.29</td>
<td>Monte et al. (2018)</td>
</tr>
<tr>
<td>Life span of housing structures $t$</td>
<td>40</td>
<td>ACS</td>
</tr>
<tr>
<td>Housing supply elasticity $\eta_n$</td>
<td>-</td>
<td>Section E.1 in the Appendix</td>
</tr>
</tbody>
</table>

The table reports estimated and calibrated parameters entering our model.

A.2 Additional details

Parameters provided by the literature: The trade elasticity is calibrated according to Simonovska and Waugh (2014) to a value of $-4$. By making this result comparable to our study, this yields $\sigma - 1 = 4$, which is $\sigma = 5$. This is within the range of accepted parameters by the trade literature and equivalent to Redding and Rossi-Hansberg (2017). Moreover, Desmet et al. (2018) and Redding (2016) consider a traded good across countries and use the parameter of $\sigma = 4$ estimated by Bernard et al. (2003) using plant-level data of the U.S. manufacturing sector. In contrast, Allen and Arkolakis (2014) estimate $\sigma = 9$ and argue this must be the upper range of an acceptable parameter.
Commuting flows: We compute total employment $\bar{L}$ by adding the number of workers for counties belonging to our sample. Note that $\bar{L}_\omega$ is assumed to vary for the counterfactual analysis since people can change mode of tenure, whereas the total number of employees $\bar{L}$ is assumed to be fixed. To this end, we use (24) and (25) to recover tenure-choice specific numbers of residents $R_n^\omega$ and employees $L_n^\omega$ at region $n$ with data on bilateral commuting shares $\lambda_{ni}^\omega$ and the total number of workers $L^\omega$.

A.3 Descriptives

Figure A.1 shows the spatial distribution of the observed and recovered variables from the model.

Figure A.1: Overview of variables

(a) Wages ($w_n$)  
(b) Residents ($R_n$)  
(c) Productivity ($a_n$)  
(d) Net-in-Commuting ($L_n/R_n$)

Note: The figures depict quantiles of the reported variables. A darker shading in the map indicates a higher value, where a green (red) color illustrates a positive (negative) effect. The unit of observation is at the county level.
B Additional model details

This section presents additional derivations of equations of the main paper.

B.1 Regional income

Imputed rent from owner-occupancy for all owners commuting from \( n \) to \( i \) is \( H_n^O r_n^O \) and total rent payments in location \( n \) are equal to \( \sum_i H_n r_n = H_n r_n \). The parameter \( H_n^O \) denotes the amount and \( r_n^O \) is the cost of owner-occupied housing consumed in location \( n \). Owner-occupiers pay federal taxes \( \tau \) on their income. Moreover, owner-occupiers pay interests \( m_{ni} \) on their mortgages, which are deductible from taxable income. These mortgage interests are paid to an absent financial institute. The disposable income of owner-occupiers living in location \( n \) working in \( i \) can be stated as

\[
y_{ni}^O = (1 - \tau) \left( w_i - (1 - \theta) \frac{m_{ni}^O}{\ell n^O \lambda_{ni}} - \theta m_{ni}^O \right).
\]  

(B.1)

By Cobb-Douglas preferences households spend a constant fraction \((1 - \alpha)\) of income to finance housing expenditure. It follows that \( \frac{H_n^O r_n^O}{\ell n^O \lambda_{ni}} = (1 - \alpha)y_{ni}^O \). Using the definition of mortgage interest in (10) and converting prices into rents as defined in (11) we get that \( m_{ni} = (1 - \alpha)\phi y_{ni}^O \), where \( \phi = \xi \chi^{(1+\chi)(1-\chi)^{-1}} \) defines the size of mortgage interests. Substituting the definition for imputed rent and mortgage interest yields

\[
y_{ni}^O = (1 - \tau)w_i + (1 - \alpha)y_{ni}^O - (1 - \tau + \tau\theta)(1 - \alpha)\phi y_{ni}^O.
\]  

(B.2)

Rearranging terms yields

\[
y_{ni}^O = \frac{(1 - \tau)w_i}{\alpha + \phi(1 - \alpha) + \phi(1 - \alpha)\tau(\theta - 1)}.
\]  

(B.3)
C  Counterfactual analysis

In this section we derive a system of equations that allow us to undertake a model-based counterfactual analysis of reciprocal tax agreements. Following Dekle et al. (2007) we denote a counterfactual change as \( \hat{x} = \frac{x'}{x} \), where \( x \) is the observed variable and \( x' \) is the unobserved counterfactual value of \( x \). In our counterfactual simulations we change the parameter \( \theta \), which regulates the tax deductability of mortgage interest rates. To isolate the pure effect of housing subsidies on workers’ decisions we allow the federal government to adjust the income tax rate to keep the provision of the public good unaffected \( \hat{G} = 1 \) by changes in \( \theta \). First, the counterfactual wage equilibrium follows directly from equilibrium wages (18):

\[
\hat{w}_i w_i \hat{L}_i \hat{L}_i = \alpha \sum_{n \in N} \hat{\pi}_n \hat{\pi}_n \hat{R}_n R_n \hat{y}_n \hat{y}_n. 
\]  
(C.1)

Changes in residents and employers are linked to changes in commutes and can be derived from (24) and (25)

\[
\hat{R}_n R_n = \hat{L} \sum_{k \in N} \hat{\lambda}_{nk} \hat{\lambda}_{nk}', \]  
(C.2)

\[
\hat{L}_n \hat{L}_n = \hat{L} \sum_{k \in N} \hat{\lambda}_{kn} \hat{\lambda}_{kn}'. \]  
(C.3)

Consequently, for total workers and residents this implies

\[
\hat{R}_n R_n = \hat{R}_n R_n + \hat{R}_n R_n,
\]  
(C.4)

\[
\hat{L}_n L_n = \hat{L}_n L_n + \hat{L}_n L_n,
\]  
(C.5)

From (4) and (5) we can state per-capita income for every pair of residential and working place location in the counterfactual situation given changes in wages and tax rates,

\[
\hat{y}_n \hat{y}_n = t t \hat{w}_i w_i,
\]  
(C.6)

\[
\hat{y}_n \hat{y}_n = \frac{t t \hat{w}_i w_i}{\alpha + \phi(1 - \alpha) + \phi(1 - \alpha) \tau(\theta - 1)},
\]  
(C.7)
where for convenience reasons we denote the counterfactual change in tax rate as \( \hat{t} = \frac{1-\tau'}{1-\tau} \). Expected wages in the counterfactual situation can be expressed by using (7)

\[
\hat{y}_n \hat{y}_n^\omega = L^R \sum_{k \in N} \lambda_n^\omega \hat{\lambda}_{nk}^\omega \hat{y}_{nk} \hat{y}_{nk}^\omega \frac{R_n^\omega}{R_n^\omega},
\]

(C.8)

Consequently, total income is the sum of expected income of both groups as in (6)

\[
\hat{y}_n \hat{y}_n = \frac{1}{R_n^\omega} \left( \hat{y}_n^R \hat{y}_n^R \hat{R}_n^R R_n^R + \hat{y}_n^O \hat{y}_n^O \hat{R}_n^O R_n^O \right).
\]

(C.9)

Dividing counterfactual by equilibrium productivity using (14) we get

\[
\hat{a}_n = \hat{L}_n^\nu.
\]

(C.10)

Changes in consumption price index are derived from (17) and are

\[
\hat{P}_n = \left( \frac{1}{\hat{\pi}_{nn}} \right)^{1/(1-\sigma)} \frac{\hat{a}_n \hat{w}_n}{\hat{a}_n}.
\]

(C.11)

Counterfactual changes in the housing rents follows from (13) and are equal to

\[
\hat{r}_n^\omega = \left( \frac{\hat{y}_n^R \hat{y}_n^R \hat{R}_n^R}{\hat{y}_n} \right)^{1/\eta \omega}.
\]

(C.12)

Changes in mortgage interest rates follow from substituting (9) and (11) in (10)

\[
\hat{m}_{ni}^O = \hat{y}_{ni}^O.
\]

(C.13)

Next, we divide the counterfactual by the equilibrium trade share using (16) and obtain:

\[
\hat{\pi}_{ni} = \left( \frac{\hat{w}_i \hat{d}_{ni}}{\hat{a}_i} \right)^{1-\sigma} \frac{\pi_{nk}}{\sum_{k \in N} \left( \frac{\hat{w}_k \hat{d}_{nk}}{\hat{a}_k} \right)^{1-\sigma} \pi_{nk}}.
\]

(C.14)

Similarly, we can express the counterfactual commuting change by dividing the counterfactual population mobility condition by the equilibrium mobility condition.
\[
\hat{\lambda}_{\omega ni} = \frac{\left(\hat{G}\right)^{\beta c} \left(\frac{\hat{y}_{\omega ni}}{P_{\omega ni}^{1-\alpha}}\right)^{(1-\beta)c}}{\sum_{l\in\omega} \sum_{f\in N} \sum_{k\in N} \left(\hat{G}\right)^{\beta c} \left(\frac{\hat{y}_{lk}}{P_{\omega nl}^{1-\alpha}}\right)^{(1-\beta)c} \lambda_{kf}}. \tag{C.15}
\]

From these changes we calculate the provision of the public good in county \(n\) using (8)

\[
\hat{G}G = \frac{1}{L} \sum_{n\in N} \left(\hat{L}\tau \sum_{k\in N} \lambda_{nk} \hat{\lambda}_{nk} w_k \hat{w}_k - \tau (1 - \theta) \hat{L}^O \sum_{k\in N} \hat{\lambda}^O_{nk} \lambda^O_{nk} \hat{m}_{nk} \hat{m}_{nk}\right). \tag{C.16}
\]

Equations (C.1)-(C.16) hold for each location and enable us to solve for counterfactual changes in commuting \(\hat{\lambda}_{\omega ni}\), changes in provision of public good \(\hat{G}\) and real income \(\hat{G}y_{\omega ni}\hat{P}_{\alpha n}^{1-\alpha}\omega_{ni}\) for all locations \(n\). In order to assess the welfare effects of housing policy reforms we substitute these changes by using expected utility (23) to get (27)

\[
\hat{V} = \left(\frac{1}{\lambda_{\omega ni}}\right)^{\frac{1}{\beta}} \left(\hat{G}\right)^{\beta c} \left(\frac{\hat{y}_{\omega ni}}{P_{\omega ni}^{1-\alpha}}\right)^{1-\beta}. \tag{C.17}
\]

So far counterfactual changes in utility are equalized across space. To set renters and owner-occupiers indifferent, we increase (decrease) the total number of renters \(\hat{L}^R\) as long as indirect utility for renters is bigger (lower) than for owners until utility changes across tenure are equalized, i.e. \(\hat{V}^R = \hat{V}^O\). Thereby, we ensure no population growth such that the total number of owners is equal to \(\hat{L}^O = \hat{L} - \hat{L}^R\).

\section{D Extensions of the model}

In the following we discuss several extension of our baseline model. First, we introduce the MID at the state level. Second, we show the model with local property taxes and maintenance costs. Third, we embed taxation of imputed rent. Fourth, we discuss how housing rents can be distributed using a global portfolio.
D.1 State taxes

In this section, we introduce state taxes \( \tau_n^s \) and denote federal taxes as \( \tau^f \). Since MID at the state level is not prevalent in every state, we differentiate between taxes paid on wages and taxes applied on the MID. Wage tax rates consist of federal and state income taxes according to the following tax schedule

\[
(1 - \tau_n) = (1 - \tau^f)(1 - \tau_n^s). \tag{D.1}
\]

Mortgage interests are deducted according the following tax schedule

\[
(1 - \tilde{\tau}_n) = (1 - \tau^f)(1 - \zeta_n \tau_n^s), \tag{D.2}
\]

where \( \zeta_n \) indicates whether there is MID at the state level. Note that if \( \zeta_n = 0 \) there is no MID at the state level, i.e. \( \tilde{\tau}_n = \tau^f \). In contrast, if \( \zeta_n = 1 \), mortgage interests can also be deducted at the state level and tax rates consist of both federal and state taxes, i.e. \( \tilde{\tau}_n = \tau^f + \tau_n^s - \tau^f \tau_n^s \). When introducing state taxes to the model, the per capita income of owner-occupiers (3) becomes

\[
y_{ni}^O = (1 - \tau_n) w_i - (1 - \tilde{\tau}_n)(1 - \theta) m_{ni}^O + \frac{H_{ni}^O r_{ni}^O}{L_{ni}^O \lambda_{ni}^O} - \theta m_{ni}^O, \tag{D.3}
\]

and consists of labor income \( w_i \) and imputed rent from owner-occupancy \( \frac{H_{ni}^O r_{ni}^O}{L_{ni}^O \lambda_{ni}^O} \). Moreover, owner-occupiers pay interests \( m_{ni}^O \) on their mortgages, which are deductible according to a tax rate \( \tilde{\tau}_n \). Parameters \( \zeta_n \) and \( \theta \) are defined according to the deductibility of mortgages interest rates at the federal and state level. With the introduction of state taxes, disposable income of owner-occupiers (4) becomes

\[
y_{ni}^D = \frac{(1 - \tau_n)w_i}{\alpha + \phi(1 - \alpha) + \phi(1 - \alpha)\tilde{\tau}_n(\theta - 1)}. \tag{D.4}
\]

Disposable income of renters (5) becomes

\[
y_{ni}^R = (1 - \tau_n) w_i. \tag{D.5}
\]
When introducing state taxes the government budget (8) changes to

\[ G = \frac{1}{L} \sum_{n \in N} \left( \tau_n \bar{L} \sum_{k \in N} \lambda_{nk} w_k - \bar{\tau}_n (1 - \theta) \bar{L}^O \sum_{k \in N} \lambda^O_{nk} m_{nk} \right), \quad (D.6) \]

For all other equations in our model, we introduce a residential/employment specific notation of disposable income \( y^\omega_{ni} \) due to tax rates varying at the state.

### D.2 Local property taxes and maintenance costs

Property taxes are a major source of revenue for county governments. In 2013 property taxes made up to 73% of local governments’ tax revenue.\(^{16}\) Of particular relevance, houses typically require maintenance to preserve the value. In the following, we show the role of property taxes \( \tau^p_n \) and maintenance costs \( \psi \) in our model, where regional income (3) becomes

\[ y^O_{ni} = (1 - \tau) \left( w_i - (1 - \theta) m^O_{ni} \right) - \theta m^O_{ni} + \left( 1 - \phi (\tau^p_n + \psi) \right) \frac{H^O_{ni} \varphi^O_{ni}}{L^O \lambda^O_{ni}}. \quad (D.7) \]

Owner-occupiers pay property taxes and maintenance costs on the local housing value. Disposable income of owner-occupiers (4) then becomes

\[ y^O_{ni} = \left( 1 - \tau \right) \frac{(1 - \tau) w_i}{\alpha + \phi (1 - \alpha) (1 + \tau^p_n + \psi) + \phi (1 - \alpha) \tau (\theta - 1)}. \quad (D.8) \]

With the taxation of property taxes and maintenance costs the income of owner-occupiers decreases compared to the benchmark model. The government budget (8) becomes local and is expanded by the accruals from property taxes

\[ G^O_n = \frac{1}{L} \left( \tau \bar{L} \sum_{k \in N} \lambda_{nk} w_k + \tau^p_n H^O_n P^O_n - \bar{\tau}_n (1 - \theta) \bar{L}^O \sum_{k \in N} \lambda^O_{nk} m_{nk} \right). \quad (D.9) \]

For all other equations in our model, we introduce a residential/employment specific notation of income \( y^O_{ni} \) and government public good provision \( G^O_n \) due to local

---

\(^{16}\) At the state level property taxes only account for less than 1% of fiscal revenues.
property tax rates.

D.3 Taxation of imputed rent

To allow for the possibility of taxing imputed rent, as in many other countries like Italy, the Netherlands, or Switzerland, we introduce the parameter $\psi \in \{0, 1\}$ for the degree of taxation of imputed rent into the per capita income of owner-occupiers (3):

$$y_{ni}^{O} = (1 - \tau) \left( w_i + (1 - \psi) \frac{H_{ni}^{O}r_{ni}^{O}}{L_{ni}^{O}q_{ni}^{O}} - (1 - \theta)m_{ni}^{O} \right) + \psi \frac{H_{ni}^{O}r_{ni}^{O}}{L_{ni}^{O}q_{ni}^{O}} - \theta m_{ni}^{O}, \quad (D.10)$$

Note that if $\psi = 1$ imputed rent is not taxed and this model is exactly the same as our main model. In contrast, if $\psi = 0$ imputed rent is fully taxed as income. With this extension disposable income of owner-occupiers (4) becomes

$$y_{ni}^{O} = \frac{(1 - \tau)w_i}{\alpha + \phi(1 - \alpha) + \phi(1 - \alpha)\tau(\theta - 1) + (1 - \alpha)\tau(1 - \psi)}. \quad (D.11)$$

With taxation of imputed rent $\psi = 0$ the income of owner-occupiers decreases compared to the benchmark model. The federal government has an additional source of tax revenue. Thus, government revenue (8) is defined as

$$G = \frac{1}{L} \sum_{n \in N} \left( \tau L \sum_{k \in N} \lambda_{nk} w_k - \tau(1 - \theta)L^{O} \sum_{k \in N} \lambda_{nk}^{O} m_{nk} + \tau(1 - \psi)(1 - \alpha)L^{O} \sum_{k \in N} \lambda_{nk}^{O} y_{nk}^{O} \right). \quad (D.12)$$

For all other equations in our model, we introduce a residential/employment specific notation of disposable income $y_{ni}^{O}$ due to tax rates varying at the state.
D.4 Global portfolio

In our baseline model, owner-occupiers pay mortgage interests and renters pay rents to an absent financial institution. In this extension, we instead assume that housing and interests are redistributed to workers throughout the economy. Therefore, workers pay rents and mortgage interests to a global portfolio \( \psi = \sum_{n \in N} \sum_{i \in N} \frac{(1-\alpha)}{L} y_{ni}^R + m_{ni}^O \), which is owned in equal shares by residents. The per capita income of owner-occupiers (3) and of renters (5) become

\[
y_{ni}^O = (1-\tau) \left( w_i + \psi - (1-\theta)m_{ni}^O \right) + \frac{H_{ni}^{O} \lambda_{ni}^{O}}{L} \lambda_{ni}^{O} - \theta m_{ni}^O,
\]

(D.13)

and

\[
y_{ni}^R = (1-\tau) \left( w_i + \psi \right),
\]

(D.14)

respectively. With redistribution of housing rents and mortgage interests over a global portfolio, disposable income of owner-occupiers (4) becomes

\[
y_{ni}^{O} = \frac{(1-\tau)(w_i + \psi)}{\alpha + \phi(1-\alpha) + \phi(1-\alpha)\tau(\theta - 1)}.
\]

(D.15)

Since the additional income from the portfolio is taxed, government revenue (8) becomes

\[
G = \frac{1}{L} \sum_{n \in N} \left( \tau L \sum_{k \in N} \lambda_{nk}^{O} w_k - \tau (1-\theta) L m_{nk}^{O} + \tau \psi \right).
\]

(D.16)

E Estimation

In this section we describe how we estimate the housing supply elasticity.
E.1 Estimating local housing supply elasticities

Introducing an additional subscript to denote time variation, we rewrite equation (12) from our structural framework as

\[ \log P_{nt} = \alpha_t + \eta_n \log H_{nt} + \tilde{h}_{nt}, \]  

(E.1)

where \( \alpha_t = E(\log \tilde{H}_{nt}) \) is the county-average value of (the log of) supply shifters, and \( \tilde{h}_{nt} = \log \tilde{H}_{nt} - E(\log \tilde{H}_{nt}) \) represents their demeaned value. As evident from equilibrium equation (13), observed prices and quantities in equation (E.1) results from the interplay of demand and supply forces. This interaction leads to endogeneity bias if \( \eta_n \) is estimated by standard OLS. To trace out the responsiveness of the supply function, we must isolate exogenous housing demand shocks. To this end, we build on Saiz (2010) and proceed in two steps.

First, we compute the following two-period first difference model

\[ \Delta \log P_{nt} = \alpha + \eta_n \Delta \log H_{nt} + \tilde{h}_{nt}^*, \]  

(E.2)

where \( \Delta \log P_{nt} \) and \( \Delta \log H_{nt} \) represent price and residents growth over the considered period, respectively, e.g. \( \Delta \log x_{nt} = \log x_{nt} - \log x_{nt-1}. \) The error term \( \tilde{h}_{nt}^* = \Delta \tilde{h}_{nt} \) represents unobserved price dynamics. We consider price and quantity growth from 1980 to 2000. Focusing on long-run elasticities allows us to neglect shorter term housing dynamics, such as seasonal cyclicalities and lagged construction shocks. Note that time-invariant local characteristics affecting housing supply have been partialled out in equation (E.2), such that \( \tilde{h}_{nt}^* \) might affect \( \Delta \log H_{nt} \) endogenously only through purely dynamic shocks.

Second, according to Hilber and Robert-Nicoud (2013), Hsieh and Moretti (2018) and Saiz (2010) the housing supply elasticity is a function of regulation, which can be proxied by the existing level of development. Following Saiz (2010), we parsimoniously parameterize the inverse local housing supply elasticity \( \eta_n = \eta + \eta^\text{built} S^\text{built}_n, \) where \( S^\text{built}_n \) is the share of developed land in a given county and \( \eta \) and \( \eta^\text{built} \) are parameters that have to be estimated. To avoid potential endogeneity concerns, we rely on the predetermined share of developed land as measured in 1976.
The resulting regression equation is

\[ \Delta \log P_{nt} = \alpha + \eta \Delta \log H_{nt} + \eta^{\text{built}} \Delta \log H_{nt} + \bar{h}^{*}_{nt}. \]  

(E.3)

We estimate \( \eta \) and \( \eta^{\text{built}} \) of equation (E.3) by instrumenting relative changes in the housing stock \( \Delta \log H_{nt} \) between 1980 and 2000 using three alternative local demand shifters \( Z^\Delta_{n} \log H,g,n = 1, 2, 3 \). We instrument the endogenous interaction term \( \bar{h}^{*}_{nt} \Delta \log H_{nt} \) by interacting each instrument with the share of developed land, i.e. with \( S^{\text{built}}_{n} Z^\Delta_{n} \log H,g,n = 1, 2, 3 \). The identifying assumption is

\[ E(\bar{h}^{*}_{nt} \mid Z^\Delta_{n} \log H,g) = 0, \quad g = 1, 2, 3. \]  

(E.4)

We predict local housing demand shocks using i) the log of the mean temperature in January from 1941 to 1970, ii) fertility rates in 1970, and iii) a shift-share instrument for changes in the racial composition of local residents from 1970 to 1990. We motivate the choice of instruments as follows.\(^{17}\) Counties displaying higher average temperatures are (ceteris paribus) more attractive places to live in. We thus expect temperature to positively correlate with an increase in demand over time. To the extent that individuals decide to live in the same county in which they are born – due for example to high idiosyncratic migration costs – predetermined fertility rates are also expected to shift housing demand upward as young adults start to bid on local housing markets. Moreover, local housing demand is also expected to evolve according to the racial composition of the residents. As pointed out by Altonji and Card (1991), existing settlement patterns of immigrants affect subsequent immigration inflows. We build on this proposition, and assume that the 1980-2000 growth in local residents can be predicted by a weighted average of the growth (at the state level) of individuals belonging to a specific race, where the weights are given by the initial distribution of racial groups in 1970. To calculate the shift-share instrument we follow the empirical strategy of Bartik (1991) and construct an exogenous labor demand shock by interacting the predetermined local race composition of the population with the racial growth rates at the state level. The instrument should capture

\(^{17}\)Two of our instruments, average temperature and shift-share of racial composition, relate to those used by Saiz (2010), who predicts demand shocks at the MSA level using the average number of sun hours and number of new immigrants.
exogenous shifts of given races in counties predicted by the state-specific growth, while avoiding the endogeneity associated using local growth rates. In detail, we calculate the instrument as follows

$$Z_n^{\Delta \log H, 3} = \sum_k \gamma_{n,k} \eta_k,$$

(E.5)

where \( \eta_k = \frac{\text{Pop}_{k,n,1990} - \text{Pop}_{k,n,1970}}{\text{Pop}_{k,n,1970}} \) represents the average race growth at the state level, excluding residents of county \( n \), and \( \gamma_{n,k} = \frac{\text{Pop}_{kn,1970}}{\text{Pop}_{n,1970}} \) denotes the local residential share of race \( k \) at the beginning of the period. Races \( k \) are defined according to the race classification used in our data source assigning population to White, Black or African American, American Indian and Alaska Native, and Asian and Pacific Islander and other race residents.

Table E.1: Local housing supply elasticity estimates

<table>
<thead>
<tr>
<th>Dependent variable: Change in log housing prices between 1980 and 2000 (( \Delta \log P ))</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \Delta \log H )</td>
<td>0.538***</td>
<td>0.383**</td>
<td>0.322**</td>
<td>0.390**</td>
</tr>
<tr>
<td></td>
<td>(0.1752)</td>
<td>(0.1713)</td>
<td>(0.1432)</td>
<td>(0.1540)</td>
</tr>
<tr>
<td>( s_{\text{built}} \Delta \log H )</td>
<td>2.125**</td>
<td>2.283**</td>
<td>2.204***</td>
<td>2.283**</td>
</tr>
<tr>
<td></td>
<td>(0.8803)</td>
<td>(0.9138)</td>
<td>(0.8127)</td>
<td>(0.9202)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Instruments</th>
<th>Log-temperature</th>
<th>Yes</th>
<th>Yes</th>
<th>No</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fertility rate</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Shift-share race</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Observations</td>
<td>3'098</td>
<td>3'098</td>
<td>3'098</td>
<td>3'098</td>
<td></td>
</tr>
<tr>
<td>Underidentification (K-P LM p-val)(^a)</td>
<td>0.001</td>
<td>0.003</td>
<td>0.001</td>
<td>0.004</td>
<td></td>
</tr>
<tr>
<td>Weak identification (K-P F stat)(^b)</td>
<td>12.35</td>
<td>7.876</td>
<td>16.26</td>
<td>15.70</td>
<td></td>
</tr>
<tr>
<td>Overidentification (p-val)</td>
<td>0.673</td>
<td>0.225</td>
<td>0.660</td>
<td>0.491</td>
<td></td>
</tr>
</tbody>
</table>

Notes: Clustered standard errors at the state level in parentheses *** \( p < 0.01 \), ** \( p < 0.05 \), * \( p < 0.1 \). \(^a\) Kleibergen-Paap LM statistic. \(^b\) Kleibergen-Paap F statistic. Critical values (5/10/20%/ relative bias) for columns 1-3 are 15.72/9.48/6.08 and for column 4 are 11.04/7.56/5.57.

Table E.1 shows estimated values of the parameters \( \eta \) and \( \eta_{\text{built}} \) present in equation (E.3). In columns 1-3 we report parameter estimates if the relative of housing stock is instrumented using every two-way combination of instruments, and in column 4 we report result if all three instruments are used altogether. Estimates obtained, including first-stage results, using each instruments individually are reported in Appendix E.1.1. As required by the theory, the sign of estimated parameters is
positive. In particular, the higher the share of developed land in a given county, the higher $\eta_n$, thus resulting into a lower local housing supply elasticity. The magnitude of the estimated coefficient is extremely stable across the set of instruments used to predict housing demand growth, despite the set of instrument used in column 2 might be weak. In general, the other instrument combinations are strong, as suggested by the high value of the Kleibergen-Paap F statistic. Underidentification is not an issue across all group of instruments. Overall, we provide support for the exogeneity assumption of our instruments, as estimates of all combination of instruments converge to values within a range of one standard deviation and all the overidentification tests are never rejected.

We conclude this section by computing local housing supply elasticities using the formula $\frac{1}{\eta_n} = \frac{1}{(\eta + n^{\text{built}} S_n^{\text{built}})}$ together with the estimated parameter values of model specification (3) and specific values for $S_n^{\text{built}}$. Note, that local housing supply elasticities of a few counties are not included in our estimation procedure due to data restrictions on historic local housing prices. However, for the computation of the housing supply elasticity we include those counties, since the share of developed land is derived from satellite land cover data and is available for every county. Given the above, we compare the estimated housing supply elasticities with those estimated Saiz (2010). To do so, in a first step we aggregate local housing supply elasticities at the MSA level and find the median value. We then compute the correlation coefficient with the elasticity of Saiz (2010) and obtain a value of 0.60. For further details, see Appendix E.1.1.

E.1.1 Housing supply elasticities: additional insights

In the first part of this section we first describe how we calculate our shift- share instrument and show how our estimation results for the housing supply elasticity look if we use all the instruments separately. Then, we conclude and compare our estimated housing supply elasticities to values found in the empirical framework of Saiz (2010).
### E.1.2 Estimation results using instruments separately

Table E.2: Local housing supply elasticity estimates

Panel A: IV-second stage estimates

<table>
<thead>
<tr>
<th></th>
<th>Column (1)</th>
<th>Column (2)</th>
<th>Column (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \Delta \log H )</td>
<td>0.616***</td>
<td>0.420***</td>
<td>0.291*</td>
</tr>
<tr>
<td>( S_{\text{built}} ) ( \Delta \log H )</td>
<td>2.094**</td>
<td>2.184***</td>
<td>1.900**</td>
</tr>
<tr>
<td>Observations</td>
<td>3'098</td>
<td>3'098</td>
<td>3'098</td>
</tr>
<tr>
<td>Underidentificationa</td>
<td>0.002</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Weak identificationb</td>
<td>8.963</td>
<td>13.89</td>
<td>10.25</td>
</tr>
</tbody>
</table>

Panel B: IV-first stage estimates

<table>
<thead>
<tr>
<th></th>
<th>( Z_{n} \Delta \log H, temp )</th>
<th>( Z_{n} \Delta \log H, temp S_{\text{built}} )</th>
<th>( Z_{n} \Delta \log H, fert )</th>
<th>( Z_{n} \Delta \log H, fert S_{\text{built}} )</th>
<th>( Z_{n} \Delta \log H, race )</th>
<th>( Z_{n} \Delta \log H, race S_{\text{built}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.156***</td>
<td>0.005***</td>
<td>14.732***</td>
<td>0.153</td>
<td>0.407***</td>
<td>-0.002</td>
</tr>
<tr>
<td></td>
<td>(0.037)</td>
<td>(0.002)</td>
<td>(2.704)</td>
<td>(0.211)</td>
<td>(0.096)</td>
<td>(0.005)</td>
</tr>
<tr>
<td></td>
<td>0.000</td>
<td>0.042***</td>
<td>-0.911</td>
<td>7.195***</td>
<td>(3.756)</td>
<td>(1.064)</td>
</tr>
<tr>
<td></td>
<td>(0.021)</td>
<td>(0.004)</td>
<td>(2.704)</td>
<td>(0.211)</td>
<td>(0.096)</td>
<td>(0.005)</td>
</tr>
</tbody>
</table>

Notes: Clustered standard errors at the state level in parentheses *** \( p < 0.01 \), ** \( p < 0.05 \), * \( p < 0.1 \). a) Kleibergen-Paap LM statistic, (p-value). b) Kleibergen-Paap (F-statistic). Critical values (5/10/20% relative bias) for columns 1-3 are 15.72/9.48/6.08 and for column 4 are 11.04/7.56/5.57.
E.1.3 Comparison with Saiz (2010) MSA elasticities

To compare our results with measures derived by Saiz (2010), we assign each county to a Metropolitan Statistical Area (MSA) and calculate population weighted aggregates. As Figure E.1c illustrates, our measure reveals a strong relationship with housing supply elasticities of Saiz (2010). As is evident from this figure we tend to recover higher housing supply elasticities as Saiz (2010). The reason for this is that Saiz (2010)’s likely underestimates the supply elasticities as he looks at transaction data at the MSA level. His data at the MSA level might be over-represented by transactions in dense places. In contrast to this, in our case we recover the housing supply elasticity at the county level and therefore get higher values of the supply elasticities.
Figure E.1: Comparison of housing supply elasticity with Saiz (2010)

(a) Our

(b) Saiz (2010)

(c) Comparison with Saiz (2010)

Note: In panel a) and b) we show recovered housing supply elasticities of our model report quantiles and in b) estimates of Saiz (2010) respectively. A darker shading in the map indicates a higher quantile. In panel c) we compare our housing supply elasticity with estimates described in Saiz (2010), which are based on U.S. metropolitan statistical areas (MSA). We calculate population weighted averages for counties belonging to the same MSA and get a correlation coefficient between Saiz (2010) and our measures of 0.63.
F Tables

F.1 Summary statistics of exogenous and recovered variables

We present summary statistics of all our exogenous and recovered variables in Table F.1.

Table F.1: Summary statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production amenities ($\bar{a}_n$)</td>
<td>29.54</td>
<td>15.3</td>
<td>0.54</td>
<td>198.1</td>
</tr>
<tr>
<td>Commuters ($\bar{L} \sum_{n \neq i} \lambda_{ni}$)</td>
<td>15.87</td>
<td>41.27</td>
<td>0.03</td>
<td>789</td>
</tr>
<tr>
<td>Commuters ($\bar{L}^R \sum_{n \neq i} \lambda_{ni}^R$)</td>
<td>5.2</td>
<td>18.82</td>
<td>0.01</td>
<td>495.95</td>
</tr>
<tr>
<td>Commuters ($\bar{L}^O \sum_{n \neq i} \lambda_{ni}^O$)</td>
<td>10.67</td>
<td>24.72</td>
<td>0.02</td>
<td>348.98</td>
</tr>
<tr>
<td>Housing supply elasticity ($\eta^R_n$)</td>
<td>2.15</td>
<td>0.66</td>
<td>0.39</td>
<td>3.09</td>
</tr>
<tr>
<td>Housing supply elasticity ($\eta^O_n$)</td>
<td>2.15</td>
<td>0.66</td>
<td>0.39</td>
<td>3.09</td>
</tr>
<tr>
<td>Own trade shares, in % ($\pi_{nn}$)</td>
<td>0.03</td>
<td>0.14</td>
<td>0</td>
<td>3.67</td>
</tr>
<tr>
<td>Wages per-capita ($w_n$)</td>
<td>45.65</td>
<td>13.81</td>
<td>2.86</td>
<td>204.26</td>
</tr>
<tr>
<td>Income per-capita ($\bar{y}_n$)</td>
<td>49.01</td>
<td>11.97</td>
<td>20.77</td>
<td>185.97</td>
</tr>
<tr>
<td>Income per-capita ($\bar{y}^O_n$)</td>
<td>52.35</td>
<td>12.85</td>
<td>23.57</td>
<td>195.22</td>
</tr>
<tr>
<td>Income per-capita ($\bar{y}^R_n$)</td>
<td>40.29</td>
<td>9.89</td>
<td>18.14</td>
<td>150.21</td>
</tr>
<tr>
<td>Workers ($L_n$)</td>
<td>58.57</td>
<td>206.16</td>
<td>0.14</td>
<td>5939</td>
</tr>
<tr>
<td>Workers ($L^O_n$)</td>
<td>37.89</td>
<td>117.28</td>
<td>0.1</td>
<td>2876.75</td>
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<tr>
<td>Workers ($L^R_n$)</td>
<td>20.68</td>
<td>92.27</td>
<td>0.04</td>
<td>3062.25</td>
</tr>
<tr>
<td>Residents ($R_n$)</td>
<td>58.57</td>
<td>189.32</td>
<td>0.08</td>
<td>5734.31</td>
</tr>
<tr>
<td>Residents ($R^O_n$)</td>
<td>37.89</td>
<td>106.3</td>
<td>0.04</td>
<td>2689.48</td>
</tr>
<tr>
<td>Residents ($R^R_n$)</td>
<td>20.68</td>
<td>87.21</td>
<td>0.04</td>
<td>3044.83</td>
</tr>
<tr>
<td>Housing rent ($r^R_n$)</td>
<td>0.68</td>
<td>0.18</td>
<td>0.25</td>
<td>1.73</td>
</tr>
<tr>
<td>Housing rent ($r^O_n$)</td>
<td>6.26</td>
<td>3.69</td>
<td>1.7</td>
<td>45.17</td>
</tr>
<tr>
<td>Price index ($P_n$)</td>
<td>0.06</td>
<td>0</td>
<td>0.06</td>
<td>0.06</td>
</tr>
<tr>
<td>Public good provision ($G_n$)</td>
<td>1726.13</td>
<td>5719.03</td>
<td>0.94</td>
<td>155161.69</td>
</tr>
<tr>
<td>Tax rates, in % ($t_n$)</td>
<td>14.05</td>
<td>1.4</td>
<td>11.36</td>
<td>16.83</td>
</tr>
</tbody>
</table>

Note: Commuters, residents and workers are measured in thousand inhabitants, per capita wages, per capita income and rents are reported in thousand Dollars, Public good provision in million Dollars, and tax rates and trade shares in percent.
G  Figures

Figure G.1: Impact of homogenous housing subsidy, with varying public good provision

(a) Residents ($\hat{R}_n$)  (b) Residents owners ($\hat{R}^O_n$)  (c) Residents renters ($\hat{R}^R_n$)

(d) Stayers ($\hat{\lambda}_{nn}$)  (e) Housing prices ($\hat{r}^O_n$)  (f) Housing rent ($\hat{r}^R_n$)

(g) Exp. income owners ($\hat{\gamma}^O_n$)  (h) Exp. income renters ($\hat{\gamma}^R_n$)  (i) Public good prov. ($\hat{G}_n/\hat{R}_n$)

Note: The Figure depicts changes in the respective variable reported by quantiles of a homogenous housing subsidy paid to owner-occupiers. A darker shading represents a stronger effect, where a green (red) color illustrates a positive (negative) effect. The unit of observation is at the county level.
Figure G.2: Impact of homogenous housing subsidy - With varying federal public good provision

(a) Residents ($\hat{R}_n$)  (b) Residents owners ($\hat{R}^O_n$)  (c) Residents renters ($\hat{R}^R_n$)

(d) Stayers ($\hat{\lambda}_nn$)  (e) Housing prices ($\hat{r}^O_n$)  (f) Housing rent ($\hat{r}^R_n$)

(g) Exp. income owners ($\hat{y}_n^O$)  (h) Exp. income renters ($\hat{y}_n^R$)  (i) Public good prov. ($\hat{G}_n/\hat{R}_n$)

Note: The Figure depicts changes in the respective variable reported by quantiles of a homogenous housing subsidy paid to owner-occupiers. A darker shading represents a stronger effect, where a green (red) color illustrates a positive (negative) effect. The unit of observation is at the county level.
Figure G.3: Impact of homogenous housing subsidy - with MID and inter-regional transfers

(a) Residents ($\hat{R}_n$)  (b) Residents owners ($\hat{R}_n^O$)  (c) Residents renters ($\hat{R}_n^R$)

(d) Stayers ($\hat{X}_n^{\hat{O}}$)  (e) Housing prices ($\hat{r}_n^O$)  (f) Housing rent ($\hat{r}_n^R$)

(g) Exp. income owners ($\hat{y}_n^O$) (h) Exp. income renters ($\hat{y}_n^R$)  (i) Public good prov. ($\hat{G}_n/\hat{R}_x$)

Note: The Figure depicts changes in the respective variable reported by quantiles of a homogenous housing subsidy paid to owner-occupiers. A darker shading represents a stronger effect, where a green (red) color illustrates a positive (negative) effect. The unit of observation is at the county level.
Figure G.4: Impact of homogenous housing subsidy - with MID and varying public good provision

(a) Residents ($\hat{R}_n$)  (b) Residents owners ($\hat{R}_n^O$)  (c) Residents renters ($\hat{R}_n^R$)

(d) Stayers ($\hat{\lambda}^O_{nn}$)  (e) Housing prices ($\hat{r}_n^O$)  (f) Housing rent ($\hat{r}_n^R$)

(g) Exp. income owners ($\hat{\tilde{y}}^O_n$)  (h) Exp. income renters ($\hat{\tilde{y}}^R_n$)  (i) Public prov. ($\hat{G}_n/\hat{R}_n$)

Note: The Figure depicts changes in the respective variable reported by quantiles of a homogenous housing subsidy paid to owner-occupiers. A darker shading represents a stronger effect, where a green (red) color illustrates a positive (negative) effect. The unit of observation is at the county level.
Figure G.5: Impact of homogenous housing subsidy - with MID and varying federal public good provision

(a) Residents ($\hat{R}_n$)
(b) Residents owners ($\hat{R}_n^O$)
(c) Residents renters ($\hat{R}_n^R$)
(d) Stayers ($\hat{X}_{nn}$)
(e) Housing prices ($\hat{r}_n^O$)
(f) Housing rent ($\hat{r}_n^R$)
(g) Exp. income owners ($\hat{y}_n^O$)
(h) Exp. income renters ($\hat{y}_n^R$)
(i) Public good prov. ($\hat{G}_n/\hat{R}_n$)

Note: The Figure depicts changes in the respective variable reported by quantiles of a homogenous housing subsidy paid to owner-occupiers. A darker shading represents a stronger effect, where a green (red) color illustrates a positive (negative) effect. The unit of observation is at the county level.